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(54) **Apparatus for the metallization of metal components and relevant metallization method**

(57) An apparatus (4) for the metallization of metal components (8) and relevant metallization method. The apparatus (4) and the method of the present invention allow coating light alloy metal components having even very small thickness, ensuring high surface hardness and improved resistance to fatigue of the component itself.

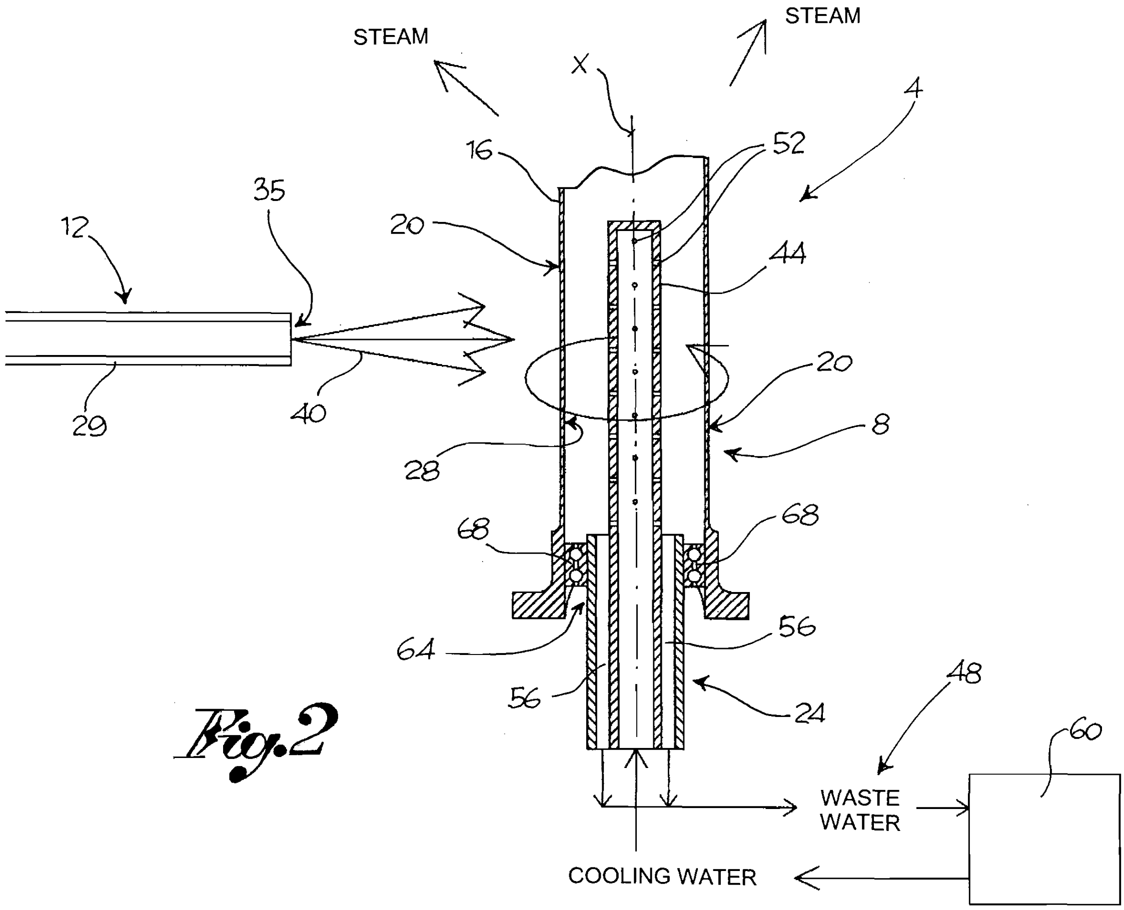

Fig.2

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Description

[0001] The present invention relates to an apparatus for the metallization of metal components and a relative method of metallization and in particular, an apparatus and a method for the metallization of light alloys.

[0002] Surface hardening processes are known in the art, aimed at improving the resistance of mechanical components stressed to fatigue. In fact, such fatigue resistance is strongly influenced by the features of the surface of the components themselves. For example, the surface roughness is one of the first parameters that must be kept into account in the design and manufacture of components subject to fatigue. Also the residual tensions, at the surface as well, greatly influence the behaviour at fatigue; in fact compression tensions greatly increase the resistance capacity while tractions drastically reduce resistance. Mechanical treatments are used to induce residual compression tensions, such as shot-peening or rolling, whereas to improve the mechanical features, on the surface as well, thermo-chemical treatments such as case hardening or ammonia hardening are used.

[0003] Over the last decades, in order to improve abrasion resistance characteristics, various metallization processes have been introduced that allow coating substrates with a poor abrasion resistance with materials having high hardness. For example, in the petrochemical field it has been a decade since the valve balls are coated with tungsten or chromium carbides to prevent abrasion problems due to very hard particles found in the fluids. Such processes use instruments capable of sending a supersonic flow directly against the surface to be coated.

[0004] As regards light alloy components, such as aluminium alloys, the process of application on light alloy substrates causes an excessive surface heating, given by the impact of the particles (and by the partial transformation of their kinetic energy into heat) and by the impact of the combustion gas at a high temperature. Since the mechanical properties of light alloys quickly decay in the presence of relatively low temperatures (a little above 120°C), with any method used the metallization imparts no surface improvement to light alloy components.

[0005] To solve this technical problem it is known to cool the surface of the parts to be metallized by gas jets at a low temperature, generally nitrogen. This allows reducing the temperature of the applied layer, but it does not considerably reduce the temperature of the application/substrate interface, due to the high thermal exchange induced by the transformation of the kinetic energy into heat during the impact of the particles.

[0006] In fact, no suitable surface hardness is obtained by applying metal layers on light alloy layers. The smaller the thickness of the component to be metallized, the stronger this limitation.

[0007] In the prior art, therefore, there are no apparatus or methods of metallization of light alloy components suitable for significantly improving the surface features thereof.

[0008] The problem of the present invention is to solve the limits and disadvantages mentioned with reference to the prior art.

[0009] Such disadvantages and limits are solved with an apparatus in accordance with claim 1 and with a method in accordance with claim 15.

[0010] Further embodiments of the apparatus according to the invention are described in the following claims.

[0011] Further features and the advantages of the present invention will appear more clearly from the following description of preferred non-limiting embodiments thereof, wherein:

- figure 1 shows a schematic view of an apparatus according to an embodiment of the present invention, in an operating step;
- figure 2 shows a schematic view of the apparatus of figure 1 in a further operating step;
- figure 3 shows a schematic view of a detail of the apparatus of figure 1;
- figure 4 shows a diagram that illustrates the mechanical features of a specimen obtained according to prior art metallization techniques;
- figure 5 shows a diagram that illustrates the mechanical features of a specimen obtained according to the apparatus and the method of the present invention.

[0012] Elements or parts of elements in common between the embodiments described below are referred to with the same reference numerals.

[0013] With reference to the above figures, reference numeral 4 globally denotes an apparatus for metallization, suitable for providing a metal coating on a component 8, preferably a component of metal material in a light alloy.

[0014] Apparatus 4 comprises means 12 for depositing a metal layer on a component, said deposition means 12 being directly facing a wall to be coated 16 of said component 8 so as to address a flow of metal material on a first surface 20 of said wall to be coated 16.

[0015] advantageously, said apparatus 4 comprises a cooling head 24 suitable for sending a cooling fluid flow on a second surface 28 of said wall to be coated 16, the second surface 28 being opposite the first surface 20 so as to not be impinged by the flow of metal material.

[0016] For example, component 8 may be a globally cylindrical component, wherein the first surface 20 consists of the outer side surface or portion thereof and the second surface 28 consists of the inner side surface or portion thereof.

[0017] According to a preferred embodiment, the deposition means 12 comprise a metallization gun 29 suitable for performing an HVOF (High Velocity Oxyfuel) method for metal coating.

[0018] In this method (figure 3) the combustible, typically paraffin and the comburent, typically oxygen, get mixed and they atomise after passing through respective inlet orifices 30, 31 inside the combustion chamber 32 wherein the combustion takes place by the use of a spark plug 32'.

Pressure in the combustion chamber 32 is monitored constantly to ensure proper combustion and constant pressure.

The particle speed is directly related to the pressure of chamber 32; the gun comprises a converging-diverging nozzle 33 having such shape and size as to create a supersonic jet. Particles of metal powder, which make up the coating, are introduced downstream of the diverging portion through inlets 34 and are then brought to such temperature as to make them partially plastic. A flow of metal particles 40 at high speed is therefore obtained wherein the metal particles exit at a high speed from an outlet 35 of gun 29 and thus impact against the wall to be coated, thus transforming the high kinetic energy into a plastic deformation and heat during the impact and creating the adhesion to the component substrate. Gun 29 preferably comprises also inlet and outlet ducts 36, 38 for a cooling circuit.

[0019] According to an embodiment, the cooling head 24 comprises a delivery duct 44, in fluid connection to a cooling fluid circuit 48, said delivery duct 44 being provided with at least one delivery hole 52 for the dispersion of coolant on said second surface 28 of the wall to be coated 16.

[0020] Preferably, said delivery duct 44 comprises a plurality of delivery holes 52 for fluid dispersion, said holes 52 being for example equally spaced along a prevailing extension axis X of the delivery duct 44.

[0021] Preferably, the delivery holes 52 are arranged according to an axial-symmetric arrangement relative to said prevailing extension axis X of the delivery duct 44.

[0022] According to an embodiment, the cooling head 24 comprises at least one collecting duct 56 suitable for collecting the coolant after this has come into contact with the second surface 28 of the wall to be coated 16 and for conveying it in removal from said head 24 in said cooling circuit 48.

[0023] For example, the collecting duct 56 is in fluid connection with coolant recirculation means (not shown) suitable for conveying the coolant coming from the collecting duct 56 in a heat exchanger 60, for decreasing the temperature of the coolant.

[0024] The recirculation means are in fluid connection with exchanger 60 so as to deliver the coolant, previously cooled by the exchanger, into the delivery duct 44.

[0025] Preferably, the collecting duct 56 is arranged coaxially to the delivery duct 44 relative to the prevailing extension axis X.

[0026] The cooling head 24 comprises, preferably on an outer portion 64 of the collecting duct 56, sealing means 68 suitable for realising a seal between head 24 and the second surface 28 of the wall to be coated 16 of component 8. In other words (figure 2), head 24 is inserted into the component so as to be surrounded by the second surface 28 of component 8, having the delivery holes 52 directly facing the second surface 28; the sealing means abut against said second surface so as to prevent the coolant to escape through the air space between the cooling head and the second surface 28 of component 8. In the practice, the sealing means 68 force the coolant, after this has contacted the second surface 28, to flow back into the collecting ducts 56 and leave head 24 and component 8 through said collecting ducts to be reintroduced into coolant 48.

[0027] Preferably, apparatus 4 comprises motor means (not shown) of said component 8, suitable for rotating said component 8 relative to a working axis preferably coinciding with said prevailing extension axis X.

The metallization method of a metal component according to the present invention shall now be described.

[0028] The metallization method of a metal component according to the present invention comprises the steps of providing means of deposition of a metal layer on a component, addressing by said deposition means, a flow of metal material on a first surface of a wall to be coated of the metal component, the method being characterised in that during the deposition of the metallization flow on a first surface, there is provided the step of addressing a coolant flow, by a cooling head, on a second surface of the wall to be coated, opposite said first surface and not impinged by the metallization flow.

[0029] Preferably, the metallization method comprises the steps of providing a collecting duct for collecting the coolant after it has contacted the wall and conveying said fluid away from said head.

[0030] Advantageously, said recirculation means of the coolant convey the coolant coming from the collecting duct in a heat exchanger, for decreasing the temperature of the coolant and send the fluid thus cooled in said delivery duct.

[0031] The sealing means 68 realise a seal between the cooling head 24 and the second surface 28 of the wall to be coated 16 of component 8 so as to convey all the coolant into the collecting duct 56, after the fluid has contacted the second surface of component 28.

[0032] In the practice, the sealing means 68 force the coolant, after this has contacted the second surface 28, to flow back into the collecting ducts 56 and leave head 24 and component 8 through said collecting ducts to be reintroduced into coolant 48.

[0033] Advantageously, the component metallization comprises the step of rotating said component 8 relative to a working axis coinciding with the extension axis X of head 24 both during the metal deposition through gun 29 and in the cooling step through the delivery of coolant from the cooling head 24.

[0034] As can be appreciated from the description, the apparatus and the method according to the invention allow overcoming the disadvantages of the prior art.

[0035] Thanks to the high thermal exchange between the component wall and the coolant, which continuously flows into the component, it is possible to control the rise of temperature of the component wall preventing it from undergoing a decrease of the mechanical properties, with particular reference to hardness. The component rotation relative to the cooling head ensures a constant cooling on the entire wall to be coated, at both the first and the second surface.

[0036] Thanks to the geometrical continuity of the application made along the cylindrical surface of the component or specimen, preferably by rotation of the component during the step of deposition of the metal layer, it is possible to apply a metal layer having highly even geometrical and mechanical features.

[0037] To prove the considerable advantages obtained by the present invention, some laboratory tests have been carried out trying to compare the results obtained with the apparatus according to the invention with the results obtained by the known metallization technique.

[0038] For example figure 4 shows the profiles of hardness obtained by applications of tungsten carbide on aluminium substrates having thickness of about one millimetre, by prior art processes. The hardness values shown are of the Vickers type and have been measured with a standard load equal to 0.1 kg.

[0039] As can be seen, the hardness values are affected by the layer concerned by the temperature induced by the metallization technique, so the mechanical features decrease along with the fatigue resistance of the application-substrate assembly. In other words, moving from the surface directly impinged by the metallization flow, and thus subject to higher heating, to the inner wall portion, it may be noted how micro-hardness increases. Of course this result is stronger when the thickness of the wall to be metallized is greater, since an increasingly larger portion of wall is subject to an excessive heating, with subsequent decay of the mechanical features up to the wall core.

[0040] An application of tungsten carbide has therefore been made on the same substrate (about one millimetre), by the apparatus and the method according to the present invention. The results are shown in figure 5. As can be clearly seen, the substrate hardness has not been considerably altered unlike the clear decay of the hardness found with the prior art (see figure 4).

[0041] Moreover, it has been noted that thanks to the metallization obtained according to the present invention, also the fatigue resistance of the components thus coated is greatly increased, with special reference to light alloy components.

[0042] To prove what stated, experimental tests have been carried out using specimens of alloy 6082 at state T6, with rectangular section of about 180x15x8 mm, subject to bending fatigue on four points. The thickness of the application is about 1/10 of millimetre, and the application has been made on one face only of the specimens.

[0043] The fatigue tests gave the results shown in the following table:

Specimen not coated	Specimen coated
σ_{FAf}=152+/-18 MPa	σ_{FAf}=319+/-29 MPa

[0044] By σ_{FAF} it is meant the limit of alternating bending fatigue, that is, the strain below which the fatigue breakage for an alternating bending stress does not occur. Moreover, the execution of the application on hollow specimens of the same alloy was experimented, having a 32 millimetre diameter with a substrate thickness of 1.1 millimetres.

[0045] Also in this case, the application thickness was of about 0.1 millimetres. The fatigue test results, with the same load applied, are as follows:

Specimen not coated	Specimen coated
n. of break cycles 20,000-25,000	n. of break cycles 625,000-640,000

[0046] Therefore it has been noticed that the coatings made on light alloys according to the present invention considerably increase (up to more than 20 times) the number of loading cycles that lead to fatigue breakage.

[0047] A man skilled in the art may make several changes and adjustments to the apparatus and methods described above in order to meet specific and incidental needs, all falling within the scope of protection defined in the following claims.

Claims

1. Apparatus (4) for the metallization of a metal component, comprising

   - means (12) for depositing a metal layer on a component (8), said means (12) being facing a wall to be coated (16) of said component so as to address a flow of metal material (40) on a first surface (20) of said wall to be coated (16),

   characterised in that
   said apparatus (4) comprises a cooling head (24) suitable for sending a cooling fluid flow on a second surface (28) of said wall to be coated (16), the second surface (28) being opposite the first surface (20) so as not to be impinged by the flow of metal material (40).

2. Apparatus according to claim 1, wherein said cooling head (24) comprises a delivery duct (44), in fluid connection to a cooling fluid circuit (48), said delivery duct (44) being provided with at least one delivery hole (52) for the dispersion of coolant on said second surface (28) of the wall to be coated.

3. Apparatus according to claim 2, wherein said delivery duct extends along a prevailing extension axis (X) and comprises a plurality of delivery holes (52) for fluid dispersion, said holes (52) being equally spaced along said prevailing extension axis (X).

4. Apparatus according to claim 3, wherein said delivery holes (52) are arranged according to an axial-symmetric arrangement relative to said prevailing extension axis (X) of the delivery duct (44).

5. Apparatus according to any one of claims 1 to 4, wherein the cooling head (24) comprises at least one collecting duct (56) suitable for collecting the coolant after this has come into contact with the second surface (28) of the wall to be coated (16) and for conveying it in removal from said head (24) in said cooling circuit (48).

6. Apparatus according to claim 5, wherein said collecting duct (56) is in fluid connection with coolant recirculation means suitable for conveying the coolant coming from the collecting duct (56) in a heat exchanger (60), for decreasing the temperature of the coolant.

7. Apparatus according to claim 6, wherein said recirculation means are in fluid connection with the exchanger (60) so as to deliver the coolant previously cooled by the exchanger into said delivery duct (44).

8. Apparatus according to any one of previous claims, wherein the collecting duct (56) is arranged coaxially to the delivery duct (44) relative to the prevailing extension axis (X).

9. Apparatus according to any one of the previous claims, wherein said cooling head comprises sealing means (68) suitable for realising a seal between the head (24) and the second surface (28) of said wall to be coated (16), so as to convey the coolant, after this has contacted the second surface (2), to flow back into the collecting ducts (56) to be reintroduced into the cooling circuit (48).

10. Apparatus according to claim 9, wherein said sealing means (68) are arranged in an outer portion (64) of the collecting duct (56), facing said second surface (28).

11. Apparatus according to any one of the previous claims, further comprising motor means of said component, suitable for rotating said component relative to a working axis.

12. Apparatus according to claim 11, wherein said working axis coincides with said prevailing extension axis (X).

13. Apparatus according to any one of the previous claims, wherein said deposition means comprise a metallization gun (29) suitable for realising a supersonic jet of metal particles to be addressed towards the wall to be metallized.

14. Apparatus according to claim 13, wherein the deposition means (12) comprise a metallization gun (29) suitable for performing an HVOF (High Velocity Oxyfuel) method for metal coating.

15. Metallization method of a metal component, comprising the steps of:

- providing deposition means (12) of a metal layer on a component (8),
- addressing, by said deposition means (12), a flow of metal material (40) on a first surface (20) of a wall to be coated (16) of the metal component (8)

the method being **characterised in that**
during the deposition of the metallization flow (40) on the first surface (20) it comprises the step of addressing a flow of coolant, by a cooling head (24), on a second surface (28) of the wall to be coated (16), opposite said first surface (20) and not impinged by the metallization flow (40).

16. Metallization method of a metal component according to claim 15, comprising the steps of providing a collecting duct (56) for collecting the coolant after it has contacted the wall (16)
and conveying said fluid away from said cooling head (24).

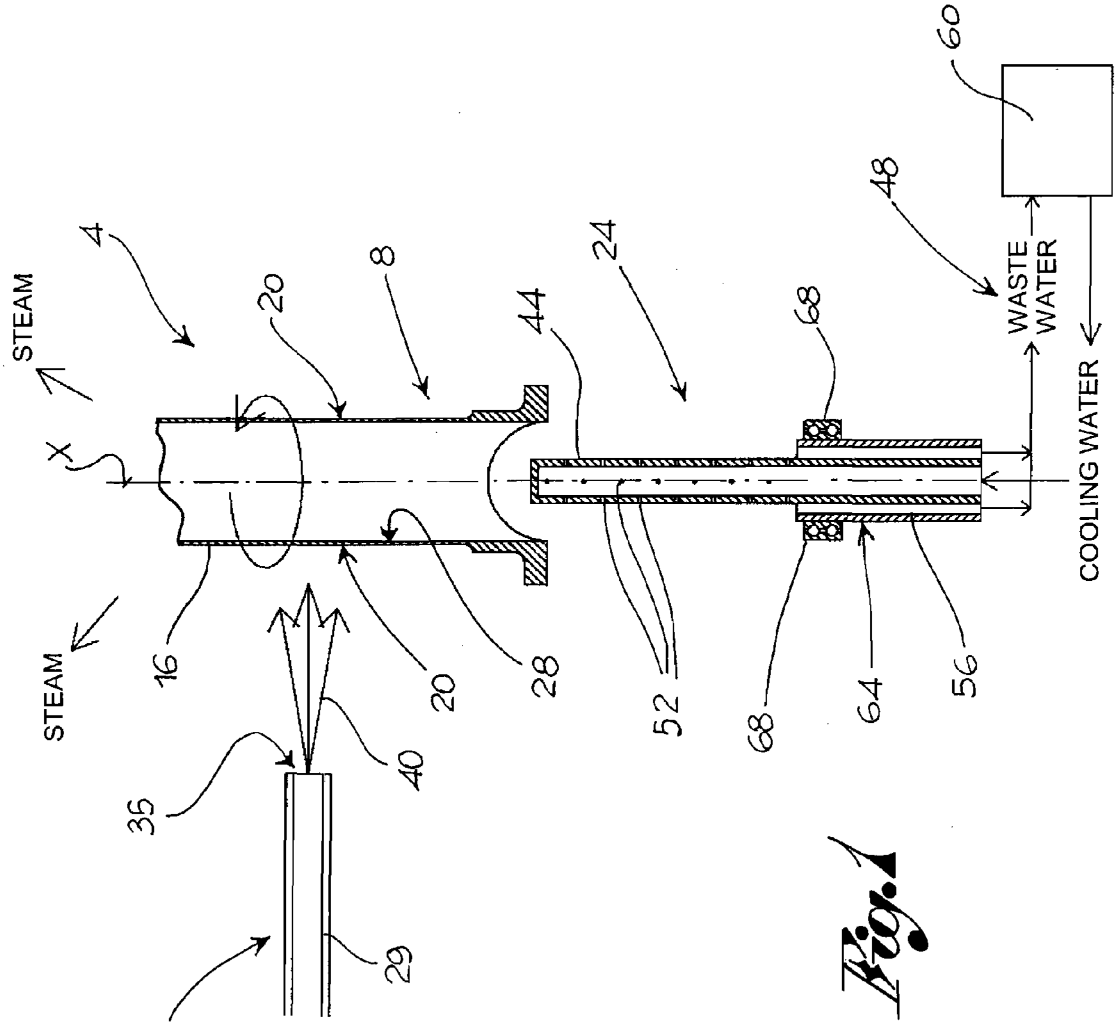
17. Metallization method of a metal component according to claim 16, comprising the steps of:

providing recirculation means of the coolant suitable for conveying the coolant coming from the collecting duct (56) in a heat exchanger (60), for decreasing the temperature of the coolant and sending the fluid thus cooled in said delivery duct (44).

18. Metallization method of a metal component according to any one of claims 15 to 17, comprising the steps of providing, on an outer portion (64) of the collecting duct (56), sealing means (68), suitable for realising a seal between the head (24) and said wall (16) of the component (8) so as to convey all the coolant into the collecting duct (56), after the fluid has contacted the second surface (28) of the component (8).

19. Metallization method of a metal component according to any one of claims 15 to 18, comprising the step of rotating said component (8) relative to a working axis during the metallization and cooling step.

20. Metallization method of a metal component according to claim 19, wherein said working axis coincides with a prevailing extension axis (X) of the cooling head (24).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WASTE WATER
COOLING WATER

Fig. 1

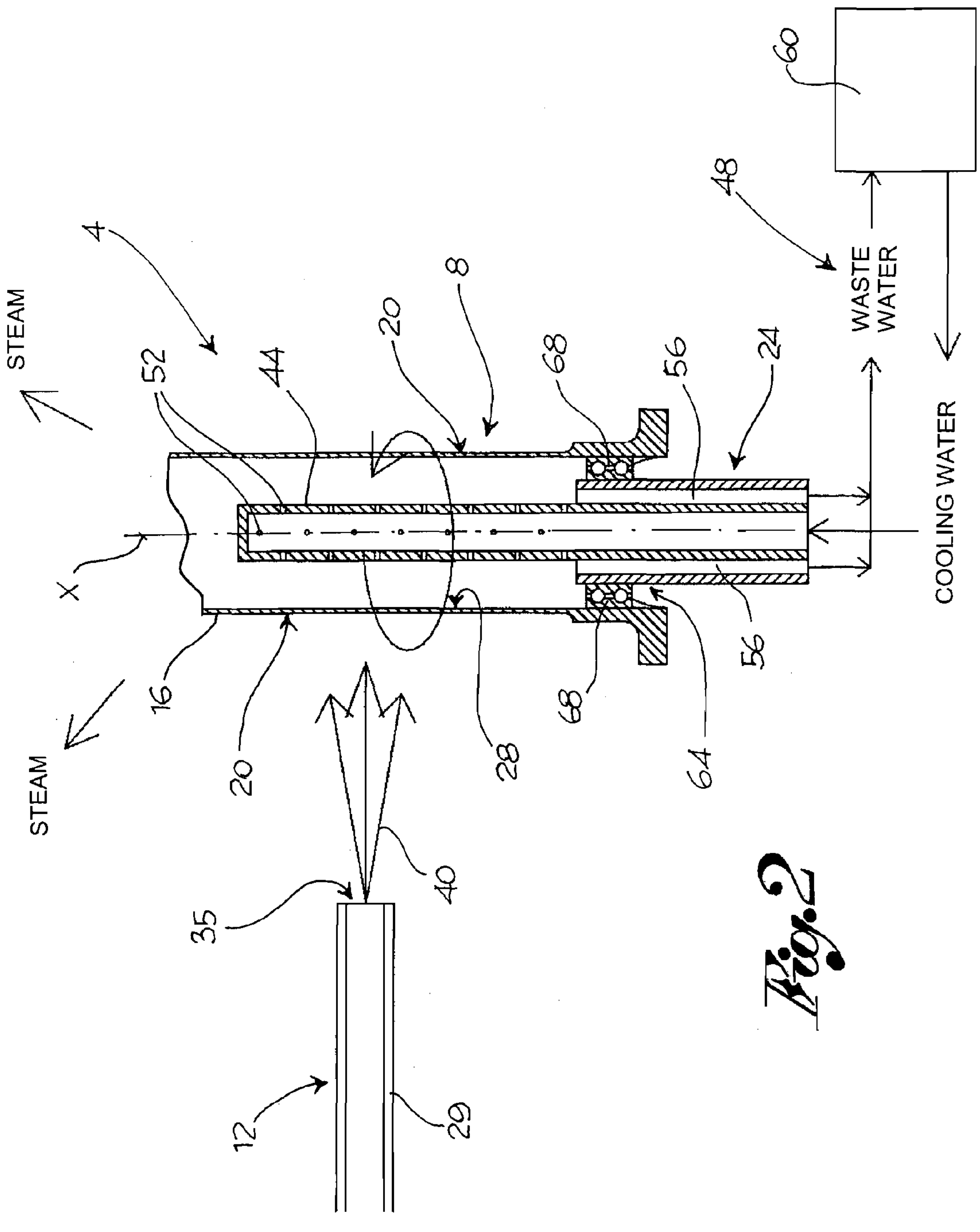
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Fig.2

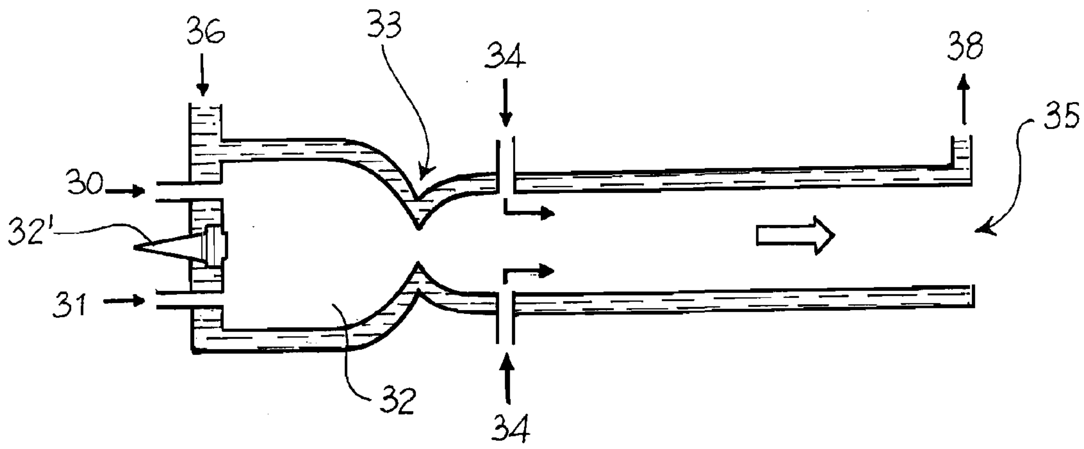
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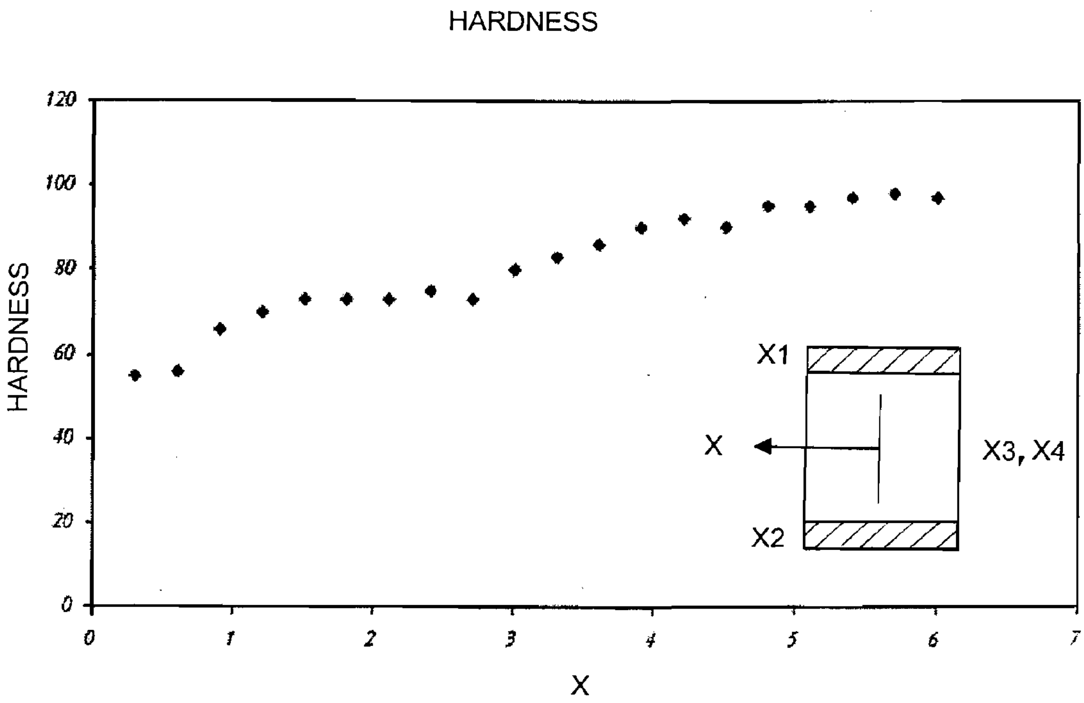
Fig.3

Fig.4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X1
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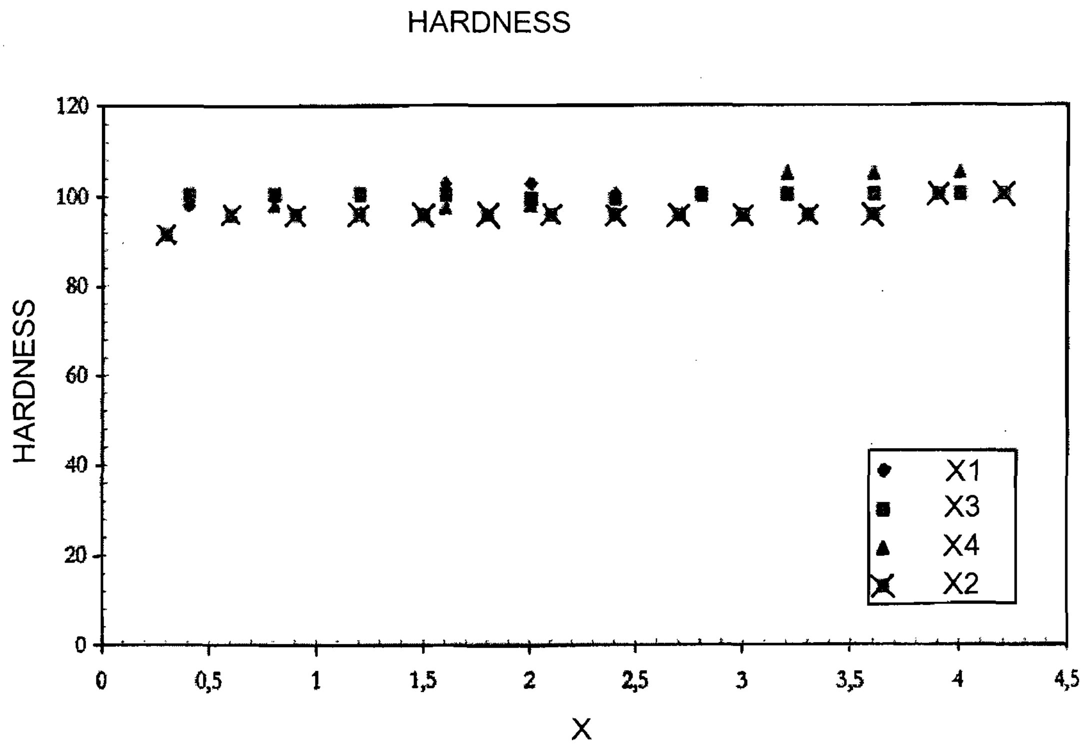
X3, X4
X2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X1
X3
X4
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Fig.5