JS 44 (Rev. 12/07)

CIVIL COVER SHEET

The JS 44 civil cover sheet and the information contained herein neither replace nor supplement the filing and service of pleadings or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. (SEE INSTRUCTIONS ON THE REVERSE OF THE FORM.)

I. (a) PLAINTIFFS
Conicity Technologies, LLC

DEFENDANTS
Mutschler Edge Technologies, LLC

(b) County of Residence of First Listed Plaintiff Monroe County, PA
(EXCEPT IN U.S. PLAINTIFF CASES)

County of Residence of First Listed Defendant Lorian County, OH
(IN U.S. PLAINTIFF CASES ONLY)
NOTE: IN LAND CONDEMNATION CASES, USE THE LOCATION OF THE LAND INVOLVED.

(c) Attorney's (Firm Name, Address, and Telephone Number)
Joseph L. Vullo, Esquire, Burke Vullo Reilly Roberts, 1460 Wyoming Ave., Forty Fort, PA 18704 (570) 288-6441 (SEE ATTACHED)

Attorneys (If Known)

II. BASIS OF JURISDICTION (Place an "X" in One Box Only)

- ☐ 1 U.S. Government Plaintiff
- ☒ 3 Federal Question (U.S. Government Not a Party)
- ☐ 2 U.S. Government Defendant
- ☐ 4 Diversity (Indicate Citizenship of Parties in Item III)

III. CITIZENSHIP OF PRINCIPAL PARTIES (Place an "X" in One Box for Plaintiff and One Box for Defendant)
(For Diversity Cases Only)

	PTF	DEF		PTF	DEF
Citizen of This State	☐ 1	☐ 1	Incorporated *or* Principal Place of Business In This State	☐ 4	☐ 4
Citizen of Another State	☐ 2	☐ 2	Incorporated *and* Principal Place of Business In Another State	☐ 5	☐ 5
Citizen or Subject of a Foreign Country	☐ 3	☐ 3	Foreign Nation	☐ 6	☐ 6

IV. NATURE OF SUIT (Place an "X" in One Box Only)

CONTRACT
- ☐ 110 Insurance
- ☐ 120 Marine
- ☐ 130 Miller Act
- ☐ 140 Negotiable Instrument
- ☐ 150 Recovery of Overpayment & Enforcement of Judgment
- ☐ 151 Medicare Act
- ☐ 152 Recovery of Defaulted Student Loans (Excl. Veterans)
- ☐ 153 Recovery of Overpayment of Veteran's Benefits
- ☐ 160 Stockholders' Suits
- ☐ 190 Other Contract
- ☐ 195 Contract Product Liability
- ☐ 196 Franchise

REAL PROPERTY
- ☐ 210 Land Condemnation
- ☐ 220 Foreclosure
- ☐ 230 Rent Lease & Ejectment
- ☐ 240 Torts to Land
- ☐ 245 Tort Product Liability
- ☐ 290 All Other Real Property

TORTS

PERSONAL INJURY
- ☐ 310 Airplane
- ☐ 315 Airplane Product Liability
- ☐ 320 Assault, Libel & Slander
- ☐ 330 Federal Employers' Liability
- ☐ 340 Marine
- ☐ 345 Marine Product Liability
- ☐ 350 Motor Vehicle
- ☐ 355 Motor Vehicle Product Liability
- ☐ 360 Other Personal Injury

PERSONAL INJURY
- ☐ 362 Personal Injury - Med. Malpractice
- ☐ 365 Personal Injury - Product Liability
- ☐ 368 Asbestos Personal Injury Product Liability

PERSONAL PROPERTY
- ☐ 370 Other Fraud
- ☐ 371 Truth in Lending
- ☐ 380 Other Personal Property Damage
- ☐ 385 Property Damage Product Liability

CIVIL RIGHTS
- ☐ 441 Voting
- ☐ 442 Employment
- ☐ 443 Housing/ Accommodations
- ☐ 444 Welfare
- ☐ 445 Amer. w/Disabilities - Employment
- ☐ 446 Amer. w/Disabilities - Other
- ☐ 440 Other Civil Rights

PRISONER PETITIONS
- ☐ 510 Motions to Vacate Sentence

Habeas Corpus:
- ☐ 530 General
- ☐ 535 Death Penalty
- ☐ 540 Mandamus & Other
- ☐ 550 Civil Rights
- ☐ 555 Prison Condition

FORFEITURE/PENALTY
- ☐ 610 Agriculture
- ☐ 620 Other Food & Drug
- ☐ 625 Drug Related Seizure of Property 21 USC 881
- ☐ 630 Liquor Laws
- ☐ 640 R.R. & Truck
- ☐ 650 Airline Regs.
- ☐ 660 Occupational Safety/Health
- ☐ 690 Other

LABOR
- ☐ 710 Fair Labor Standards Act
- ☐ 720 Labor/Mgmt. Relations
- ☐ 730 Labor/Mgmt.Reporting & Disclosure Act
- ☐ 740 Railway Labor Act
- ☐ 790 Other Labor Litigation
- ☐ 791 Empl. Ret. Inc. Security Act

IMMIGRATION
- ☐ 462 Naturalization Application
- ☐ 463 Habeas Corpus - Alien Detainee
- ☐ 465 Other Immigration Actions

BANKRUPTCY
- ☐ 422 Appeal 28 USC 158
- ☐ 423 Withdrawal 28 USC 157

PROPERTY RIGHTS
- ☐ 820 Copyrights
- ☒ 830 Patent
- ☐ 840 Trademark

SOCIAL SECURITY
- ☐ 861 HIA (1395ff)
- ☐ 862 Black Lung (923)
- ☐ 863 DIWC/DIWW (405(g))
- ☐ 864 SSID Title XVI
- ☐ 865 RSI (405(g))

FEDERAL TAX SUITS
- ☐ 870 Taxes (U.S. Plaintiff or Defendant)
- ☐ 871 IRS—Third Party 26 USC 7609

OTHER STATUTES
- ☐ 400 State Reapportionment
- ☐ 410 Antitrust
- ☐ 430 Banks and Banking
- ☐ 450 Commerce
- ☐ 460 Deportation
- ☐ 470 Racketeer Influenced and Corrupt Organizations
- ☐ 480 Consumer Credit
- ☐ 490 Cable/Sat TV
- ☐ 810 Selective Service
- ☐ 850 Securities/Commodities/ Exchange
- ☐ 875 Customer Challenge 12 USC 3410
- ☐ 890 Other Statutory Actions
- ☐ 891 Agricultural Acts
- ☐ 892 Economic Stabilization Act
- ☐ 893 Environmental Matters
- ☐ 894 Energy Allocation Act
- ☐ 895 Freedom of Information Act
- ☐ 900Appeal of Fee Determination Under Equal Access to Justice
- ☐ 950 Constitutionality of State Statutes

V. ORIGIN (Place an "X" in One Box Only)
☒ 1 Original Proceeding ☐ 2 Removed from State Court ☐ 3 Remanded from Appellate Court ☐ 4 Reinstated or Reopened ☐ 5 Transferred from another district (specify) ☐ 6 Multidistrict Litigation ☐ 7 Appeal to District Judge from Magistrate Judgment

VI. CAUSE OF ACTION
Cite the U.S. Civil Statute under which you are filing **(Do not cite jurisdictional statutes unless diversity)**:
28 U.S.C. §1331, 1332 and 1338
Brief description of cause:
Patent infringment

VII. REQUESTED IN COMPLAINT: ☐ CHECK IF THIS IS A CLASS ACTION UNDER F.R.C.P. 23 **DEMAND $** Preliminary Injunction & Other Relief CHECK YES only if demanded in complaint: **JURY DEMAND:** ☒ Yes ☐ No

VIII. RELATED CASE(S) IF ANY (See instructions): JUDGE _____ DOCKET NUMBER _____

DATE 10/28/2009 SIGNATURE OF ATTORNEY OF RECORD

FOR OFFICE USE ONLY

RECEIPT # _____ AMOUNT _____ APPLYING IFP _____ JUDGE _____ MAG. JUDGE _____

SUPPLEMENT TO CIVIL COVER SHEET

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JS 44 (Rev. 12/07)

CIVIL COVER SHEET

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Conicity Technologies, LLC

DEFI
Muts

(b) County of Residence of First Listed Plaintiff Monroe County, PA
(EXCEPT IN U.S. PLAINTIFF CASES)

County

IE

(c) Attorney's (Firm Name, Address, and Telephone Number)
Joseph L. Vullo, Esquire, Burke Vullo Reilly Roberts, 1460 Wyoming Ave., Forty Fort, PA 18704 (570) 288-6441

Attor

← (See Attachment)

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- ☐ 1 U.S. Government Plaintiff
- ☒ 3 Federal Question (U.S. Government Not a Party)
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III. CITIZE
(For Dive

r Plaintiff
int)
DEF

Citizen of This ☐ 4

Citizen of Anc ☐ 5

Citizen or Subject of a Foreign Country ☐ 3 ☐ 3 Foreign Nation ☐ 6 ☐ 6

IV. NATURE OF SUIT (Place an "X" in One Box Only)

CONTRACT	TORTS		FORFEITURE/PENALTY	BANKRUPTCY	OTHER STATUTES
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☐ 220 Foreclosure	☐ 442 Employment	Habeas Corpus:	☐ 791 Empl. Ret. Inc. Security Act	FEDERAL TAX SUITS	☐ 893 Environmental Matters
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☐ 240 Torts to Land	☐ 444 Welfare	☐ 535 Death Penalty	IMMIGRATION	☐ 871 IRS—Third Party 26 USC 7609	☐ 895 Freedom of Information Act
☐ 245 Tort Product Liability	☐ 445 Amer. w/Disabilities - Employment	☐ 540 Mandamus & Other	☐ 462 Naturalization Application		☐ 900Appeal of Fee Determination Under Equal Access to Justice
☐ 290 All Other Real Property	☐ 446 Amer. w/Disabilities - Other	☐ 550 Civil Rights	☐ 463 Habeas Corpus - Alien Detainee		☐ 950 Constitutionality of State Statutes
	☐ 440 Other Civil Rights	☐ 555 Prison Condition			

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☒ 1 Original Proceeding ☐ 2 Removed from State Court ☐ 3 Remanded from Appellate Court

Preliminary Injunction and other relief

1 from trict ☐ 6 Multidistrict Litigation ☐ 7 Appeal to District Judge from Magistrate Judgment

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Cite the U.S. Civil Statute under whic
28 U.S.C. §1331, 1332 and 1
Brief description of cause:
Patent infringment

itutes unless diversity):

VII. REQUESTED IN COMPLAINT: ☐ CHECK IF THIS IS A CLASS ACTION UNDER F.R.C.P. 23

DEMAND $

CHECK YES only if demanded in complaint:
JURY DEMAND: ☑ Yes ☐ No

VIII. RELATED CASE(S) IF ANY (See instructions): JUDGE _____ DOCKET NUMBER _____

DATE
10/28/2009

SIGNATURE OF ATTORNEY OF RECORD

FOR OFFICE USE ONLY

RECEIPT # _____ AMOUNT _____ APPLYING IFP _____ JUDGE _____ MAG. JUDGE _____

JS 44 Reverse (Rev. 12/07)

INSTRUCTIONS FOR ATTORNEYS COMPLETING CIVIL COVER SHEET FORM JS 44

Authority For Civil Cover Sheet

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I. (a) Plaintiffs-Defendants. Enter names (last, first, middle initial) of plaintiff and defendant. If the plaintiff or defendant is a government agency, use only the full name or standard abbreviations. If the plaintiff or defendant is an official within a government agency, identify first the agency and then the official, giving both name and title.

(b) County of Residence. For each civil case filed, except U.S. plaintiff cases, enter the name of the county where the first listed plaintiff resides at the time of filing. In U.S. plaintiff cases, enter the name of the county in which the first listed defendant resides at the time of filing. (NOTE: In land condemnation cases, the county of residence of the "defendant" is the location of the tract of land involved.)

(c) Attorneys. Enter the firm name, address, telephone number, and attorney of record. If there are several attorneys, list them on an attachment, noting in this section "(see attachment)".

II. Jurisdiction. The basis of jurisdiction is set forth under Rule 8(a), F.R.C.P., which requires that jurisdictions be shown in pleadings. Place an "X" in one of the boxes. If there is more than one basis of jurisdiction, precedence is given in the order shown below.

United States plaintiff. (1) Jurisdiction based on 28 U.S.C. 1345 and 1348. Suits by agencies and officers of the United States are included here.

United States defendant. (2) When the plaintiff is suing the United States, its officers or agencies, place an "X" in this box.

Federal question. (3) This refers to suits under 28 U.S.C. 1331, where jurisdiction arises under the Constitution of the United States, an amendment to the Constitution, an act of Congress or a treaty of the United States. In cases where the U.S. is a party, the U.S. plaintiff or defendant code takes precedence, and box 1 or 2 should be marked.

Diversity of citizenship. (4) This refers to suits under 28 U.S.C. 1332, where parties are citizens of different states. When Box 4 is checked, the citizenship of the different parties must be checked. (See Section III below; federal question actions take precedence over diversity cases.)

III. Residence (citizenship) of Principal Parties. This section of the JS 44 is to be completed if diversity of citizenship was indicated above. Mark this section for each principal party.

IV. Nature of Suit. Place an "X" in the appropriate box. If the nature of suit cannot be determined, be sure the cause of action, in Section VI below, is sufficient to enable the deputy clerk or the statistical clerks in the Administrative Office to determine the nature of suit. If the cause fits more than one nature of suit, select the most definitive.

V. Origin. Place an "X" in one of the seven boxes.

Original Proceedings. (1) Cases which originate in the United States district courts.

Removed from State Court. (2) Proceedings initiated in state courts may be removed to the district courts under Title 28 U.S.C., Section 1441. When the petition for removal is granted, check this box.

Remanded from Appellate Court. (3) Check this box for cases remanded to the district court for further action. Use the date of remand as the filing date.

Reinstated or Reopened. (4) Check this box for cases reinstated or reopened in the district court. Use the reopening date as the filing date.

Transferred from Another District. (5) For cases transferred under Title 28 U.S.C. Section 1404(a). Do not use this for within district transfers or multidistrict litigation transfers.

Multidistrict Litigation. (6) Check this box when a multidistrict case is transferred into the district under authority of Title 28 U.S.C. Section 1407. When this box is checked, do not check (5) above.

Appeal to District Judge from Magistrate Judgment. (7) Check this box for an appeal from a magistrate judge's decision.

VI. Cause of Action. Report the civil statute directly related to the cause of action and give a brief description of the cause. **Do not cite jurisdictional statutes unless diversity.** Example: U.S. Civil Statute: 47 USC 553
Brief Description: Unauthorized reception of cable service

VII. Requested in Complaint. Class Action. Place an "X" in this box if you are filing a class action under Rule 23, F.R.Cv.P.

Demand. In this space enter the dollar amount (in thousands of dollars) being demanded or indicate other demand such as a preliminary injunction.

Jury Demand. Check the appropriate box to indicate whether or not a jury is being demanded.

VIII. Related Cases. This section of the JS 44 is used to reference related pending cases if any. If there are related pending cases, insert the docket numbers and the corresponding judge names for such cases.

Date and Attorney Signature. Date and sign the civil cover sheet.

IN THE UNITED STATES DISTRICT COURT
FOR THE MIDDLE DISTRICT OF PENNSYLVANIA

CONICITY TECHNOLOGIES, LLC Plaintiff, v. MUTSCHLER EDGE TECHNOLOGIES LLC Defendant.	CIVIL ACTION NO. **COMPLAINT AND JURY DEMAND** **ELECTRONICALLY FILED**

Plaintiff Conicity Technologies, LLC (hereinafter "Conicity") alleges against Mutschler Edge Technologies LLC ("MET") as follows:

Nature of the Action

1. This is a complaint for infringement of United States patents under 35 U.S.C. §§ 271 and 281.

Jurisdiction and Venue

2. The Court has jurisdiction over the subject matter of this action pursuant to 28 U.S.C. §§ 1331, 1332 and 1338.

3. Venue in this district is proper under 28 U.S.C. §§ 1391(b) and (c).

Parties

4. Conicity is a Pennsylvania limited liability company having its principal place of business at One Weiler Drive, Cresco, Pennsylvania, 18326-0149.

5. On information and belief, defendant "MET" is an Ohio limited liability company having a place of business at 33549 E Royalton Road, Suite 9, Columbia Station, OH 44028, and solicits and otherwise does business throughout the country and in the Middle District of Pennsylvania and is subject to the jurisdiction of this Court.

6. Conicity is the assignee of the entire right, title and interest in and to United States Letters Patent No. 6,287,177 ("the '177 patent") entitled "Method of and Apparatus for High Tolerance Brush Honing," which duly and legally issued on September 11, 2001. A copy of the '177 patent is attached hereto as Exhibit A.

7. Conicity is the assignee of the entire right, title and interest in and to United States Letters Patent No. 6,669,531 ("the '531 patent") entitled "Apparatus for High Tolerance Brush Honing," which duly and legally issued on December 30, 2003. A copy of the '531 patent is attached hereto as Exhibit B.

8. Conicity is the assignee of the entire right, title and interest in and to United States Letters Patent No. 6,802,677 ("the '677 patent") entitled "Tool Having Honed Cutting Edge," which duly and legally issued on October 12, 2004. A copy of the '677 patent is attached hereto as Exhibit C.

COUNT I

INFRINGEMENT OF US PATENT NO. 6,287,177

9. This cause of action for patent infringement arises under 35 U.S.C. §§ 271(a), (b), and (c).

10. The '177 patent grants Conicity the right to prevent others from making, having made, using, importing, advertising, selling and offering for sale a process (including selling

product that practices a process) for honing at least one edge on a workpiece as recited in the claims.

11. On information and belief, MET has directly infringed and continues to infringe the '177 patent by honing a precision edge on tools, and offering services to do so, using a process covered by at least claims 1, 4, 5, 10, 11, and 12 of the '177 patent. Specifically, MET provides honing services using a machine called the "MET-1 Universal Edge Prep System" (Attached Exhibits D and E from MET's website) that is believed to operate in accordance with the processing steps covered by at least the above claims.

12. On information and belief, MET has directly infringed and continues to infringe the '177 patent under 35 U.S.C. §§ 271(c) by offering for sale and/or selling a machine for honing an edge on tools that operates in accordance with the patented process steps covered by at least claims 1, 4, 5, 10, 11, and 12 of the '177 patent. Specifically, MET sells or is offering for sale the "MET-1 Universal Edge Prep System" shown in Exhibit D.

13. On information and belief, MET has induced and continues to induce others to infringe the '177 patent under 35 U.S.C. §§ 271(b) by instructing the users to hone the edge on tools in accordance with the patented process steps covered by at least claims 1, 4, 5, 10, 11, and 12 of the '177 patent using a machine sold by MET. Specifically, MET sells or is offering for sale the "MET-1 Universal Edge Prep System" shown in Exhibit D and instructs its customers on how to operate the machine to hone tool edges in accordance with at least the claims referred to above.

14. MET's infringement of the '177 patent has deprived, and will deprive, Conicity of sales which it otherwise would have made.

15. On information and belief, MET's infringement has been and continues to be with knowledge of the '177 patent and has been and is willful and deliberate, and Conicity is entitled to treble damages pursuant to 35 U.S.C. § 284.

16. MET's willful and deliberate infringement makes this an exceptional case pursuant to 35 U.S.C. § 285, and Conicity is entitle to recover its attorney fees and costs in prosecuting this action.

COUNT II

INFRINGEMENT OF US PATENT NO. 6,669,531

17. This cause of action for patent infringement arises out of 35 U.S.C. §§ 271(a), (b), and (c).

18. The '531 patent grants Conicity the right to prevent others from making, having made, using, importing, advertising, selling and offering for sale an apparatus for high tolerance brush honing at least one edge on a workpiece as recited in the claims. Specifically, claims 1-16 recite the elements of an apparatus which is constructed to hone a precision edge on a tool.

19. On information and belief, MET has directly infringed and continues to infringe the '531 patent by making, having made, using, importing, advertising, selling and offering for sale a machine that provides high tolerance honing of a cutting edge of a tool covered by at least claims 1, 4, 5, 6, 7, 9, 10, 11, 15, and 16 of the '531 patent. Specifically, MET sells a machine called the "MET-1 Universal Edge Prep System" that is believed to be covered by at least the above claims.

20. MET's infringement of the '531 patent has deprived, and will deprive, Conicity of sales which it otherwise would have made.

21. On information and belief, MET's infringement has been and continues to be with knowledge of the '531 patent and has been and is willful and deliberate, and Conicity is entitled to treble damages pursuant to 35 U.S.C. § 284.

22. MET's willful and deliberate infringement makes this an exceptional case pursuant to 35 U.S.C. § 285, and Conicity is entitle to recover its attorney fees and costs in prosecuting this action.

COUNT III

INFRINGEMENT OF US PATENT NO. 6,802,677

23. This cause of action for patent infringement arises out of 35 U.S.C. §§ 271(a), (b), and (c).

24. The '677 patent grants Conicity the right to prevent others from making, having made, using, importing, advertising, selling and offering for sale tools with a honed cutting edge made in accordance with specific process steps recited in the claims. Claims 1-15 recite a tool with a honed edge that is formed by specific process steps.

25. On information and belief, MET has directly infringed and continues to infringe the '677 patent by making, having made, using, importing, advertising, selling and offering for sale tools having a honed edge that is made using the process steps recited in at least claims 1, 2, 6, 10, 11, and 15 of the '677 patent. Specifically, MET provides honing services for honing the edge of a tool using a machine called the "MET-1 Universal Edge Prep System" that is believed to operate in accordance with the process steps recited in at least the above claims.

26. On information and belief, MET has induced and continues to induce others to infringe the '677 patent under 35 U.S.C. §§ 271(b) by instructing purchasers of its "MET-1

Universal Edge Prep System" to manufacture a tool with a honed edge in accordance with the process steps recited in at least claims 1, 2, 6, 10, 11, and 15 of the '677 patent.

27. MET's infringement of the '677 patent has deprived, and will deprive, Conicity of sales which it otherwise would have made.

28. On information and belief, MET's infringement has been and continues to be with knowledge of the '677 patent and has been and is willful and deliberate, and Conicity is entitled to treble damages pursuant to 35 U.S.C. § 284.

29. MET's willful and deliberate infringement makes this an exceptional case pursuant to 35 U.S.C. § 285, and Conicity is entitle to recover its attorney fees and costs in prosecuting this action.

PRAYERS FOR RELIEF

WHEREFORE, Conicity Technologies, LLC demands judgment against Mutschler Edge Technologies, LLC, and demands relief as follows:

A. That this Court preliminarily and permanently enjoin MET, and those officers, directors, agents, employees and any person or entity in active concert or participation with any of them, from infringing the '177, 531 and '677 patents;

B. That MET be ordered to deliver up for destruction all infringing MET-1 Universal Edge Prep System apparatus in its possession or under its control;

C. That this Court award Conicity money damages under 35 U.S.C. § 284 sufficient to compensate Conicity for the financial damage caused by MET's infringement, including treble damages for MET's willful infringement, and Conicity's reasonable attorney fees under 35 U.S.C. § 285;

D. That this Court award to Conicity its costs for prosecuting this action;

E. That this Court enter an Order placing reasonable but effective restrictions on the future transactions of MET so as to assure its ability to pay, and the prompt payment of, the judgment entered against it in this action: and

F. That this Court award to Conicity such other and further relief as is authorized by statute or is deemed appropriate by this Court.

JURY DEMAND

Conicity Technologies, LLC hereby demands a trial before a jury on all counts contained in its Complaint.

Respectfully submitted,

CONICITY TECHNOLOGIES, LLC

Dated: October 28, 2009

BY: S/ JOSEPH L. VULLO

JOSEPH VULLO, ESQUIRE
Burke Vullo Reilly Roberts
1460 Wyoming Avenue
Forty Fort, PA 18704
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PA #41279

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Tel: (215) 988-3309
Fax: (215) 988-2757
PA #34874
Attorneys for
CONICITY TECHNOLOGIES, LLC

EXHIBIT "A"

US006287177B1

(12) **United States Patent**
Shaffer

(10) **Patent No.: US 6,287,177 B1**
(45) **Date of Patent: Sep. 11, 2001**

(54) **METHOD OF AND APPARATUS FOR HIGH TOLERANCE BRUSH HONING**

(75) Inventor: **William R. Shaffer**, Greensburg, PA (US)

(73) Assignee: **Conicity Technologies, Llc.**, Cresco, PA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/428,726**

(22) Filed: **Oct. 28, 1999**

(51) **Int. Cl.**[7] **B24B 3/02**

(52) **U.S. Cl.** **451/59**; 457/48; 457/466; 457/916

(58) **Field of Search** 457/466, 45, 48, 457/489, 916, 5; 26/102, 107.1, 108.1; 408/18, 45; 409/66

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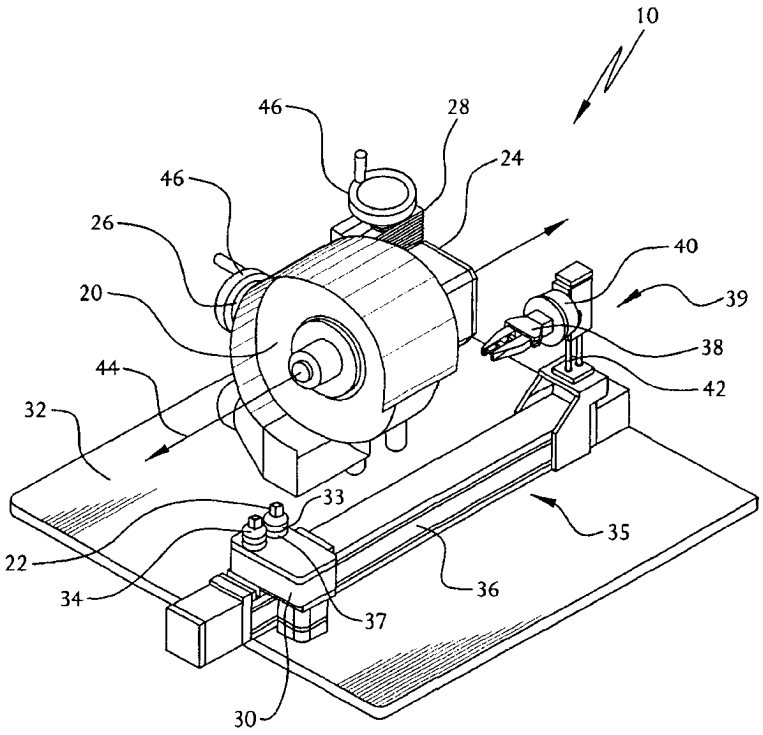
(57) **ABSTRACT**

The present invention relates to a honing method and apparatus which provides greater control over the edge shape, as well as reductions in the effort required to hone multiple edges on workpieces. The invention accomplishes these improvements by controlling the speed of the abrasive wheel, as well as the orientation and position of the workpiece prior to and/or while it is in contact with the abrasive brush. This provides for greater control over the hone shape, hone size, and hone distribution along all the cutting edges of the tool.

12 Claims, 12 Drawing Sheets



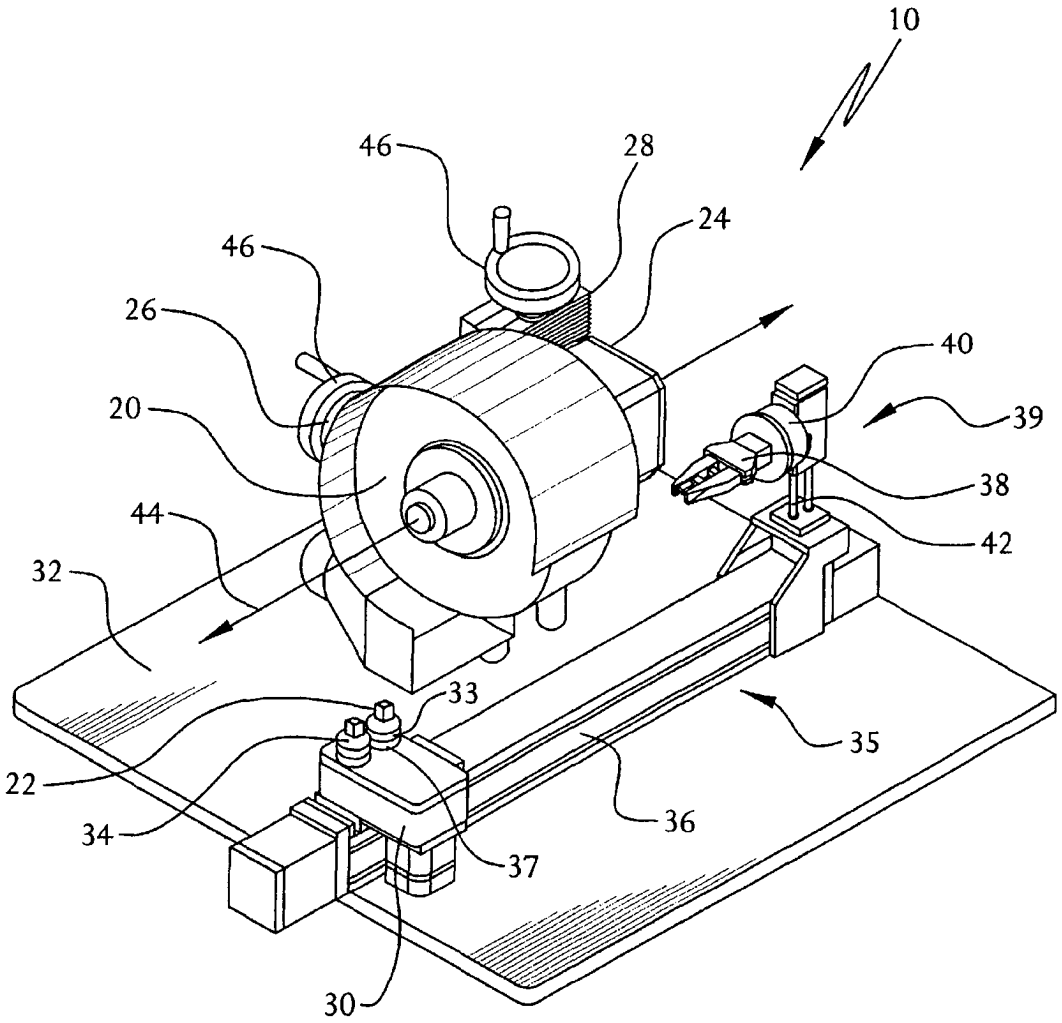


FIG. 1

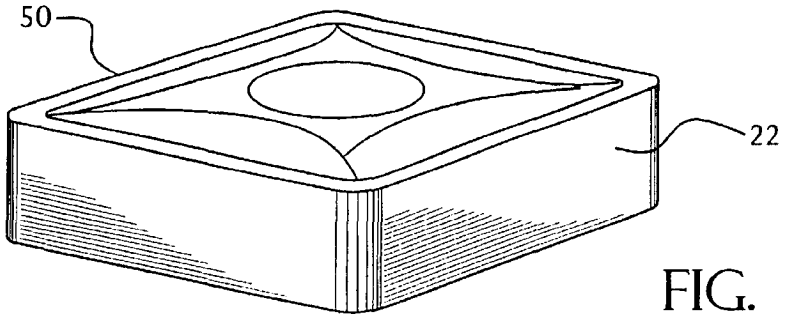


FIG. 2a

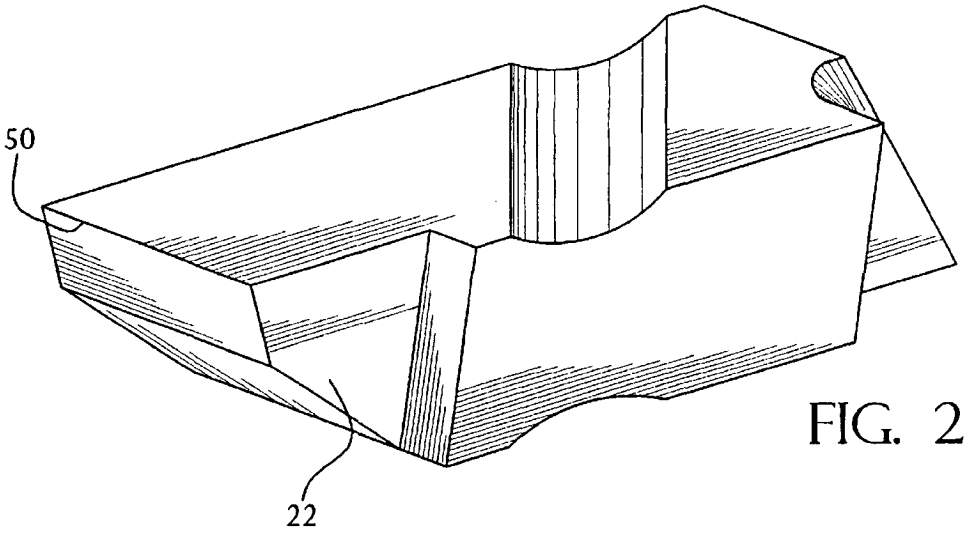


FIG. 2b

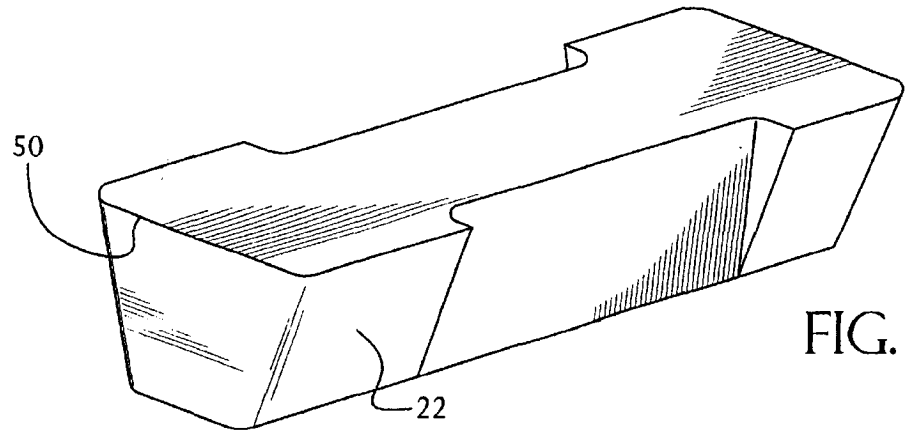


FIG. 2c

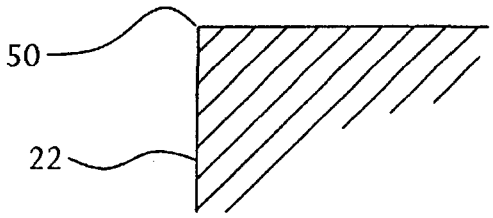


FIG. 3a

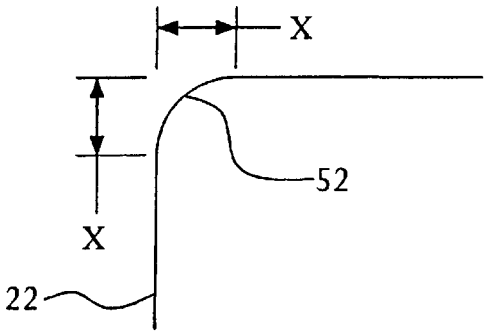


FIG. 3b

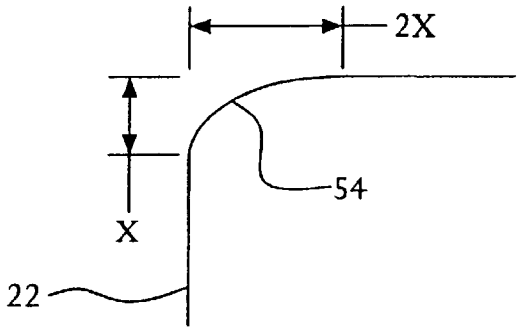


FIG. 3c

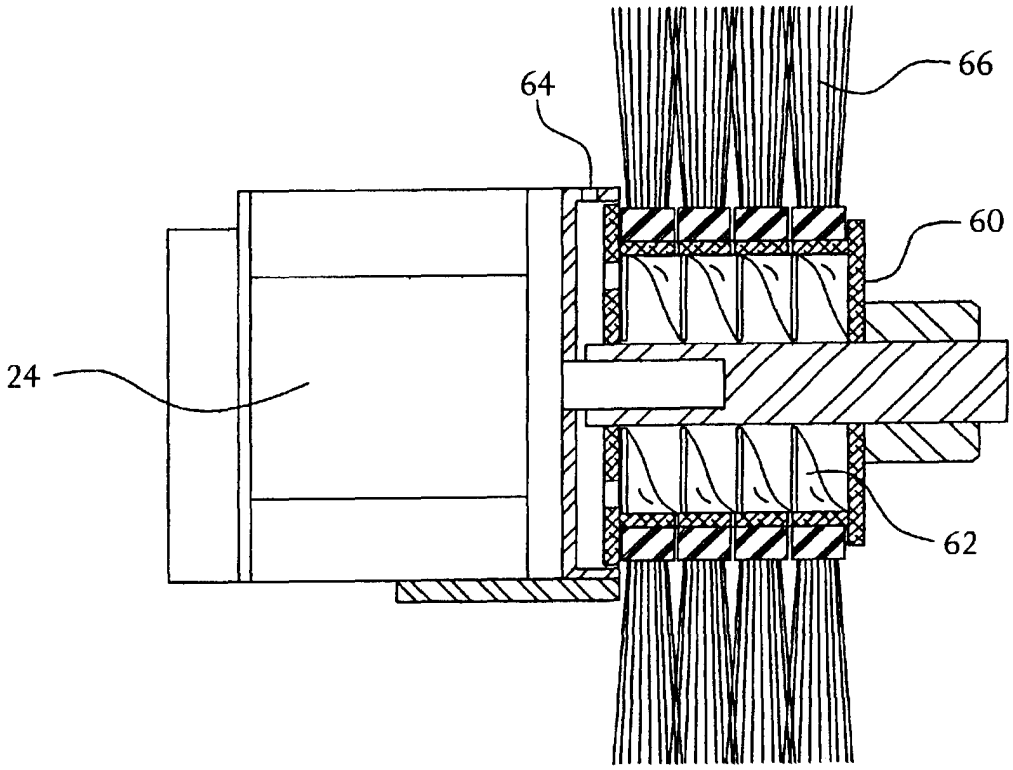


FIG. 4

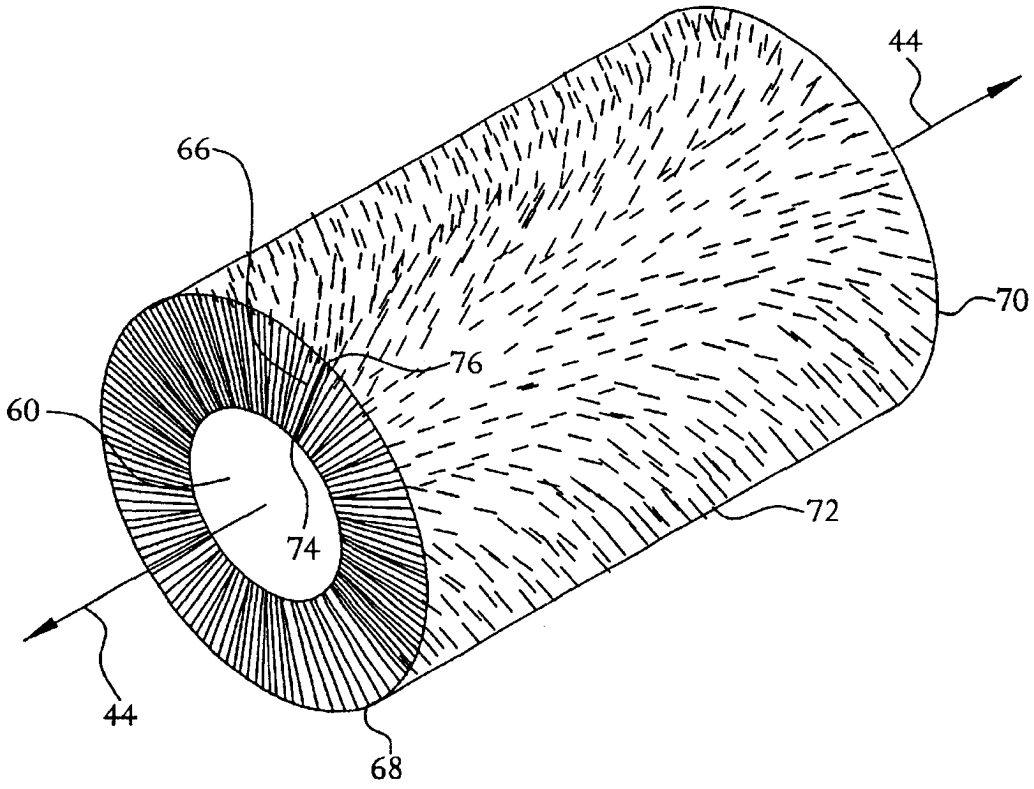


FIG. 5

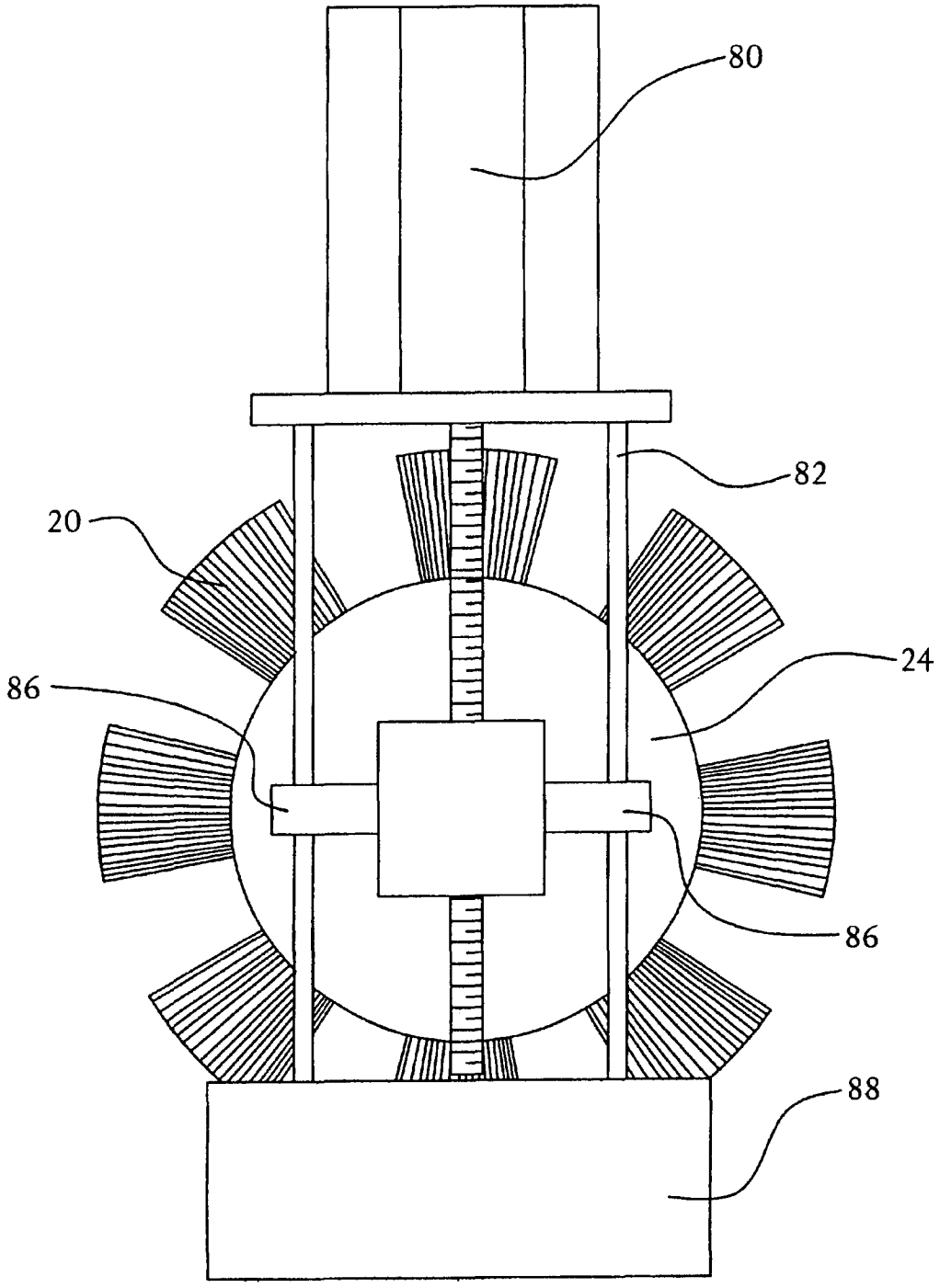


FIG. 6

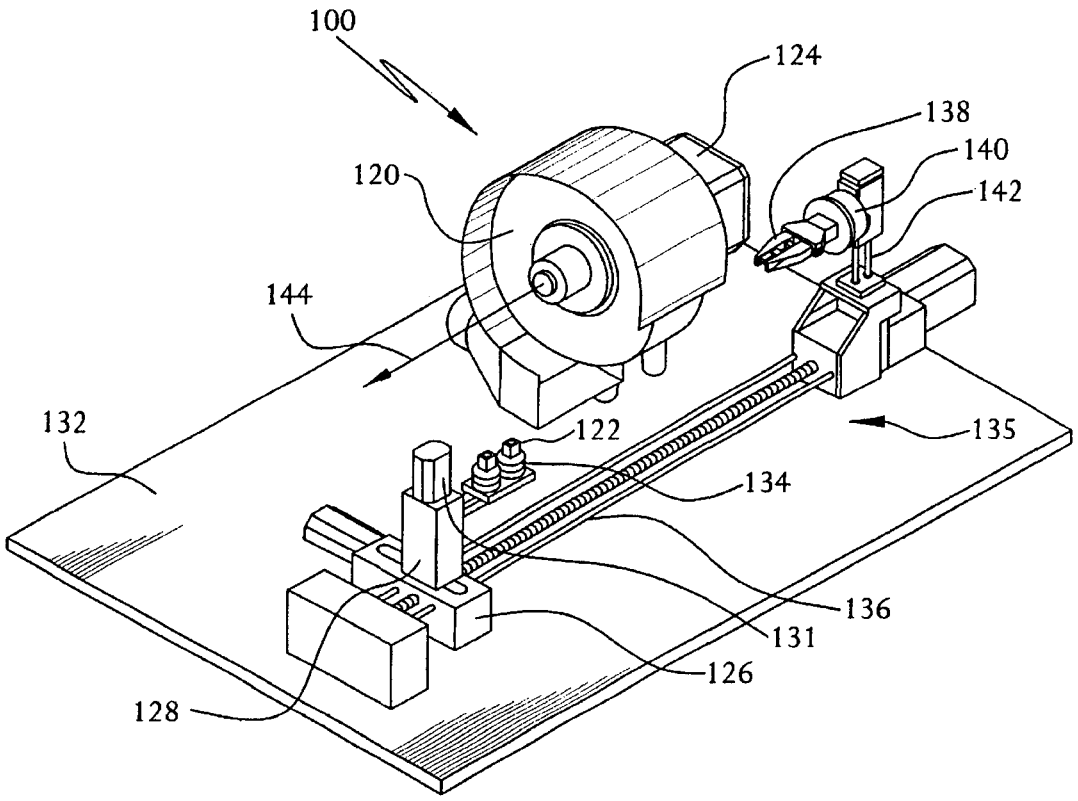
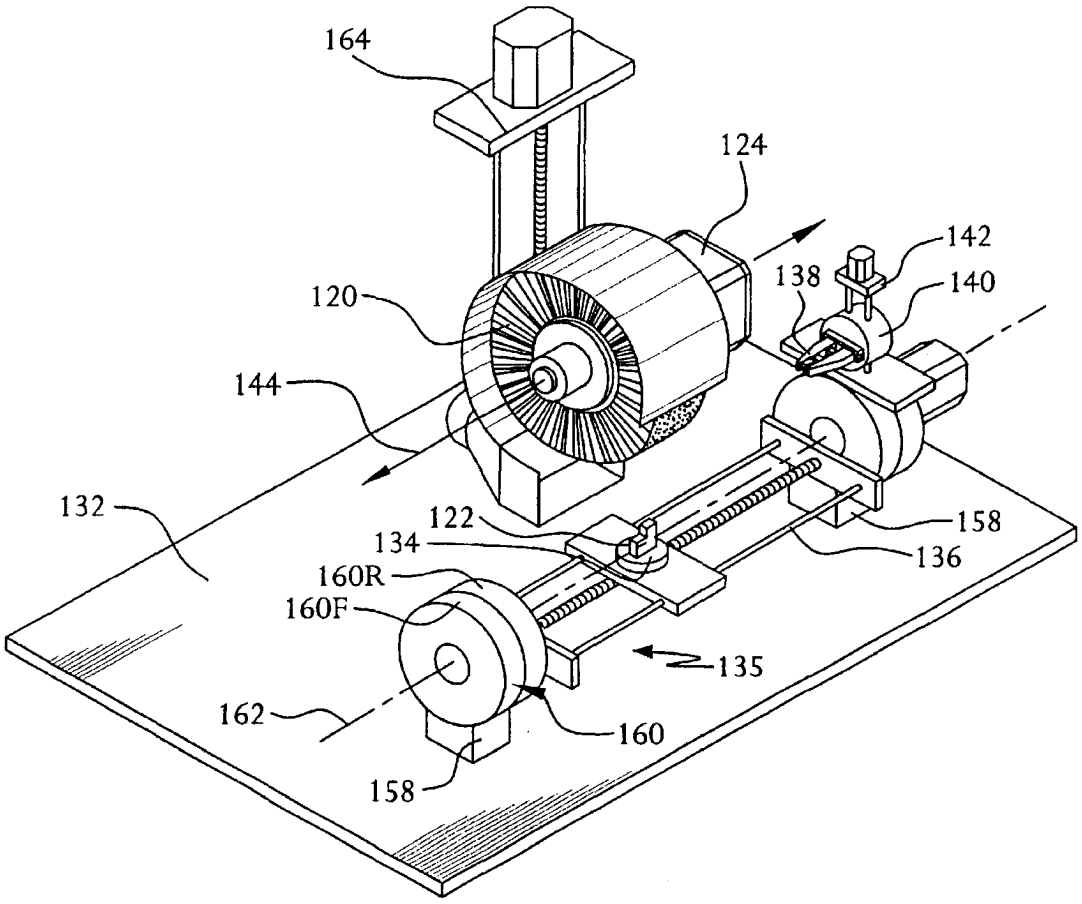


FIG. 7


164
124
142
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160R
160F
135
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160
158

FIG. 8

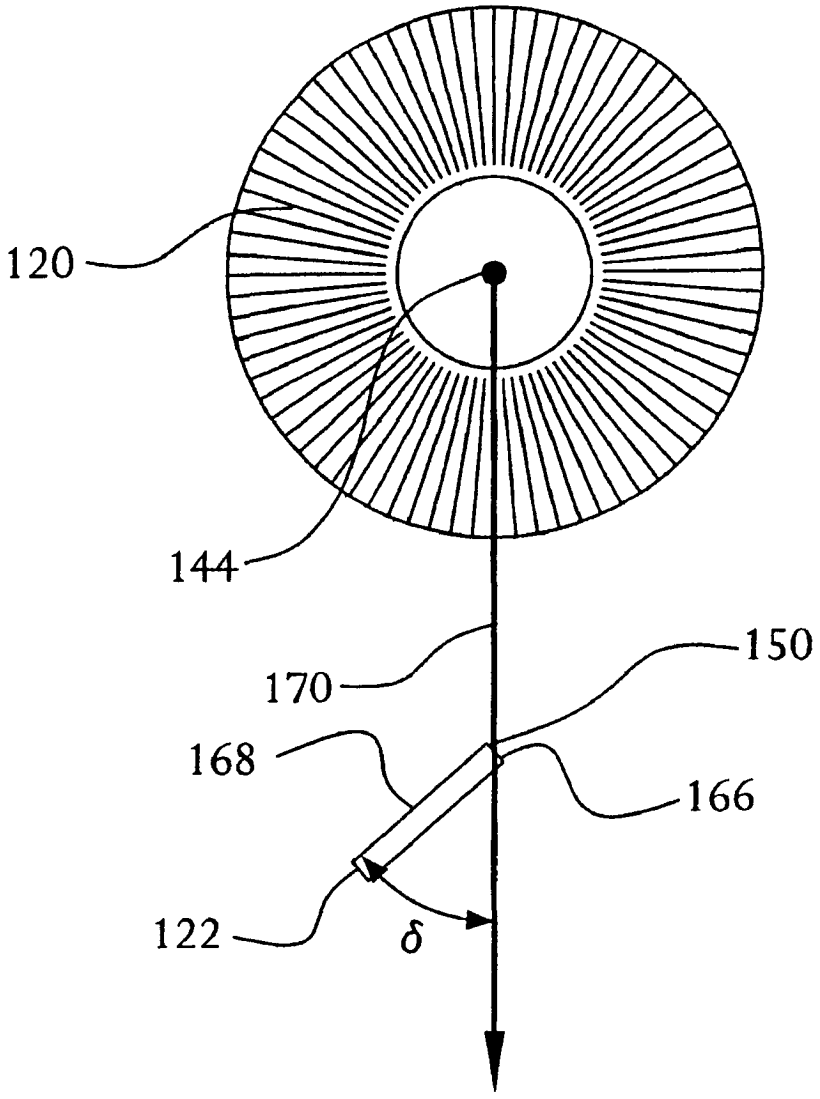

FIG. 9

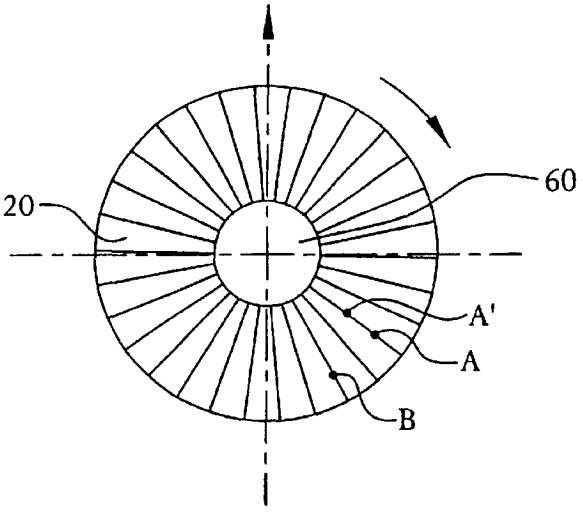

FIG. 10

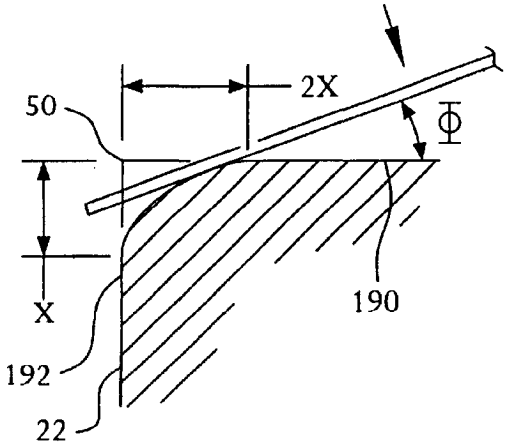

FIG. 11

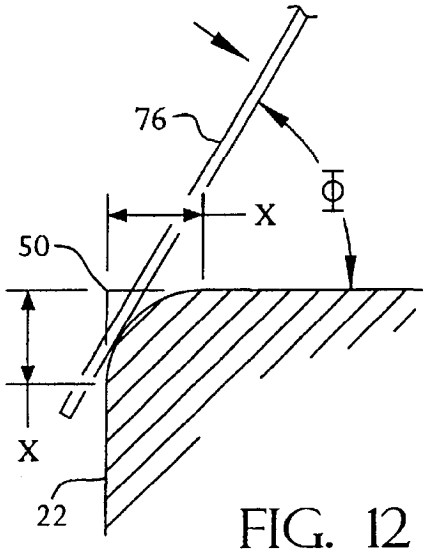

FIG. 12

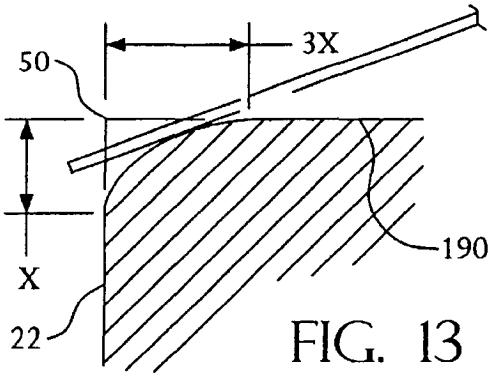

FIG. 13

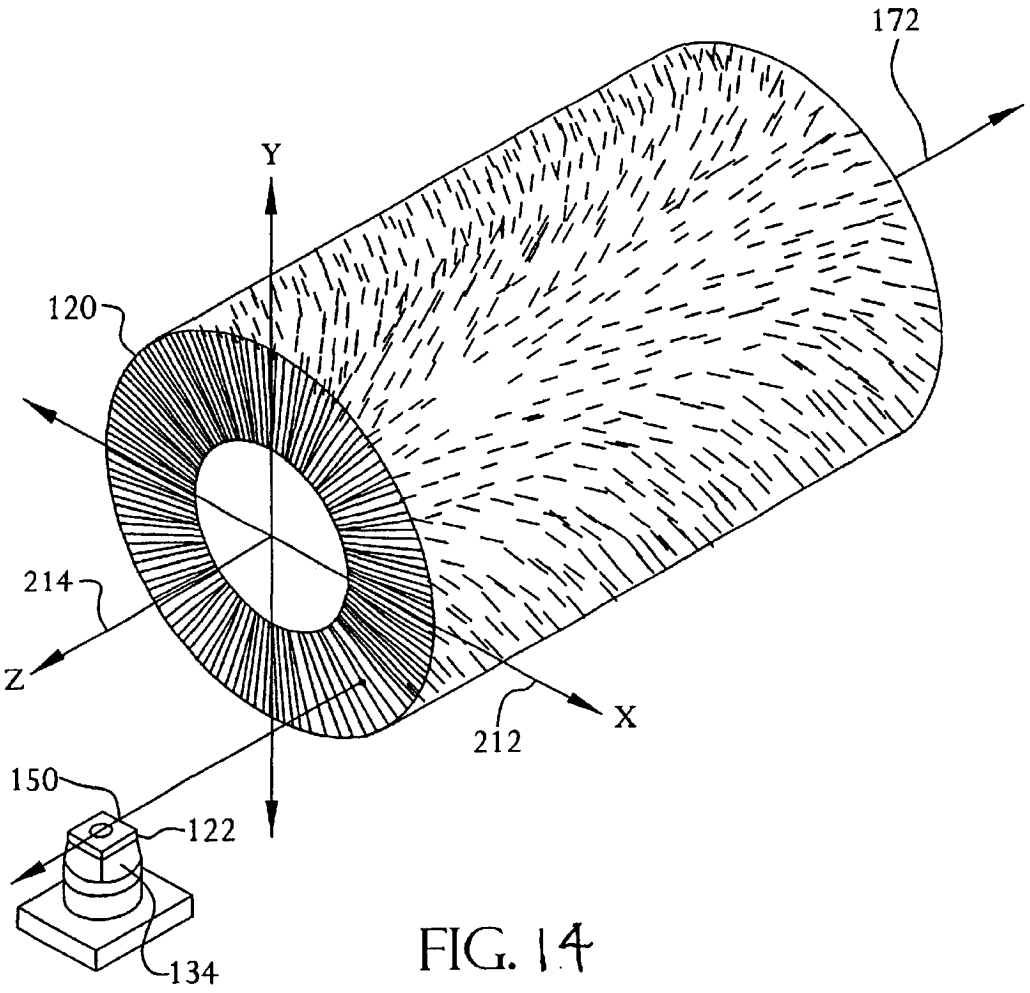

FIG. 14

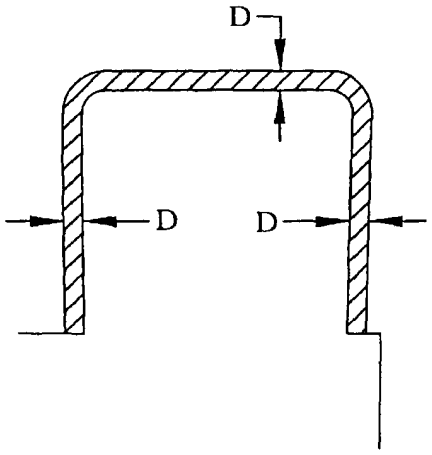

FIG. 15a

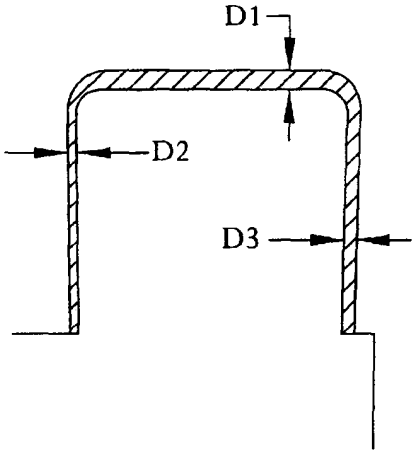

FIG. 15b

METHOD OF AND APPARATUS FOR HIGH TOLERANCE BRUSH HONING

FIELD OF THE INVENTION

The present invention pertains to a method and apparatus for honing precision edges on a workpiece, such as a cutting tool, using an abrasive brush. The invention particularly relates to a process and apparatus for controlling the position of a cutting tool edge relative to an abrasive honing brush in order to provide precise controlled edge honing.

BACKGROUND OF THE INVENTION

Cutting tools for cutting and shaping materials must be very hard to maintain their edges and withstand the high concentrated forces which are present at the cutting edge of the tool. These tools are frequently fabricated from carbide, ceramic, diamond coated carbide, CBN coated carbide or other tool materials which possess the necessary hardness. The disadvantage of using a hard material is that such materials tend to be brittle, and susceptible to crack formation. When cracks form, the material begins to chip, destroying the utility of the tool.

The predominant method of forming carbide edges on cutting tools uses a powder metallurgy process which involves placing powdered materials into a mold, and mechanically compacting them into specific tool geometric forms. The compacted tool form is then densified through a sintering process. The edges created by this process, however, are rough. Rough edges can adversely affect the performance of the tool, by increasing the tendency of the material to crack or chip. Furthermore, forces applied to the rough edge are not evenly distributed but, rather, are concentrated on high points of the edge. The low points of the edge tend to be sharp creating stress concentrations that increase the likelihood of crack formation. The rough edges on cutting tools can be smoothed by honing the edges before the tool is used in a machining process. Honing involves forming a rounded shape on the cutting edge of the tool. Early shapes were directed towards true radii, where the curvature of the smoothed edge was uniform across both surfaces adjacent to the edge.

More recently, edges having varying taper, i.e., non-uniform tapers about the periphery of the edge and generally called waterfall hones (see, FIG. 3*c*). Also, the correct sizing of the edge hone has been shown to affect tool life. As a result, the higher the precision with which the tool edges can be formed, the greater the resultant tool life.

Many different processes were originally used to smooth the edges of a cutting tool, including vibratory honing, mass media honing, slurry honing, honing inserts with media impregnated rubber wheels, dry blasting, wet blasting, and tumbling. These methods have several disadvantages, including intense labor requirements and poor predictability of edge hone characteristics between different tools exposed to the same honing process.

During the late 1970's, a process of honing using a brush having bristles impregnated with abrasive media was developed. In this process, bristles are forced into contact with the edge of the cutting tool. The forced contact results in the removal of material along the edge. Brush honing the cutting tool edges has typically required high brush rotational speeds, resulting in the abrasive bristles striking the cutting tool edge, rather than being dragged across the edge.

In a conventional honing process, the brush is rotated such that the speed of the tips of the brush range from 3,000 to 12,000 feet per minute. In order for these conventional processes to be commercially feasible, a high speed has been necessary in order to hone a sufficient quantity of cutting tools in a short period of time.

The apparatus used in conventional honing processes require the placement of the cutting tools to be honed on a rotating table. As the table rotates, the part is translated along an arcuate path past a rotating abrasive brush. The rotating table allows a continuous honing process to be used, with cutting tools being loaded at one position, honed at a second position, and removed from the table at a third position. The individual cutting tools were rotated as they are passed through the stationary, rotating brush. The circular formation of the table also presents a compact area within which the honing process can be accomplished.

One drawback to the use of a rotary table to feed the cutting tool to the honing brush is that the arcuate path produces an uneven hone on the work piece. More particularly, the arcuate path causes the contact between the tool edge and the honing brush to vary depending on the location of the tool on the path. As such, the resulting hone will vary across the edge of the part making precision honing very difficult.

Another deficiency with the prior methods of honing edges on the cutting tools is that the high bristle speeds result in the generation of excessive heat at the bristle tips. This heat causes the nylon bristles to partially melt, leading to nylon being deposited on the workpiece. The deposited nylon must then be removed before the tool can be coated, adding an additional step to the honing process. Attempts have been made to cool the bristles by using fluid coolants to alleviate or reduce the build up of heat at the bristle tips. The coolant, however, creates a material disposal problem which is not desirable.

Also, conventional processes for honing tool edges do not typically permit variation of the rotational speed of the brush during the honing process. Instead, the speed of the table is normally controlled to vary the amount of material removed from the tool.

The present invention overcomes the disadvantages of the prior art by controlling the contact of the cutting tool edge with the bristles of the abrasive brush so that the cutting tool edge moves through the volume occupied by the bristles. Thus, the material removal action is distributed over a greater portion of the bristle, thereby reducing the build-up of heat in the bristles. The movement of the cutting tool edge into the volume of the bristles further results in a greater material removal rate due to the greater contact between the individual bristles and the cutting tool edge.

SUMMARY OF THE INVENTION

An apparatus is disclosed for honing at least one edge on a workpiece, such as a cutting tool. In one embodiment of the invention, the apparatus includes a base with a variable speed motor mounted on it. An abrasive brush is mounted to the motor and includes a plurality of bristles attached to a hub. The bristles each have a tip end and an interior end, with the interior end being fixed to the hub. The motor is adapted to cause the abrasive brush to rotate about an axis of rotation. The width of the abrasive brush is defined by first and second ends. The combination of the width of the brush and the length of the bristles defines a volume. The honing apparatus also includes a rotational controller means for controlling the rotational speed of the motor.

A mount for holding a workpiece is attached to the base. The mount includes a fixture for holding the workpiece, and

a translational movement mechanism for controlling the position of an edge of the workpiece along a path substantially parallel to the axis of rotation of the abrasive brush.

In another embodiment, the motor is a fixed speed motor and the position of the workpiece edge relative to the abrasive brush is controlled by horizontal and vertical movement mechanisms.

A honing process is also disclosed for controlling the formation of a hone on the edge of a workpiece by controlling the movement and positioning of the workpiece through the volume of the rotating bristles. The movement and position of the workpiece is controlled so as to control the angle of impact between the bristles of the abrasive brush and an edge of the workpiece. The process results in the formation of precise tapered edges on the workpiece edge.

The foregoing and other features and advantages of the present invention will become more apparent in light of the following detailed description of the preferred embodiments thereof, as illustrated in the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of illustrating the invention, the drawings show a form of the invention which is presently preferred. However, it should be understood that this invention is not limited to the precise arrangements and instrumentalities shown in the drawings.

FIG. **1** is a perspective view of an embodiment of a brush honing apparatus according to the present invention.

FIG. **2** is an illustration of several generic cutting tools showing a representative tool edge.

FIGS. **3***a*–**3***c* are partial sectional views of the generic cutting tool of FIG. **2** showing variations in the honing of the edges in more detail.

FIG. **4** is a section view of the motor and abrasive brush.

FIG. **5** is a perspective view of an abrasive brush.

FIG. **6** is a side elevation of a motor and a vertical movement mechanism.

FIG. **7** is a perspective view of an alternate embodiment of the apparatus incorporating horizontal and vertical movement mechanisms into the mount.

FIG. **8** is a perspective view of an alternate embodiment of the apparatus incorporating a distance positioning mechanism into the motor and an orientation mechanism into the mount.

FIG. **9** is a side view of an abrasive brush and a cutting tool identifying an alternate orientation of a cutting tool to an abrasive brush.

FIG. **10** is a side view of an abrasive brush identifying reference points on the first end of the abrasive brush.

FIG. **11** is a side view of a cutting tool and abrasive bristle, showing the relation between the bristle and the cutting tool with the cutting tool inside the brush volume along a path through reference point A in FIG. **10**.

FIG. **12** is a side perspective of a cutting tool and abrasive bristle, showing the relation between the bristle and the cutting tool with the cutting tool inside the brush volume along a path through reference point B in FIG. **10**.

FIG. **13** is a side perspective of a cutting tool and abrasive bristle, showing the relation between the bristle and the cutting tool with the cutting tool inside the brush volume along a path through reference point A' in FIG. **10**.

FIG. **14** is a perspective view of an abrasive brush identifying reference elements of the honing process.

FIGS. **15***a* and **15***b* are cross-sectional illustrations comparing a workpiece with a constant hone and a workpiece with a variable hone.

DESCRIPTION OF THE INVENTION

Referring now to the drawings, wherein like reference numerals illustrate corresponding or similar elements throughout the several views, FIG. **1** is an isometric illustration of one embodiment of a honing apparatus **10** according to the present invention. The apparatus **10** is designed to provide precise honing of an edge of a workpiece **22**. The invention can be used on a wide variety of workpieces which require honing, including components subject to wear, such as seal rings, piston plungers, slitter knives, valve seats, counter-balance weights and carbide or ceramic bushings. The invention has particular use in honing edges of cutting tools, such as drills, end mills, milling inserts, threading tools, burrs, router bits grooving tools, form tools and tools designed to cut materials, such as metal and wood.

The apparatus **10** includes an abrasive brush **20** driven by a motor **24**. The motor **24** is mounted to a base **32**. The workpiece **22** is mounted such that its position relative to the abrasive brush **20** can be controlled to vary the shape of the resulting hone.

Referring to FIGS. **2**, and **3***a*–**3***c*, the workpiece **22** is shown with its edge **50** in an un-honed condition (FIG. **3***a*), with a radius hone **52** (FIG. **3***b*) and a tapered hone, such as the waterfall hone **54** (FIG. **3***c*). In order to form the various hones, the apparatus **10** is configured to control the position of the workpiece edge relative to the abrasive brush. In the embodiment of the invention shown in FIG. **1**, the relative location of the workpiece edge from the abrasive brush is achieved by changing the position of the motor **24** through the use of a horizontal movement mechanism **26** and a vertical movement mechanism **28** as will be discussed in more detail below.

As shown in FIG. **4**, the abrasive brush consists generally of a hub **60** to which a plurality of bristles **66** are attached. The bristles **66** have a tip end and an interior or root end **74**, which is attached to the hub **60**. The hub **60** is designed to removably attach to the motor **24**. As shown in FIG. **5**, the width of the abrasive brush **20** is defined by a first end **68** and a second end **70**, and the radius of the brush is defined by the distance from the bristle tips **76** to the axis of rotation **44** of the brush. As is apparent from the figures, the width of the brush, in combination with the length of the bristles **66**, defines a volume **72** which is illustrated and preferably in the form of a right cylinder. Although the present embodiment shows the abrasive brush **20** having bristles **66** fully surrounding the hub, the bristles **66** may be located in discrete rows along the hub, with spaces between the rows, as shown in FIG. **6**, or other patterns which do not completely fill the volume **72**. The preferred diameter for the abrasive brush is approximately 14 inches.

As described above, during operation, the contact between the bristles of the brush and a workpiece causes the bristles to heat up. In order to reduce the temperature of the bristles **66**, one embodiment of the present invention incorporates an impeller **62** in the hub that has a series of vanes designed to draw air into the hub **60** through an air intake **64**. The impeller **66** forces the air out through the bristles **66** of the abrasive brush **20**, thereby reducing their temperature.

In order to control the rate of material removal, the present invention preferably incorporates a means for controlling the speed of the abrasive brush. Referring to FIG. **4**, in one embodiment, the motor **24** that drives the abrasive brush **20** is a variable speed motor. This permits that rate of material removal to be varied depending on the workpiece and/or material being honed. Alternatively, a transmission (not shown) could be interposed between a fixed speed

motor **24** and the abrasive brush, allowing variation of the rotational speed of the abrasive brush. A continuously variable transmission (CVT) would be a preferable transmission if a fixed speed motor were to be used.

The abrasive brush **20** is preferably rotated within a speed range which yields a linear speed of 180 to 1800 feet per minute at the tips of the bristles. The linear speed of the bristles tips can be calculated by multiplying the diameter of the abrasive brush times the rotational speed of the abrasive brush times π. As is obvious to one of skill in the art, the motor rotational speed does not need to be equal to the desired rotational speed of the abrasive brush, since gears or pulleys may be used between the motor and the abrasive brush to create non-unitary ratios of the rotational speed of the motor to the rotational speed of the abrasive brush.

The present invention also incorporates a controller **200** to allow an operator of the apparatus or a software program to control the rotational speed of the abrasive brush. The speed can be controlled depending on the desired hone, the location of the workpiece within the brush, and/or the type of material being honed. The controller **200** can be a conventional motor speed controller of a type dependent on whether the motor uses alternating current or direct current. If a CVT is used to vary the speed of the brush, the controller **200** could also be used to control the CVT.

The honing apparatus **10** also includes a mount **35** for positioning and moving the workpiece relative to the abrasive brush **20**. The mount includes a translational movement mechanism or translator **30** for moving the workpiece **22** along a linear path parallel to the axis of rotation **44** of the abrasive brush. It has been determined that linear translation of the workpiece through the abrasive brush produces a consistent and precise hone on the workpiece. The translational movement mechanism **30** is slidably attached to a guide **36** that preferably extends along a linear path parallel to the rotational axis of the abrasive brush **20**. The workpiece is held within a fixture **34** attached to the translational movement mechanism **30**. The translational movement mechanism preferably is driven along the guide **36** by a motor-driven screw drive. It is contemplated, however, that other drive systems can be substituted for the preferred screw-drive without detracting from the invention.

The present invention also preferably incorporates a controller (such as controller **200** discussed above) which includes a process control software program to accurately control movement of the workpiece on the translational movement mechanism with respect to the abrasive brush. For example, the controller **200** can be programmed to control the translational movement mechanism such that the workpiece moves in the forward direction through the abrasive brush, the reverse direction through the abrasive brush **20**, is stopped within the rotating abrasive brush, or oscillates in the forward and reverse directions within the abrasive brush. Those skilled in the art would readily be capable of making such a substitution.

In one embodiment of the invention, the fixture **34** that holds the workpiece **22** is attached to a rotating base **33**. The rotating base **33** is, in turn, attached to a positioning motor **37**, either directly or indirectly, through a transmission or direct drive. The positioning motor **37** positions or rotates the fixture **34** containing the workpiece while the translational movement mechanism **30** moves the workpiece **22** through the rotating abrasive brush **20**. A controller, such as controller **200**, controls the positioning motor **37** to vary the rotation of the fixture **34** in accordance with a predetermined program, such as a numerical control program, which accurately rotates, positions or stops the rotation of the positioning motor **37**. Alternately, the controller permits an operator to provide positioning commands to the motor **37**.

As shown in FIG. **1**, a vertical movement mechanism **28** is employed which adjusts the vertical position of the motor **20** relative to the base. In one embodiment, the vertical movement mechanism **28** includes a screw driven actuator that is controlled either manually, as by a handle **46** (FIG. 1), or by a control motor **80** (FIG. **6**). If a control motor **80** is utilized, the motor **24** is preferably engaged to one or more guide rails **84** through linear bearings **86**. A screw **82** turned by the control motor **80** passes through a threaded fitting on the motor **24**, such that rotation of the screw **82** causes the motor **24** to move up or down. It is contemplated that the movement of the motor **24** and abrasive brush **20** may be preprogrammed into a computer or other control device (such as the controller **200**) to provide automated and repeatable workpiece honing.

The embodiment of the invention shown in FIG. **1** also preferably includes a horizontal movement mechanism **26** for moving the motor **24** and abrasive brush **26** relative to the base **32**. Similar to the vertical movement mechanism **28**, the horizontal movement mechanism **26** preferably uses a screw drive to control the position of the motor **24** relative to the workpiece. The screw drive may be controlled by a handle **46** or a control motor system as discussed above.

It is contemplated that the apparatus **10** may include a device for inverting workpieces **22** after they have been honed. A suitable inverting device **39** is shown in FIG. **1** and includes a parallel gripper **38** which is adapted to pick up workpieces from and place workpieces on the fixture **34**. A vertical actuator **42** is attached to the mount **36** and raises and lowers the gripper **38**. A rotary actuator **40** attaches the gripper **38** to the vertical actuator **42**. The rotary actuator **40** is designed to rotate the gripper **38** up to 180 degrees about a horizontal axis for inverting the workpiece **22**.

In operation, after the workpiece passes through the abrasive bristles **66**, the gripper **38** grabs the workpiece. The gripper **38** is then translated upward and rotated a suitable amount to position another edge in an appropriate position for honing. The gripper **38** is then lowered until the workpiece is again placed in the fixture.

An alternate embodiment of the invention is shown in FIG. **7**. In this embodiment, instead of the motor **24** and abrasive brush **26** being vertically and horizontally adjustable with respect to the workpiece, the workpiece is mounted such that it can be appropriately positioned relative to a fixed abrasive brush **120**. Preferably, one or more control motors are used to position the workpiece **122** horizontally and vertically relative to the abrasive brush **120**. Alternatively, manual handles can also be used, similar to the handles described in the previous embodiment.

More particularly, in this embodiment, a vertical movement mechanism **131**, preferably attached to the mount **135**, moves the fixture **134** vertically relative to the base **132**. A horizontal movement mechanism **128** is also preferably engaged with the mount **135** and is designed to move the fixture **134** horizontally toward and away from the abrasive brush (i.e., substantially parallel to the base **132**). A translational movement mechanism **126** moves the workpiece **122**, fixture **134**, vertical movement mechanism **131**, and horizontal movement mechanism **128** along guides **136** which preferably define a linear path parallel to the axis of rotation **144** of the abrasive brush **120**. As with the previous embodiment, a rotating base and positioning motor can be incorporated to rotate the fixture and/or workpiece. As

shown, an inverting device, including a parallel gripper **138**, a rotary actuator **140**, and a vertical actuator **142**, can be incorporated for inverting the workpiece after honing, as discussed above.

A further embodiment of the invention is shown in FIG. **8**. In this embodiment, a mechanism for controlling the distance between the workpiece edge **50** and the axis of rotation **144** of the abrasive brush **120** is incorporated into the apparatus **10**. Referring to FIG. **9**, the position of the workpiece edge **150** relative to the abrasive brush **120** is shown. The orientation of the workpiece edge **50** is defined by the angle δ between a side surface **168** of the workpiece **122** and a radial line **170** extending from the axis of rotation **144** of the abrasive brush **120** through the workpiece edge **150**. Rotation of the workpiece **122** about the workpiece edge **150** causes the point of contact between the bristles **166** and a top surface **166** and the side surface **168** of the workpiece **122** to vary, thereby controlling the resulting shape of the hone.

Referring back to FIG. **8**, an orientation actuator **160** is used to control the orientation of the workpiece (e.g., cutting tool) with respect to the abrasive brush **120**. The orientation actuator **160** includes a fixed portion **160**F and a rotary portion **160**R. The fixed portion **160**F is mounted to the base **132**. The rotary portion **160**R is rotatably engaged to the fixed portion **160**F. The guides **136** are attached to the rotary portion **160**R. The fixture **134**, which holds the work piece **122**, is slidably attached to the guides **130**. In order to rotate the workpiece, the orientation actuator **160** is controlled (e.g., via a controller, such as controller **200** in FIG. **1**) so as to rotate the rotary portion **160**R. This, in turn, causes the guides **136** and the fixture **134** to rotate about an orientation axis of rotation **162**. Depending on the location of the guides **136**, fixture **134** and workpiece **122**, the orientation axis may lie along the workpiece edge **150**. Rotation of the workpiece **122** about this axis changes the angle δ between the side surface **168** and the radial line **170**. As such, the point on the workpiece edge **122** that contacts the abrasive brush **120** will vary.

In this embodiment of the invention, the vertical position of the abrasive brush **120** is controlled by a distance positioning mechanism **164** which increases or decreases the distance between the axis of rotation **144** of the abrasive brush **120** and the workpiece edge **150**. Alternatively, the fixture **134** can be vertically translated or rotated relative to the abrasive brush **120** in a manner similar to the various embodiments described above. As with the above embodiments, an inverting device can be incorporated into the apparatus to invert the workpiece.

The apparatus described in the various embodiments above is useful for honing precise edges on work pieces. The process for honing those edges will now be described in detail. One feature of the process according to the instant invention is the placement of the workpiece edge to be honed at a specific location within the volume of the bristles of the abrasive brush. This proper positioning, in combination with the operation of the abrasive brush at a preferred rotational speed, permits high precision workpiece edge honing.

FIG. **10** illustrates a cross-sectional schematic of an abrasive brush **20**. As discussed in detail above, the present invention permits the workpiece edge **22** to be precisely located within the volume of the bristles. Various paths through the bristle volume **72** are shown in FIG. **10**, each of which produces a different hone on the workpiece. At position A, assuming that the workpiece is oriented such that its top surface is parallel to the x-axis in the figure, a contact angle Φ between individual bristles **66** and the top surface **190** of the workpiece is relatively shallow (see, FIG. **11**). This shallow contact angle results in more material being removed from the top surface **190** then the side surface **192**, producing a waterfall hone (shown by the dashed lines) on the workpiece edge.

If the workpiece were located at position B, an approximately even amount of material would be removed on the top and side surfaces **190, 192** by the bristles. This results in a radiused hone.

Referring to FIG. **14**, the process according to the present invention involves first placing the workpiece **122** into the fixture **134**. The fixture **134** is then positioned relative to the abrasive brush **120** such that the workpiece edge **150** to be honed is located along a desired path **216** through the volume **172** of the abrasive brush. The location of this path in the volume **172** will depend on the desired hone shape as discussed above. The path **216** of translation through the bristle volume **172** is substantially parallel to the axis of rotation **214** of the abrasive brush. After proper positioning of the workpiece edge **150**, the fixture **134** is translated through the volume **172**.

Once the workpiece edge has passed through the bristle volume **172**, an inverting device can be utilized to reposition the workpiece in the fixture **134** to permit a different edge **50** to be processed. For example, since cutting tools typically have cutting edges on opposed sides of the tool, the parallel gripper **38** is rotated 180 degrees before the workpiece is returned to the fixture **134**. With the new edge positioned relative to the abrasive brush **20**, the fixture is translated back through the bristles of the abrasive brush **20**. If a different hone shape is desired on the new edge, the fixture can be repositioned relative to the abrasive brush prior to translation.

It is contemplated that the position and orientation of the work piece within the volume of bristles and the speed of rotation of the abrasive brush can be altered during translation (i. e., while the work piece is within the volume). This allows for the formation of a complex honed edge on the work piece and allows controlled variation of the hone along the workpiece edge. For example, in forming a threading tool, the hone on the thread forming edge can be intentionally varied from the tip end of the tool to the base of the tool. At the tip end, it may be desirable to have a larger hone to permit the thread forming edge, when in use, to dig through the raw material. Conversely, at the base of the thread forming edge it may be desirable to have a sharper hone to permit more precise finishing of the threads in the material. The present invention allows such precise hone control over the finished workpiece.

Another example of the use of the present invention for providing controller hone variation is shown in FIGS. **15***a* and **15***b*. FIG. **15***a* is a cross-sectional illustration of a grooving tool with a constant hone (designated "D" on all three sides). FIG. **15***b* is a cross-sectional illustration of a grooving tool with a controlled variable hone. As shown, the hone on the top (designated "D1") is greater than the hones on the sides (designated "D2" and "D3").

The various positioning mechanisms discussed above allow complex workpiece edges to be precisely honed. The use of a controller in the present invention allows the honing process to be programmed and automated to ensure repeatability.

Although the invention has been described and illustrated with respect to the exemplary embodiments thereof, it

should be understood by those skilled in the art that the foregoing and various other changes, omissions and additions may be made therein and thereto, without parting from the spirit and scope of the present invention.

What is claimed is:

1. A process for honing at least one edge on a workpiece comprising the steps of:

placing a workpiece in a fixture;

rotating an abrasive brush about an axis of rotation, the abrasive brush including a plurality of abrasive bristles which define a volume;

positioning the workpiece edge relative to the axis of rotation of the abrasive brush such that the workpiece edge to be honed is substantially parallel to the axis of rotation;

positioning the workpiece edge to be honed at a circumferential location relative to the axis of rotation of the abrasive brush, the circumferential position being selected to provide a desired hone shape;

positioning the workpiece edge to be honed at a radial distance from the axis of rotation of the abrasive brush, the distance being less than the radial length of the bristles of the abrasive brush; and

translating the workpiece along a path substantially parallel to the axis of rotation of the abrasive brush such that the workpiece edge passes through at least a portion of the volume of the abrasive brush.

2. The process of claim 1, further comprising the steps of:

re-orienting the workpiece relative to the abrasive brush to position a second workpiece edge to be honed substantially parallel to the axis of rotation after the workpiece has been translated through at least a portion of the volume of the abrasive brush;

positioning the workpiece edge relative to the axis of rotation of the abrasive brush such that the workpiece edge to be honed is substantially parallel to the axis of rotation;

positioning the workpiece edge to be honed at a circumferential location relative to the axis of rotation of the abrasive brush, the circumferential position being selected to provide a desired hone shape;

positioning the workpiece edge to be honed at a radial distance from the axis of rotation of the abrasive brush, the distance being less than the radial length of the bristles of the abrasive brush; and

translating the workpiece along a path substantially parallel to the axis of rotation of the abrasive brush such that the workpiece edge again passes through at least a portion of the volume of the abrasive brush.

3. A process according to claim 1 further comprising the step of adjusting the rotational speed of the abrasive brush to remove a sufficient amount of material from the workpiece to achieve the intended hone shape.

4. A process for honing at least one edge on a workpiece comprising the steps of:

placing a workpiece in a fixture;

rotating an abrasive brush about a rotational axis, the abrasive brush including a plurality of abrasive bristles which define a volume;

adjusting the position of the workpiece edge relative to the axis of rotation of the abrasive brush such that at least a portion of the workpiece edge to be honed is substantially parallel to the axis of rotation of the abrasive brush and in the proper position to be honed;

translating the workpiece along a path substantially parallel to the axis of rotation of the abrasive brush such that the workpiece edge passes through at least a portion of the volume of the abrasive brush.

5. A process according to claim 4 wherein the step of adjusting the position of the workpiece edge relative to the axis of rotation of the brush involves the steps of:

adjusting the vertical distance between the workpiece edge and the axis of rotation of the abrasive brush; and

adjusting the horizontal distance between the workpiece edge and the axis of rotation of the abrasive brush.

6. A process according to claim 5 wherein the step of adjusting the vertical distance involves adjusting the vertical position of the abrasive brush relative to the workpiece; and wherein the step of adjusting the horizontal distance includes moving the abrasive brush relative to the workpiece.

7. A process according to claim 5 wherein the step of adjusting the vertical distance involves adjusting the vertical position of the workpiece relative to the brush; and wherein the step of adjusting the horizontal distance includes moving the workpiece relative to the brush.

8. A process according to claim 5 wherein the step of adjusting the position of the workpiece edge relative to the axis of rotation of the brush involves the step of rotating the workpiece relative to the path substantially parallel to the axis of rotation of the abrasive brush.

9. A process according to claim 4 further comprising the step of rotating the workpiece about a vertical axis.

10. A process according to claim 4 further comprising the step of rotating the workpiece during translation through the bristles to control the resulting hone formed on the workpiece edge.

11. A process according to claim 4 wherein the step of adjusting the position of the abrasive brush selectively occurs before, during or after translation of the workpiece.

12. A process according to claim 4 further comprising the step of adjusting the speed of rotation of the abrasive brush selectably before, during or after translation of the workpiece.

* * * * *

EXHIBIT "B"

US006669531B1

(12) **United States Patent**
Shaffer

(10) **Patent No.: US 6,669,531 B1**
(45) **Date of Patent: Dec. 30, 2003**

(54) **APPARATUS FOR HIGH TOLERANCE BRUSH HONING**

(75) Inventor: **William R. Shaffer**, Greensburg, PA (US)

(73) Assignee: **Conicity Technologies, LLC**, Cresco, PA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 206 days.

(21) Appl. No.: **09/828,653**

(22) Filed: **Apr. 6, 2001**

Related U.S. Application Data

(62) Division of application No. 09/428,726, filed on Oct. 28, 1999, now Pat. No. 6,287,177.

(51) **Int. Cl.**[7] **B24B 3/02**

(52) **U.S. Cl.** **451/5**; 451/10; 451/11; 451/916; 451/466; 451/45

(58) **Field of Search** 451/466, 45, 489, 451/916, 5, 9, 10, 11; 408/18, 45; 409/66

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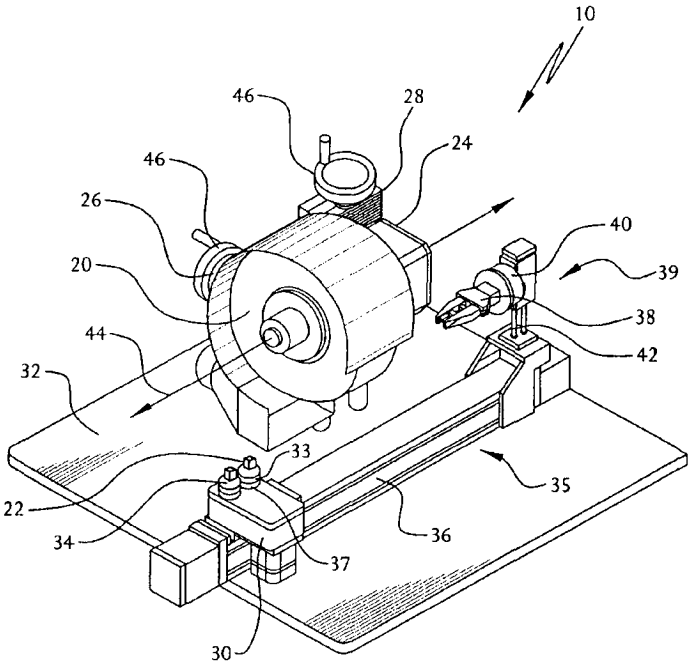
Primary Examiner—George Nguyen
(74) *Attorney, Agent, or Firm*—Drinker Biddle & Reath LLP

(57) **ABSTRACT**

The present invention relates to a honing method and apparatus which provides greater control over the edge shape, as well as reductions in the effort required to hone multiple edges on workpieces. The invention accomplishes these improvements by controlling the speed of the abrasive wheel, as well as the orientation and position of the workpiece prior to and/or while it is in contact with the abrasive brush. This provides for greater control over the hone shape, hone size, and hone distribution along all the cutting edges of the tool.

16 Claims, 12 Drawing Sheets



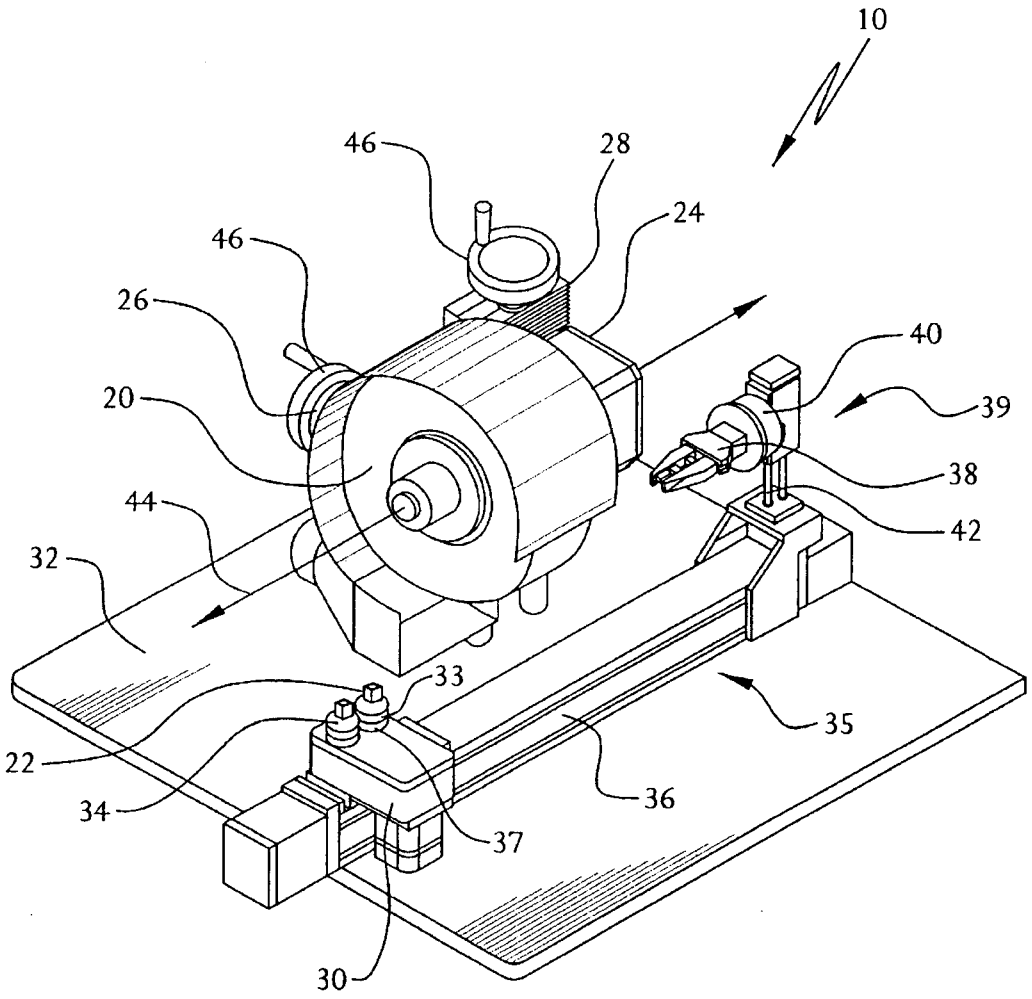


FIG. 1

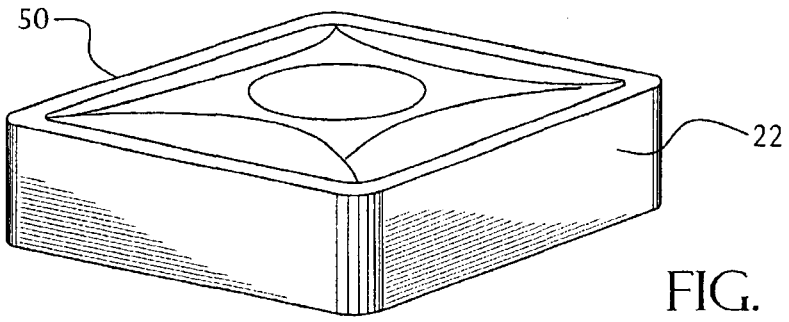


FIG. 2a

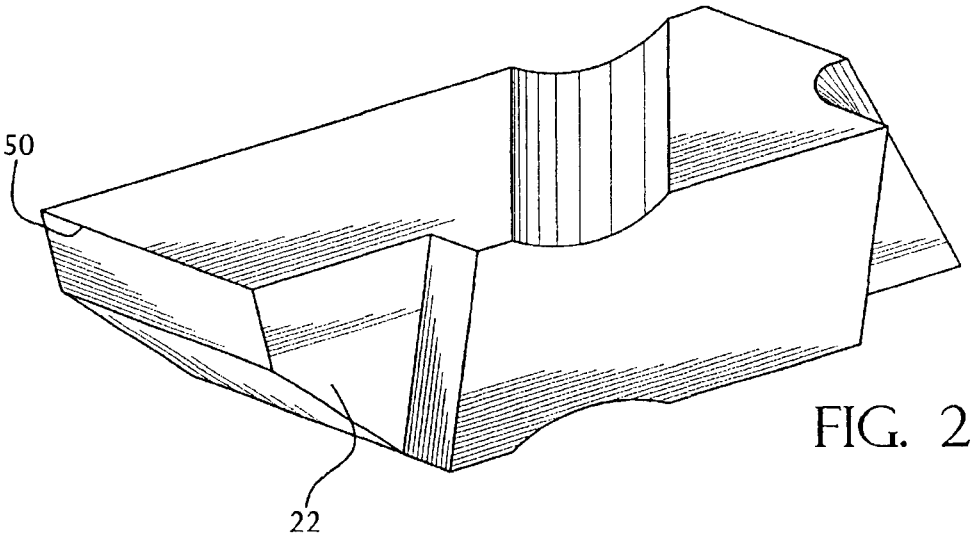


FIG. 2b

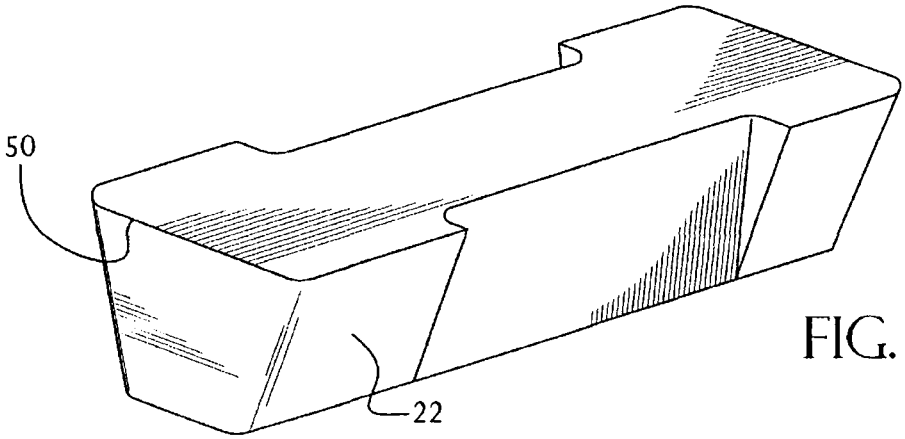


FIG. 2c

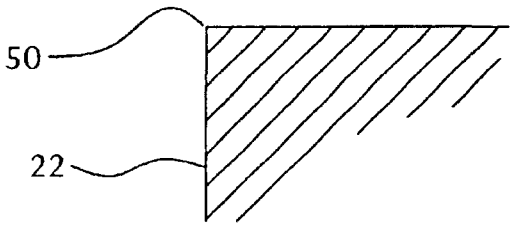


FIG. 3a

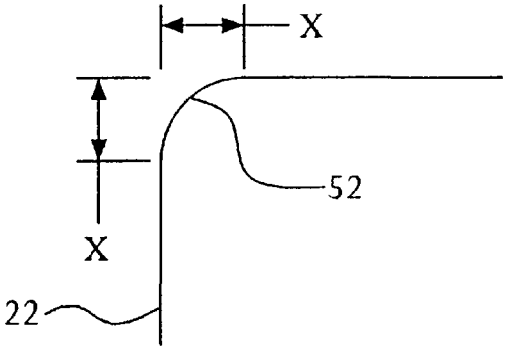


FIG. 3b

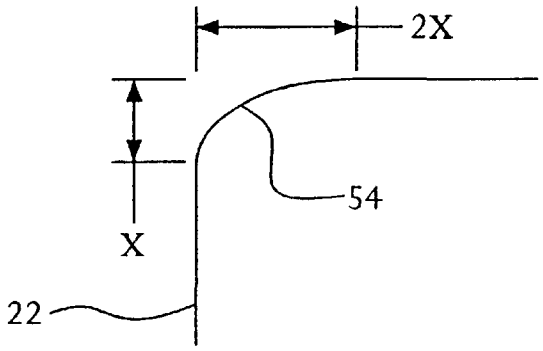


FIG. 3c

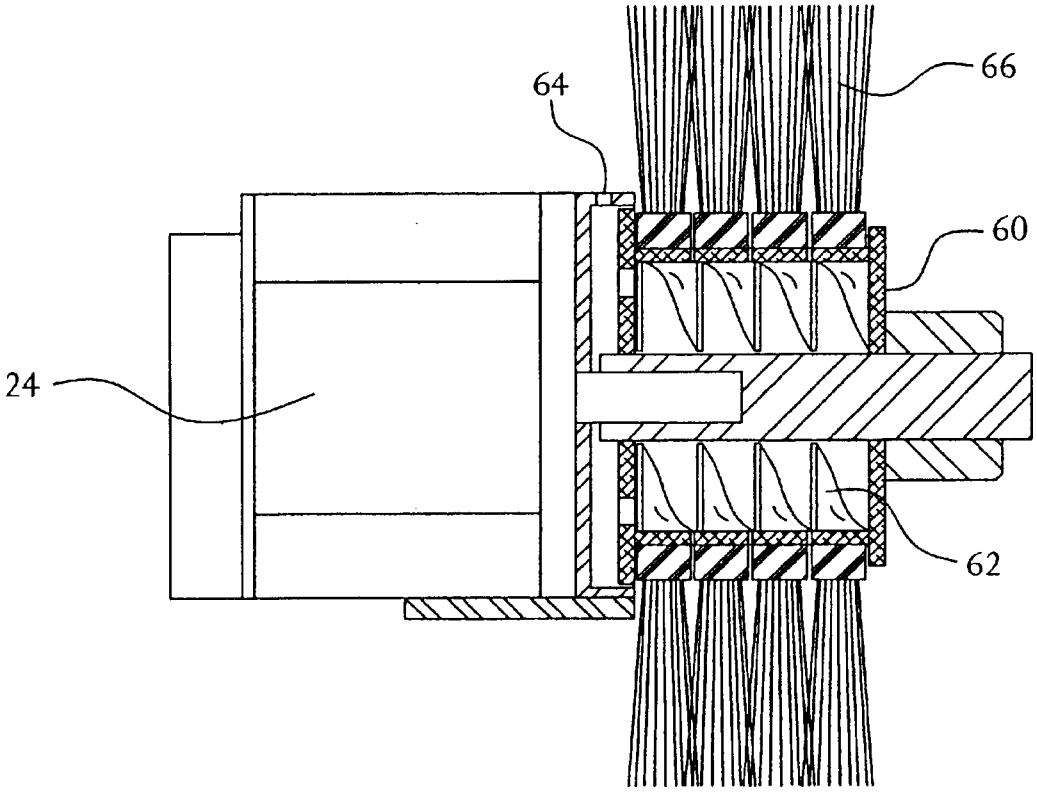


FIG. 4

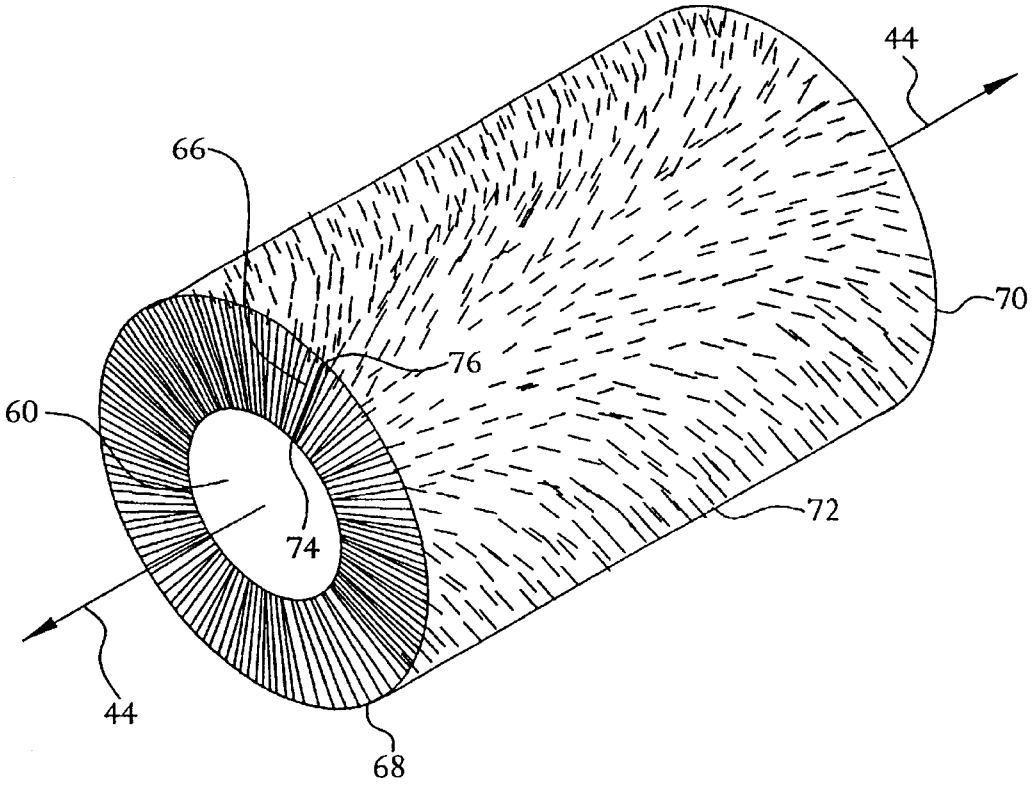


FIG. 5

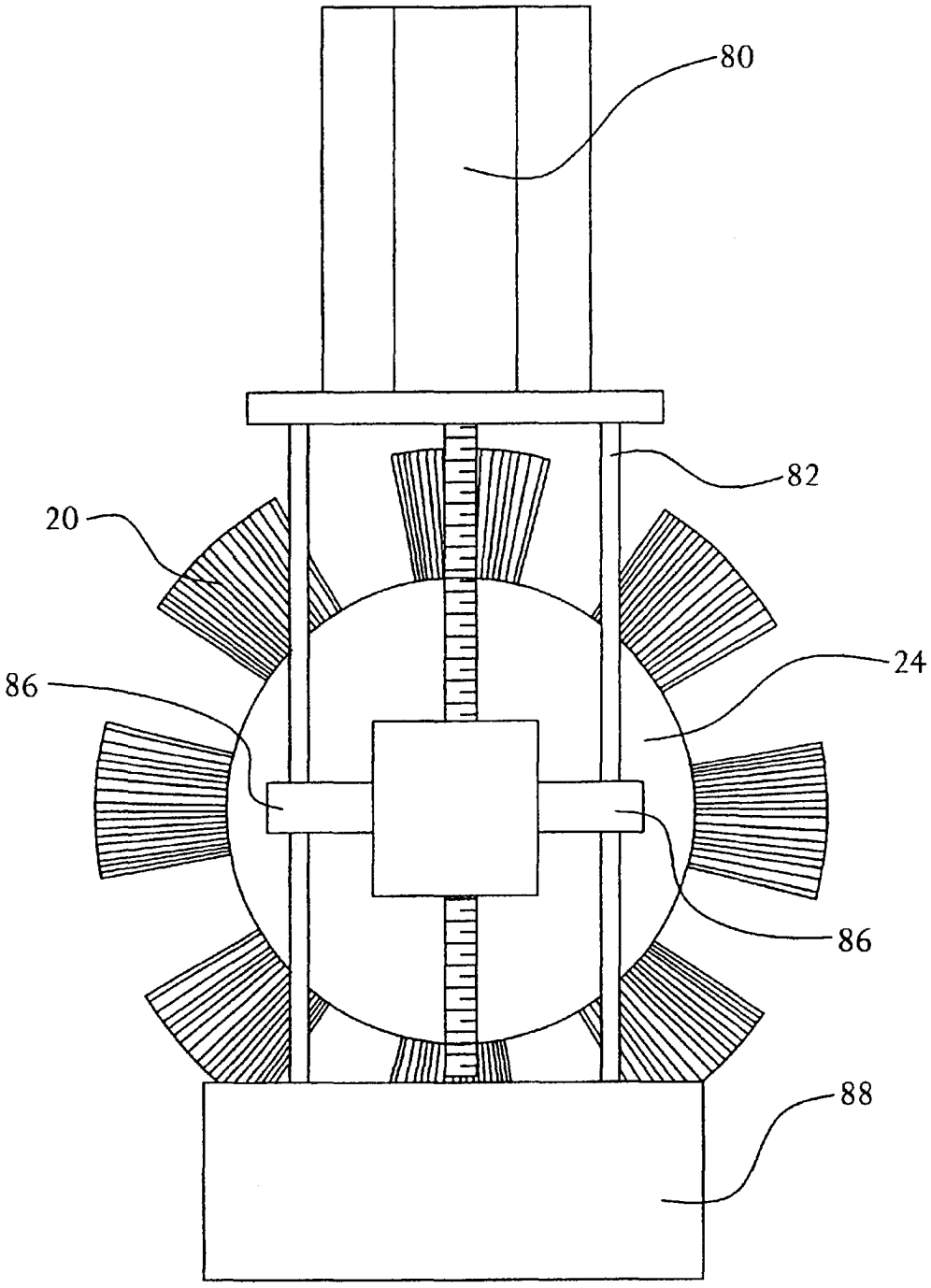


FIG. 6

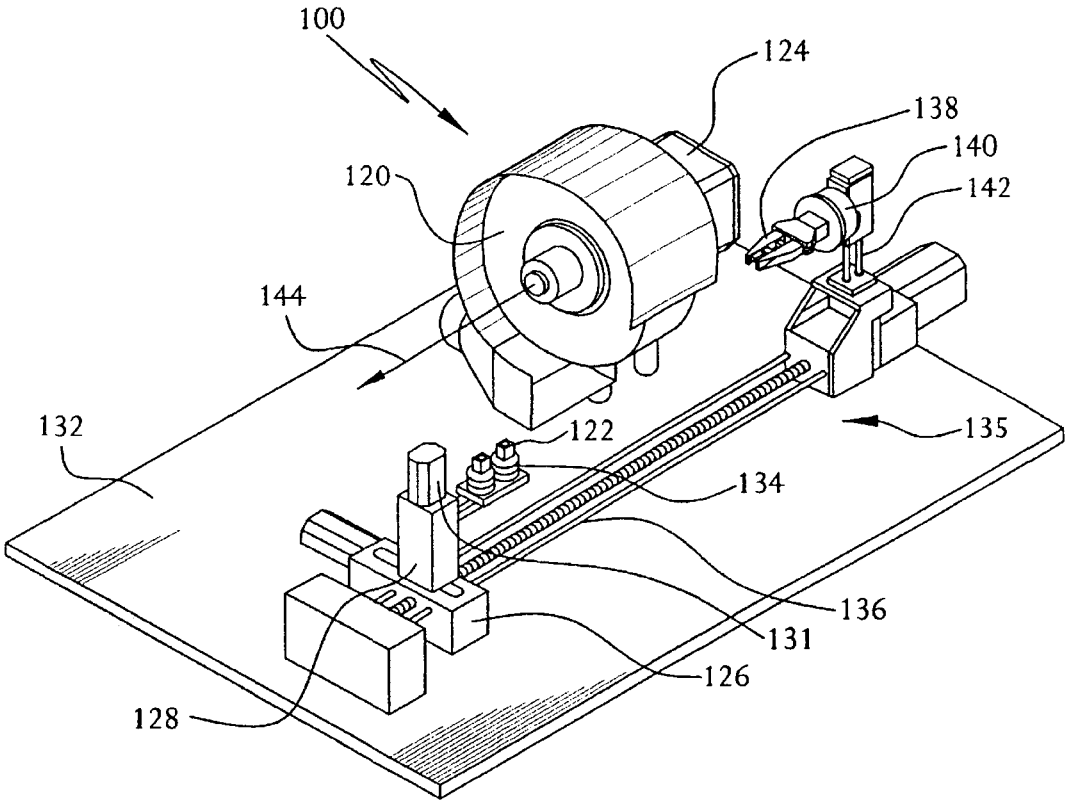


FIG. 7

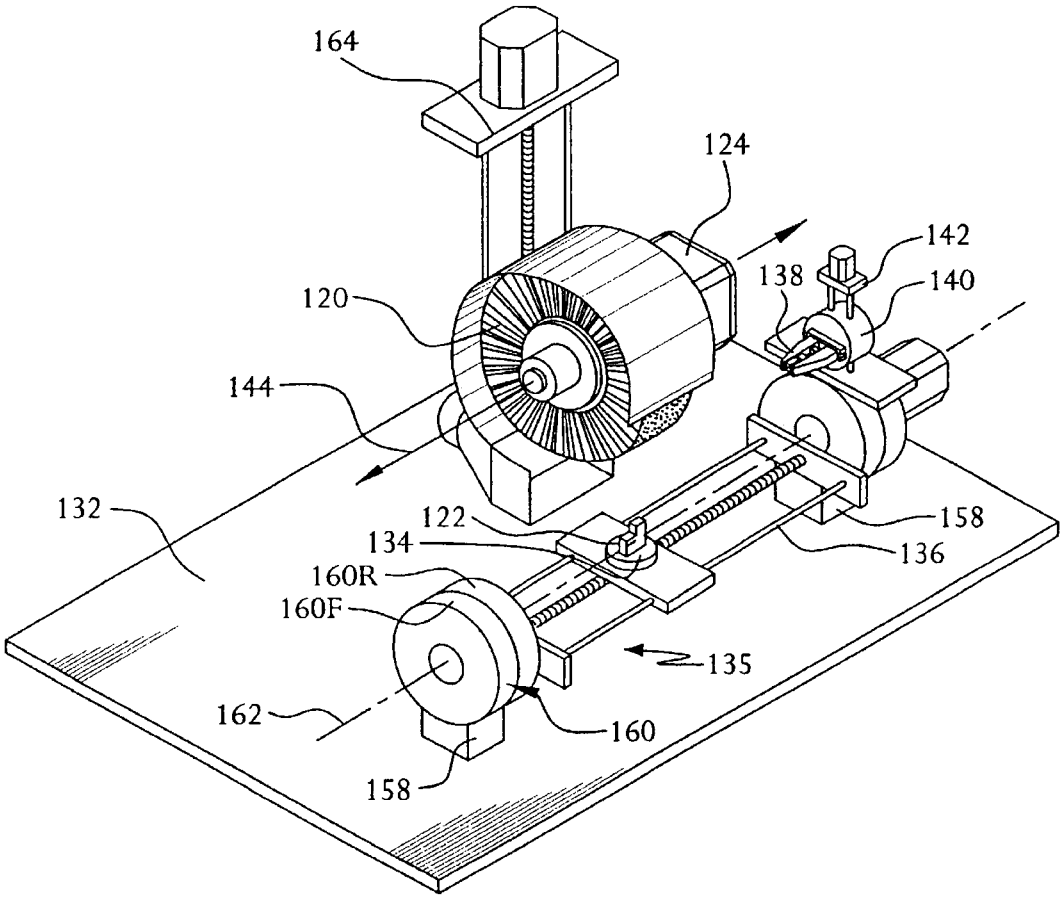

164
124
142
138
140
120
144
132
122
158
134
136
160R
160F
135
162
160
158

FIG. 8

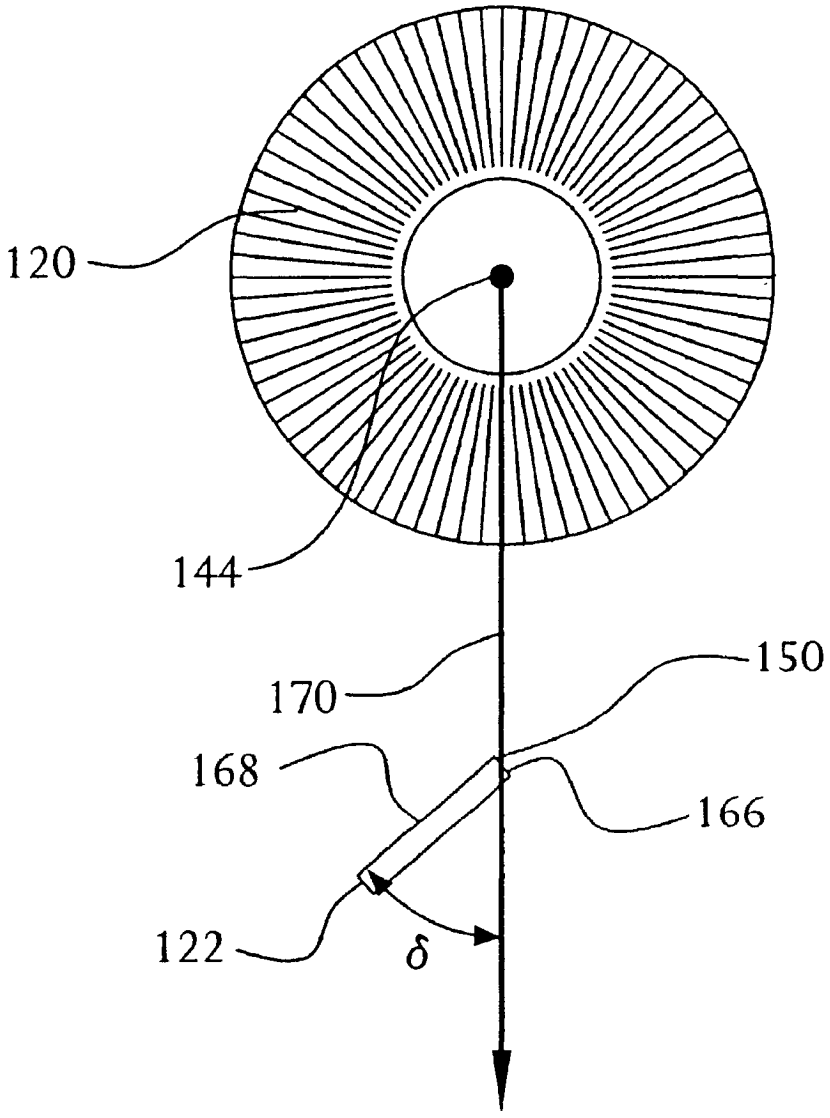


FIG. 9

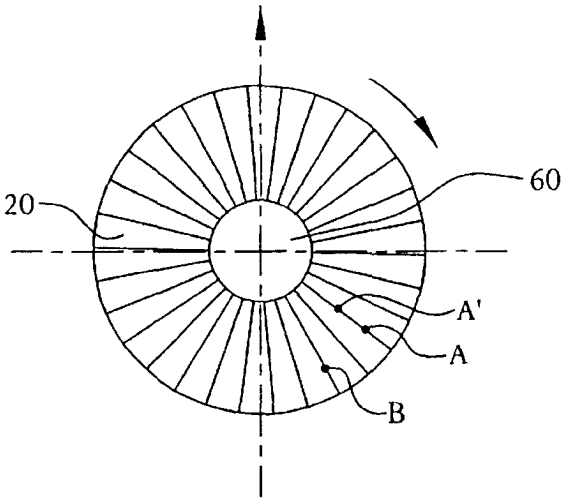


FIG. 10

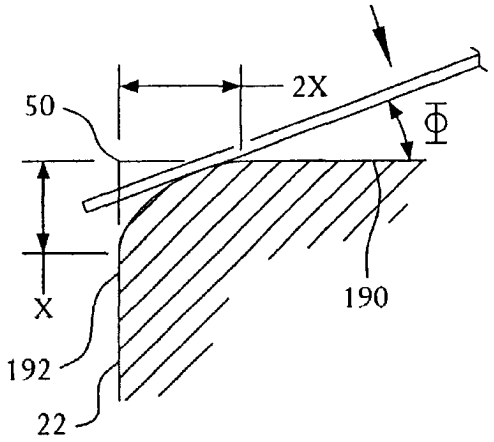


FIG. 11

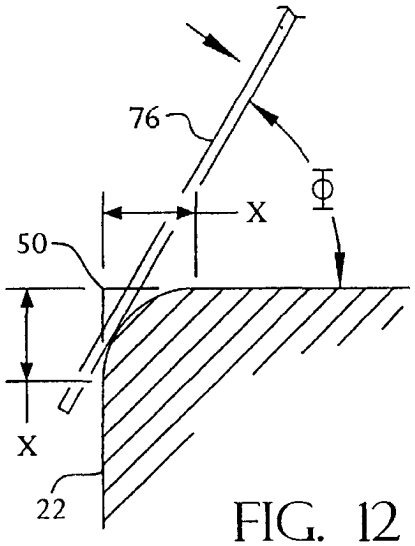


FIG. 12

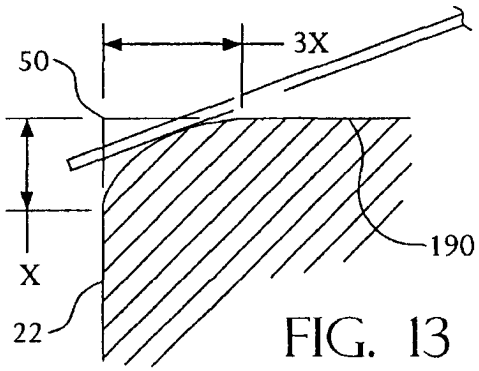


FIG. 13

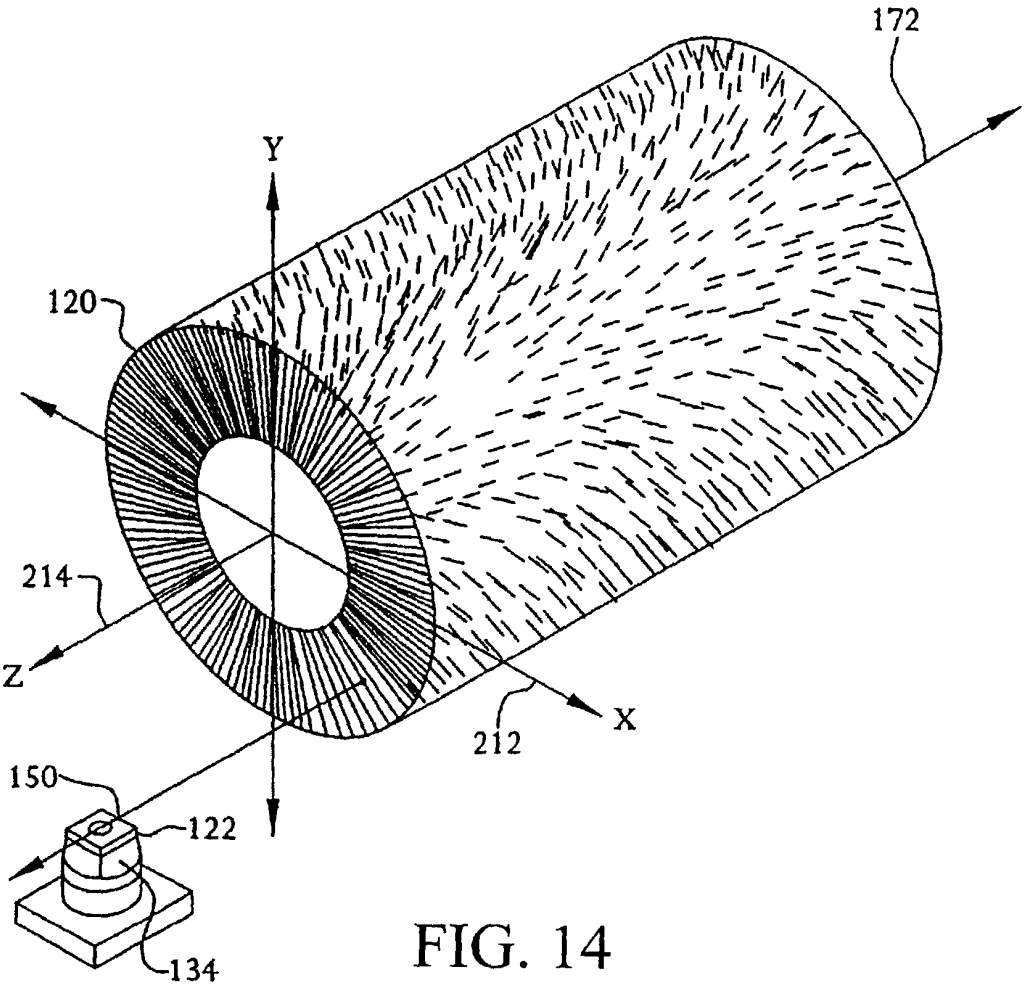


FIG. 14

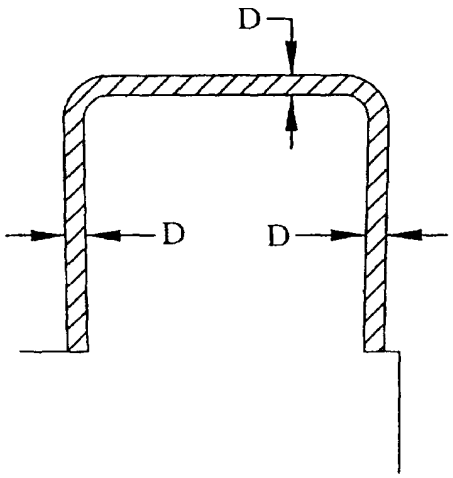


FIG. 15a

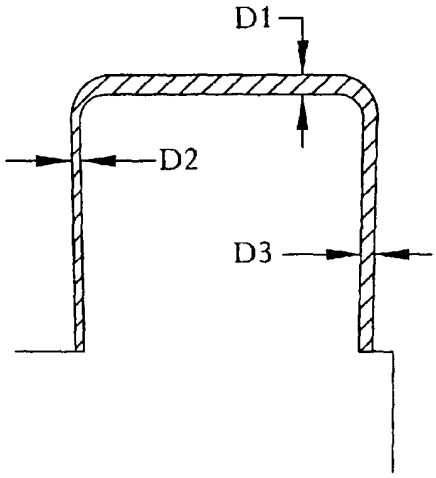


FIG. 15b

APPARATUS FOR HIGH TOLERANCE BRUSH HONING

This application is a divisional Ser. No. 09/428,726 filed Oct. 28, 1999, U.S. Pat. No. 6,287,177.

FIELD OF THE INVENTION

The present invention pertains to a method and apparatus for honing precision edges on a workpiece, such as a cutting tool, using an abrasive brush. The invention particularly relates to a process and apparatus for controlling the position of a cutting tool edge relative to an abrasive honing brush in order to provide precise controlled edge honing.

BACKGROUND OF THE INVENTION

Cutting tools for cutting and shaping materials must be very hard to maintain their edges and withstand the high concentrated forces which are present at the cutting edge of the tool. These tools are frequently fabricated from carbide, ceramic, diamond coated carbide, CBN coated carbide or other tool materials which possess the necessary hardness. The disadvantage of using a hard material is that such materials tend to be brittle, and susceptible to crack formation. When cracks form, the material begins to chip, destroying the utility of the tool.

The predominant method of forming carbide edges on cutting tools uses a powder metallurgy process which involves placing powdered materials into a mold, and mechanically compacting them into specific tool geometric forms. The compacted tool form is then densified through a sintering process. The edges created by this process, however, are rough. Rough edges can adversely affect the performance of the tool, by increasing the tendency of the material to crack or chip. Furthermore, forces applied to the rough edge are not evenly distributed but, rather, are concentrated on high points of the edge. The low points of the edge tend to be sharp creating stress concentrations that increase the likelihood of crack formation. The rough edges on cutting tools can be smoothed by honing the edges before the tool is used in a machining process. Honing involves forming a rounded shape on the cutting edge of the tool. Early shapes were directed towards true radii, where the curvature of the smoothed edge was uniform across both surfaces adjacent to the edge.

More recently, edges having varying taper, i.e., non-uniform tapers about the periphery of the edge and generally called waterfall hones (see, FIG. 3c). Also, the correct sizing of the edge hone has been shown to affect tool life. As a result, the higher the precision with which the tool edges can be formed, the greater the resultant tool life.

Many different processes were originally used to smooth the edges of a cutting tool, including vibratory honing, mass media honing, slurry honing, honing inserts with media impregnated rubber wheels, dry blasting, wet blasting, and tumbling. These methods have several disadvantages, including intense labor requirements and poor predictability of edge hone characteristics between different tools exposed to the same honing process.

During the late 1970's, a process of honing using a brush having bristles impregnated with abrasive media was developed. In this process, bristles are forced into contact with the edge of the cutting tool. The forced contact results in the removal of material along the edge. Brush honing the cutting tool edges has typically required high brush rotational speeds, resulting in the abrasive bristles striking the cutting tool edge, rather than being dragged across the edge.

In a conventional honing process, the brush is rotated such that the speed of the tips of the brush range from 3,000 to 12,000 feet per minute. In order for these conventional processes to be commercially feasible, a high speed has been necessary in order to hone a sufficient quantity of cutting tools in a short period of time.

The apparatus used in conventional honing processes require the placement of the cutting tools to be honed on a rotating table. As the table rotates, the part is translated along an arcuate path past a rotating abrasive brush. The rotating table allows a continuous honing process to be used, with cutting tools being loaded at one position, honed at a second position, and removed from the table at a third position. The individual cutting tools were rotated as they are passed through the stationary, rotating brush. The circular formation of the table also presents a compact area within which the honing process can be accomplished.

One drawback to the use of a rotary table to feed the cutting tool to the honing brush is that the arcuate path produces an uneven hone on the work piece.

More particularly, the arcuate path causes the contact between the tool edge and the honing brush to vary depending on the location of the tool on the path. As such, the resulting hone will vary across the edge of the part making precision honing very difficult.

Another deficiency with the prior methods of honing edges on the cutting tools is that the high bristle speeds result in the generation of excessive heat at the bristle tips. This heat causes the nylon bristles to partially melt, leading to nylon being deposited on the workpiece. The deposited nylon must then be removed before the tool can be coated, adding an additional step to the honing process.

Attempts have been made to cool the bristles by using fluid coolants to alleviate or reduce the build up of heat at the bristle tips. The coolant, however, creates a material disposal problem which is not desirable.

Also, conventional processes for honing tool edges do not typically permit variation of the rotational speed of the brush during the honing process. Instead, the speed of the table is normally controlled to vary the amount of material removed from the tool.

The present invention overcomes the disadvantages of the prior art by controlling the contact of the cutting tool edge with the bristles of the abrasive brush so that the cutting tool edge moves through the volume occupied by the bristles. Thus, the material removal action is distributed over a greater portion of the bristle, thereby reducing the build-up of heat in the bristles. The movement of the cutting tool edge into the volume of the bristles further results in a greater material removal rate due to the greater contact between the individual bristles and the cutting tool edge.

SUMMARY OF THE INVENTION

An apparatus is disclosed for honing at least one edge on a workpiece, such as a cutting tool. In one embodiment of the invention, the apparatus includes a base with a variable speed motor mounted on it. An abrasive brush is mounted to the motor and includes a plurality of bristles attached to a hub. The bristles each have a tip end and an interior end, with the interior end being fixed to the hub. The motor is adapted to cause the abrasive brush to rotate about an axis of rotation. The width of the abrasive brush is defined by first and second ends. The combination of the width of the brush and the length of the bristles defines a volume. The honing apparatus also includes a rotational controller means for controlling the rotational speed of the motor.

A mount for holding a workpiece is attached to the base. The mount includes a fixture for holding the workpiece, and a translational movement mechanism for controlling the position of an edge of the workpiece along a path substantially parallel to the axis of rotation of the abrasive brush.

In another embodiment, the motor is a fixed speed motor and the position of the workpiece edge relative to the abrasive brush is controlled by horizontal and vertical movement mechanisms.

A honing process is also disclosed for controlling the formation of a hone on the edge of a workpiece by controlling the movement and positioning of the workpiece through the volume of the rotating bristles. The movement and position of the workpiece is controlled so as to control the angle of impact between the bristles of the abrasive brush and an edge of the workpiece. The process results in the formation of precise tapered edges on the workpiece edge.

The foregoing and other features and advantages of the present invention will become more apparent in light of the following detailed description of the preferred embodiments thereof, as illustrated in the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of illustrating the invention, the drawings show a form of the invention which is presently preferred. However, it should be understood that this invention is not limited to the precise arrangements and instrumentalities shown in the drawings.

FIG. **1** is a perspective view of an embodiment of a brush honing apparatus according to the present invention.

FIGS. **2***a*–**2***c* are illustrations of generic cutting tools showing a representative cutting edge.

FIGS. **3***a*–**3***c* are partial sectional views of the generic cutting tool of FIG. **2** showing variations in the honing of the edges in more detail.

FIG. **4** is a section view of the motor and abrasive brush.

FIG. **5** is a perspective view of an abrasive brush.

FIG. **6** is a side elevation of a motor and a vertical movement mechanism.

FIG. **7** is a perspective view of an alternate embodiment of the apparatus incorporating horizontal and vertical movement mechanisms into the mount.

FIG. **8** is a perspective view of an alternate embodiment of the apparatus incorporating a distance positioning mechanism into the motor and an orientation mechanism into the mount.

FIG. **9** is a side view of an abrasive brush and a cutting tool identifying an alternate orientation of a cutting tool to an abrasive brush.

FIG. **10** is a side view of an abrasive brush identifying reference points on the first end of the abrasive brush.

FIG. **11** is a side view of a cutting tool and abrasive bristle, showing the relation between the bristle and the cutting tool with the cutting tool inside the brush volume along a path through reference point A in FIG. **10**.

FIG. **12** is a side perspective of a cutting tool and abrasive bristle, showing the relation between the bristle and the cutting tool with the cutting tool inside the brush volume along a path through reference point B in FIG. **10**.

FIG. **13** is a side perspective of a cutting tool and abrasive bristle, showing the relation between the bristle and the cutting tool with the cutting tool inside the brush volume along a path through reference point A' in FIG. **10**.

FIG. **14** is a perspective view of an abrasive brush identifying reference elements of the honing process.

FIGS. **15***a* and **15***b* are cross-sectional illustrations comparing a workpiece with a constant hone and a workpiece with a variable hone.

DESCRIPTION OF THE INVENTION

Referring now to the drawings, wherein like reference numerals illustrate corresponding or similar elements throughout the several views, FIG. **1** is an isometric illustration of one embodiment of a honing apparatus **10** according to the present invention. The apparatus **10** is designed to provide precise honing of an edge of a workpiece **22**. The invention can be used on a wide variety of workpieces which require honing, including components subject to wear, such as seal rings, piston plungers, slitter knives, valve seats, counter-balance weights and carbide or ceramic bushings. The invention has particular use in honing edges of cutting tools, such as drills, end mills, milling inserts, threading tools, burrs, router bits grooving tools, form tools and tools designed to cut materials , such as metal and wood.

The apparatus **10** includes an abrasive brush **20** driven by a motor **24**. The motor **24** is mounted to a base **32**. The workpiece **22** is mounted such that its position relative to the abrasive brush **20** can be controlled to vary the shape of the resulting hone.

Referring to FIGS. **2***a*–**3***c*, the workpiece **22** is shown with its edge **50** in an un-honed condition (FIG. **3***a*), with a radius hone **52** (FIG. **3***b*) and a tapered hone, such as the waterfall hone **54** (FIG. **3***c*). In order to form the various hones, the apparatus **10** is configured to control the position of the workpiece edge relative to the abrasive brush. In the embodiment of the invention shown in FIG. **1**, the relative location of the workpiece edge from the abrasive brush is achieved by changing the position of the motor **24** through the use of a horizontal movement mechanism **26** and a vertical movement mechanism **28** as will be discussed in more detail below.

As shown in FIG. **4**, the abrasive brush consists generally of a hub **60** to which a plurality of bristles **66** are attached. The bristles **66** have a tip end and an interior or root end **74**, which is attached to the hub **60**. The hub **60** is designed to removably attach to the motor **24**. As shown in FIG. **5**, the width of the abrasive brush **20** is defined by a first end **68** and a second end **70**, and the radius of the brush is defined by the distance from the bristle tips **76** to the axis of rotation **44** of the brush. As is apparent from the figures, the width of the brush, in combination with the length of the bristles **66**, defines a volume **72** which is illustrated and preferably in the form of a right cylinder. Although the present embodiment shows the abrasive brush **20** having bristles **66** fully surrounding the hub, the bristles **66** may be located in discrete rows along the hub, with spaces between the rows, as shown in FIG. **6**, or other patterns which do not completely fill the volume **72**. The preferred diameter for the abrasive brush is approximately **14** inches.

As described above, during operation, the contact between the bristles of the brush and a workpiece causes the bristles to heat up. In order to reduce the temperature of the bristles **66**, one embodiment of the present invention incorporates an impeller **62** in the hub that has a series of vanes designed to draw air into the hub **60** through an air intake **64**. The impeller **66** forces the air out through the bristles **66** of the abrasive brush **20**, thereby reducing their temperature.

In order to control the rate of material removal, the present invention preferably incorporates a means for controlling the speed of the abrasive brush. Referring to FIG. **4**, in one embodiment, the motor **24** that drives the abrasive

brush **20** is a variable speed motor. This permits that rate of material removal to be varied depending on the workpiece and/or material being honed. Alternatively, a transmission (not shown) could be interposed between a fixed speed motor **24** and the abrasive brush, allowing variation of the rotational speed of the abrasive brush. A continuously variable transmission (CVT) would be a preferable transmission if a fixed speed motor were to be used.

The abrasive brush **20** is preferably rotated within a speed range which yields a linear speed of 180 to 1800 feet per minute at the tips of the bristles. The linear speed of the bristles tips can be calculated by multiplying the diameter of the abrasive brush times the rotational speed of the abrasive brush times π. As is obvious to one of skill in the art, the motor rotational speed does not need to be equal to the desired rotational speed of the abrasive brush, since gears or pulleys may be used between the motor and the abrasive brush to create non-unitary ratios of the rotational speed of the motor to the rotational speed of the abrasive brush.

The present invention also incorporates a controller **200** to allow an operator of the apparatus or a software program to control the rotational speed of the abrasive brush. The speed can be controlled depending on the desired hone, the location of the workpiece within the brush, and/or the type of material being honed. The controller **200** can be a conventional motor speed controller of a type dependent on whether the motor uses alternating current or direct current. If a CVT is used to vary the speed of the brush, the controller **200** could also be used to control the CVT.

The honing apparatus **10** also includes a mount **35** for positioning and moving the workpiece relative to the abrasive brush **20**. The mount includes a translational movement mechanism or translator **30** for moving the workpiece **22** along a linear path parallel to the axis of rotation **44** of the abrasive brush. It has been determined that linear translation of the workpiece through the abrasive brush produces a consistent and precise hone on the workpiece. The translational movement mechanism **30** is slidably attached to a guide **36** that preferably extends along a linear path parallel to the rotational axis of the abrasive brush **20**. The workpiece is held within a fixture **34** attached to the translational movement mechanism **30**. The translational movement mechanism preferably is driven along the guide **36** by a motor-driven screw drive. It is contemplated, however, that other drive systems can be substituted for the preferred screw-drive without detracting from the invention.

The present invention also preferably incorporates a controller (such as controller **200** discussed above) which includes a process control software program to accurately control movement of the workpiece on the translational movement mechanism with respect to the abrasive brush. For example, the controller **200** can be programmed to control the translational movement mechanism such that the workpiece moves in the forward direction through the abrasive brush, the reverse direction through the abrasive brush **20**, is stopped within the rotating abrasive brush, or oscillates in the forward and reverse directions within the abrasive brush. Those skilled in the art would readily be capable of making such a substitution.

In one embodiment of the invention, the fixture **34** that holds the workpiece **22** is attached to a rotating base **33**. The rotating base **33** is, in turn, attached to a positioning motor **37**, either directly or indirectly, through a transmission or direct drive. The positioning motor **37** positions or rotates the fixture **34** containing the workpiece while the translational movement mechanism **30** moves the workpiece **22** through the rotating abrasive brush **20**. A controller, such as controller **200**, controls the positioning motor **37** to vary the rotation of the fixture **34** in accordance with a predetermined program, such as a numerical control program, which accurately rotates, positions or stops the rotation of the positioning motor **37**. Alternately, the controller permits an operator to provide positioning commands to the motor **37**.

As shown in FIG. **1**, a vertical movement mechanism **28** is employed which adjusts the vertical position of the motor **20** relative to the base. In one embodiment, the vertical movement mechanism **28** includes a screw driven actuator that is controlled either manually, as by a handle **46** (FIG. 1), or by a control motor **80** (FIG. 6). If a control motor **80** is utilized, the motor **24** is preferably engaged to one or more guide rails **84** through linear bearings **86**. A screw **82** turned by the control motor **80** passes through a threaded fitting on the motor **24**, such that rotation of the screw **82** causes the motor **24** to move up or down. It is contemplated that the movement of the motor **24** and abrasive brush **20** may be pre-programmed into a computer or other control device (such as the controller **200**) to provide automated and repeatable workpiece honing.

The embodiment of the invention shown in FIG. **1** also preferably includes a horizontal movement mechanism **26** for moving the motor **24** and abrasive brush **26** relative to the base **32**. Similar to the vertical movement mechanism **28**, the horizontal movement mechanism **26** preferably uses a screw drive to control the position of the motor **24** relative to the workpiece. The screw drive may be controlled by a handle **46** or a control motor system as discussed above.

It is contemplated that the apparatus **10** may include a device for inverting workpieces **22** after they have been honed. A suitable inverting device **39** is shown in FIG. **1** and includes a parallel gripper **38** which is adapted to pick up workpieces from and place workpieces on the fixture **34**. A vertical actuator **42** is attached to the mount **36** and raises and lowers the gripper **38**. A rotary actuator **40** attaches the gripper **38** to the vertical actuator **42**. The rotary actuator **40** is designed to rotate the gripper **38** up to 180 degrees about a horizontal axis for inverting the workpiece **22**.

In operation, after the workpiece passes through the abrasive bristles **66**, the gripper **38** grabs the workpiece. The gripper **38** is then translated upward and rotated a suitable amount to position another edge in an appropriate position for honing. The gripper **38** is then lowered until the workpiece is again placed in the fixture.

An alternate embodiment of the invention is shown in FIG.7. In this embodiment, instead of the motor **24** and abrasive brush **26** being vertically and horizontally adjustable with respect to the workpiece, the workpiece is mounted such that it can be appropriately positioned relative to a fixed abrasive brush **120**. Preferably, one or more control motors are used to position the workpiece **122** horizontally and vertically relative to the abrasive brush **120**. Alternatively, manual handles can also be used, similar to the handles described in the previous embodiment.

More particularly, in this embodiment, a vertical movement mechanism **131**, preferably attached to the mount **135**, moves the fixture **134** vertically relative to the base **132**. A horizontal movement mechanism **128** is also preferably engaged with the mount **135** and is designed to move the fixture **134** horizontally toward and away from the abrasive brush (i.e., substantially parallel to the base **132**). A translational movement mechanism **126** moves the workpiece **122**, fixture **134**, vertical movement mechanism **131**, and horizontal movement mechanism **128** along guides **136**

which preferably define a linear path parallel to the axis of rotation **144** of the abrasive brush **120**. As with the previous embodiment, a rotating base and positioning motor can be incorporated to rotate the fixture and/or workpiece. As shown, an inverting device, including a parallel gripper **138**, a rotary actuator **140**, and a vertical actuator **142**, can be incorporated for inverting the workpiece after honing, as discussed above.

A further embodiment of the invention is shown in FIG. **8**. In this embodiment, a mechanism for controlling the distance between the workpiece edge **50** and the axis of rotation **144** of the abrasive brush **120** is incorporated into the apparatus **10**. Referring to FIG. **9**, the position of the workpiece edge **150** relative to the abrasive brush **120** is shown. The orientation of the workpiece edge **50** is defined by the angle δ between a side surface **168** of the workpiece **122** and a radial line **170** extending from the axis of rotation **144** of the abrasive brush **120** through the workpiece edge **150**. Rotation of the workpiece **122** about the workpiece edge **150** causes the point of contact between the bristles **166** and a top surface **166** and the side surface **168** of the workpiece **122** to vary, thereby controlling the resulting shape of the hone.

Referring back to FIG. **8**, an orientation actuator **160** is used to control the orientation of the workpiece (e.g., cutting tool) with respect to the abrasive brush **120**. The orientation actuator **160** includes a fixed portion **160**F and a rotary portion **160**R. The fixed portion **160**F is mounted to the base **132**. The rotary portion **160**R is rotatably engaged to the fixed portion **160**F. The guides **136** are attached to the rotary portion **160**R. The fixture **134**, which holds the work piece **122**, is slidably attached to the guides **130**. In order to rotate the workpiece, the orientation actuator **160** is controlled (e.g., via a controller, such as controller **200** in FIG. **1**) so as to rotate the rotary portion **160**R. This, in turn, causes the guides **136** and the fixture **134** to rotate about an orientation axis of rotation **162**. Depending on the location of the guides **136**, fixture **134** and workpiece **122**, the orientation axis may lie along the workpiece edge **150**. Rotation of the workpiece **122** about this axis changes the angle δ between the side surface **168** and the radial line **170**. As such, the point on the workpiece edge **122** that contacts the abrasive brush **120** will vary.

In this embodiment of the invention, the vertical position of the abrasive brush **120** is controlled by a distance positioning mechanism **164** which increases or decreases the distance between the axis of rotation **144** of the abrasive brush **120** and the workpiece edge **150**. Alternatively, the fixture **134** can be vertically translated or rotated relative to the abrasive brush **120** in a manner similar to the various embodiments described above. As with the above embodiments, an inverting device can be incorporated into the apparatus to invert the workpiece.

The apparatus described in the various embodiments above is useful for honing precise edges on work pieces. The process for honing those edges will now be described in detail. One feature of the process according to the instant invention is the placement of the workpiece edge to be honed at a specific location within the volume of the bristles of the abrasive brush. This proper positioning, in combination with the operation of the abrasive brush at a preferred rotational speed, permits high precision workpiece edge honing.

FIG. **10** illustrates a cross-sectional schematic of an abrasive brush **20**. As discussed in detail above, the present invention permits the workpiece edge **22** to be precisely located within the volume of the bristles. Various paths through the bristle volume **72** are shown in FIG. **10**, each of which produces a different hone on the workpiece. At position A, assuming that the workpiece is oriented such that its top surface is parallel to the x-axis in the figure, a contact angle Φ between individual bristles **66** and the top surface **190** of the workpiece is relatively shallow (see, FIG. **11**). This shallow contact angle results in more material being removed from the top surface **190** then the side surface **192**, producing a waterfall hone (shown by the dashed lines) on the workpiece edge.

If the workpiece were located at position B, an approximately even amount of material would be removed on the top and side surfaces **190**, **192** by the bristles. This results in a radiused hone.

Referring to FIG. **14**, the process according to the present invention involves first placing the workpiece **122** into the fixture **134**. The fixture **134** is then positioned relative to the abrasive brush **120** such that the workpiece edge **150** to be honed is located along a desired path **216** through the volume **172** of the abrasive brush. The location of this path in the volume **172** will depend on the desired hone shape as discussed above. The path **216** of translation through the bristle volume **172** is substantially parallel to the axis of rotation **214** of the abrasive brush. After proper positioning of the workpiece edge **150**, the fixture **134** is translated through the volume **172**.

Once the workpiece edge has passed through the bristle volume **172**, an inverting device can be utilized to reposition the workpiece in the fixture **134** to permit a different edge **50** to be processed. For example, since cutting tools typically have cutting edges on opposed sides of the tool, the parallel gripper **38** is rotated 180 degrees before the workpiece is returned to the fixture **134**. With the new edge positioned relative to the abrasive brush **20**, the fixture is translated back through the bristles of the abrasive brush **20**. If a different hone shape is desired on the new edge, the fixture can be repositioned relative to the abrasive brush prior to translation.

It is contemplated that the position and orientation of the work piece within the volume of bristles and the speed of rotation of the abrasive brush can be altered during translation (i.e., while the work piece is within the volume). This allows for the formation of a complex honed edge on the work piece and allows controlled variation of the hone along the workpiece edge. For example, in forming a threading tool, the hone on the thread forming edge can be intentionally varied from the tip end of the tool to the base of the tool. At the tip end, it may be desirable to have a larger hone to permit the thread forming edge, when in use, to dig through the raw material. Conversely, at the base of the thread forming edge it may be desirable to have a sharper hone to permit more precise finishing of the threads in the material. The present invention allows such precise hone control over the finished workpiece.

Another example of the use of the present invention for providing controller hone variation is shown in FIGS. **15***a* and **15***b*. FIG. **15***a* is a cross-sectional illustration of a grooving tool with a constant hone (designated "D" on all three sides). FIG. **15***b* is a cross-sectional illustration of a grooving tool with a controlled variable hone. As shown, the hone on the top (designated "D**1** ") is greater than the hones on the sides (designated "D**2**" and "D**3**").

The various positioning mechanisms discussed above allow complex workpiece edges to be precisely honed. The use of a controller in the present invention allows the honing process to be programmed and automated to ensure repeatability.

Although the invention has been described and illustrated with respect to the exemplary embodiments thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions and additions may be made therein and thereto, without parting from the spirit and scope of the present invention.

What is claimed is:

1. An apparatus for honing at least one edge on a workpiece, comprising:

a base;

a motor mounted to the base;

an abrasive brush mounted to the motor, the abrasive brush being formed of a plurality of bristles attached to a hub, the bristles each having a tip and an interior end fixed to the hub, the motor adapted to cause the abrasive brush to rotate about an axis of rotation, the abrasive brush having a first end and a second end, and a volume defined by a cylindrical shape extending between said first and second ends with a surface defined by the tips of the bristles, and a radius defined as the distance from the axis of rotation to the tips of the bristles;

a controller for controlling the rotational speed of the brush;

a mount for holding a workpiece, the mount attached to the base, the mount including a fixture for engaging the workpiece to the mount, the fixture mounted to a rotatable base, the mount further including a translational movement mechanism adapted to translate the workpiece along a path substantially parallel to the axis of rotation of the abrasive brush;

a depth positioning mechanism for controlling the radial distance between the workpiece edge and the axis of rotation of the abrasive brush, the depth positioning mechanism controlling radial movement of the abrasive brush relative to the workpiece edge; and

an orientation mechanism for orienting the workpiece edge relative to the abrasive brush, the orientation mechanism including a positioning motor engaged with the rotatable base for rotating the fixture on the translational movement mechanism relative to the brush.

2. An apparatus according to claim 1, wherein the abrasive brush is engaged to the motor by the hub, the hub including an impeller for forcing cooing air through the bristles of the abrasive brush.

3. An apparatus according to claim 1, further comprising a device for repositioning the workpiece on the fixture, the device including a parallel gripper connected to a rotary actuator and a vertical actuator.

4. An apparatus for honing at least one edge on a workpiece, comprising:

a base;

a motor mounted to the base;

an abrasive brush mounted to the motor, the abrasive brush being formed of a plurality of bristles attached to a hub, the bristles each having a tip and an interior end fixed to the hub, the motor adapted to cause the abrasive brush to rotate about an axis of rotation, the abrasive brush having a first end and a second end, and a volume defined by a cylindrical shape extending between said first and second ends with a surface defined by the tips of the bristles, and a radius defined as the distance from the axis of rotation to the tips of the bristles;

a controller for controlling the rotational speed of the brush;

a mount for holding a workpiece, the mount attached to the base, the mount including a fixture for engaging the workpiece to the mount, and a translational movement mechanism adapted to translate the workpiece along a path substantially parallel to the axis of rotation of the abrasive brush;

a depth positioning mechanism for controlling the radial distance between the workpiece edge and the axis of rotation of the abrasive brush, the depth positioning mechanism controlling radial movement of the abrasive brush relative to the workpiece edge;

an orientation mechanism for orienting the workpiece edge relative to the abrasive brush; and

a repositioning device for repositioning the workpiece on the a fixture, the device including a parallel gripper connected to a rotary actuator and a vertical actuator.

5. An apparatus for honing at least one edge on a workpiece comprising:

a base;

a variable speed motor;

an abrasive brush mounted to the motor, the abrasive brush being formed of bristles attached to a hub, the bristles each having a tip and an interior end fixed to the hub, the motor adapted to cause the abrasive brush to rotate about an axis of rotation, the abrasive brush having a first end and a second end, and a volume defined by a cylindrical shape extending between said first and second ends with an outer surface formed by the tips of the plurality of bristles, and a radius defined as the distance from the axis of rotation to the tips of the bristles;

a controller for controlling the rotational speed of the abrasive brush;

a vertical movement mechanism adapted to move the motor along a vertical path in a direction substantially perpendicular to the axis of rotation of the abrasive brush;

a horizontal movement mechanism adapted to control the position of the motor along a horizontal path in a direction substantially perpendicular to the axis of rotation of the abrasive brush;

a mount for holding a workpiece, the mount being attached to the base and including a fixture mounted to a rotatable base and adapted to engage the workpiece, the mount further including and a translational movement mechanism adapted to translate the workpiece along a path substantially parallel to the axis of rotation of the abrasive brush; and

a positioning motor engaged with the rotatable base for rotating the fixture on the translational movement mechanism relative to the brush.

6. An apparatus according to claim 5, wherein the translational movement mechanism is adapted to translate the fixture into the volume defined by the bristles.

7. An apparatus according to claim 5, wherein the controller controls the translational movement mechanism.

8. An apparatus according to claim 5, wherein the abrasive brush is engaged to the motor by the hub, the hub including an impeller for forcing cooling air through the bristles of the abrasive brush.

9. An apparatus for honing at least one edge on a workpiece comprising:

a base;

a variable speed motor;

an abrasive brush mounted to the motor, the abrasive brush being formed of bristles attached to a hub, the

bristles each having a tip and an interior end fixed to the hub, the motor adapted to cause the abrasive brush to rotate about an axis of rotation, the abrasive brush having a first end and a second end, and a volume defined by a cylindrical shape extending between said first and second ends with an outer surface formed by the tips of the plurality of bristles, and a radius defined as the distance from the axis of rotation to the tips of the bristles;

a controller for controlling the rotational speed of the abrasive brush;

a vertical movement mechanism adapted to move the motor along a vertical path in a direction substantially perpendicular to the axis of rotation of the abrasive brush;

a horizontal movement mechanism adapted to control the position of the motor along a horizontal path in a direction substantially perpendicular to the axis of rotation of the abrasive brush;

a mount for holding a workpiece, the mount being attached to the base and including a fixture adapted to engage the workpiece, and a translational movement mechanism adapted to translate the workpiece along a path substantially parallel to the axis of rotation of the abrasive brush; and

a device for removing and replacing a workpiece on the fixture, the device including a parallel gripper connected to a rotary actuator and a vertical actuator.

10. An apparatus for honing at least one edge on a workpiece comprising:

a base;

a motor;

an abrasive brush mounted to the motor, the abrasive brush being formed of a plurality of bristles attached to the hub, the bristles each having a tip, and an interior end fixed to the hub, the motor adapted to cause the abrasive brush to rotate about an axis of rotation, the abrasive brush having a first end and a second end, and a volume defined by a cylindrical shape extending between said first and second ends with the an outer surface defined by the tips of the plurality of bristles, and a radius defined as the distance from the axis of rotation to the tips of the bristles;

a controller for controlling the rotational speed of the brush;

a mount for holding a workpiece, the mount including a fixture for engaging the workpiece to the mount, the fixture mounted to a rotatable base;

a translational movement mechanism for moving the mount in a direction substantially parallel to the axis of rotation of the abrasive brush;

a vertical movement mechanism for moving the fixture in a vertical direction substantially perpendicular to the axis of rotation of the abrasive brush;

a horizontal movement mechanism for moving the fixture in a horizontal direction substantially perpendicular to the axis of rotation of the abrasive brush; and

an orientation mechanism for orienting the workpiece edge relative to the abrasive brush, the orientation mechanism including a positioning motor engaged with the rotatable base for rotating the fixture on the translational movement mechanism relative to the brush.

11. An apparatus according to claim **10**, wherein the controller sends signals to control the translational movement mechanism, the vertical movement mechanism and the horizontal movement mechanism.

12. An apparatus according to claim **10**, wherein the motor driving the abrasive brush is a variable speed motor, and wherein the speed of the motor is controlled to vary the resulting hone on the workpiece.

13. An apparatus according to claim **10**, wherein the abrasive brush is engaged to the motor by the hub, the hub including an impeller for forcing cooling air through the bristles of the abrasive brush.

14. An apparatus according to claim **10**, further comprising a repositioning device for changing the position of the workpiece in the fixture, the device including a parallel gripper connected to a rotary actuator and a vertical actuator.

15. An apparatus according to claim **10**, wherein the translation movement mechanism is adapted to translate the fixture into the volume defined by the bristles, and wherein the controller provides signals for repositioning the fixture relative to the brush during translation.

16. An apparatus for honing at least one edge on a workpiece comprising:

a base;

a motor;

an abrasive brush mounted to the motor, the abrasive brush being formed of a plurality of bristles attached to a hub, the bristles each having a tip, and an interior end fixed to the hub, the motor adapted to cause the abrasive brush to rotate about an axis of rotation;

a fixture for holding the workpiece, the fixture being mounted to a rotatable base;

a positioning motor engaged with the rotatable base for rotating the fixture relative to the base;

a controller for controlling rotation of the positioning motor; and

means for controlling the vertical and horizontal distance between the workpiece and the axis of rotation of the abrasive brush.

* * * * *

EXHIBIT "C"

US006802677B2

(12) **United States Patent**
Shaffer

(10) **Patent No.: US 6,802,677 B2**
(45) **Date of Patent: Oct. 12, 2004**

(54) **TOOL HAVING HONED CUTTING EDGE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 98 days.

(21) Appl. No.: **09/828,660**

(22) Filed: **Apr. 6, 2001**

(65) **Prior Publication Data**

US 2002/0016140 A1 Feb. 7, 2002

Related U.S. Application Data

(62) Division of application No. 09/428,726, filed on Oct. 28, 1999, now Pat. No. 6,287,177.

(51) **Int. Cl.**[7] **B23B 27/22**
(52) **U.S. Cl.** **407/113**; 407/114
(58) **Field of Search** 407/113, 114, 407/115, 116, 117, 118, 119, 21, 22, 24–28; 76/104.1

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Gerber Maschinenbau, BP–M Brushing–Polishing Machines, undated.
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Ewag, Switzerland, Edge Honing Brochure, undated.

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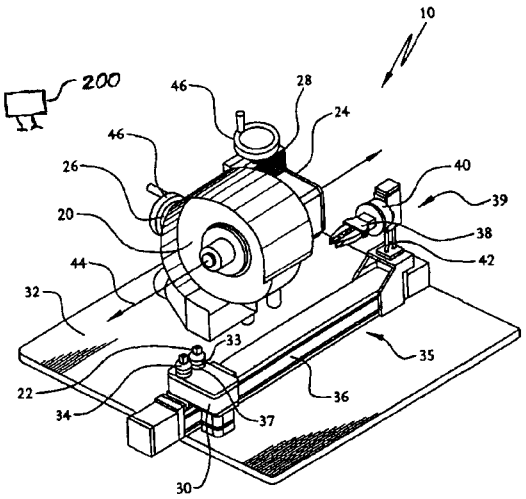
Primary Examiner—Henry W. H. Tsai
(74) *Attorney, Agent, or Firm*—Drinker Biddle & Reath LLP

(57) **ABSTRACT**

The present invention relates to a honing method and apparatus which provides greater control over the edge shape, as well as reductions in the effort required to hone multiple edges on workpieces. The invention accomplishes these improvements by controlling the speed of the abrasive wheel, as well as the orientation and position of the workpiece prior to and/or while it is in contact with the abrasive brush. This provides for greater control over the hone shape, hone size, and hone distribution along all the cutting edges of the tool.

15 Claims, 13 Drawing Sheets



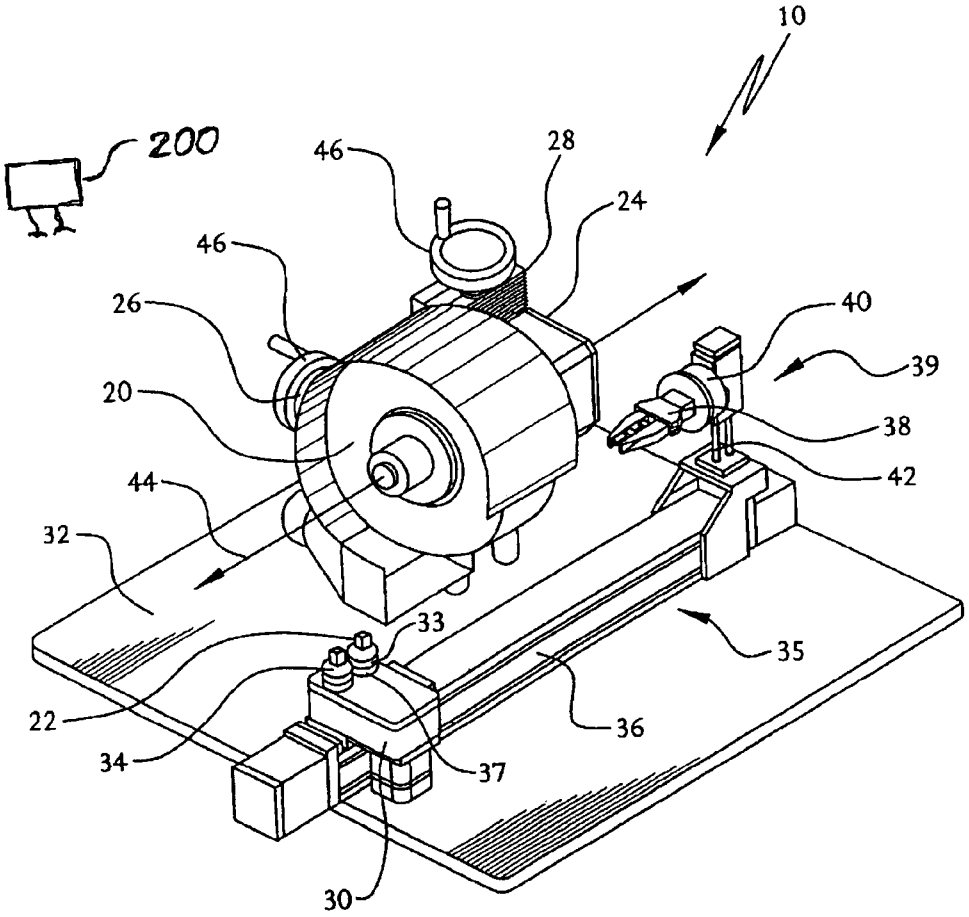


FIG. 1

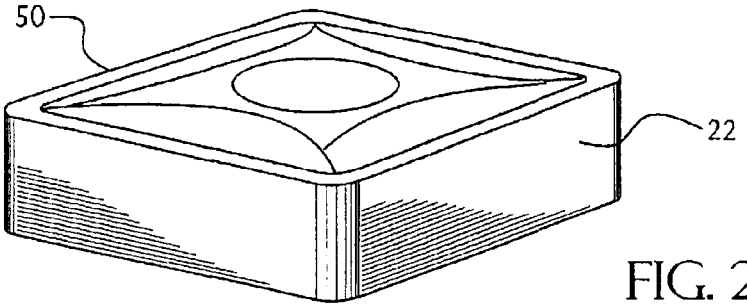


FIG. 2A

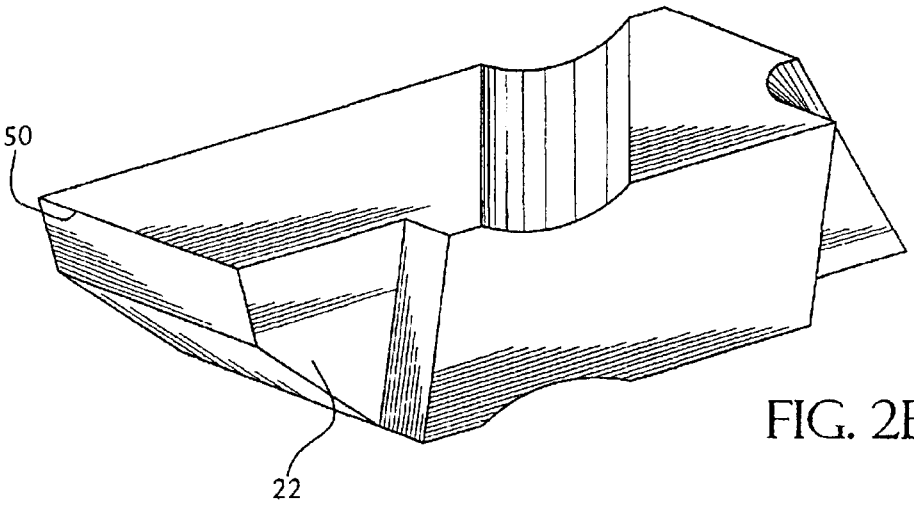


FIG. 2B

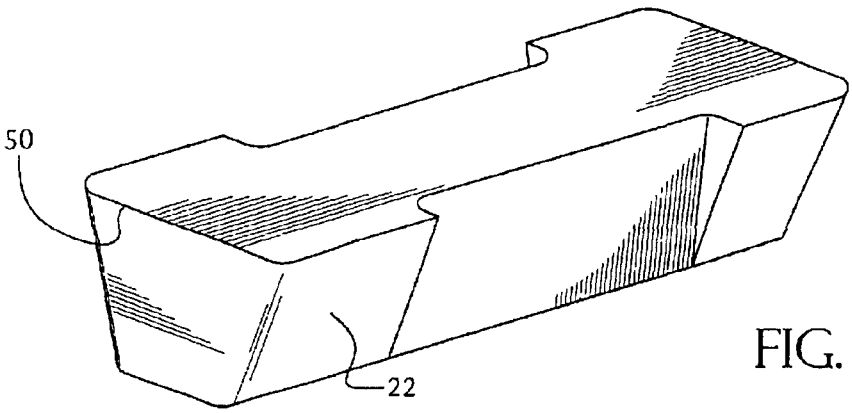


FIG. 2C

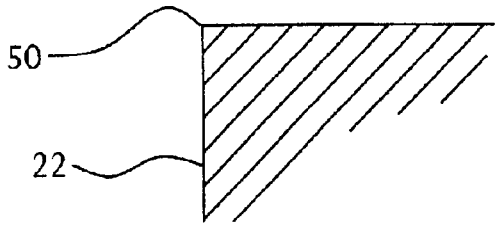


FIG. 3A

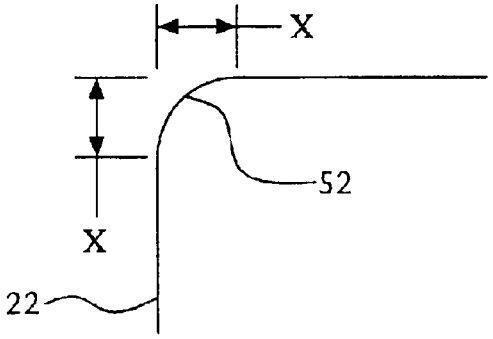


FIG. 3B

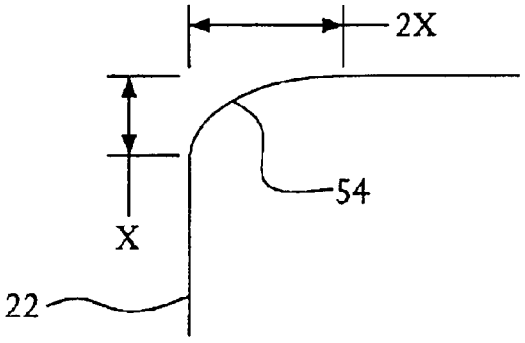


FIG. 3C

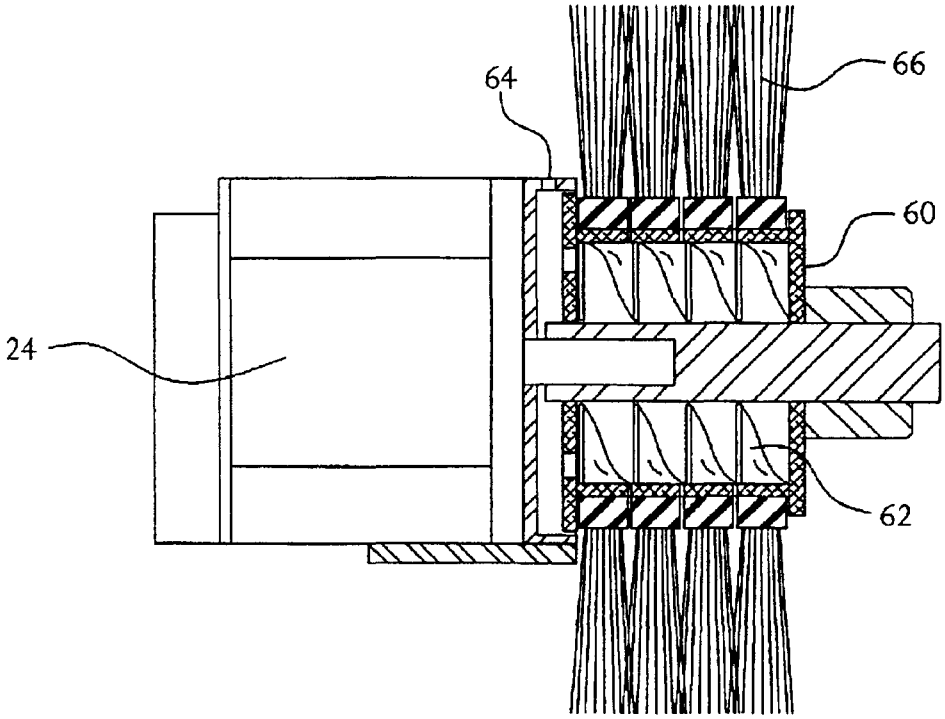


FIG. 4

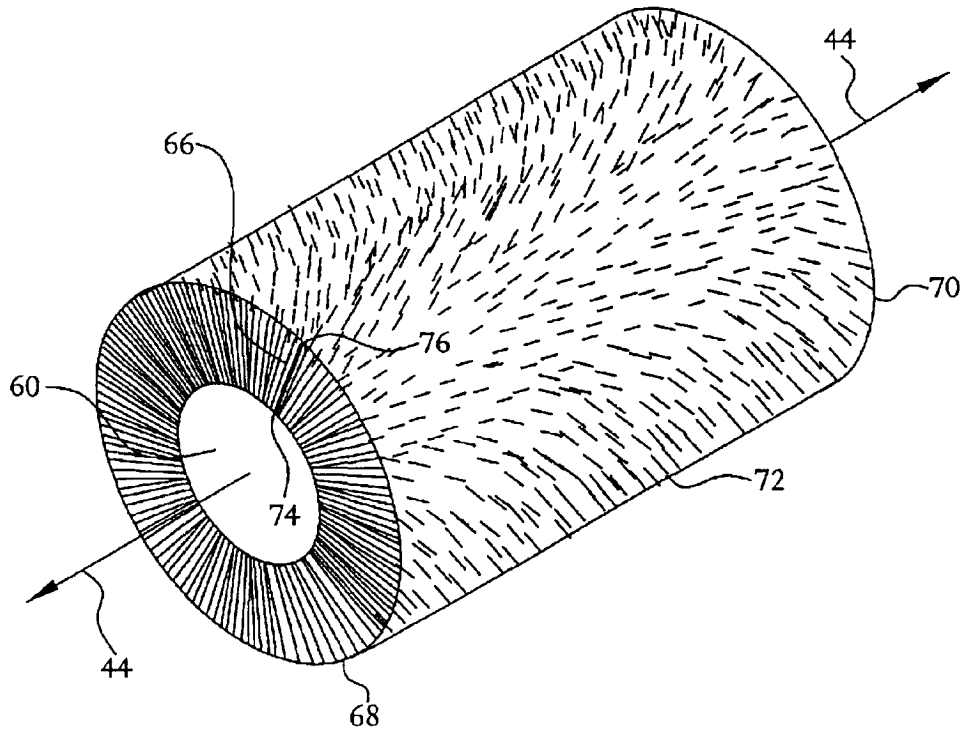


FIG. 5

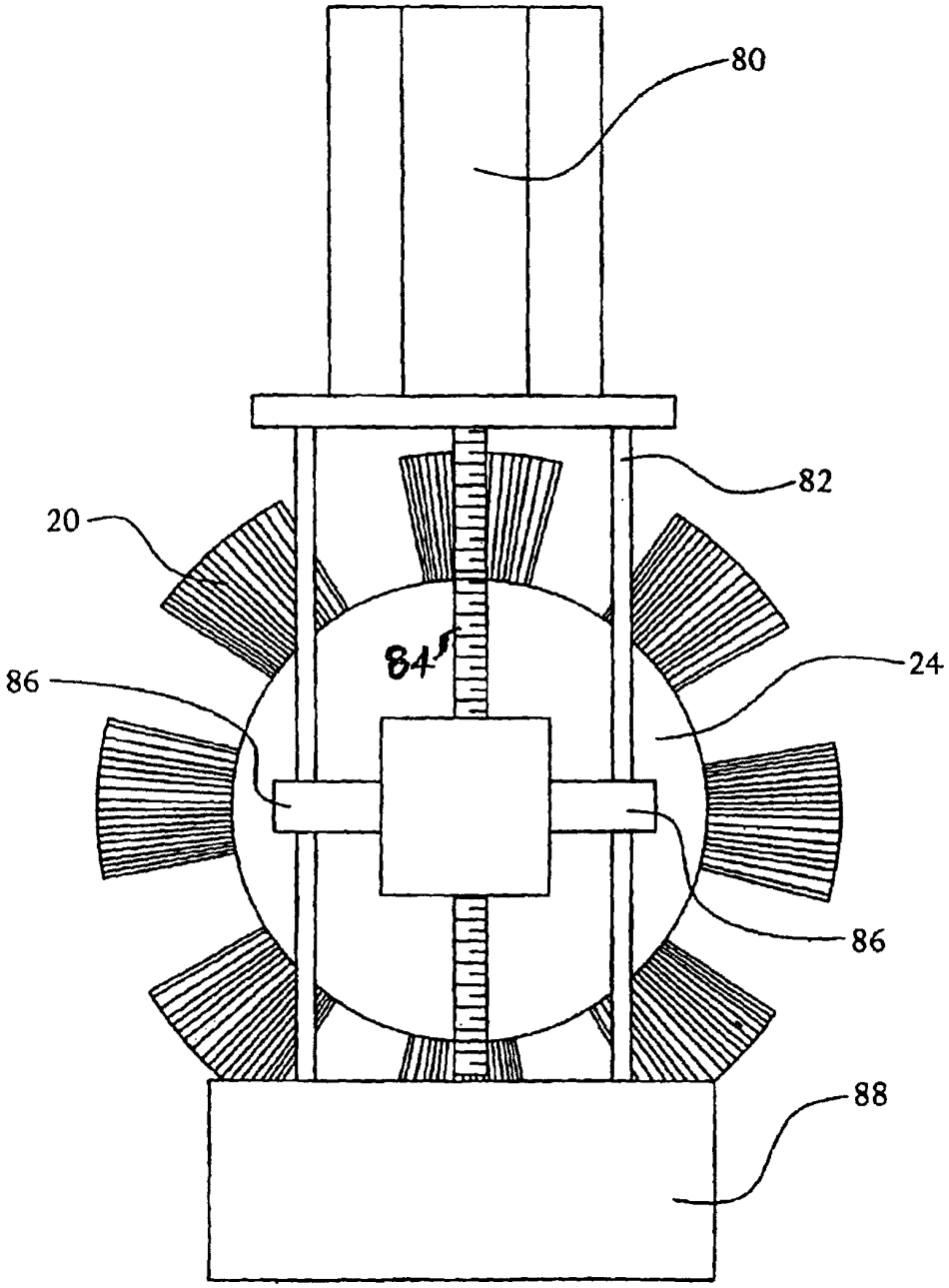


FIG. 6

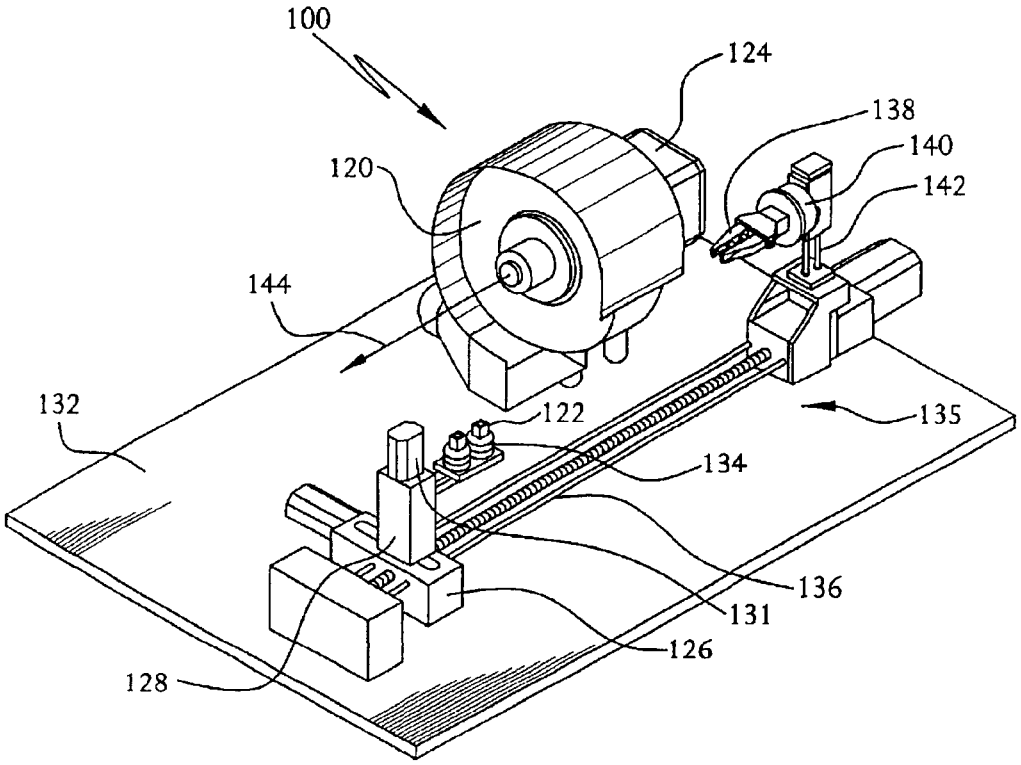
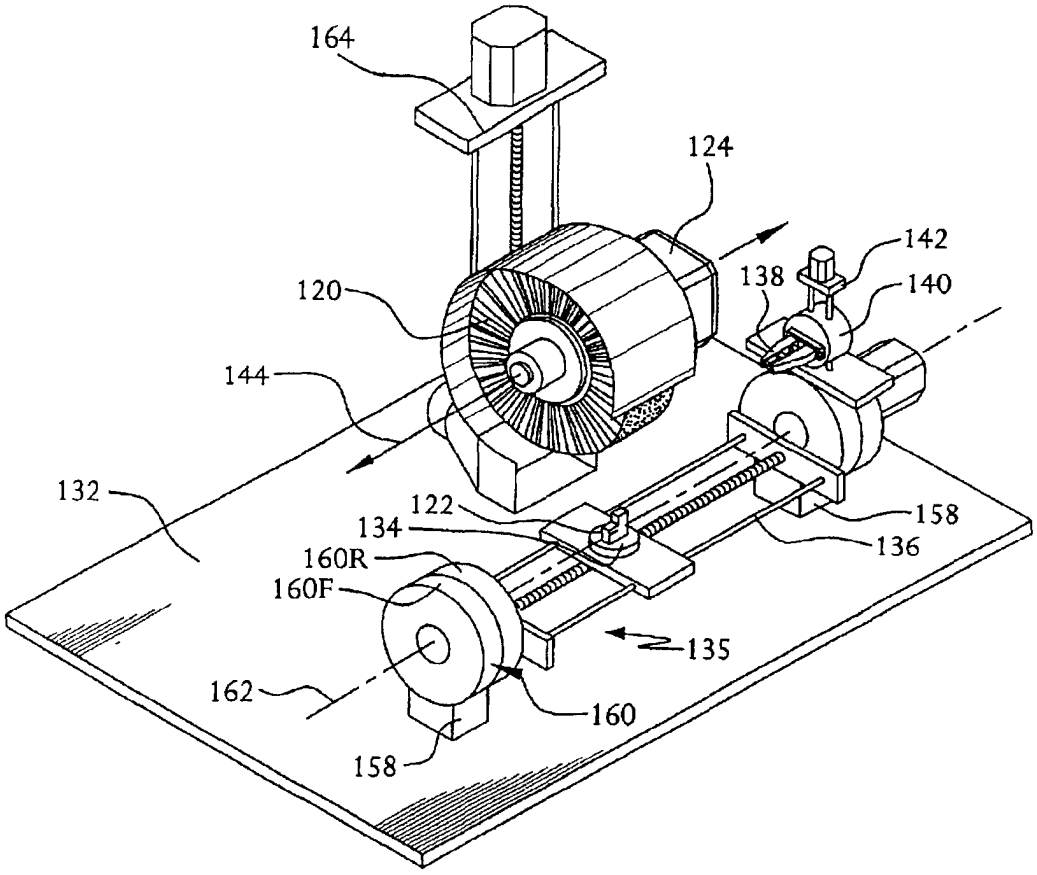


FIG. 7


164
124
142
138
140
120
144
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122
134
158
160R
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160F
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162
160
158

FIG. 8

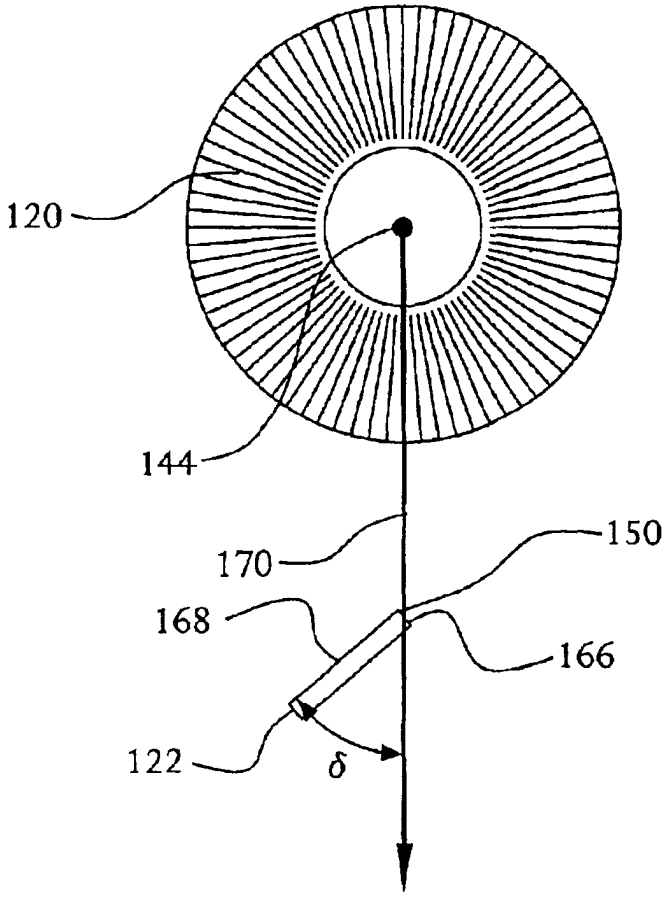


FIG. 9

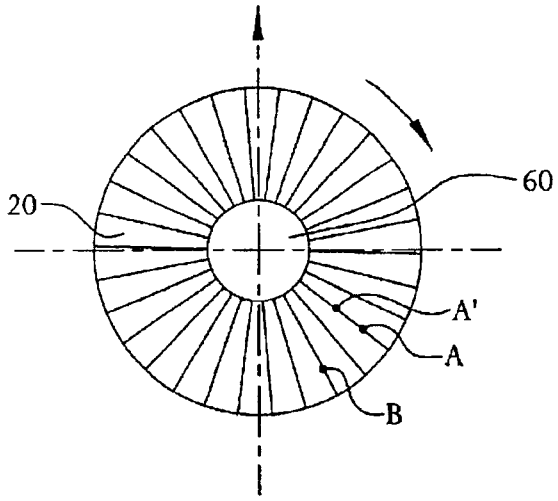


FIG. 10

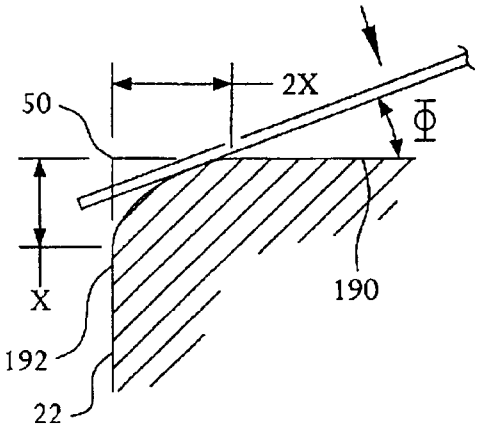


FIG. 11

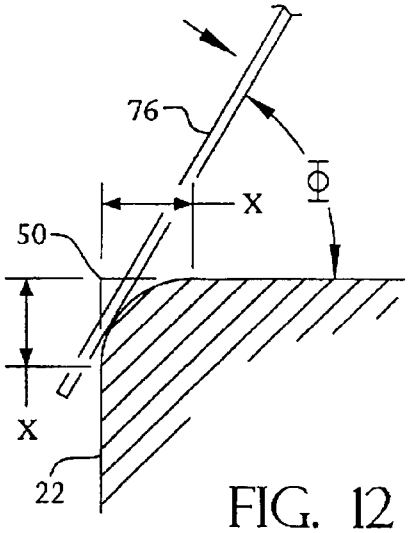


FIG. 12

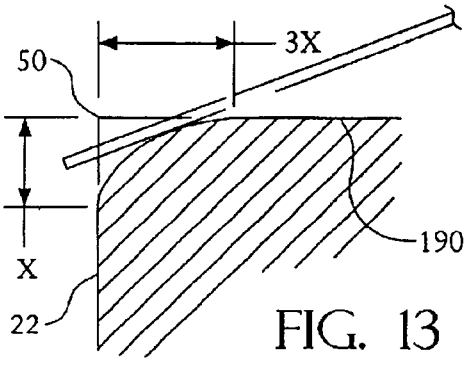


FIG. 13

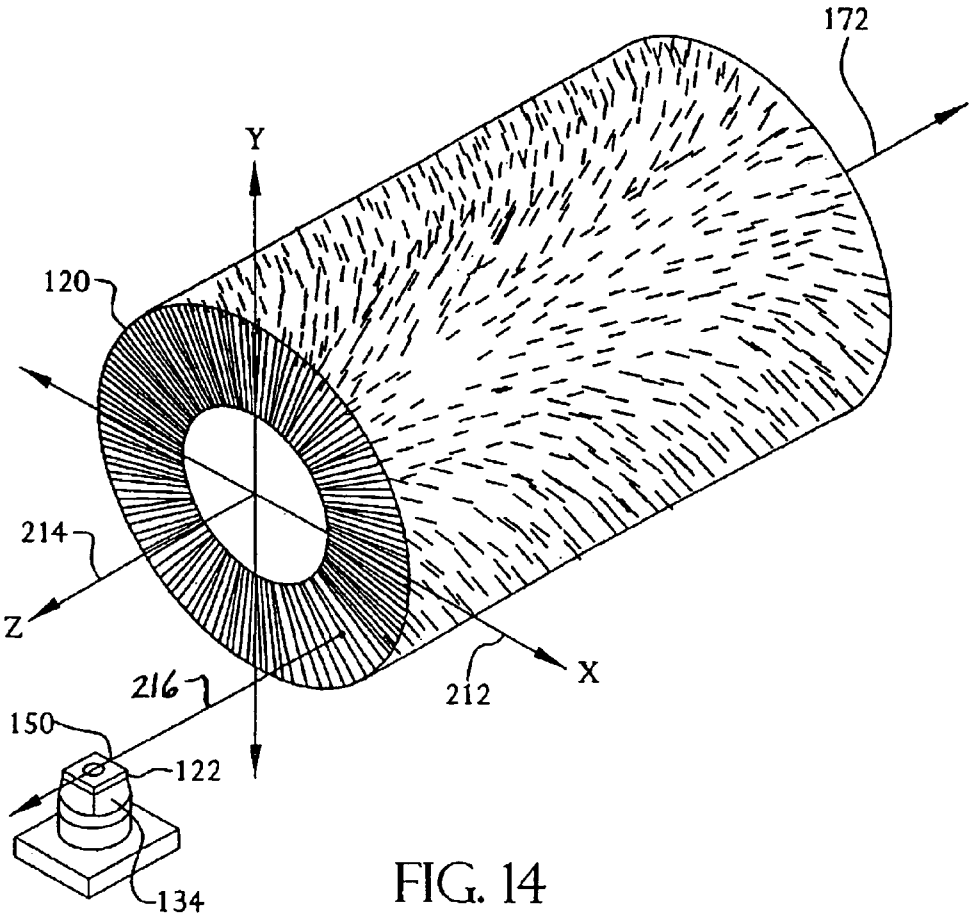


FIG. 14

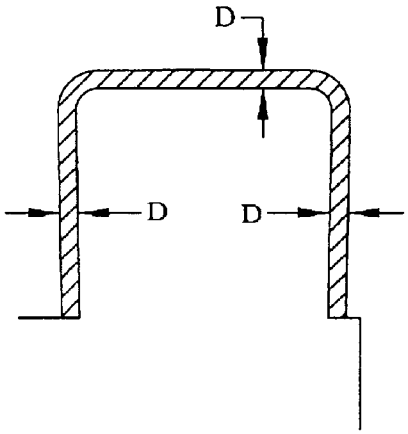


FIG. 15A

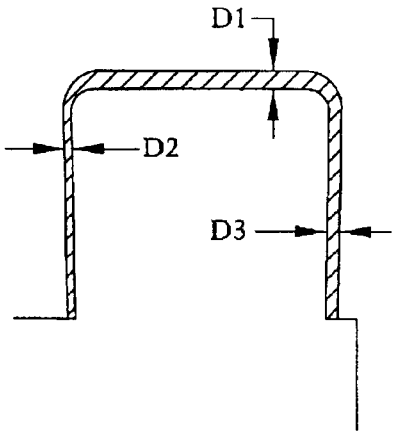


FIG. 15B

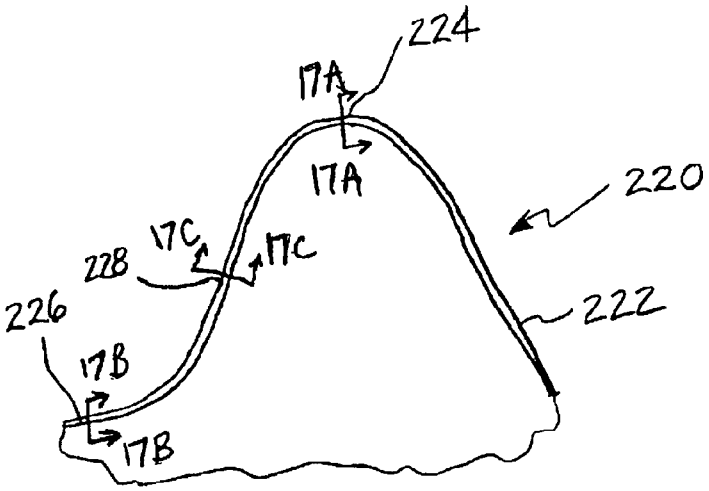


FIG. 16

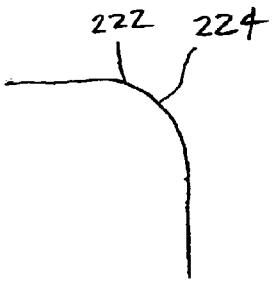


FIG. 17A

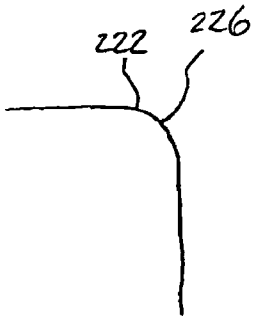


FIG. 17B

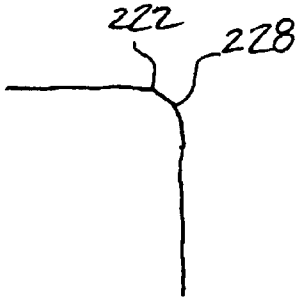


FIG 17C

TOOL HAVING HONED CUTTING EDGE

This application is a Div of Ser. No. 09/428,726 filed on Oct. 28, 1999, now U.S. Pat. No. 6,287,177.

FIELD OF THE INVENTION

The present invention pertains to a method and apparatus for honing precision edges on a workpiece, such as a cutting tool, using an abrasive brush. The invention particularly relates to a process and apparatus for controlling the position of a cutting tool edge relative to an abrasive honing brush in order to provide precise controlled edge honing.

BACKGROUND OF THE INVENTION

Cutting tools for cutting and shaping materials must be very hard to maintain their edges and withstand the high concentrated forces which are present at the cutting edge of the tool. These tools are frequently fabricated from carbide, ceramic, diamond coated carbide, CBN coated carbide or other tool materials which possess the necessary hardness. The disadvantage of using a hard material is that such materials tend to be brittle, and susceptible to crack formation. When cracks form, the material begins to chip, destroying the utility of the tool.

The predominant method of forming carbide edges on cutting tools uses a powder metallurgy process which involves placing powdered materials into a mold, and mechanically compacting them into specific tool geometric forms. The compacted tool form is then densified through a sintering process. The edges created by this process, however, are rough. Rough edges can adversely affect the performance of the tool, by increasing the tendency of the material to crack or chip. Furthermore, forces applied to the rough edge are not evenly distributed but, rather, are concentrated on high points of the edge. The low points of the edge tend to be sharp creating stress concentrations that increase the likelihood of crack formation. The rough edges on cutting tools can be smoothed by honing the edges before the tool is used in a machining process. Honing involves forming a rounded shape on the cutting edge of the tool. Early shapes were directed towards true radii, where the curvature of the smoothed edge was uniform across both surfaces adjacent to the edge.

More recently, edges having varying taper, i.e., non-uniform tapers about the periphery of the edge and generally called waterfall hones (see, FIG. 3*c*). Also, the correct sizing of the edge hone has been shown to affect tool life. As a result, the higher the precision with which the tool edges can be formed, the greater the resultant tool life.

Many different processes were originally used to smooth the edges of a cutting tool, including vibratory honing, mass media honing, slurry honing, honing inserts with media impregnated rubber wheels, dry blasting, wet blasting, and tumbling. These methods have several disadvantages, including intense labor requirements and poor predictability of edge hone characteristics between different tools exposed to the same honing process.

During the late 1970's, a process of honing using a brush having bristles impregnated with abrasive media was developed. In this process, bristles are forced into contact with the edge of the cutting tool. The forced contact results in the removal of material along the edge. Brush honing the cutting tool edges has typically required high brush rotational speeds, resulting in the abrasive bristles striking the cutting tool edge, rather than being dragged across the edge.

In a conventional honing process, the brush is rotated such that the speed of the tips of the brush range from 3,000 to 12,000 feet per minute. In order for these conventional processes to be commercially feasible, a high speed has been necessary in order to hone a sufficient quantity of cutting tools in a short period of time.

The apparatus used in conventional honing processes require the placement of the cutting tools to be honed on a rotating table. As the table rotates, the part is translated along an arcuate path past a rotating abrasive brush. The rotating table allows a continuous honing process to be used, with cutting tools being loaded at one position, honed at a second position, and removed from the table at a third position. The individual cutting tools were rotated as they are passed through the stationary, rotating brush. The circular formation of the table also presents a compact area within which the honing process can be accomplished.

One drawback to the use of a rotary table to feed the cutting tool to the honing brush is that the arcuate path produces an uneven hone on the work piece. More particularly, the arcuate path causes the contact between the tool edge and the honing brush to vary depending on the location of the tool on the path. As such, the resulting hone will vary across the edge of the part making precision honing very difficult.

Another deficiency with the prior methods of honing edges on the cutting tools is that the high bristle speeds result in the generation of excessive heat at the bristle tips. This heat causes the nylon bristles to partially melt, leading to nylon being deposited on the workpiece. The deposited nylon must then be removed before the tool can be coated, adding an additional step to the honing process. Attempts have been made to cool the bristles by using fluid coolants to alleviate or reduce the build up of heat at the bristle tips. The coolant, however, creates a material disposal problem which is not desirable.

Also, conventional processes for honing tool edges do not typically permit variation of the rotational speed of the brush during the honing process. Instead, the speed of the table is normally controlled to vary the amount of material removed from the tool.

The present invention overcomes the disadvantages of the prior art by controlling the contact of the cutting tool edge with the bristles of the abrasive brush so that the cutting tool edge moves through the volume occupied by the bristles. Thus, the material removal action is distributed over a greater portion of the bristle, thereby reducing the build-up of heat in the bristles. The movement of the cutting tool edge into the volume of the bristles further results in a greater material removal rate due to the greater contact between the individual bristles and the cutting tool edge.

SUMMARY OF THE INVENTION

An apparatus is disclosed for honing at least one edge on a workpiece, such as a cutting tool. In one embodiment of the invention, the apparatus includes a base with a variable speed motor mounted on it. An abrasive brush is mounted to the motor and includes a plurality of bristles attached to a hub. The bristles each have a tip end and an interior end, with the interior end being fixed to the hub. The motor is adapted to cause the abrasive brush to rotate about an axis of rotation. The width of the abrasive brush is defined by first and second ends. The combination of the width of the brush and the length of the bristles defines a volume. The honing apparatus also includes a rotational controller means for controlling the rotational speed of the motor.

A mount for holding a workpiece is attached to the base. The mount includes a fixture for holding the workpiece, and

a translational movement mechanism for controlling the position of an edge of the workpiece along a path substantially parallel to the axis of rotation of the abrasive brush.

In another embodiment, the motor is a fixed speed motor and the position of the workpiece edge relative to the abrasive brush is controlled by horizontal and vertical movement mechanisms.

A honing process is also disclosed for controlling the formation of a hone on the edge of a workpiece by controlling the movement and positioning of the workpiece through the volume of the rotating bristles. The movement and position of the workpiece is controlled so as to control the angle of impact between the bristles of the abrasive brush and an edge of the workpiece. The process results in the formation of precise tapered edges on the workpiece edge.

The foregoing and other features and advantages of the present invention will become more apparent in light of the following detailed description of the preferred embodiments thereof, as illustrated in the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of illustrating the invention, the drawings show a form of the invention which is presently preferred. However, it should be understood that this invention is not limited to the precise arrangements and instrumentalities shown in the drawings.

FIG. **1** is a perspective view of an embodimentof a brush honing apparatus according to the present invention.

FIGS. **2***a*–**2***c* are illustrations of generic cutting tools showing a representative cutting edge.

FIGS. **3***a*–**3***c* are partial sectional views of the generic cutting tool of FIG. **2** showing variations in the honing of the edges in more detail.

FIG. **4** is a section view of the motor and abrasive brush.

FIG. **5** is a perspective view of an abrasive brush.

FIG. **6** is a side elevation of a motor and a vertical movement mechanism.

FIG. **7** is a perspective view of an alternate embodiment of the apparatus incorporating horizontal and vertical movement mechanisms into the mount.

FIG. **8** is a perspective view of an alternate embodiment of the apparatus incorporating a distance positioning mechanism into the motor and an orientation mechanism into the mount.

FIG. **9** is a side view of an abrasive brush and a cutting tool identifying an alternate orientation of a cutting tool to an abrasive brush.

FIG. **10** is a side view of an abrasive brush identifying reference points on the first end of the abrasive brush.

FIG. **11** is a side view of a cutting tool and abrasive bristle, showing the relation between the bristle and the cutting tool with the cutting tool inside the brush volume along a path through reference point A in FIG. **10**.

FIG. **12** is a side perspective of a cutting tool and abrasive bristle, showing the relation between the bristle and the cutting tool with the cutting tool inside the brush volume along a path through reference point B in FIG. **10**.

FIG. **13** is a side perspective of a cutting tool and abrasive bristle, showing the relation between the bristle and the cutting tool with the cutting tool inside the brush volume along a path through reference point A' in FIG. **10**.

FIG. **14** is a perspective view of an abrasive brush identifying reference elements of the honing process.

FIGS. **15***a* and **15***b* are cross-sectional illustrations comparing a workpiece with a constant hone and a workpiece with a variable hone.

FIG. **16** is a side elevational view of a thread forming tool according to the present invention.

FIGS. **17A–17C** are partial sectional views showing a tip end, a root end and an intermediate point, respectively, of the cutting edge of the thread forming tool of FIG. **16**.

DESCRIPTION OF THE INVENTION

Referring now to the drawings, wherein like reference numerals illustrate corresponding or similar elements throughout the several views, FIG. **1** is an isometric illustration of one embodiment of a honing apparatus **10** according to the present invention. The apparatus **10** is designed to provide precise honing of an edge of a workpiece **22**. The invention can be used on a wide variety of workpieces which require honing, including components subject to wear, such as seal rings, piston plungers, slitter knives, valve seats, counter-balance weights and carbide or ceramic bushings. The invention has particular use in honing edges of cutting tools, such as drills, end mills, milling inserts, threading tools, burrs, router bits grooving tools, form tools and tools designed to cut materials, such as metal and wood.

The apparatus **10** includes an abrasive brush **20** driven by a motor **24**. The motor **24** is mounted to a base **32**. The workpiece **22** is mounted such that its position relative to the abrasive brush **20** can be controlled to vary the shape of the resulting hone.

Referring to FIGS. **2***a*–**3***c*, the workpiece **22** is shown with its edge **50** in an un-honed condition (FIG. **3***a*), with a radius hone **52** (FIG. **3***b*) and a tapered hone, such as the waterfall hone **54** (FIG. **3***c*). In order to form the various hones, the apparatus **10** is configured to control the position of the workpiece edge relative to the abrasive brush. In the embodiment of the invention shown in FIG. **1**, the relative location of the workpiece edge from the abrasive brush is achieved by changing the position of the motor **24** through the use of a horizontal movement mechanism **26** and a vertical movement mechanism **28** as will be discussed in more detail below.

As shown in FIG. **4**, the abrasive brush consists generally of a hub **60** to which a plurality of bristles **66** are attached. The bristles **66** have a tip end and an interior or root end **74**, which is attached to the hub **60**. The hub **60** is designed to removably attach to the motor **24**. As shown in FIG. **5**, the width of the abrasive brush **20** is defined by a first end **68** and a second end **70**, and the radius of the brush is defined by the distance from the bristle tips **76** to the axis of rotation **44** of the brush. As is apparent from the figures, the width of the brush, in combination with the length of the bristles **66**, defines a volume **72** which is illustrated and preferably in the form of a right cylinder. Although the present embodiment shows the abrasive brush **20** having bristles **66** fully surrounding the hub, the bristles **66** may be located in discrete rows along the hub, with spaces between the rows, as shown in FIG. **6**, or other patterns which do not completely fill the volume **72**. The preferred diameter for the abrasive brush is approximately 14 inches.

As described above, during operation, the contact between the bristles of the brush and a workpiece causes the bristles to heat up. In order to reduce the temperature of the bristles **66**, one embodiment of the present invention incorporates an impeller **62** in the hub that has a series of vanes designed to draw air into the hub **60** through an air intake **64**. The impeller **62** forces air out through the bristles **66** of the abrasive brush **20**, thereby reducing their temperature.

In order to control the rate of material removal, the present invention preferably incorporates a means for con-

trolling the speed of the abrasive brush. Referring to FIG. **4**, in one embodiment, the motor **24** that drives the abrasive brush **20** is a variable speed motor. This permits that rate of material removal to be varied depending on the workpiece and/or material being honed. Alternatively, a transmission (not shown) could be interposed between a fixed speed motor **24** and the abrasive brush, allowing variation of the rotational speed of the abrasive brush. A continuously variable transmission (CVT) would be a preferable transmission if a fixed speed motor were to be used.

The abrasive brush **20** is preferably rotated within a speed range which yields a linear speed of 180 to 1800 feet per minute at the tips of the bristles. The linear speed of the bristles tips can be calculated by multiplying the diameter of the abrasive brush times the rotational speed of the abrasive brush times π. As is obvious to one of skill in the art, the motor rotational speed does not need to be equal to the desired rotational speed of the abrasive brush, since gears or pulleys may be used between the motor and the abrasive brush to create non-unitary ratios of the rotational speed of the motor to the rotational speed of the abrasive brush.

The present invention also incorporates a controller **200** to allow an operator of the apparatus or a software program to control the rotational speed of the abrasive brush. The speed can be controlled depending on the desired hone, the location of the workpiece within the brush, and/or the type of material being honed. The controller **200** can be a conventional motor speed controller of a type dependent on whether the motor uses alternating current or direct current. If a CVT is used to vary the speed of the brush, the controller **200** could also be used to control the CVT.

The honing apparatus **10** also includes a mount **35** for positioning and moving the workpiece relative to the abrasive brush **20**. The mount includes a translational movement mechanism or translator **30** for moving the workpiece **22** along a linear path parallel to the axis of rotation **44** of the abrasive brush. It has been determined that linear translation of the workpiece through the abrasive brush produces a consistent and precise hone on the workpiece. The translational movement mechanism **30** is slidably attached to a guide **36** that preferably extends along a linear path parallel to the rotational axis of the abrasive brush **20**. The workpiece is held within a fixture **34** attached to the translational movement mechanism **30**. The translational movement mechanism preferably is driven along the guide **36** by a motor-driven screw drive. It is contemplated, however, that other drive systems can be substituted for the preferred screw-drive without detracting from the invention.

The present invention also preferably incorporates a controller (such as controller **200** discussed above) which includes a process control software program to accurately control movement of the workpiece on the translational movement mechanism with respect to the abrasive brush. For example, the controller **200** can be programmed to control the translational movement mechanism such that the workpiece moves in the forward direction through the abrasive brush, the reverse direction through the abrasive brush **20**, is stopped within the rotating abrasive brush, or oscillates in the forward and reverse directions within the abrasive brush. Those skilled in the art would readily be capable of making such a substitution.

In one embodiment of the invention, the fixture **34** that holds the workpiece **22** is attached to a rotating base **33**. The rotating base **33** is, in turn, attached to a positioning motor **37**, either directly or indirectly, through a transmission or direct drive. The positioning motor **37** positions or rotates the fixture **34** containing the workpiece while the translational movement mechanism **30** moves the workpiece **22** through the rotating abrasive brush **20**. A controller, such as controller **200**, controls the positioning motor **37** to vary the rotation of the fixture **34** in accordance with a predetermined program, such as a numerical control program, which accurately rotates, positions or stops the rotation of the positioning motor **37**. Alternately, the controller permits an operator to provide positioning commands to the motor **37**.

As shown in FIG. **1**, a vertical movement mechanism **28** is employed which adjusts the vertical position of the motor **24** relative to the base. In one embodiment, the vertical movement mechanism **28** includes a screw driven actuator that is controlled either manually, as by a handle **46** (FIG. **1**), or by a control motor **80** (FIG. **6**). If a control motor **80** is utilized, the motor **24** is preferably engaged to one or more guide rails **82** through linear bearings **86**. A screw **84** turned by the control motor **80** passes through a threaded fitting on the motor **24**, such that rotation of the screw **84** causes the motor **24** to move up or down. It is contemplated that the movement of the motor **24** and abrasive brush **20** may be pre-programed into a computer or other control device (such as the controller **200**) to provide automated and repeatable workpiece honing.

The embodiment of the invention shown in FIG. **1** also preferably includes a horizontal movement mechanism **26** for moving the motor **24** and abrasive brush **26** relative to the base **32**. Similar to the vertical movement mechanism **28**, the horizontal movement mechanism **26** preferably uses a screw drive to control the position of the motor **24** relative to the workpiece. The screw drive may be controlled by a handle **46** or a control motor system as discussed above.

It is contemplated that the apparatus **10** may include a device for inverting workpieces **22** after they have been honed. A suitable inverting device **39** is shown in FIG. **1** and includes a parallel gripper **38** which is adapted to pick up workpieces from and place workpieces on the fixture **34**. A vertical actuator **42** is attached to the mount **36** and raises and lowers the gripper **38**. A rotary actuator **40** attaches the gripper **38** to the vertical actuator **42**. The rotary actuator **40** is designed to rotate the gripper **38** up to 180 degrees about a horizontal axis for inverting the workpiece **22**.

In operation, after the workpiece passes through the abrasive bristles **66**, the gripper **38** grabs the workpiece. The gripper **38** is then translated upward and rotated a suitable amount to position another edge in an appropriate position for honing. The gripper **38** is then lowered until the workpiece is again placed in the fixture.

An alternate embodiment of the invention is shown in FIG. **7**. In this embodiment, instead of the motor **24** and abrasive brush **26** being vertically and horizontally adjustable with respect to the workpiece, the workpiece is mounted such that it can be appropriately positioned relative to a fixed abrasive brush **120**. Preferably, one or more control motors are used to position the workpiece **122** horizontally and vertically relative to the abrasive brush **120**. Alternatively, manual handles can also be used, similar to the handles described in the previous embodiment.

More particularly, in this embodiment, a vertical movement mechanism **131**, preferably attached to the mount **135**, moves the fixture **134** vertically relative to the base **132**. A horizontal movement mechanism **128** is also preferably engaged with the mount **135** and is designed to move the fixture **134** horizontally toward and away from the abrasive brush (i.e., substantially parallel to the base **132**). A translational movement mechanism **126** moves the workpiece

122, fixture 134, vertical movement mechanism 131, and horizontal movement mechanism 128 along guides 136 which preferably define a linear path parallel to the axis of rotation 144 of the abrasive brush 120. As with the previous embodiment, a rotating base and positioning motor can be incorporated to rotate the fixture and/or workpiece. As shown, an inverting device, including a parallel gripper 138, a rotary actuator 140, and a vertical actuator 142, can be incorporated for inverting the workpiece after honing, as discussed above.

A further embodiment of the invention is shown in FIG. 8. In this embodiment, a mechanism for controlling the distance between a workpiece 122 and the axis of rotation 144 of the abrasive brush 120 is incorporated into the apparatus 10. Referring to FIG. 9, the position of an edge 150 of the workpiece 122 relative to the abrasive brush 120 is shown. The orientation of the workpiece edge 150 is defined by the angle δ between a side surface 168 of the workpiece 122 and a radial line 170 extending from the axis of rotation 144 of the abrasive brush 120 through the workpiece edge 150. Rotation of the workpiece 122 about the workpiece edge 150 causes the point of contact between the abrasive brush 120 and a top surface 166 and the side surface 168 of the workpiece 122 to vary, thereby controlling the resulting shape of the hone.

Referring back to FIG. 8, an orientation actuator 160 is used to control the orientation of the workpiece 122 (e.g., cutting tool) with respect to the abrasive brush 120. The orientation actuator 160 includes a fixed portion 160F and a rotary portion 160R. The fixed portion 160F is mounted to the base 132. The rotary portion 160R is rotatably engaged to the fixed portion 160F. The guides 136 are attached to the rotary portion 160R. The fixture 134, which holds the workpiece 122, is slidably attached to the guides 136. In order to rotate the workpiece, the orientation actuator 160 is controlled (e.g., via a controller, such as controller 200 in FIG. 1) so as to rotate the rotary portion 160R. This, in turn, causes the guides 136 and the fixture 134 to rotate about an orientation axis of rotation 162. Depending on the location of the guides 136, fixture 134 and workpiece 122, the orientation axis may lie along the workpiece edge 150. Rotation of the workpiece 122 about this axis changes the angle δ between the side surface 168 and the radial line 170. As such, the point on the workpiece edge 150 that contacts the abrasive brush 120 will vary.

In this embodiment of the invention, the vertical position of the abrasive brush 120 is controlled by a distance positioning mechanism 164 which increases or decreases the distance between the axis of rotation 144 of the abrasive brush 120 and the workpiece edge 150. Alternatively, the fixture 134 can be vertically translated or rotated relative to the abrasive brush 120 in a manner similar to the various embodiments described above. As with the above embodiments, an inverting device can be incorporated into the apparatus to invert the workpiece.

The apparatus described in the various embodiments above is useful for honing precise edges on work pieces. The process for honing those edges will now be described in detail. One feature of the process according to the instant invention is the placement of the workpiece edge to be honed at a specific location within the volume of the bristles of the abrasive brush. This proper positioning, in combination with the operation of the abrasive brush at a preferred rotational speed, permits high precision workpiece edge honing.

FIG. 10 illustrates a cross-sectional schematic of an abrasive brush 20. As discussed in detail above, the present invention permits the workpiece edge 22 to be precisely located within the volume of the bristles. Various paths through the bristle volume 72 are shown in FIG. 10, each of which produces a different hone on the workpiece. At position A, assuming that the workpiece is oriented such that its top surface is parallel to the x-axis in the figure, a contact angle Φ between individual bristles 66 and the top surface 190 of the workpiece is relatively shallow (see, FIG. 11). This shallow contact angle results in more material being removed from the top surface 190 then the side surface 192, producing a waterfall hone (shown by the dashed lines) on the workpiece edge.

If the workpiece were located at position B, an approximately even amount of material would be removed on the top and side surfaces 190, 192 by the bristles. This results in a radiused hone.

Referring to FIG. 14, the process according to the present invention involves first placing the workpiece 122 into the fixture 134. The fixture 134 is then positioned relative to the abrasive brush 120 such that the workpiece edge 150 to be honed is located along a desired path 216 through the volume 172 of the abrasive brush. The location of this path in the volume 172 will depend on the desired hone shape as discussed above. The path 216 of translation through the bristle volume 172 is substantially parallel to the axis of rotation 214 of the abrasive brush. After proper positioning of the workpiece edge 150, the fixture 134 is translated through the volume 172.

Once the workpiece edge has passed through the bristle volume 172, an inverting device can be utilized to reposition the workpiece in the fixture 134 to permit a different edge 50 to be processed. For example, since cutting tools typically have cutting edges on opposed sides of the tool, the parallel gripper 38 is rotated 180 degrees before the workpiece is returned to the fixture 134. With the new edge positioned relative to the abrasive brush 20, the fixture is translated back through the bristles of the abrasive brush 20. If a different hone shape is desired on the new edge, the fixture can be repositioned relative to the abrasive brush prior to translation.

It is contemplated that the position and orientation of the workpiece within the volume of bristles and the speed of rotation of the abrasive brush can be altered during translation (i.e., while the workpiece is within the volume). This allows for the formation of a complex honed edge on the workpiece and allows controlled variation of the hone along the workpiece edge. Referring to FIG. 16 and FIGS. 17A–17C, for example, there is shown a threading tool 220 having a hone on the thread forming edge 222 that is varied from the tip end 224 to the base 226 of the thread forming edge of the tool. Referring to FIGS. 17A, it may desirable at the tip end 224 to have a larger hone to permit the thread forming edge 222, when in use, to dig through the raw material. Conversely, at the base 226 of the thread forming edge 222, shown in FIG. 17B, it may be desirable to have a sharper hone to permit more precise finishing of the threads in the material. FIG. 17C shows the hone formed at an intermediate point 228 along the thread forming edge 222. The present invention allows such precise hone control over the finished workpiece.

Another example of the use of the present invention for providing controller hone variation is shown in FIGS. 15*a* and 15*b*. FIG. 15*a* is a cross-sectional illustration of a grooving tool with a constant hone (designated "D" on all three sides). FIG. 15*b* is a cross-sectional illustration of a grooving tool with a controlled variable hone. As shown, the

hone on the top (designated "D1") is greater than the hones on the sides (designated "D2" and "D3").

The various positioning mechanisms discussed above allow complex workpiece edges to be precisely honed. The use of a controller in the present invention allows the honing process to be programmed and automated to ensure repeatability.

Although the invention has been described and illustrated with respect to the exemplary embodiments thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions and additions may be made therein and thereto, without parting from the spirit and scope of the present invention.

What is claimed is:

1. A tool having a cutting edge with a hone thereon that varies from a tip end to a root end, the hone being formed in accordance with a process comprising the steps of:

placing the tool in a fixture;

rotating an abrasive brush about a rotational axis, the abrasive brush including a plurality of abrasive bristles which define a volume;

adjusting the position of the cutting edge relative to the axis of rotation of the abrasive brush such that at least a portion of the cutting edge to be honed is substantially parallel to the axis of rotation of the abrasive brush and in a desired position to be honed;

translating the tool along a path substantially parallel to the axis of rotation of the abrasive brush such that a portion of the cutting edge passes through at least a portion of the volume of the abrasive brush to form a hone on the cutting edge having a first shape;

adjusting the position of the cutting edge relative to the axis of rotation of the abrasive brush such that another portion of the cutting edge is substantially parallel to the axis of rotation of the abrasive brush and in a desired position to be honed; and

translating the tool along a path substantially parallel to the axis of rotation of the abrasive brush such that said other portion of the cutting edge passes through at least a portion of the volume of the abrasive brush to form a hone on the cutting edge having a second shape different from the first shape.

2. A tool having a cutting edge with a hone thereon that varies from a tip end to a root end, the hone being formed in accordance with a process comprising the steps of:

positioning the cutting edge relative to an abrasive brush rotating about an axis of rotation, the abrasive brush having a plurality of abrasive bristles;

translating the tool along a path substantially parallel to the axis of rotation of the abrasive brush such that a portion of the cutting edge passes through at least a portion of the abrasive bristles to form a hone on the cutting edge having a first shape; and

repositioning the cutting edge while translating the tool through the abrasive bristles such that a second portion of the cutting edge is substantially parallel to the axis of rotation of the abrasive brush, the repositioning causing a hone having a shape different from the first shape to be formed on the second portion of the cutting edge being honed.

3. A tool as in claim **2**, wherein the shape of the hone at the tip end and the shape the shape of the hone at the root end are substantially the same.

4. A tool as in claim **2**, wherein the shape of the hone at the tip end and the shape of the hone at the root end are substantially the same and the shape of the hone in an intermediate portion of the cutting edge is variable between the tip end and the root end.

5. A tool as in claim **4**, wherein the shape of the hone in the intermediate portion of the cutting edge varies continuously from the tin end to the root end.

6. A high precision cutting tool comprising

a plurality of cutting edges formed on a portion of the tool, each cutting edge having a controlled hone formed on it; the magnitude of the hone on one edge being different than the magnitude of the hone on at least one other edge, the hone being formed in accordance with a process comprising the steps of:

placing the tool in a fixture;

rotating an abrasive brush about a rotational axis, the abrasive brush including a plurality of abrasive bristles which define a volume;

adjusting the position of the cutting tool relative to the axis of rotation of the abrasive brush such that at least a portion of a first cutting edge to be honed is substantially parallel to the axis of rotation of the abrasive brush and in a desired position to be honed;

translating the tool along a path substantially parallel to the axis of rotation of the abrasive brush such that a portion of the first cutting edge passes through at least a portion of the volume of the abrasive brush to form a hone on the first cutting edge having a first shape;

adjusting the position of the cutting tool relative to the axis of rotation of the abrasive brush such that a second cutting edge is substantially parallel to the axis of rotation of the abrasive brush and in a desired position to be honed; and

translating the tool along a path substantially parallel to the axis of rotation of the abrasive brush such that the second cutting edge passes through at least a portion of the volume of the abrasive brush to form a hone on the second cutting edge having a second shape different from the first shape.

7. A high precision cutting tool according to claim **6** wherein the magnitude of the hones on adjacent edges are different.

8. A high precision cutting tool according to claim **6** wherein the magnitude of the hone on an edge varies along at least a portion of the edge.

9. A high precision cutting tool according to claim **6** wherein the shape of the hone is non-symmetrical on at least one edge.

10. A tool having a cutting edge with a hone thereon that varies from a tip end to a root end, the hone being formed in accordance with a process comprising the steps of:

placing the tool in a fixture;

rotating an abrasive brush about a rotational axis, the abrasive brush including a plurality of abrasive bristles which define a volume;

adjusting the position of the cutting edge relative to the axis of rotation of the abrasive brush such that at least a portion of the cutting edge to be honed is substantially parallel to the axis of rotation of the abrasive brush and in a desired position to be honed;

translating the tool along a path substantially parallel to the axis of rotation of the abrasive brush such that a first portion of the cutting edge passes through at least a portion of the volume of the abrasive brush to form a hone on the first portion of the cutting edge, the hone on the first portion defining a dimension;

adjusting the position of the cutting edge relative to the axis of rotation of the abrasive brush such that a second portion of the cutting edge is substantially parallel to the axis of rotation of the abrasive brush and in a desired position to be honed; and

translating the tool along a path substantially parallel to the axis of rotation of the abrasive brush such that the second portion of the cutting edge passes through at least a portion of the volume of the abrasive brush to form a hone on the second portion of the cutting edge, the hone on the second portion defining a dimension corresponding to the dimension defined by the first portion that is different from the first portion dimension.

11. A tool having a cutting edge with a hone thereon that varies from a tip end to a root end, the hone being formed in accordance with a process comprising the steps of:

positioning the cutting edge relative to an abrasive brush rotating about an axis of rotation, the abrasive brush having a plurality of abrasive bristles;

translating the tool along a path substantially parallel to the axis of rotation of the abrasive brush such that a first portion of the cutting edge passes through at least a portion of the abrasive bristles to form a hone on the cutting edge defining a dimension; and

repositioning the cutting edge while translating the tool through the abrasive bristles such that a second portion of the cutting edge is substantially parallel to the axis of rotation of the abrasive brush, the repositioning causing a hone to be formed on the second portion of the cutting edge, the hone on the second portion defining a dimension corresponding to the dimension defined by the first portion that is different from the first portion dimension.

12. A tool as in claim **11**, wherein the dimension varies continuously from the tip end to the root end.

13. A tool as in claim **11**, wherein the dimension at the tip end is different from the dimension at the root end.

14. A tool as in claim **11**, wherein the dimension at the tip end is the same as the corresponding dimension at the root end, and the dimension along an intermediate portion is different from the dimension at the tip and root ends.

15. A high precision cutting tool comprising

a plurality of cutting edges formed on a portion of the tool, each cutting edge having a controlled hone formed on it defining a dimension; the dimension defined by the hone on one edge being different than a corresponding dimension defined by at least one other edge, the hones being formed in accordance with a process comprising the steps of:

placing the tool in a fixture;

rotating an abrasive brush about a rotational axis, the abrasive brush including a plurality of abrasive bristles which define a volume;

adjusting the position of the cutting tool relative to the axis of rotation of the abrasive brush such that at least a portion of a first cutting edge to be honed is substantially parallel to the axis of rotation of the abrasive brush and in a desired position to be honed;

translating the tool along a path substantially parallel to the axis of rotation of the abrasive brush such that a portion of the first cutting edge passes through at least a portion of the volume of the abrasive brush to form a hone on the first cutting edge;

adjusting the position of the cutting tool relative to the axis of rotation of the abrasive brush such that a second cutting edge is substantially parallel to the axis of rotation of the abrasive brush and in a desired position to be honed; and

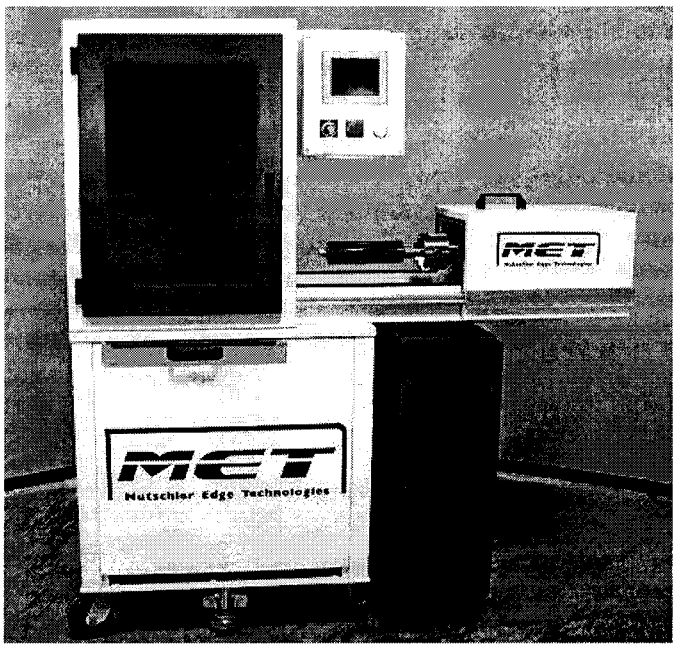
translating the tool along a path substantially parallel to the axis of rotation of the abrasive brush such that the second cutting edge passes through at least a portion of the volume of the abrasive brush to form a hone on the second cutting edge.

* * * * *

EXHIBIT "D"

Get An "Edge" On The Competition!

Mutschler Edge Technologies specializes in automated Edge Prep machines for the cutting tool industry, focusing on drills, end mills, reamers, gear cutting tools, and inserts. Edge prepping your tools can improve tool life up to 300%, decreasing down time, tool costs, perishable costs, and improving your overall product quality and consistency. Contact us **today and tell us about your edge prep application.**



MET-1 Universal Edge Prep System

EXHIBIT "E"

Get An "Edge" On The Competition!

In addition to providing automated machines for in-house processing, MET offers a piecework honing service for your tools. Give us a call, or send your inquiry to info@mutschleredgetech.com.

MET
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Edge Prep Service Guide (Round Tools)

Tool Type:	Diameter:	Cost:	Delivery:
Drill, single diameter	0 - .500"	$1.00	72 Hrs.
	.500" and up	$2.00	72 Hrs.
Drill, single diameter	0 - .500"	***$2.00***	***24 Hrs.***
	.500" and up	***$3.00***	***24 Hrs.***
End Mill, single diameter	0 - .500"	$1.50	72 Hrs.
	.500" and up	$2.50	72 Hrs.
End Mill, single diameter	0 - .500"	***$2.50***	***24 Hrs.***
	.500" and up	***$3.50***	***24 Hrs.***
Reamer	0 - .500"	$2.00	72 Hrs.
	.500" and up	$3.00	72 Hrs.
Reamer	0 - .500"	***$3.00***	***24 Hrs.***
	.500" and up	***$4.00***	***24 Hrs.***
Gundrill	0 - .500"	$1.00	72 Hrs.
	.500" and up	$2.00	72 Hrs.
Gundrill	0 - .500"	***$2.00***	***24 Hrs.***
	.500" and up	***$3.00***	***24 Hrs.***
Punch (HSS or Carbide)	0 - .500"	$2.00	72 Hrs.
	.500" and up	$3.00	72 Hrs.
Punch (HSS or Carbide)	0 - .500"	***$3.00***	***24 Hrs.***
	.500" and up	***$4.00***	***24 Hrs.***
Hobs and other tools on request		**Call for pricing**	

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Get An "Edge" On The Competition!

Cutting Tool Edge Preparation by Mutschler Edge Technologies

1.0 Why should I consider honing a cutting tool?

Honing the edge of a cutting tool has several benefits including:

- Improved tool life
- Improved surface finish of the workpiece
- Reduced spindle load
- Reduced overall cost of manufacturing

2.0 What exactly is "honing" or "edge prep"?

MET defines honing as the creation of a controlled radius and a surface finish improvement at the intersection of two points that create the cutting edge. Honed edges can be full radii, waterfall or a reverse waterfall.

3.0 What type of tools benefit from a honed edge?

We validate benefits with all types of tools, from H.S.S. to carbide. The major benefits occur on carbide prior to the coating of a tool. The radius edge allows the coating the adhere better to the tool surface since no dead sharp corners or burrs are present. If not honed prior to coating, the edge can fracture and expose substrate materials, shortening life and effectiveness of the coating and the tool. The surface finish of the edge is also improved, reducing friction and allowing for better chip evacuation. Tools include:

- Drills - all types of points
- End mills - O.D. and face - roughing and finishing
- Carbide inserts - most shapes
- Form ground round tools
- Reamers
- Taps
- Gear hobs
- Gear shaper cutters
- Spiral bevel stick blades
- Saw blades - round and hack style
- Rock drills

Tools that are not coated can also benefit from the controlled radius applied to the cutting edge by reducing friction and increasing the contact area of the cutting edge to the workpiece, strengthening the tool.

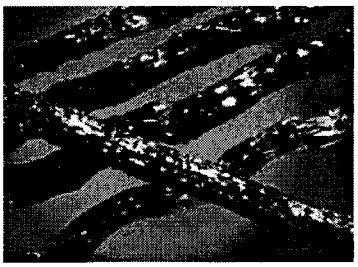
Click here to view Case Studies for Edge Prep

4.0 How does it work, and what can I expect from the process?

Honing is a dry process achieved by applying a nylon abrasive filament brush to the edges of the cutting tool. The brush filaments are constructed from a nylon carrier that is co-extruded with an abrasive grain. This means that as the brush wears, new abrasive grains are constantly being exposed to the workpiece. These flexible brush filaments act as "flexible files", wrapping and wiping across all edges evenly. There are two separate dynamics to using these brushes, one being the cut that the abrasive creates, the other being the force of the filaments as they contact the surface. Many factors determine the end result, such as speed, direction, cycle time, depth of engagement, centerline placement, etc. These settings can be pre-determined and maintained using any MET machine to create a honed edge.

The nylon abrasive brushes can be made in several different configurations. Some of the factors include:

- Filaments - The filaments can be round or rectangular, straight or crimped, and are available in many different diameters depending on the application.
- Abrasive grains - The abrasive used in the brush can also vary greatly depending on the application, some abrasives that are used are silicon carbide, aluminum oxide, ceramic, and diamond.



Depending on the hone that is desired, a brush configuration is typically available to allow that specific end result to be created.

When an edge is sharpened, the post ground material will create a ragged edge as the grinding wheel exits the cutting edge. This happens because there is no force pushing back on the edge to shear the burr away. If this edge is not addressed, the tool will have a dead sharp cutting edge that will quickly wear and fracture.

5.0 How much control and consistency can I expect?

Once a process is defined, it can be controlled to within a few tenths of an inch from part to part. The MET machine uses multiple programs to allow standard cycles to be used to achieve properly honed edges. By saving these "recipes", the process can be repeated quickly and easily with minimal effort from an operator.

6.0 How is the edge measured and validated?

The edge can be measured in a few different ways. Some common methods include visual measurements under a microscope, or the use of a contour tracing.

The contour tracing method shows the exact size and shape of the radius. It allows for better accountability to slight changes made in the development of the honed edge.

7.0 How do I know what hone my tools need?

The range of hones is as large as the range of tools. As a rule, the harder the workpiece material, the larger the hone required. The use of waterfall and reverse waterfall radii is for more specific end results. The best way to perfect the honed edge of a tool is to test the results and make adjustments accordingly, as each application is different.

8.0 How can I get my tools honed, and how much does it cost?

MET offers a honing service for all tools listed above. Contact us with your application today.

Mutschler Edge Technologies also offers several machines for sale. We will gladly show you the process and explain the machine before you purchase it. Leasing is available upon request. Please contact us and tell us about your application.

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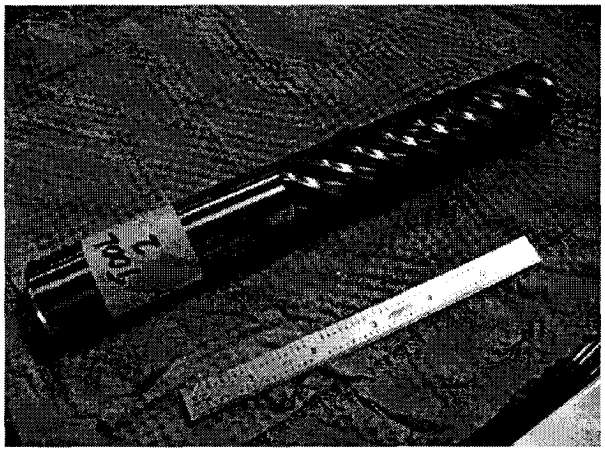
Get An "Edge" On The Competition!

Case Study 1



Tool Details: 1.25" Diameter Solid Carbide Ball Nose Endmill

6.00" Flute Length

Non-coated

Tool Price: $600.00 per tool

What It's Cutting: Titanium

What We Did: Apply a light edge prep to the tip, angle and O.D. of the tool.

The Results:

Before: Before Edge Prep, the tool cut one part before needing reconditioning

Cost Per Part: $600.00

After: After Edge Prep, the tool cut three parts before needing reconditioning

Cost Per Part: $200.00

Life Increase: **200%**

The Conclusion:

This test consisted of two tools, the first being applied a light prep, and the second being applied a medium prep. The life of the first tool was as described in this report, while the life of the second tool declined. This demonstrates the critical nature of a consistent and repeatable edge prep to the cutting tool edge.

Mutschler Edge Technologies, LLC