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(54) **Modifying surfaces of workpieces and forming tools**

(57) The invention relates to a forming tool (10), a method of modifying the surface of a workpiece wherein at least one surface of the workpiece comes into contact with the structured surface (14) of a forming tool (10) at least once and a method of structuring the outer surface of a forming tool (10). The invention is a forming tool (10) characterised in that it comprises a substrate (11) and a metallic glass layer (13) on at least the working face (12) of the forming tool (10) and the metallic glass layer (13) possesses a structured surface (14) for the purpose of reproducing the structured surface (14) of the metallic glass layer (13) in the surface of a workpiece. A tool (10) according to the invention may be used in the production of sheet and shaped parts for automotive use, the production of lithographic sheet, the production of coins and badges and the production of reflector sheet.

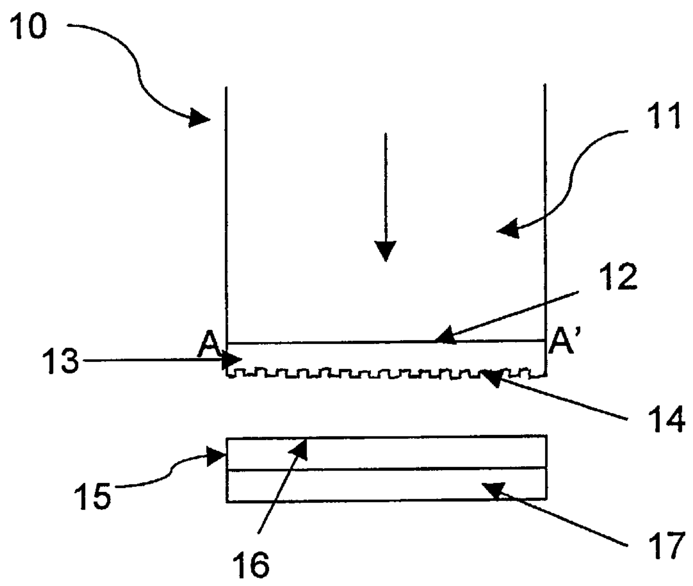

Figure 1

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Description

[0001] The present invention relates to a forming tool, a method of modifying the surface of a workpiece wherein at least one surface of the workpiece comes into contact with the structured surface of a forming tool at least once and a method of structuring the outer surface of a forming tool.

[0002] In the materials processing industries there are many types of forming operation. In the metals industry forming operations can include, for example: press forming, where the workpiece to be formed takes the shape imposed by a punch and a die; drawing, where a workpiece in the form of a flat blank of sheet is formed into a cup shape by forcing a punch against the central portion of the blank as it rests on a die ring; coining, where a workpiece is squeezed between dies and is deformed such that the details of its final form and surface appearance are defined by the shape and surface of the dies; stretch forming, where a sheet blank workpiece is formed over a form block of the required shape with the workpiece under tension; drop hammer processing; stamping, which is similar to coining; embossing, which is generally the making of shallow impressions in the surface of a workpiece by compression between two die pieces under a relatively low load; texturing, which is similar to embossing but where more load is applied leading to more deformation into the bulk workpiece; rolling, where workpieces in the form of sheets are pressed between two rotating cylindrical rolls; and cold roll forming, where the rotating rolls are shaped such that the sheet workpiece is formed into desired shapes of uniform cross-section.

[0003] A workpiece is a body of indeterminate size and shape. For example a block of metal or plastic is a workpiece and so are pre-formed articles for use as vehicle panels. Sheet, plate and foil, both in continuous form and in the form of cut pieces, are further examples of workpieces. In one form of the invention the workpiece is preferably rolled sheet or strip and is more preferably rolled sheet or strip of aluminium and aluminium-based alloys.

[0004] In this invention a structured surface is meant to be where the surface is not intended to be smooth. Of course most surfaces are not perfectly smooth, but it will be readily understand what is covered by the meaning of a structured surface if it is defined as one possessing deliberate roughness, patterns, protuberances, depressions, ridges and troughs or engraving-like features, such features to be transmitted to the surface of the workpiece such that the workpiece surface is also not smooth.

[0005] Typically forming operations like this are applied to metals, in particular metals based on iron, aluminium or copper as the main constitiuent, but they may also be applied to plastic materials. In some cases a forming method like embossing can be applied to paper-based materials.

[0006] During such forming operations, the appearance of the surface of the workpiece which was in contact with the forming surface of the forming tool after forming is typically the same as or similar to the surface appearance of forming surface of the forming tool. The surface on the workpiece may not be an exact replica of the surface of the forming tool because various factors like the amount of load applied through the forming tool or the physical properties of the material of the workpiece have an influence on the extent of deformation. It is routine practice to adjust forming conditions to take account of such factors. Often the surface of the forming tool may be exaggerated in order to ensure the final surface on the workpiece is produced.

[0007] There are also many situations where the surface of a workpiece is desirably modified in order to bring about specific benefits. The surfaces of workpieces may be modified for purely decorative reasons. Examples are where a coining operation is used to produce coins, buttons or medals to specific designs. Other examples are where a metallic sheet workpiece is treated such that it has a certain range of roughness across the surface in order to mask any defects that might be present after a rolling operation. This is often done in order to give a uniform appearance to the final product. The surface of a workpiece may also be modified in order to attain desirable physical characteristics with the aim of improving the performance of an article in a specific application, where that performance depends strongly on the surface characteristics of the workpiece.

[0008] When modifying the surface of flat sheet the forming tools may have on their surface a textured surface prepared by one of a variety of methods. Such known methods include EDT texturing, sand blasting or shot peening, mechanical brushing, structured Cr deposition (also known as Topocrom), and so on. These methods result in a working surface which is stochastic in nature and after rolling this surface structure is substantially transferred to the surface of the workpiece. Other known methods include laser beam or electron beam texturing and these can produce a deterministic structure. A deterministic structure would show a pattern, or would be one where a specific design is present and could include, for example, an imprint of wording or an imprint of a trade mark. In the case of multiple pass embossing, deterministic structures can lead to interference effects whilst stochastic structures generally will not.

[0009] In work rolls used for forming metal sheet by rolling, a deterministic structure could be imparted into the surface of the work roll by a machining operation, but this would be expensive and such work rolls have a limited life whereafter they need to be refurbished or re-machined, operations which can be expensive and time consuming. Furthermore, the quality of indentation of the deterministic structure into the surface of the workpiece may deteriorate over time due to wear of the forming surface of the forming tool leading to variable quality in the final product over long production runs.

[0010] Deterministic structures are more readily and more commonly produced in the surfaces of workpieces using methods such as coining, stamping or press forming where it is common to machine the desired design into the surface of the die or punch.

[0011] In most of the forming operations mentioned above there is eventually a need to replace dies, punches, rolls and other tools used for forming, or to refurbish the same. This, of course, depends on the material from which the workpiece is made with harder workpieces leading to faster wear of forming tools than softer workpieces.

[0012] The life of a forming tool is often extended by adding a protective layer to that surface of the forming tool that comes into contact with the workpiece. In forming operations using dies and punches, such protective coatings are usually deposited onto the working surface of the tool without any subsequent profiling step, i.e. they are applied in such a way that the shape required is still derived from the shape defined by the main body and profile of the forming tool itself.

[0013] In metal rolling, particularly aluminium rolling, a steel work roll is often protected with a chromium layer to extend the life of the working roll. Typically such work rolls have their surfaces ground flat because the intended use of such rolls is merely to reduce the thickness of plate, sheet or foil through a mill. When the main purpose is thickness reduction a major consideration is to obtain as smooth a surface as possible on the rolled sheet at the end of a series of rolling passes.

[0014] However, where a structured surface is desired, it is possible to modify the structure of the chromium layer. It is also possible to structure the underlying steel of the work roll and deposit a layer of chromium over the roll. For modifying the structure of the chromium layer itself, one known technique involves applying a photosensitive film to the chromium layer. A pulsed laser can be scanned across the surface and, where it scans, the heat of the laser polymerises the film. The unpolymerised film can be washed away exposing chromium underneath. The exposed chromium can be etched away to a required depth whilst the chromium under the polymerised masking remains as it was. This leads to the creation of an irregular roll surface with the final form of the roll surface dictated by the path of the laser.

[0015] These protective coatings, whilst beneficial in many respects, have the disadvantage that it is not possible to provide them with very fine detailed designs of a deterministic nature. For example, the chromium method described above can give structural dimensions down to 1 or 2 microns but not to dimensions below this.

[0016] Smaller surface features than this lead to interesting effects. One known effect is the creation of images from complex diffraction patterns. Although sometimes referred to as holograms, these images are not strictly holographic. Rather, variations in the number, density, length, direction, depth and shape, of lines cut into the surface of a workpiece can lead to very complex interference patterns that appear to be images. Such images may also display variations in colour.

[0017] In order to create complex diffraction patterns like this, the cut lines are sub-micron in width and it is not possible with conventional tooling methods to obtain this level of resolution within a deterministic structure directly on the surface of a forming tool.

[0018] The prior art surface structuring approaches possess a number of disadvantages. Eventually forming tools wear out and are either expensive or difficult to refurbish. Also, it is difficult and sometimes impossible to produce deterministic structures. It is especially difficult to produce very fine, sub-micron, deterministic structures within the coating on a forming tool. Furthermore, forming tools are generally used for single purposes, that is, with one kind of shape or surface structure in mind. They do not provide flexibility in the sense of it being easy and straightforward to change the surface of the forming tool.

[0019] It is an object of this invention to provide a new forming tool, one that can have its surface easily modified and one that can be produced with deterministic structures and very fine deterministic structures, the said surface features being transferable to a workpiece by any suitable forming method thereby giving the surface of the workpiece itself a fine, deterministic structure.

[0020] It is a further object of this invention to provide a new method of modifying the surface of a workpiece using a forming tool that itself has a structured surface.

[0021] It is a further object of the invention that the surface of the forming tool can be easily and inexpensively produced and eventually refurbished and to provide a method of preparing and refurbishing such forming tools.

[0022] Accordingly a first aspect of the invention is a forming tool characterised in that it comprises a substrate and a metallic glass layer on at least the working face of the forming tool and the metallic glass layer possesses a structured surface for the purpose of reproducing the structured surface of the metallic glass layer in the surface of a workpiece.

[0023] It will be readily appreciated that the metallic glass layer need not be directly adjacent to the working face of the forming tool and that other intermediate and functional layers may be incorporated, for example a compliant layer to accommodate differences in thermal expansion coefficients.

[0024] Metallic glasses are multi-component metallic alloys that, when cooled from a molten state at a fast enough rate, retain an amorphous state when solid. These materials can be up to twice as strong as steel, have greater wear and corrosion resistance and have higher elasticity values than steel.

[0025] Metallic glasses suitable for the purpose herein described can be, for example, any one of the following group of general alloy systems: Au-Pb-Sb, Pd-Ni-P, La-Al-Ni, La-Al-Cu, La-Al-Ni-Cu, Mg-Cu-Y, Zr-Al-Ni-Cu, Zr-Ti-Cu-Ni-Al, Zr-Ti-Cu-Ni-Be, Zr-Ti-Nb-Cu-Ni-Be, Pd-Cu-Ni-P, Ni-Nb-Ta, Al-Co-Zr, Al-Ni-Ce-B, Al-Ni-Y-Co-B. These alloy systems are particularly useful because they can be cooled at slower rates than other metallic glasses yet still retain their amorphous state. One specific alloy that could be used is one containing, by weight percent, Zr 56.2, Ti 13.8, Nb 5, Cu7, Ni 5.5, Be 12.5. They can be cooled such that thickness of the metallic glass is of the order of 0.01 to 10mm. This is important in this invention because the glass coating is on a substrate and the combined thermal mass means that extremely fast cooling rates are not always possible. In many situations the substrate itself can be used as an effective heat sink, either alone or in combination with other cooling means.

[0026] Where the intention is to make very fine deterministic structures the thickness of the metallic glass layer need not be very high. For example it could be a thin layer between 0.01 mm and 2mm thick. Where the surface structure desired contains more prominent features then the metallic glass layer will preferably be thicker, between 0.5mm and 10mm thick. There is no need to have a large excess of glass because that would simply be a waste of material but there needs to be enough to enable the required structure to be formed within its surface. The lower thickness limit of the metallic glass is 0.01 mm and preferably 0.5mm. The upper thickness limit of the metallic glass depends on the intended application but is not required to be more than 10mm, preferably 8mm, more preferably 5mm.

[0027] The substrate could comprise any suitable shape typical of conventional forming tools that might be used in any of the forming methods previously mentioned. Also there is no particular requirement that the shape of the surface onto which the metallic glass is deposited to be of a certain kind. The metallic glass layer need not be deposited on the whole of the forming tool, merely on that face which comes into contact with the workpiece to be formed or modified, herein referred to as the working face. In other words, the working face is that face of the forming tool through which load is applied to the workpiece. The working face could be substantially planar or profiled, (in the sense that its shape face varies in at least two dimensions). Alternatively the shape of the working face may be at least a segment of the surface of a cylinder, as would be the case with a work roll for a metal rolling mill. In the latter case the substrate itself may be at least partly cylindrical or it could be a complete cylinder.

[0028] A particular advantage of the invention is that the structured surface of the metallic glass layer can be provided with a very fine deterministic structure. It is a preferred embodiment of the invention that the structured surface be deterministic and a more preferred embodiment that the deterministic structured surface contain features which are sub-micron in size.

[0029] A second aspect of the invention is a method of modifying the surface of a workpiece wherein at least one surface of the workpiece comes into contact with the structured surface of a forming tool at least once, characterised in that the forming tool is comprised of a substrate and a metallic glass layer on at least the working face of the forming tool and the metallic glass layer possesses a structured surface whereby the structured surface of the metallic glass layer reproduces in the surface of the workpiece.

[0030] The nature of the metallic glass layer in terms of its composition and thickness are typically the same as those described above in connection with the forming tool. Likewise, the structured surface can be stochastic in nature but it is preferred that it is deterministic and even more preferred that it contains features which are sub-micron in size.

[0031] Often forming operations of this nature take place in a number of repeat actions and therefore another embodiment of the invention is that this method involves a plurality of contacts between the workpiece and forming tool. This is often desirable because the transfer of the structural features from the surface of the forming tool to the workpiece is rarely perfect and more than one impression may be needed to generate the final desired surface on the workpiece.

[0032] In addition the transfer of the structure from the forming tool to the workpiece may take place under very low loading such that there is little or no reduction in the thickness of the workpiece. This is particularly useful in embossing operations.

[0033] A preferred embodiment involves the use of this method in the rolling of metal sheet where the forming tool is a work roll of a metal rolling mill. This embodiment is particularly suited to the rolling of aluminium and aluminium alloys.

[0034] A further aspect of the invention is a method of structuring the outer surface of a forming tool characterised in that the forming tool comprises a substrate and a metallic glass layer comprising the steps of:

(a) heating at least the outer surface of the metallic glass layer to a temperature above its glass transition temperature,

(b) bringing the outer surface of the metallic glass layer into contact with the structured surface of a template for a period of time and under pressure such that the structured surface of the template is reproduced in the outer surface of the metallic glass layer to create a structured outer surface on the metallic glass layer,

(c) at least the structured outer surface of the metallic glass layer is cooled down at a rate sufficient to retain an amorphous structure throughout the metallic glass layer,

(d) and the forming tool and the template are separated, the features of the structured surface of the template being retained within the structured outer surface of the metallic glass layer,

[0035] It has been surprisingly found that the surface of metallic glasses can be heated up until they are soft and can then be pressed against a template, the template possessing on its surface the structure or pattern desired in the surface of the metallic glass. After coming into contact with the template, at least the outer surface of the metallic glass layer is cooled and separated from the template. Of course the bulk of the metallic glass layer itself will also cool to some extent, it may even cool at a rate similar to the cooling rate of the outer surface. The cooling rate is sufficient such that the amorphous state is retained throughout the metallic glass. The surface structure of the template, which has been reproduced in the surface of the metallic glass, is retained after cooling in the outer surface of the metallic glass layer. Where the surface structure of the template contains large impressions or indentations then some of the bulk of the metallic glass layer may also be deformed so that the metallic glass layer as a whole displays the same external profile. A forming tool with a metallic glass layer thus formed is then used to modify the surface of the chosen workpiece.

[0036] The template could be made from conventional materials such as copper, aluminium or steel but is preferably made from a material that is able to withstand the high temperatures involved. Therefore steel or nickel templates are preferred. In order to facilitate the release of the template from the metallic glass at the relatively high temperatures in question a release agent may be applied to the surface of the template prior to coming into contact with the softened metallic glass.

[0037] The metallic glass, after coming into contact with the template, has to be cooled down at a rate fast enough to ensure that the metallic glass retains its amorphous structure below the glass transition temperature. The cooling rate necessary for this will depend on the metallic glass used but will normally be >10°C/sec, preferably >100°C/sec, more preferably >200°C/sec. In some situations, for example where the metallic glass has a large critical casting thickness, or the thickness of the metallic glass is small, effective cooling can be achieved by using forced gas, as for example air but in other situations it may be necessary to use means such as a fluid, as for example water or a water spray to bring about faster cooling rates. Other cooling means are solid materials having a high thermal conductivity such as metals, preferably copper and the like.

[0038] The invention will now be illustrated by reference to the following examples.

[0039] Figure 1 is a schematic of a simple forming tool incorporating the metallic glass layer on its working face and a method of using the forming tool.

[0040] Figure 2 is a schematic of one method of structuring the outer surface of a metallic glass layer, in this case in connection with a work roll suitable for metal sheet rolling.

[0041] In Figure 1, the forming tool (10) is made up of a substrate (11) and a metallic glass layer (13) on the working face (12) of the forming tool. The metallic glass layer has a structured surface (14). Under load, as shown by the arrow, the structured surface (14) is brought into contact with the surface (16) of the workpiece (15). In this example the workpiece (15) is supported on a base plate (17). With a sufficient load applied, the surface of the workpiece will be modified and the features of the structured surface of the forming tool will be reproduced in the surface of the workpiece. It will be readily appreciated that the profile of the working face, as shown by line A-A', need not be flat but could be profiled. Likewise the base plate (17) could be a shaped die to match the profile of the forming tool. As mentioned above, the surface of the workpiece may not be an exact replica of the structured surface of the forming tool and the forming action may be repeated a number of times, preferably 2, 3, 4 times or more, to ensure the final surface of the workpiece has the desired features.

[0042] In Figure 2 the forming tool (20) is in the form of a cylindrical work roll intended for further use in rolling metal sheet. The forming tool (20) comprises a cylindrical substrate (21) and a metallic glass layer (23) on the working face (22). In this embodiment the cylindrical forming tool is made to rotate and the outer surface (27a) at least of the metallic glass layer (23) is heated up by a suitable heater (24) to a temperature above the glass transition temperature of the metallic glass. Above the glass transition temperature the metallic glass layer, or at least its outer surface, is soft enough to be modified. The outer surface of the metallic glass layer is then brought into contact with a template (25). In this example the template is a nickel shim which possesses, at least on one face a structured surface (26), either stochastic or deterministic in nature. The structured surface (26) of the template is brought into contact with the soft outer surface of the metallic glass and pressure is applied with the aid of two drive rolls (28a and 28b). After contact the outer surface of the metallic glass layer is modified and is converted into a structured outer surface (27b) of the metallic glass layer. In order to preserve the newly structured outer surface of the metallic glass layer at least the structured outer surface of the metallic glass layer is cooled down at a rate layer. It is possible, as well, to cool down the metallic glass layer from the working face side and the outer surface. This method may be a continuous system and it is within the bounds of the invention that the surface modification method herein described may be repeated a number of times. If this is the case in this embodiment, the structured outer surface (27b) of the metallic glass layer may, on further rotation, be heated up as before and structured a second or third time by contact with the template. In this way, if the initial structured surface of the metallic glass layer is not deemed to be adequate for its intended purpose it can be further improved and refined.

[0043] In another embodiment the template may be fed round another series of rolls (not illustrated) back to the start in a continuous loop. In such a case the length of template may be carefully controlled to correspond to the diameter of the substrate cylindrical work roll, especially if the structure to be created is deterministic. The diameter of the cylindrical work roll is not critical. The forming tool and the template are separated in the region of point B. In some circumstances, for example when the glass transition temperature is high and there is a danger of the metallic glass and the template sticking together, a suitable release agent is applied to the structured surface of the template to make separation easier.

[0044] A typical heater would be an induction heater, heating by conduction or convection heater as an infrared heater but may also include for example contact heaters, flame heaters, Joule effect heaters or any other adequate heating device.

[0045] The structured surface of the metallic glass layer and the metallic glass layer itself may start to cool down even as the template and forming tool are in contact, i.e. before they are separated in this case. The cooling can be effected by the bulk of the substrate itself acting as a heat sink, which can be improved with the use of a cooling system built into the substrate. It is common for cylindrical work rolls to contain a chilled fluid such as a water system and this can be used to help provide the fast cooling required. Cooling can be further enhanced by forced gas, for example air cooling, applied on the exit side in the vicinity of the area marked B.

[0046] The forming tool with its surface structured according to the method illustrated by Figure 2 can then be used in a conventional rolling mill to modify the structure of workpieces such as steel, aluminium and copper sheet.

[0047] The tool and processes according to the invention offer a range of advantages. They allow a greater degree of reproducibility from one manufacturing plant to another. For example, two similar forming tools can be created in different locations because the same template can be used to produce almost identical tools. The template can be moved from one manufacturing plant to another and the working surface of the forming tool can be structured in exactly the same way at different locations. This will ensure consistency in the final form of the workpieces being manufactured. Further, the very first structured forming tool can be used as a master tool and it can be used to generate a number of templates for use in other locations, again making production consistent from one manufacturing facility to another.

[0048] The processes described enable the creation of very small and deterministic surface features in a simple and effective way. This will have a wide range of benefits in many forming industries and has the potential to eliminate some subsequent processing steps. For example, if the forming operation also enables marking of the workpiece, a subsequent marking or printing step using another process can be dispensed with. This provides the user with the means to individualise their manufactured products more easily and distinctively.

[0049] The tool and processes according to the invention facilitate longer forming tool life. The properties of the metallic glass layer are well suited to prolonging tool life. Their high elastic strain limits, combined with high strength and high toughness means that the metallic glass layer remains in the fully elastic range during forming operations, far away from the metallic glass yield strength. As a result the structured surface of the metallic glass layer retains its integrity for much longer than other forming tool protective layers.

[0050] Furthermore, by re-heating the metallic glass surface layer and refurbishing the structure in exactly the same way as it had previously been formed, the life of the forming tool and its working surface can be further extended and any deterioration in the quality of the surface structure can be easily corrected.

[0051] In addition, the same conditioning and refurbishing process allows the manufacturer to change the structure of the working surface with a minimum of effort. This provides enhanced flexibility in design and production scheduling.

[0052] A forming tool according to the invention and the method of modifying the surfaces of workpieces according to the invention may be used, by way of example, in the production of sheet and shaped parts for automotive use, the production of lithographic sheet, the production of coins and badges and the production of reflector sheet.

Claims

1. A forming tool (10, 20) **characterised in that** it comprises a substrate (11, 21) and a metallic glass layer (13, 23) on at least the working face (12, 22) of the forming tool (10, 20) and the metallic glass layer (13, 23) possesses a structured surface (14, 27b) for the purpose of reproducing the structured surface (14, 27b) of the metallic glass layer in the surface (16) of a workpiece (15).

2. A forming tool as claimed in claims 1 **characterised in that** there is at least one other functional layer between the working face of the forming tool and the metallic glass layer.

3. A method as claimed in claims 1 and 2 **characterised in that** the metallic glass layer has a thickness between 10μm and 10mm.

4. A method as claimed in claims 1 to 3 **characterised in that** the metallic glass layer has a lower limit of its thickness of 0.5mm.

5. A method as claimed in claims 1 to 4 **characterised in that** the metallic glass layer has an upper limit of its thickness of 8mm.

6. A method as claimed in claims 1 to 5 **characterised in that** the metallic glass layer has an upper limit of its thickness of 5mm.

7. A forming tool as claimed in claims 1 to 6 **characterised in that** the working face of the substrate is substantially planar.

8. A forming tool as claimed in claim 1 to 6 **characterised in that** the working face of the substrate is profiled.

9. A forming toll as claimed in claim 1 to 6 **characterised in that** the shape of the forming tool is at least partly cylindrical.

10. A forming tool as claimed in claim 9 **characterised in that** the forming tool is a cylindrical work roll.

11. A forming tool as claimed in claims 1 to 10 **characterised in that** the structured surface of the metallic glass is deterministic.

12. A forming tool as claimed in claim 11 **characterised in that** the deterministic structure comprises features having dimensions below 1μm in size.

13. A forming tool as claimed in claims 1 to 12 **characterised in that** the composition of the metallic glass layer is an alloy from a group consisting of the following alloy systems: Au-Pb-Sb, Pd-Ni-P, La-Al-Ni, La-Al-Cu, La-Al-Ni-Cu, Mg-Cu-Y, Zr-Al-Ni-Cu, Zr-Ti-Cu-Ni-Al, Zr-Ti-Cu-Ni-Be, Zr-Ti-Nb-Cu-Ni-Be, Pd-Cu-Ni-P, Ni-Nb-Ta, Al-Co-Zr, Al-Ni-Ce-B, Al-Ni-Y-Co-B.

14. A method of modifying the surface (16) of a workpiece (15) wherein at least one surface (16) of the workpiece (15) comes into contact with the structured surface (14) of a forming tool (10) at least once, **characterised in that** the forming tool (10) is comprised of a substrate (11) and a metallic glass layer (13) on at least the working face (12) of the forming tool (10) and the metallic glass layer (13) possesses a structured surface (14) whereby the structured surface (14) of the metallic glass layer (13) reproduces in the surface (16) of the workpiece (15).

15. A method as claimed in claim 14 **characterised in that** there is a plurality of contacts, preferably 2, 3 or 4, between the workpiece and the forming tool.

16. A method as claimed in claim 14 and 15 **characterised in that** the forming tool is a work roll of a metal rolling mill.

17. A method as claimed in claims 14 to 16 **characterised in that** the workpiece is at least a part of a metal sheet.

18. A method as claimed in claims 14 to 17 **characterised in that** the metal is aluminium or an aluminium alloy.

19. A method as claimed in claims 14 to 18 **characterised in that** the pressure applied during forming provides essentially no reduction in the thickness of the workpiece.

20. A method of structuring the outer surface (27a) of a forming tool (20) **characterised in that** the forming tool (20) comprises a substrate (21) and a metallic glass layer (23) comprising the steps of:

(a) heating at least the outer surface (27a) of the metallic glass layer (23) to a temperature above its glass transition temperature,
(b) bringing the outer surface (27a) of the metallic glass layer (23) into contact with the structured surface (26) of a template (25) for a period of time and under pressure such that the shaped surface (26) is reproduced in the structured outer surface (27b) of the metallic glass layer (23),
(c) at least the structured outer surface (27b) of the metallic glass layer (23) is cooled down at a rate sufficient to retain an amorphous structure throughout the metallic glass layer (23),
(d) and the forming tool (20) and the template (25) are separated, the features of the structured surface (26) of the template (25) being retained within the structured outer surface (27b) of the metallic glass layer (23).

21. A method as claimed in claim 20 **characterised in that** the steps (a) to (d) are repeated at least once.

22. A method as claimed in claims 20 and 21 **characterised in that** the heating step is carried out using an induction heater.

23. A method as claimed in claim 20 and 21 **characterised in that** the heating step is carried out using an infrared heater.

24. A method as claimed in claims 20 to 23 **characterised in that** cooling of the metallic glass layer is assisted by a cooling system within the substrate.

25. A method as claimed in claims 20 to 24 **characterised in that** the template is a nickel shim.

26. A method as claimed in claims 20 to 25 **characterised in that** the forming tool is a cylindrical work roll for use in a metal rolling mill.

27. A method as claimed in claims 20 to 26 **characterised in that** a release agent is deposited onto the shaped surface of the template.

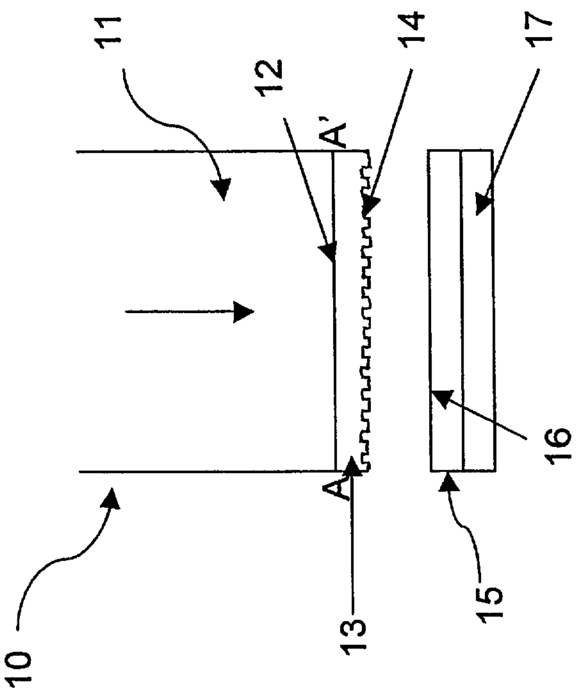

Figure 1

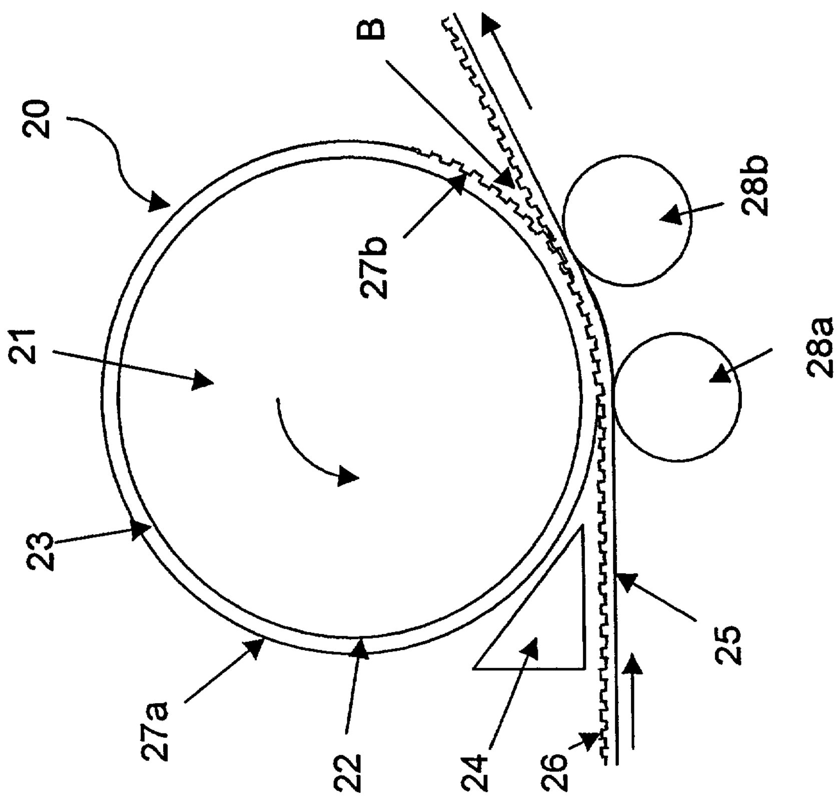

Figure 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 40 5604

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.7)
A	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 01, 29 January 1999 (1999-01-29) & JP 10 265917 A (INOUE AKIHISA), 6 October 1998 (1998-10-06) * abstract * -----	1,14,20	B21D13/02 B21D13/04 B21D22/02 C22C45/02 B21D37/20
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B21D
C22C

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	4 February 2005	Vinci, V

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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