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(54) **MACHINING OF A MEMORY METAL**

BEARBEITUNG VON FORMGEDÄCHTNISMETALLEN

USINAGE D'UN METAL A MEMOIRE

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(73) Proprietor: **SANDVIK AKTIEBOLAG**
811 81 Sandviken (SE)

(72) Inventors:
- **THORVALDSSON, Tomas**
  S-811 35 Sandviken (SE)
- **FRODIGH, Johan**
  S-811 33 Sandviken (SE)
- **FORSSELL, Ola**
  S-811 62 Sandviken (SE)

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Description

[0001] The present invention relates to a process for the extrusion of tubes of a memory metal, in particular a memory metal of the type NiTi, and a tube produced according to this process.

[0002] So called memory metals relate to a group of materials which are characterized by their deviating thermo-mechanical properties. To these belong *inter alia* NiTi-based alloys and copper alloys of so called β-brass. The compositions, properties and applications of the memory metals are known by a number of publications in this area (see, e.g., Walter S. Owen: Shape memory effects and applications, an overview. Shape memory effects in alloys, edited by Jeff Perkins, 1975, Plenum Press New York; Process of Int. Symposium on shape memory effects and applications, Toronto, Canada, 19. - 22.5.1975). The memory metals are characterized in that their phase transformation (transition from a martensitic to an austenitic state and vice versa) takes place within a very limited temperature range in the order of magnitude 30°C.

[0003] The reason for extrusion of memory metal being desirable is that these materials are difficult to machine by cutting tools, because of rapid wear of the tool and slow production. Thus, it would be very advantageous to be able to produce these tubes by extrusion instead of cutting machining, e.g. when producing couplings and bit rings. A method of extruding clad wire of memory metal with a core of memory metal suitable for material of an ornament such as an eyeglass frame is shown in document EP-A- 0 555 062. However, a heat treatment, such as an extrusion, of a memory metal of NiTi-type is very difficult, since this material has a high affinity for oxygen at high temperatures, which leads to a strong oxidation and wasted material.

[0004] Thus, a primary object of the present invention is to provide a process that makes possible an extrusion of memory metal in general and of NiTi-based memory metal in particular.

[0005] A second object of the present invention is to provide an extruded tube of memory metal in general and of NiTi-based memory metals in particular.

[0006] For illustrative but non-limiting purposes, the invention will now be described in more detail with reference to the appended figure which schematically shows the production of a tube according to the present invention.

[0007] The used memory metal according to the exemplified embodiment consists of a NiTi-based alloy with an addition of niobium. The amounts can suitably vary from 35 to 60 % by weight Ni, 35 to 60 % b.w. Ti and 1 to 30 % b.w. Nb, preferably from 40 to 60 % b.w. of Ni and Ti, respectively and 1 to 20 % b.w. of Nb. In the concrete example, the concentrations of both Ni and Ti were 45 ± 2 % b.w. and Nb was 10 ± 4 % b.w., plus naturally occurring impurities.

[0008] In accordance with the invented process, one starts off from a solid bar 1 of memory metal, see step a). Through and concentrically with this bar, a hole 2 is drilled in a conventional manner, which hole thus should be centered around the central axis of the bar, in accordance with step d). If the bar 1 is not perfectly round or is uneven and/or rough on the outer surface, then a turning operation should be effected in order to attain sufficiently good surface smoothness and cylindricity. This is suitable in order to later attain a good fit in the cap 5; cf. underneath. In this case, the turning should be performed after the central drilling.

[0009] After the central drilling, possible turning and degreasing, e.g. by a suitable alcaline solution, the pre-prepared blank 3 is capped in, primarily for the exclusion of the oxygen of the air; see step b). However, before this encasing takes place, a core 4 of suitable fit and of the same length as the blank 3 is suitably introduced into the hole 2 according to step e). Preferably, there is a gap between the blank and the core for the introduction of a suitable release agent, such as talcum or a talcum-containing mixture. Such a core 4 is used instead of an internal mandrel at the extrusion, since the encasing prevents the use of such a mandrel. Further, a sleeve or cap 5 of equally good fit is threaded over the envelope surface of the blank 3, which cap has the same length as the blank 3. After this, two gable pieces 6 and 7 are welded to and around the end surfaces of the casing 5. The front gable 7, as seen in the direction of extrusion, is suitably rounded off around the edge, which is beneficial for the extrusion.

[0010] The materials used for the the core 4, the casing 5 and the gables 6, 7, respectively, can of course vary within broad limits, but at the tests the following alloys were used, % by weight being meant:

Table 1

	Steel	C	Si	Mn	Cr	Ni
Casing+gables	SS2172	0,20	0,30	1,5	<0,3	-
Core	15M13N2*	0,75	-	13	-	2

* Designation of Sandvik; also called Hadfield steel

[0011] In order to become extrudable, the ready blank or block 8 consisting of the blank 3, the core 4, the casing 5 and the gables 6, 7, were heated to about 1040°C and lubricated with glass on the outside. However, the extrusion temperature may vary, to a large extent depending upon the memory metal alloy, and may suitably lie between 900 and 1150°C, preferably between 1000 and 1050°C.

[0012] After this, the thus pre-prepared extrusion block was extruded according to step c). The dimension of the ready tube may vary within wide limits, depending upon the dimensions of the blank, the casing, the core and to which dimension one extrudes. For instance, if a thick-walled casing is used, then a ready-extruded tube of a smaller diameter is obtained. Further, a thicker core gives a more thin-walled tube. If one extrudes to a small diameter, of course a longer tube is obtained than if one extrudes to a large diameter.

[0013] After extrusion, the ends are cut according to step g). Generally it may be said that a typical extension factor before and after extrusion (i.e., also after cutting) is from 7 to 18 times, preferably from 10 to 15 times.

[0014] After cutting, cooling and straightening (e.g., by press or roller straightening), the casing 5' is removed, which can be effected in different ways. Usually, the surface of the tube 3' has to be turned clean to become sufficiently smooth, which involves that the casing 5' can be turned away in the same working operation. The casing can also be pickled away in a suitable pickling bath.

[0015] The core 4' may also be removed in different ways. When producing long tubes, for instance up to 10 m, the core is removed by extending it by between 10 and 30 %, preferably by about 20 %. Then the diameter of the core diminishes uniformly along its whole length and may then easily be removed, whereby a ready tube 3' remains , see step h). In order to extend the core, a piece of the tube has to be turned away at each end, in order to grip the part of the core that protrudes by said turning, in a traction machine. At shorter tube pieces, the core may be drilled out instead of being extended.

Example

[0016] A memory metal accoding to the above composition is prepared to a ready extrusion block according to steps a-d-e, the block having the following dimensions:

Blank diameter	71 mm
Blank diameter including casing	77 mm
Core (in "Hadfield steel")	31 mm
Length of blank and casing	350 mm

[0017] The block was extruded at 1040°C at a pressing force of 868 Mpa (8850 kp/cm^2) and with a pressing speed of 135 mm/s. Thereby, an extruded block with casing with a diameter of 19,1 mm was obtained, the ready tube having a diameter of 17,2 mm. The wall thickness of the ready tube was about 4,6 mm and its length was about 4500 mm.

[0018] The dimension ranges that are possible depend of course on the magnitude of the extrusion press that is used. In the example above, a press with a maximal pressing force of about 1300 Mpa (13 300 kp/cm^2) is used, and a maximal starting diameter of 77 mm. Thus, this means that the blank including the casing shall have a diameter that does not exceed 77 mm. On these conditions, the dimension range of the ready tube is from 10 to 47 mm. Said minimum diameter implies a tube length of about 20,6 m, while said maximum diameter results in a tube length of about 0,94 m, all under the above mentioned test parameters. Shorter and longer blanks than the above mentioned ones are of course also feasible, for instance down to 200 mm and up to 400 mm. The wall thickness can be varied by optional dimensioning of the core and may suitably lie between 2 and 15 mm.

[0019] If a larger press is used. then the dimension range can be increased upwards to larger diameters of the finished tube. Thus, with a suitable press. tube diameters of up to about 100 mm may be reached.

[0020] The extrusion of the thus encased, NiTi-based memory metal showed surprisingly good results. Thus, it turned out to be fully feasible to produce tubes from bar material, which tubes then may be machined further to the desired product. This involves *inter alia* that the necessity of the hitherto required cutting machining diminishes dramatically, or even is entirely eliminated, which brings considerable savings in time and costs. Memory metal of NiTi-type is difficult to machine by cutting, since it has a large wear resistance. Further, it was observed that the memory metal with gables, casing and core was very easy to extrude.

[0021] The fact that one needs to drill a hole into the bar 1 is not a major disadvantage, having regard to the fact that, according to the working example, the bar extends only about 30 cm, in comparison with a number of meters after extrusion. In this context it should be underlined that such long tubes of memory metal (e.g., ≥ 1/2 m) are very difficult to produce by cutting machining due to insufficient centering accuracy when drilling.

[0022] Some studies in light microscopy were made of the microstructure of the memory metal before and after extrusion. From these it is *inter alia* clear that a more homogenous structure was obtained in the extruded tube. with more evenly distributed niobium particles. This evenerdistribution is surprising *per se.* The function of the niobium particles is to increase the temperature at which the memory metal automatically reestablishes its original shape, since said particles counteract the reestablishment of the original shape of the metal.

[0023] A measurement in a bar before extrusion and in a tube after finished extrusion gave the following results with reference to niobium particles:

Bar	Average length:	79 µm
	Average width:	1,5 µm
Tube	Average length:	6.9 µm
	Average width:	1.4 µm

[0024] These measurements show that the average length of the niobium particles is stronly reduced at extrusion. No extruded tube had an average length for niobium particles of more than 15 µm.

[0025] A comparative test was also made with an identical blank, which however had not been encased but had only been provided with a core 4. An entirely inferior product was obtained, with a number of cracks. This is supposed to depend on the strong oxidation that is caused by the free access of air.

Claims

1. Process for the production of an element of memory metal,

a) one starts off from a blank of a memory metal,
b) the blank is encased by a casing, and preferably also by two gables, whereby the blank is excluded from the surrounding atmosphere,
c) the encased blank is heated and extruded,

characterized in that

d) sefore step b) a central hole is drilled in said blank,
e) after step d) and before step b) a core is introduced into the central hole,
f) after extrusion the ends of the extruded blank are removed,
g) also the core and the surrounding casing is removed, and
h) a tube is obtained that consists only of memory metal.

2. Process according to claim 1, ***characterized in that*** the starting blank is cylindrical.

3. Process according to claim 1 or 2, ***characterized in that*** the memory metal is NiTi-based.

4. Process according to claim 3, ***characterized in that*** the memory metal comprises 35 to 60 % by weight of nickel, 35 to 60 % by weight of titanium and 1 to 30 % by weight of niobium.

5. An element of NiTi-based memory metal produced by the process of claim 1, ***characterized in that*** it consists only of memory metal and is of tube-shape.

6. Element according to claim 5, ***characterized in that*** it contains 35 to 60 % by weight of nickel, 35 to 60 % by weight of titanium and 1 to 30 % by weight of niobium.

7. Element according to claim 6, ***characterized in that*** the average length of the niobium particles is < 15 µm.

8. Element according to claim 6 or 7, ***characterized in that*** its length exceeds 1/2 m.

Patentansprüche

1. Verfahren zur Herstellung eines Formgedächtnismetallelementes, in dem man

a) von einem Rohling eines Formgedächtnismetalls ausgeht,
b) den Rohling mit einem Gehäuse und vorzugsweise auch mit zwei Endstücken umgibt und der Rohling von der umgebenden Atmosphäre eingeschlossen wird,

c) den eingeschlossenen Rohling erhitzt und extrudiert,

dadurch gekennzeichnet, daß man

d) vor der Stufe b) ein mittiges Loch in den Rohling bohrt,
e) nach der Stufe a) und vor der Stufe b) einen Kern in das mittige Loch einführt,
f) nach dem Extrudieren die Enden des extrudierten Rohlings entfernt,
g) auch den Kern und das umgebende Gehäuse entfernt und
h) eine Röhre erhält, die nur aus Formgedächtnismetall besteht.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, daß** der Ausgangsrohling zylindrisch ist.

3. Verfahren nach Anspruch 1 oder 2, **dadurch gekennzeichnet, daß** das Formgedächtnismetall auf NiTi-Basis beruht.

4. Verfahren nach Anspruch 3, **dadurch gekennzeichnet, daß** das Formgedächtnismetall 35 bis 60 Gew.% Nickel, 35 bis 60 Gew.% Titan und 1 bis 30 Gew.% Niob umfaßt.

5. Formgedächtnismetallelement auf NiTi-Basis, hergestellt nach dem Verfahren des Beispiels 1, **dadurch gekennzeichnet, daß** es nur aus Formgedächtnismetall besteht und Röhrenform hat.

6. Element nach Anspruch 5, **dadurch gekennzeichnet, daß** es 35 bis 60 Gew.% Nickel, 35 bis 60 Gew.% Titan und 1 bis 30 Gew.% Niob enthält.

7. Element nach Anspruch 6, **dadurch gekennzeichnet, daß** die Durchschnittlänge der Niobteilchen <15 µm beträgt.

8. Element nach Anspruch 6 oder 7, **dadurch gekennzeichnet, daß** seine Länge ½ m überschreitet.

Revendications

1. Procédé de production d'un élément en métal à mémoire,

a) on part d'une ébauche en métal à mémoire,
b) cette ébauche est revêtue d'une capsule et également de préférence de deux parois verticales, de sorte qu'elle est ainsi isolée de l'atmosphère environnante,
c) l'ébauche ainsi enveloppée est chauffée et filée,

caractérisé en ce que

d) avant l'étape b), un trou central est percé dans ladite ébauche,
e) après l'étape d) et avant l'étape b), un noyau est introduit dans ce trou central,
f) après le filage, les extrémités de l'ébauche filée sont enlevées,
g) le noyau et la capsule qui entoure l'ébauche sont également enlevés, et
h) on obtient un tube qui ne comprend que du métal à mémoire.

2. Procédé selon la revendication 1, **caractérisé en ce que** l'ébauche de départ est de forme cylindrique.

3. Procédé selon la revendication 1 ou 2, **caractérisé en ce que** le métal à mémoire est à base de NiTi.

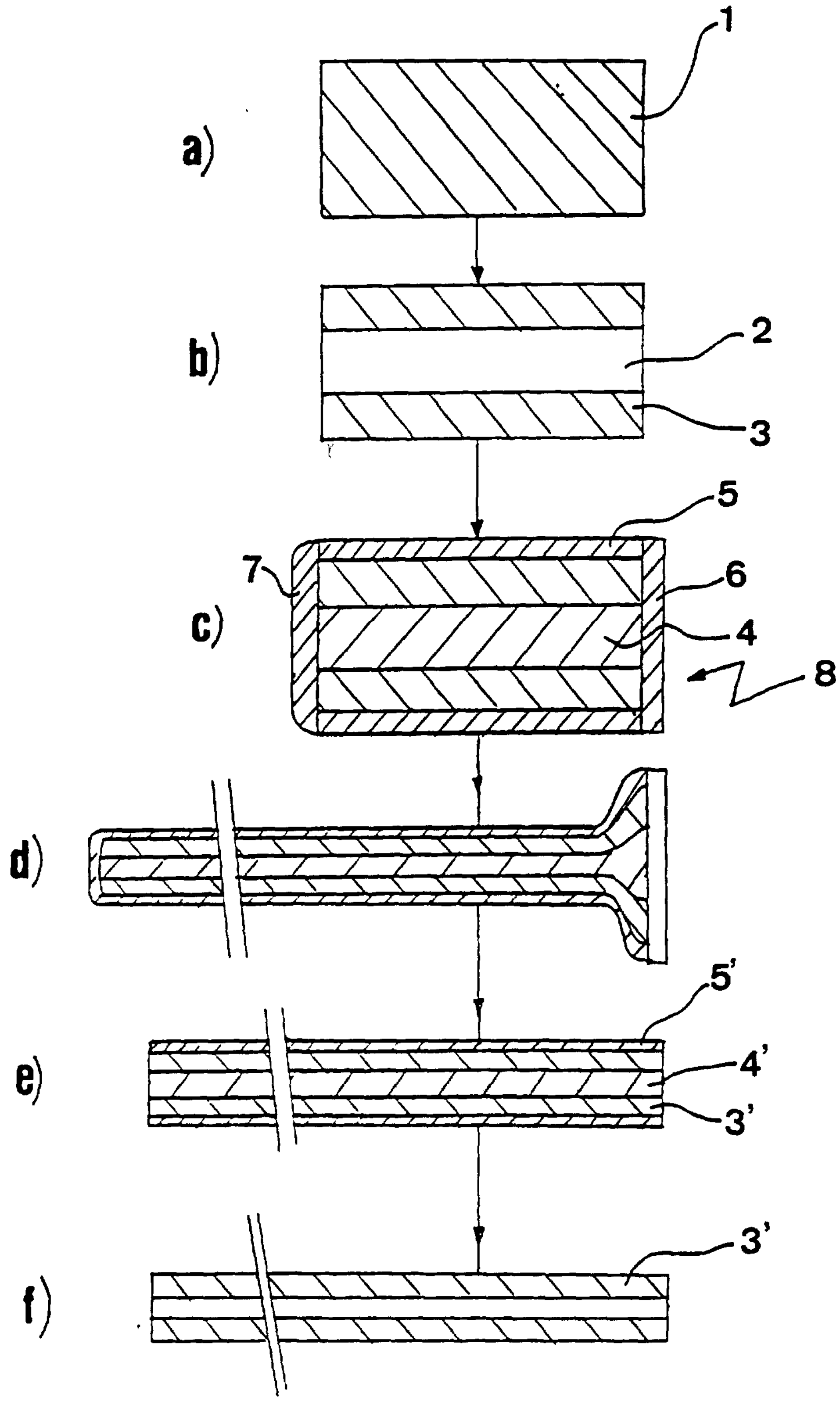
4. Procédé selon la revendication 3, **caractérisé en ce que** le métal à mémoire comprend de 35 à 60 % en poids de nickel, de 35 à 60 % en poids de titane et de 1 à 30 % en poids de niobium.

5. Elément en métal à mémoire à base de NiTi produit en utilisant le procédé selon la revendication 1, **caractérisé en ce que** cet élément ne comprend que du métal à mémoire et **en ce qu'**il est de forme tubulaire.

6. Elément selon la revendication 5, **caractérisé en ce qu'**il contient de 35 à 60 % en poids de nickel, de 35 à 60 % en poids de titane et de 1 à 30 % de niobium.

7. Elément selon la revendication 6, **caractérisé en ce que** la longueur moyenne des particules de niobium est < 15 µm.

8. Elément selon la revendication 6 ou 7, **caractérisé en ce que** sa longueur dépasse 1/2 m.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