United States Patent [19]

Chalkley et al.

[11] **3,850,590**

[45] **Nov. 26, 1974**

[54] **AN ABRASIVE TOOL COMPRISING A CONTINUOUS POROUS MATRIX OF SINTERED METAL INFILTRATED BY A CONTINUOUS SYNTHETIC RESIN**

[75] Inventors: **Jack Rigler Chalkley**, Tuffley; **David Meirion Thomas**, Gloucester, both of England

[73] Assignee: **Impregnated Diamond Products Limited**, Tuffley Crescent, Gloucester, England

[22] Filed: **June 26, 1972**

[21] Appl. No.: **266,412**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 76,372, Sept. 28, 1970, which is a continuation-in-part of Ser. No. 870,411, Oct. 1, 1969, abandoned.

[52] **U.S. Cl.** **51/298,** 51/295, 51/309

[51] **Int. Cl.** **C08g 51/12**

[58] **Field of Search** 51/295, 298, 309

[56] **References Cited**

UNITED STATES PATENTS

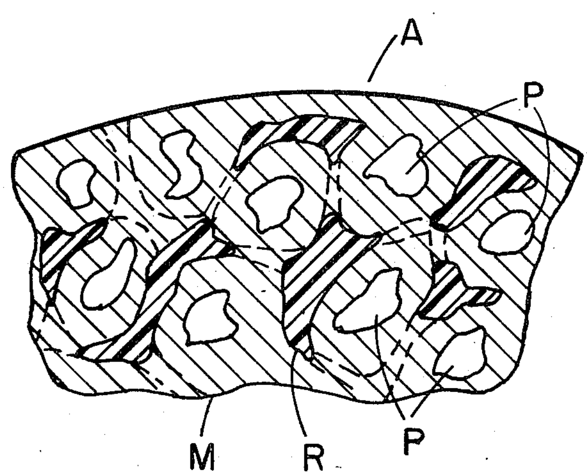
2,216,728	10/1940	Benner et al.	51/298
3,389,117	6/1968	Kozdemba et al.	51/298
3,402,035	9/1968	Martin	51/298
3,433,730	3/1969	Kennedy	51/298
3,471,276	10/1969	Bragaw	51/298
3,518,068	6/1970	Gillis	51/298
3,535,832	10/1970	Amero	51/295
3,547,609	12/1970	Gerry	51/298
3,594,141	7/1971	Houston et al.	51/295
3,650,714	3/1972	Farkas	51/298
3,664,819	5/1972	Sioui et al.	51/295

Primary Examiner—Donald J. Arnold
Attorney, Agent, or Firm—Shoemaker and Mattare

[57] **ABSTRACT**

This invention relates to an abrasive tool and to the method of making same, wherein abrasive particles are embedded in a continuous porous matrix of sintered metal and held in the metal phase, the continuous porous metal matrix being infiltrated by a resinoid material, the resinoid phase being substantially continuous throughout the porous sintered metal matrix, and the abrasive particles being at least as hard as aluminum oxide.

25 Claims, 3 Drawing Figures



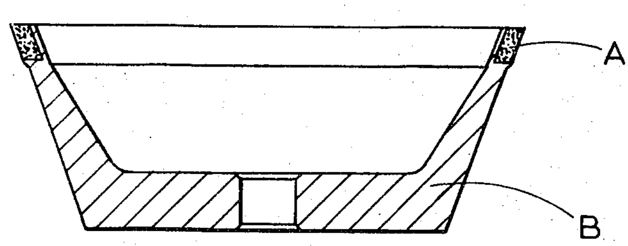


FIG. 1

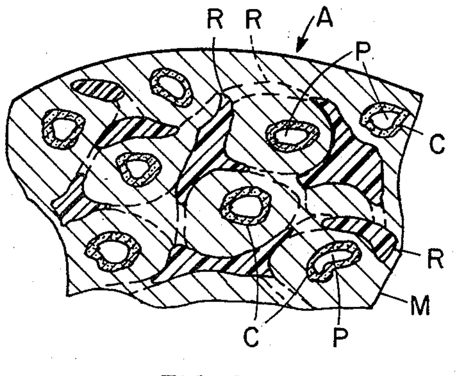


FIG. 2

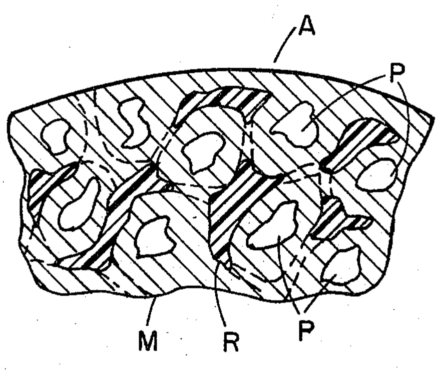


FIG. 3

INVENTORS

JACK RIGLER CHALKLEY

DAVID MEIRION THOMAS

BY

Shoemaker and Mattare

ATTORNEYS

AN ABRASIVE TOOL COMPRISING A CONTINUOUS POROUS MATRIX OF SINTERED METAL INFILTRATED BY A CONTINUOUS SYNTHETIC RESIN

This Application is a continuation-in-part of our application Ser. No. 76,372, filed Sept. 28, 1970, which is a continuation-in-part application of Ser. No. 870,411 filed Oct. 1, 1969 both now abandoned.

This invention relates to abrasive tools such as grinding wheels or cups and hones in which abrasive particles are held in a matrix.

Such tools have essentially two main component parts. The first of these is an abrasive part which in use is brought against a workpiece, and which may be in the form of a ring. In the case of a hone, the abrasive part may comprise a block or a plurality of blocks. This abrasive part comprises a matrix which is commonly of metal or of a resin bonded substance, and the abrasive particles are embedded in this matrix. The second main component part is the backing on which the abrasive part is directly carried or mounted. In the case of a wheel, such backing part may be in the form of a ring carried at the periphery of this disc.

Some of the problems of abrasive tools employing diamond as the abrading agent will be explained by way of example.

In a grinding tool employing diamond particles as the abrading agent, the diamonds must be securely held in the matrix to avoid wastage of the diamond particles before they have been worn down and utilized to optimum degree. In use, the diamond and the matrix wear and thus maintain a constant grinding action. Ideally, the surface of the tool should neither become clogged, nor should it be necessary frequently to dress the surface of the tool to remove blunted diamonds and release sharper particles more deeply embedded in the matrix.

On the other hand, excessive wear of the matrix is to be avoided to ensure maximum utilization of the diamond.

However, the material to be abraded may take many forms. Examples of typical operations are the cutting of stone which is relatively soft, and the shaping of hard cemented carbides, and hitherto it has not been possible to provide an abrasive diamond tool which is equally suitable and effective in these very different operations.

For abrading relatively soft materials, there are commonly employed metal matrices in which the diamond particles are locked in a continuous phase of metal. These hold the diamond particles well and resist the action of the abrasive grinding debris which would erode a softer matrix.

However, such metal matrices have not been regarded as suitable for abrading relatively hard materials, unless very brittle metal is employed. To obtain a fast and free cutting action, the matrix is required to break down and reveal new grinding points. If this does not happen, a blunted surface results. Brittle metal matrices, for example of epsilon bronze have proved the most satisfactory of the metal matrices for cutting hard materials. However, even these are limited as to their freedom of cut and due to their brittleness they lack structural strength and so are not suitable for some shapes of grinding tool. In particular, they are unsuitable for use with a flaring cup wheel, an example of which is shown in the accompanying drawing.

In the tool shown in the drawings, A is the abrasive part and B the backing. Such wheels are employed to shape cemented carbides, often grinding without coolant.

Accordingly, for abrading relatively hard materials and for rugged dry grinding operations, resin bonded matrices have been considered more suitable than metal matrices. Resin bonded matrices are more resilient and suffer less from brittleness. However, they wear faster than the metal counterparts and have inferior diamond holding properties leading to higher grinding costs.

It has long been sought to produce an abrasive part for a diamond grinding tool in which are combined, diamond holding properties equal to those obtained by employing a metal matrix, and properties of resilience and structural toughness equal to those obtained by employing a resin bonded matrix.

In one recent attempt to achieve this requirement, metal coated diamonds have been introduced. The diamond particles are coated with metal, for example nickel, and are embedded within a resin bonded matrix to form the abrasive part of the tool. The larger particle size afforded by the metal coating enables the diamonds to be better retained in the resin and significant improvements have been achieved. However, the diamond holding properties of such a matrix are still inferior to those obtained by employing a metal matrix.

On dry grinding, the improvements achieved using metal coated diamonds are also considered to be due, in part, to the high thermal capacity of the metal and its effectiveness as a heat sink in maintaining lower grinding point temperatures.

It will be appreciated from the foregoing that in the current practice of manufacture of diamond tools, the abrasive part is manufactured to suit the particular material to be abraded by appropriate choice of matrix, and, it should be added, choice of diamond concentration and particle size.

Analogous considerations arise when material other than diamond is employed for the abrasive particles.

The present invention has for its object to provide an improved matrix for the abrasive particles, suitable for use effectively and economically in a wider range of applications than is possible with compositions of matrix in current use.

A further object of the invention is to provide an advantageous method of manufacture of the abrasive part of a grinding tool.

Accordingly, the invention provides an abrasive tool, the abrasive part of which consists of abrasive particles embedded in a porous matrix of sintered metal and held in the metal phase, the pores of the metal matrix being infiltrated by a resinoid material, the metal phase being continuous throughout the structure and the resinoid phase being continuous or substantially continuous throughout the structure, the abrasive particles of material being selected from the group of abrasive materials which are at least as hard as aluminum oxide.

The abrasive particles employed may be metal coated or uncoated. If diamond is employed it may be natural or synthetic diamond.

By "resinoid material" in this specification and in the appended claims, we mean any polymeric material which can be infiltrated, in liquid form and at any suitable temperature and under any suitable pressure, into a porous metallic structure and which subsequently transforms into a solid phase either by setting or curing. Suitable resinoid materials are thermosetting polymers such as epoxide, polyester, polyurethane, phenolic, aminoplastic, polyamide, polyamideimide, alkyd, furan, and silicone or polymers of the silicone type. Thermoplastic materials such as acrylic, polyacetal, polyamide and polycarbonate resins may also be employed. Epoxy resin has been found particularly useful as the resinoid material.

The manufacture of an abrasive tool having an abrasive part with diamond as the abrasive will include the essential steps of sintering a mixture of at least one metal powder and diamond particles, metal coated or uncoated to form a matrix with continuous porosity; controlling growth during the sintering process to ensure that the abrasive particles are held in the metal phase; and then infiltrating the matrix with a resinoid material in liquid form, the resinoid substantially filling the pores of the metal matrix, so that the metal phase is continuous and the resinoid phase is continuous or substantially continuous throughout the structure.

The metal used for the matrix may be one element or two or more elements may be alloyed by the sintering process. As sintered metal there may be employed copper or copper-based alloy, tin or tin-based alloy, or there may be employed a sintered metal phase which consists of or contains as a major constituent one of the metals: iron, cobalt, nickel, silicon, zinc, silver, aluminum, chromium, manganese, or magnesium. For dry grinding operations alloy copper-tin allowy has been found satisfactory to form the porous matrix.

The essential requirement of the matrix is that on the one hand it should firmly hold the diamond particles, and on the other, it should be porous so as to be capable of being impregnated by the resinoid material in liquid form.

BRIEF DESCRIPTIONS OF THE DRAWINGS

FIG. 1 is a view in section of a tool according to the invention.

FIG. 2 is a greatly enlarged, diagrammatic fragmentary view in section of a portion of the abrasive part of one form of the invention wherein the abrasive particles are metal coated.

FIG. 3 is a diagrammatic view similar to FIG. 2 of a modification of the invention wherein the abrasive particles are uncoated.

FIGS. 1 and 2 are not intended to represent actual sections through the abrasive tool of the invention, but are instead graphical representations of the continuous metal and resinous phases.

In FIG. 2, the particles P are embedded in a continuous metal matrix M, through which a continuous resinoid phase R extends. The particles P are coated with a metal coating C.

In FIG. 3, the particles P are not coated and are embedded in a continuous metal matrix M, through which a continuous resinoid phase R extends.

The abrasive particle holding capacity is a function of the growth or shrinkage of the metal during the sintering process. Growth should be as low as possible, less than 2 percent when using diamond which is already metal coated and zero when using uncoated diamond. Shrinkage is less of a problem, provided that porosity is achieved, and shrinkage is advantageous when using uncoated diamond.

The copper tin alloy referred to above proved satisfactory in this respect, its growth being controlled to less than 1 percent.

By way of example, various compositions and methods of forming the abrasive part A of a 90 mm. diameter flaring cup wheel, as shown in the accompanying drawing, are described below:

EXAMPLE 1

Elemental copper and tin powders	size 300 mesh to dust
Metal coated diamond (nominally 45% by weight diamond)	150 mesh

Epoxy resin and filler are employed as starting materials.

10.4 grams tin powder, 15.6 grams copper powder, 4.7 grams coated diamond, together with a proportion of wax to add green strength (according to normal powder metallurgy technique) are well mixed and cold compacted at 14 tons per square inch, to the required shape of the diamond impregnated abrasive portion of the tool. In this example it is formed as a ring.

The "green" compact is supported on a former to maintain shape, and furnaced in an atmosphere of hydrogen, the temperature in this particular case following a cycle whereby it is heated for one hour to 230°C. and then for a further hour to 430°C. The compact is then allowed to cool under a protective atmoshpere, e.g., nitrogen, and when cool is then ready for the resin impregnation process.

Impregnation of the resinoid material is carried out by vacuum casting, although procedures such as centrifugal infiltration or ram injection could be used. The process is essentially one of forcing the liquid resinoid material into the pores of the metal structure.

Examples of other compositions of the porous sintered structure composed of metal and diamond particles are given below, all being for a 90 mm. flaring cup wheel as shown in the drawing.

EXAMPLE 2

The following elements were thoroughly mixed:

Metal coated diamond (nominally 45% by weight diamond)	4.69 grams
Fine copper powder	17.18 grams
Fine tin powder	4.29 grams

The mixture was pressed into a mould at eight tons per square inch and then furnaced for one hour with the temperature being steadily raised to 230°C. and for a further hour with the temperature being progressively raised to 420°C.

After this treatment the sinter produced according to this example was found to have a porosity of 38 percent by volume.

EXAMPLE 3

The following elements were thoroughly mixed:

Metal coated diamond (nominally 45% by weight diamond)	4.69 grams
Fine copper powder	16.9 grams
Fine tin powder	7.24 grams

The mixture was compacted at 10 tons per square inch and then furnaced as in Example 2.

After this treatment the sinter produced according to Example 3 was found to have a porosity of 30 percent by volume.

EXAMPLE 4

The following elements were thoroughly mixed:

Metal coated diamond (nominally 45% by weight diamond)	4.69 grams
Fine copper powder	16.42 grams
Fine tin powder	8.84 grams

The mixture was compacted at 12 tons per square inch and then furnaced as in Example 2.

The resulting sinter was found to have a porosity of 30 percent by volume.

EXAMPLE 5

The following elements were thoroughly mixed:

Metal coated diamond (nominally 45% by weight diamond)	4.69 grams
Fine copper powder	14.82 grams
Copper wire of approx. ⅛" staple length and 0.002" diameter	0.78 grams
Tin powder	10.40 grams

The mixture was compacted at 14 tons per square inch and then furnaced as in Example 2. The resulting sinter was found to have a porosity of 26 percent by volume.

EXAMPLE 6

The following were thoroughly mixed:

Metal coated diamond (nominally 45% by weight diamond)	4.69 grams
Fine cobalt powder	18.98 grams
Wax binder	

The mixture was compacted at 15 tons per square inch and then furnaced for 1 hour with the temperature being steadily raised to 600°C.

The resultant sinter was found to have a porosity of 48 percent by volume.

The sinter formed according to any of the above Examples 2 to 6 is suitably shaped in the compacting process and this shape is held during furnacing. After furnacing the sinter is allowed to cool in a controlled atmosphere of, for example, nitrogen.

In the resulting sinter, the metal coated diamond particles are held locked in a continuous metal phase of the matrix. In general, the matrix is required to have a specific porosity of between 10 percent and 50 percent. The resinoid material will then be infiltrated to occupy the voids in the porous sinter.

Once this has been infiltrated, the resinoid phase will be continuous or substantially continuous throughout the structure.

The only voids which remain unfilled will be those which are closed and using the compositions described in the Examples, such closed voids will be very few.

A particularly advantageous structure results if the same resinoid material employed to infiltrate the porous metal structure of the abrasive part of the tool is employed also in the back of the tool, that is the main body of the tool on which the abrasive part is carried or mounted. In such a construction the resinoid phase will be continuous across the joint between the abrasive part and the backing.

Such backing is suitably formed by casting resinoid material onto the abrasive part in a mould using standard resin casting techniques and preferably carried out prior to solidification or gelation of the infiltrated resinoid material. It may be necessary to first abrade the surface of the sinter in that region where the joint with the backing is to be formed so as to remove the skin effect caused by the sintering process, which skin effect results in loss of porosity at the exterior.

A suitable filler such as aluminum powder may be incorporated in the resinoid material employed for the backing. Such a filler will increase the mechanical strength of the backing and may also reduce the thermal gradient across the backing occasioned under arduous grinding conditions. Under such conditions, it is important to ensure that the temperature at the grinding points, that is the tips of the diamond particles engaging the work, does not approach the level, at approximately 1,000°C. when diamond degrades.

In this connection it is worth noting that although diamond is a good conductor, the continuous phase of metal embedding the diamonds provided according to the invention, acts as a heat sink.

A further means of inhibiting build-up of temperature at the grinding face is to incorporate a metal mesh, for example, aluminum mesh embedded in the resinoid material of the backing, preferably in the region adjacent the joint with the abrasive part and, in the case of the flaring cup shown in the drawing, such mesh will extend some 10 mm. inwardly of the cup from the joint.

In addition to the filler and/or the metal mesh incorporated in the backing as described above, further structural reinforcement may be obtained by incorporating in the resinoid material employed in the backing, fibres of carbon, glass or metal.

Indeed, wires or fibres of metal or carbon may also be incorporated in the diamond holding matrix for strengthening purposes. In Example 5 above, small copper wires are so incorporated and an alternative is that in Example 5 the copper wire content could be replaced by carbon fibres.

Diamond tools having abrasive parts according to the invention, have been found to have excellent abrading properties when used on a wide range of materials including very hard cemented carbides and to exhibit efficient and economical use of the diamond content. The abrasive part has adequate structural strength for use under extremely arduous grinding conditions without coolant. Economies both of manufacture and in use are to be expected by utilization of the invention.

Abrasive substances other than diamond may be employed in the abrasive tool according to the invention.

One hard abrasive substance which may be employed is crystalline cubic boron nitride. Abrasive tools using this substance as abrading agent are recommended for grinding certain special steels.

EXAMPLE 7

For the manufacture of a peripheral wheel of 150 mm. diameter × 6.35mm width with metal coated particles of crystalline cubic boron nitride distributed to a depth of 5mm., the starting materials were:

Metal coated particles of crystalline cubic boron nitride	15.71 grams
Copper	46.26 grams
Tin	30.84 grams

These materials were intimately mixed and compacted to a mould volume of 14.47 cm^3, sintered and infiltrated in the same way as the examples for diamond wheel manufacture. The ring was then fitted to an aluminum hub using the infiltrated resin as adhesive.

Performance testing of this wheel showed that it was ideally suitable for grinding certain steels.

Although diamond and similar very hard abrasive materials are to be preferred according to the invention, it is possible to employ other abrasive materials.

EXAMPLE 8

The following is an example of an abrasive tool constructed according to the invention and employing as the abrasive constituent an aluminum oxide based abrasive.

The starting materials for producing a grinding wheel of size - outside diameter 8 inches, inside diameter 2 inches, thickness 1 inch - are copper powder and white fused aluminum oxide of 85 mesh.

762 grams of the white fused aluminum oxide are mixed with 3,890 grams of copper powder. The mixture is compacted at 5 tons per square inch to the shape of the desired wheel, and then furnaced at 850°C. The resultant sinter has a porosity of approximately 25 volumes per cent and is impregnated with epoxy resin which is then cured.

The resultant wheel may be employed for electrolytic grinding since the continuous copper phase of the sinter will provide the necessary electrical conductivity.

All mesh sizes quoted in this Specification are to British Standard.

Finally it should be stated that although the abrasive particles may be all of one substance, a mixture of substances may be employed. Thus, particles of alumina and particles of diamond may be used in conjunction in one tool. Other common abrasive materials which may be employed are the aluminum oxide based abrasives such as emery and corundum, and harder abrasives such as silicon carbide or boron carbide or even tungsten carbide chips.

What is claimed is:

1. An abrasive tool the abrasive part of which consists of abrasive particles embedded in a continuous porous matrix of sintered metal and held in the metal phase, said sintered metal selected from the group consisting of: copper, copper-tin alloy, tin, iron, cobalt, nickel, silicon, zinc, silver, aluminum, chromium, manganese, and magnesium, and alloys thereof, the continuous porous metal matrix having a specific porosity of between 10 percent and 50 percent and being infiltrated by a resinoid material, the resinoid phase being substantially continuous throughout the porous sintered metal matrix and selected from the group consisting of: epoxide, polyester, polyurethane, phenolic, aminoplastic, polyamide, polyamidimide, alkyd, furan, silicone, acrylic, polyacetal, and polycarbonate resins, the abrasive particles being at least as hard as aluminum oxide.

2. An abrasive tool as claimed in claim **1** wherein the abrasive particles are metal coated.

3. An abrasive tool according to claim **2** wherein the abrasive particles are of diamond.

4. An abrasive tool according to claim **1** wherein the abrasive particles are of silicon carbide.

5. An abrasive tool according to claim **1** wherein the abrasive particles are of crystalline cubic boron nitride.

6. An abrasive tool according to claim **1** wherein the abrasive particles are of tungsten carbide.

7. An abrasive tool according to claim **1** wherein the abrasive particles are an aluminum oxide base abrasive.

8. An abrasive tool according to claim **1** wherein the abrasive particles are of boron carbide.

9. An abrasive tool according to claim **1** wherein the abrasive particles are of a mixture of different materials selected from the group consisting of diamond, silicon carbide, boron carbide, crystalline cubic boron nitride and aluminum oxide based abrasives.

10. An abrasive tool according to claim **1** wherein the sintered metal matrix is formed of an alloy of copper and tin.

11. An abrasive tool according to claim **1** wherein the metal matrix is reinforced with metallic fibres.

12. An abrasive tool according to claim **1** wherein the metal matrix is reinforced with carbon fibres.

13. An abrasive tool according to claim **1** wherein the abrasive part is mounted on a backing, said backing comprising a resinoid material identical to the resinoid material in the abrasive part, said resin phase being continuous across the joint between the abrasive part and the backing.

14. An abrasive tool according to claim **13** wherein a metallic filler is incorporated in the resinoid material forming the backing.

15. An abrasive tool according to claim **13** wherein a metal reinforcement is embedded in the material of the backing at least adjacent to the joint with the abrasive part.

16. A method of manufacturing the abrasive part of an abrasive tool, comprising sintering a mixture of at least one metal powder and abrasive particles, to form a continuous porous metal matrix having a specific porosity in the range of from 10 percent to 50 percent, said sintered metal selected from the group consisting of: copper, copper-tin alloy, tin, iron, cobalt, nickel, silicon, zinc, silver, aluminum, chromium, manganese, and magnesium, and alloys thereof; controlling growth of the metal during the sintering process to ensure that the abrasive particles are held in the metal phase; and then infiltrating the continuous porous metal matrix with a resinoid material in liquid form, the resinoid material selected from the group consisting of: epoxide, polyester, polyurethane, phenolic, aminoplastic, polyamide, polyamid-imide, alkyd, furan, silicone, acrylic, polyacetal, and polycarbonate resins, the resinoid material substantially filling the pores of the continuous metal matrix so that the resinoid phase is substantially continuous throughout the metal matrix, the abrasive particles being at least as hard as aluminum oxide.

17. A method according to claim **16** wherein the mixture of metal powders and abrasive particles is cold compacted to shape prior to the sintering process.

18. A method according to claim **16** wherein prior to impregnation, the sinter is allowed to cool under a protective atmosphere of an inert gas.

19. A method according to claim **16** wherein the impregnation of the resinoid material is carried out by vacuum casting.

20. A method according to claim **16** wherein carbon fibres are mixed with the metal powder prior to sintering.

21. A method according to claim **16** including the further step of casting a backing on to the impregnated sinter, the backing being composed of the same resinoid material as is used to impregnate the sinter.

22. A method according to claim **21** including the step of first abrading the sinter in the region where the joint with the backing is to be formed.

23. A method according to claim **21** including the step of incorporating a metallic filler in the resinoid material used to form the backing.

24. A method according to claim **21** including the step of casting the resinoid material used to form the backing about a metal mesh so that the mesh is left embedded in the backing and located in the region thereof adjacent to the joint with the abrasive part.

25. A method according to claim **21** including the step of incorporating in the backing a reinforcement consisting of material selected from the group of at least one of glass fibres, carbon fibres and metal fibres.

* * * * *