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71 Applicant: **SANDVIK AKTIEBOLAG**

S-811 81 Sandviken 1(SE)

72 Inventor: **Sundstedt, Gert**
Lövlund-Malmby

S-152 00 Strängnäs(SE)

Inventor: **Carlsson, Jan-Erik**
Lidköpingsvägen 79

S-121 49 Johanneshov(SE)

74 Representative: **Östlund, Alf Olof Anders et al**
Sandvik AB Patent Department
S-811 81 Sandviken(SE)

54 **Roll ring, comprising cemented carbide and cast iron, and method for manufacture of the same.**

57 The present invention discloses a roll ring for hot and/or cold rolling. The rolling track comprises one or several cemented carbide rings, which are cast into a casing made by an iron alloy. The cast alloy comprising a materially graphitic cast iron, which after the casting contains residual austenite. This residual austenite is at subsequent heat treatment or treatments partly or totally transformed under volume increase to mainly bainite with the aim of reducing or totally eliminating the differential shrinkage between the cast iron and the cemented carbide as a result from cooling after the casting.

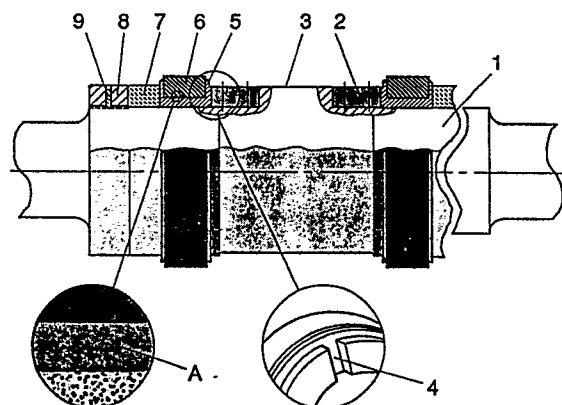


Fig. 1

EP 0 374 116 A1

Roll ring, comprising cemented carbide and cast iron, and method for manufacture of the same.

The present invention relates to casting one or several rings of cemented carbide into cast alloys based on iron, preferably cast iron. The resulting product is a composite roll ring, made in one piece only, with metallurgical bond between cemented carbide and cast iron. Possible driving devices for transmitting of torque are located in the cast iron part.

The use of roll rings of cemented carbide for hot or cold rolling has been hampered by the problem of transmitting the torque from the driving spindle to the carbide roll ring without causing serious tensile stresses. Cemented carbide belongs to the group brittle materials and has limited tensile strength with special notch sensitivity in inner corners, such as in keyway bottoms or other driving grooves, or at roots of driving lugs, made integral with the carbide ring. Methods based on such conventional joints have worked unsatisfactorily. Another method for the torque transmission is by means of frictional forces at the bore surface of the carbide ring. However, the radial force on this surface gives rise to tangential tensile stresses in the carbide ring with a maximum at its inner diameter. These tensile stresses are superimposed on other tensile stresses, generated when the roll is in use.

It is in and for itself known to cast a casing of an iron alloy onto a carbide ring for rolls used for hot and/or cold rolling (see for example the Swedish patent No. 7100170-5, publication number 371114).

It is also known to shape composite roll rings consisting of one working part of cemented carbide and a casing of a metal or a metal alloy, sintered to the carbide, where the two parts are metallurgically bonded to each other (see for example the US patent No. 3, 609, 849).

In the former case, during cooling from the casting temperature, the casing shrinks more than the carbide ring, giving rise to inwards directed forces on the carbide ring. These forces produce axially directed tensile stresses on the outer surface of the carbide ring, which are acting perpendicularly to micro cracks generated in the roll surface during rolling. Under the influence of these tensile stresses the micro cracks propagate in depth, which may cause roll breakage or need for excessive dressing amount, limiting the total rolling capacity of the roll.

In the latter case casing materials, either characterised by low hardness and low yield strength or cemented carbide, being a brittle material, are used; neither particularly suitable in the necessary torque transmission couplings.

In principle any grade of cemented carbide can

be used in roll rings according to the invention. However, the difference in linear thermal expansion of ductile iron and cemented carbide, the latter having the lower expansion, increases with reduced binding phase content in the cemented carbide. In rolls for hot rolling, cemented carbide grades with 15 or more percent by weight of binder phase, comprising cobalt, nickel and chromium in various combinations and amounts, have proved to be successful and are also used in composite roll rings according to the invention.

A composite roll ring is now in hand, where the detrimental tensile stresses have been eliminated or substantially reduced. This has been achieved by having cast the carbide into a materially graphitic cast iron with a composition adjusted to the carbon equivalent, $C_{eq.}$, in a way described in the Swedish patent No. 7601289-7, publication number 399911. The composition of the cast iron is also chosen with regard to optimal metallurgical bond to the carbide, to its strength, toughness and hardness, all necessary for the transmission of the torque, and to its machinability. By addition of ferro-silicium-magnesium and/or nickel-magnesium the cast alloy gets a magnesium content of 0,02 -0,10, preferably 0,04-0,07 percent by weight. By inoculation with ferro-silicium the cast alloy gets a silicon content of 1,9-2,8, preferably 2,1-2,5 percent by weight. Thereby a ductile iron is obtained having dispersed spheroidal graphite. This ductile iron has a hardness-toughness-strength which is well balanced to the application. In heat treated condition the Brinell hardness is 250-350. Further, the iron has been alloyed with austenite generating alloying elements such as nickel, molybdenum, manganese, and chromium, usually nickel in amounts of 3-10, preferably 4-8 percent by weight, and molybdenum in amounts of up to 3, preferably 0,1-1,5 percent by weight, resulting in a certain amount of residual austenite viz. 5-30, preferably 10-25 or rather 15-20 percent by weight after the casting.

By heat treatment in one or several steps a suitable amount of residual austenite can under volume increase be transformed to bainite. This volume increase can be so adjusted that the differential shrinkage, taking place in the composite roll ring during cooling from the casting temperature, can be totally or partly eliminated. The method for this heat treatment is adjusted according to carbide grade, composition of the iron, and roll application. The heat treatment includes heating to and holding at a temperature of 800-1000 °C, cooling to and holding at a temperature of 400-550 °C and cooling to room temperature. The first men-

tioned temperature interval 800-1000 °C results in increased toughness. With an addition of alloying elements, characterised by usually nickel in amounts of 3-6, preferably 4-5 percent by weight and molybdenum in amounts between 0,5-1,5 percent by weight, the heat treatment can be made by heating to and holding at 500-650 °C and cooling to room temperature.

The method of casting a carbide ring into cast iron follows mainly common casting technique. However, the demands on flawless metallurgical bond between cemented carbide and cast iron and on the required special properties of the cast iron call for accurate control of the casting technique, among others including the following clauses:

- Extreme over-temperature of the iron in the cradle.
- Amount and flow controlled streaming of molten iron for timed heating and melting of a surface layer of the carbide ring, located in the sand mould.
- Ignition of exothermal material kept in an ample space over the roll ring space in order to keep a certain extra amount of iron in molten state for after-filling of the roll ring space.
- Inoculation in the cradle as well as in the mould.

The ductile iron and the bond between the cemented carbide and the ductile iron in the cast composite roll ring are checked by ultrasonic methods.

The present composite roll ring generally receives the torque via conventional key joints, splines, clutches or similar known torque transmitting joints, located in the considerably less notch sensitive iron part of the composite roll ring, from which the torque is carried over to the carbide ring via the metallurgical bond between the cemented carbide and the cast iron. Still, there are rolling mills that only allow of friction drive in the roll ring bore.

In carbide roll rings the separating force is counteracted by radial force only from the spindle against the bore of the carbide roll ring. As the carbide has a Young's modulus of 2-3 times that of steel or cast iron, the separating force will elastically deform the material supporting the carbide roll ring in the bore, resulting in elastic deformation of the carbide ring and consequently in tangential tensile stresses in the carbide ring with maximum at the bore. In composite roll rings according to the invention the cast iron on both sides of the carbide ring will carry a part of the separating force, correspondingly reducing the tensile stresses.

The radial wall thickness of the carbide ring in composite roll rings according to the invention can be reduced due to the just discussed restrictions of the tensile stresses from the separating force. Furthermore, the torque transmission by conventional

key joints or similar does not add to the tangential tensile stresses. Also when driving by friction in the bore of composite roll rings, or when mounting with press fit between the composite roll ring and the spindle, the resulting tensile stress in the carbide ring is limited in relation to that of roll rings of solid carbide.

Compared to roll rings of solid carbide with keyways or lugs in the ring faces, the carbide rings in composite roll rings according to the invention can be made more narrow by locating the driving devices in the cast iron part.

Altogether the composite roll ring according to the invention is characterised by a carbide ring having smaller dimensions than roll rings of solid carbide, resulting in lower costs. Furthermore, the carbide ring has to be machined on the outer surface only, often by turning and then preferably of carbide grades containing 20 or more percent by weight of binder phase, and the machining of the bore, faces and driving devices is made in cast iron, being more easily machined than carbide, also resulting in lower costs.

The grooves necessary for torque transmission can be made in the bore or on the faces of the composite roll ring. One or several composite roll rings can be mounted on a roll body with journals in both ends, and which has parts fitting in the grooves of the composite roll ring, thereby transmitting the torque from the spindle either directly or via an intermediate sleeve. Some alternative designs are shown in figure 1 - 3.

Figure 1 shows a roll design where the torque is transmitted from the spindle 1 via keys 2, fastened in the middle part 3 of the spindle and fitting in the keyways 4 of the composite roll ring, to the ductile iron part 5 of the composite roll ring and via the metallurgical bond A to the carbide ring 6. The roll rings are fixed via the sleeve 7 by the nut 8 with a locking screw 9.

Figure 2 shows a roll design where the torque is transmitted from the spindle 1 via the key 2 to the sleeve 3, whose driving lugs 4 fitting in the grooves 5 transmit the torque to the ductile iron part 6 of the composite roll ring and via the metallurgical bond A further to the carbide ring 7. The relative axial position of the roll rings is determined by the sleeve 3 and is fixed via the sleeve 8 by the nut 9 with a locking screw 10.

Figure 3 shows a roll design where the torque is transmitted from the spindle 1 via the key 2 in the keyway 3 to the ductile iron part 4 of the composite roll ring and via the metallurgical bond A further to the carbide ring 5. The roll rings are fixed via the sleeve 6 by the nut 7 with the locking screw 8.

Figure 4 shows a composite roll ring mounted on a free spindle end i.e. the roll spindle has no

bearing on one side of the roll ring. The torque is transmitted by friction in the bore of the roll ring, generated by the tapered sleeve 2 driven up the taper part of the spindle 1, to the ductile iron part 3 of the composite roll ring and via the metallurgical bond A to the carbide ring 4.

Composite roll rings with carbide rings cast into ductile iron have been tested in finishing and intermediate rod mills, mounted on roll bodies with journals in both ends as well as on free spindle ends. They have also been tested as rolls for rolling reinforcement bars and tubes and as pinch rollers. Their performance has been in good agreement with the experience of carbide hot rolls gained since 1965. Carbide rings in the diameter range of 100-500 mm, preferably 200-450 mm, and the drive by driving devices in the ductile iron open up utilization also in bar mills. Carbide rings with diameters up to 500 mm make possible utilization in cold rolling mills and in other roll applications.

Example

A sintered cemented carbide ring with 70 % WC in a binder phase consisting of 13 % Co, 15 % Ni and 2 % Cr was blasted to clean its surface from any adhering materials. The outer diameter of the ring was 340 mm, the inner diameter 270 mm and its width 85 mm. A ring of sand was formed around the carbide ring and it was then placed in a bottom flask of a mould with suitable shape and dimensions and provided with the necessary channels and an overflow box for the molten iron. A ring of an exothermic material was placed in the top flask of the mould and the two flasks were put together and firmly locked.

Molten iron with a temperature of 1550 °C and with a composition in weight percent of 3,7 C, 2,3 Si, 0,3 Mn, 5,4 Ni, 0,2 Mo, 0,05 Mg, and balance Fe, was poured into the mould. In connection herewith inoculants of ferro-silicium-magnesium was added, included in the aforementioned analysis. The molten iron was poured into the mould in such an amount and at such a flow rate, that a suitable melting of the cemented carbide surface was obtained. When the iron had risen to the exothermic material, it started to burn adding heat to the iron. The mould cooled slowly to room temperature after which the roll was removed from the mould, excessive iron cut off and the roll cleaned. The quality of the bond and the absence of flaws in the iron was checked by ultrasonic methods.

The roll was then heat treated to transform retained austenite to bainite by heating to 900 °C and keeping at that temperature for six hours then lowering the temperature to 450 °C and keeping there for four hours before cooling to room tem-

perature. Finally, the roll was machined by turning to final shape and dimension viz. inner diameter of the bore 255 mm and width 120 mm.

Claims

Roll ring, preferably for hot and/or cold rolling by which the rolling track comprises one or several cemented carbide rings cast into a casing made by an iron alloy, characterised by a cast alloy comprising a materially graphitic cast iron, which after the casting contains 5-30, preferably 15-20 percent by weight residual austenite, which at subsequent heat treatment or treatments partly or totally is transformed under volume increase to mainly bainite with the aim of reducing or totally eliminating the differential shrinkage between the cast iron and the cemented carbide as a result from cooling after the casting.

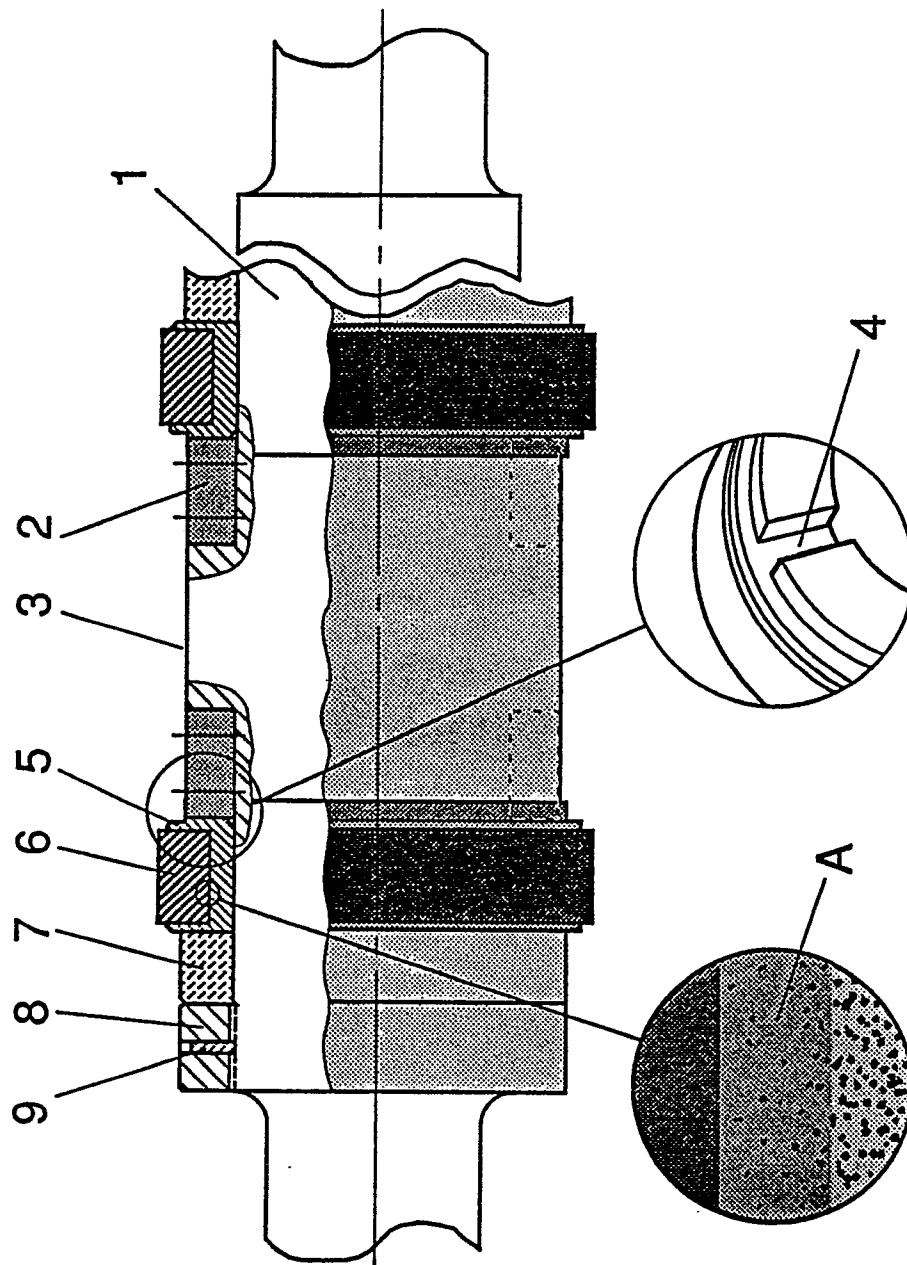


Fig. 1

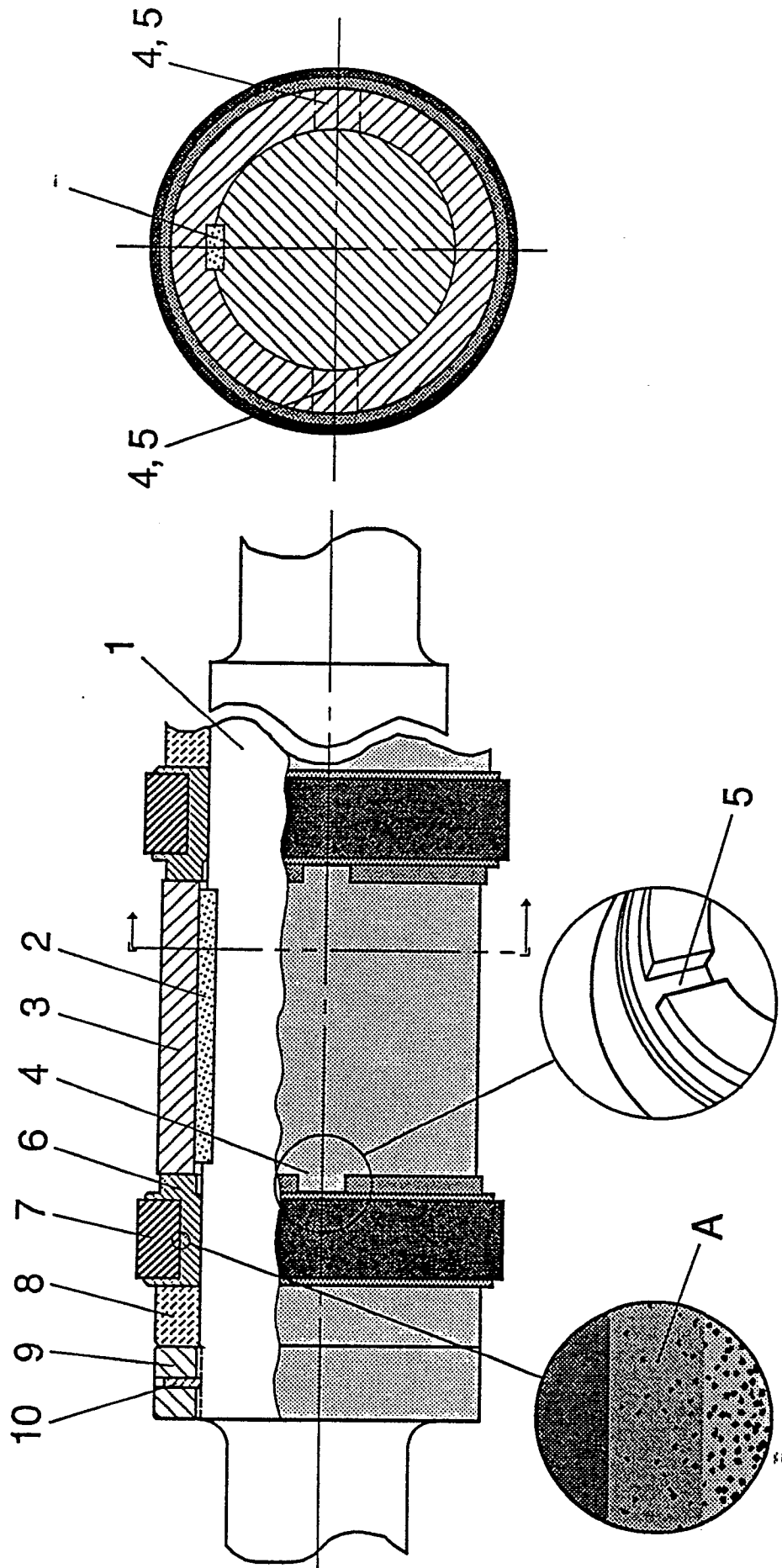


Fig. 2

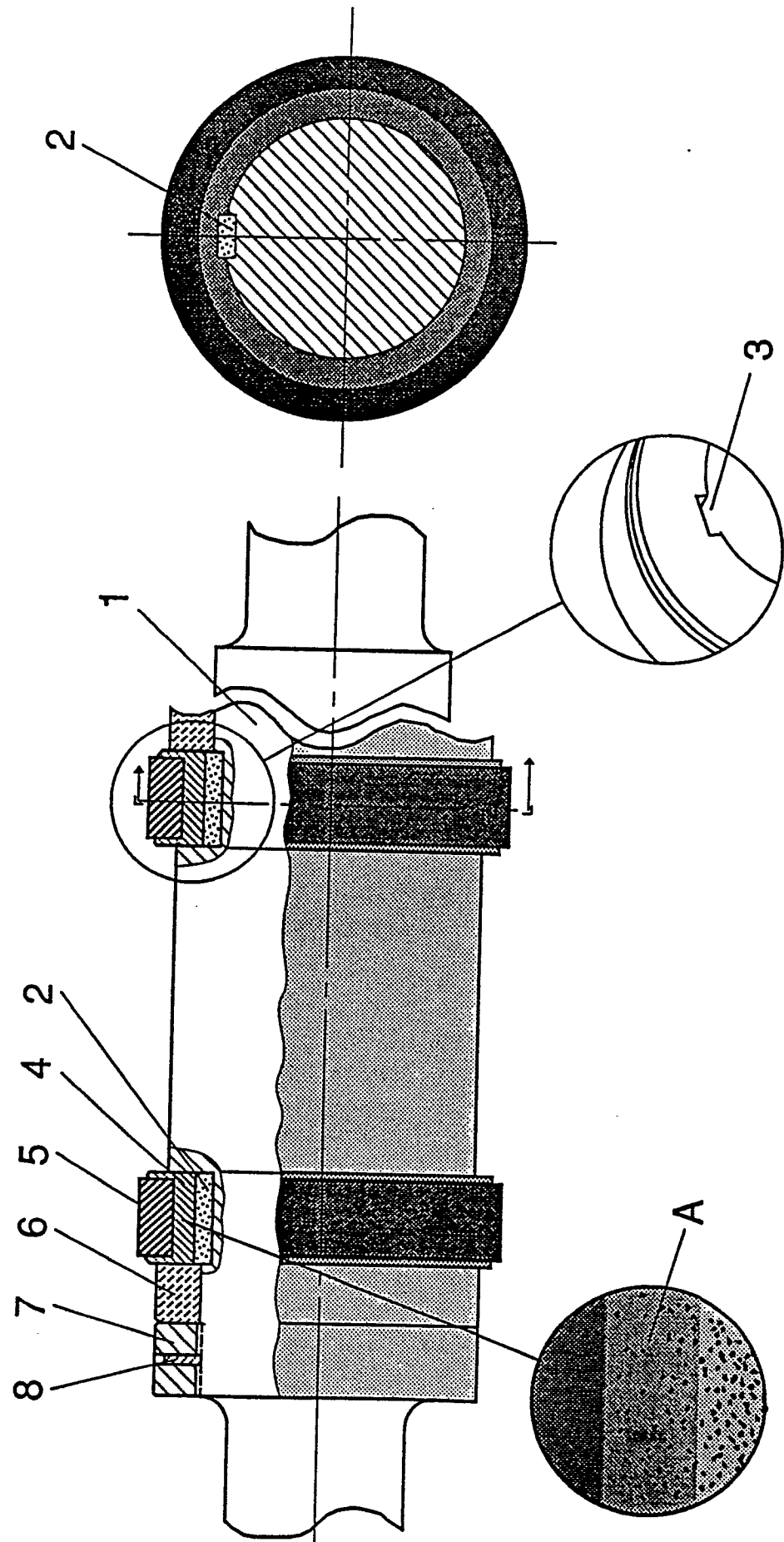


Fig. 3

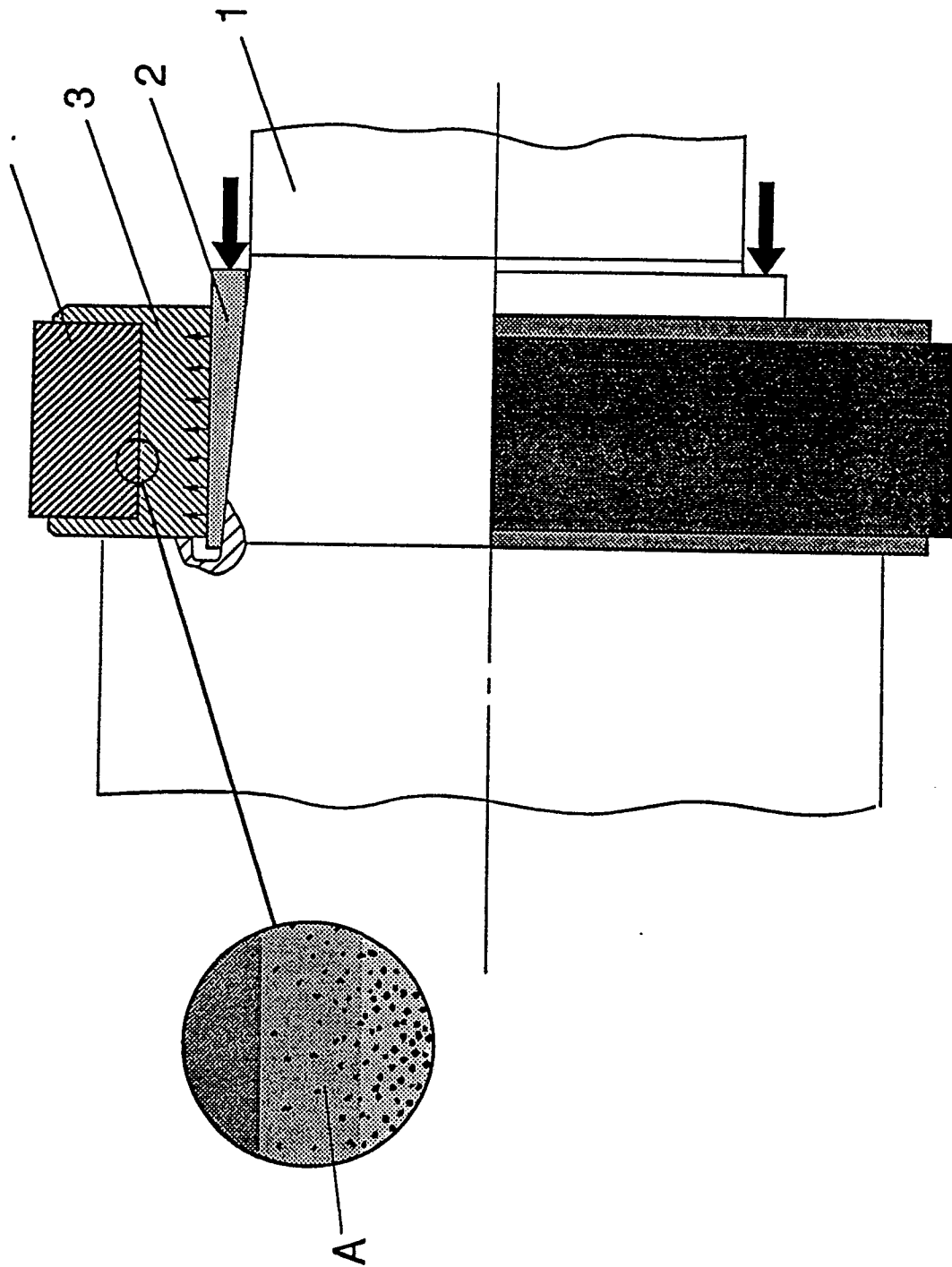


Fig. 4



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A,D	DE-B-2 200 285 (SECO TOOLS) * claim 1 * ---	1	C 21 D 5/00 C 22 C 37/04 B 22 D 19/16 B 21 B 27/03
A	PATENT ABSTRACTS OF JAPAN vol. 5, no. 33 (M-57)(705), 28 February 1981; & JP - A - 55 158 872 (KUBOTA TEKKO K.K.) 10.12.1980 ---	1	
A	US-A-3 549 430 (F.K. KIES) * claim 1 * ---	1	
A	US-A-3 860 457 (J. VOURINEN et al.) * claim 1 * ---	1	
A,D	DE-C-2 704 702 (SANDVIK) ---		
A,D	US-A-3 609 849 (J. M. KROL) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			C 21 D 5/00 C 22 C 37/04 B 22 D 19/16 B 21 B 27/03
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 09-03-1990	Examiner SUTOR W
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	