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(54) LAMINATED MATERIAL

(71) We, GLYCO-METALL-WERKE DAELEN & LOOS G.m.b.H., a German limited liability company, of 6200 Wiesbaden-Schierstein, Federal Republic of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to a laminated material comprising a support layer, member or substrate (herein called simply "a support layer") and a surface layer or coating (herein simply called "a surface layer") which comprises a suspension of different alloy components substantially insoluble in one another at least in a temperature range in which the alloy components are in the solid state. Such a liminated material may be used for instance in the manufacture of sliding bearing components. The invention also relates to a process for producing such laminated material. The process may be a continuous or a static process.

Processes are known in which, starting with wire or powder, highly heated metal is sprayed on a support material for various purposes, in most cases for protection against corrosion or scaling, or for repair or relining work, using known spray devices such as flame spraying, plasma spraying or electric are spraying equipment (see "Der Eisenbahningenieur", 15 (1964) 5, pages 127 to 132).

Preparation of the surface of the support material to ensure firm adherence of the sprayed metal is in most cases limited to cleaning the surface by sand blasting. If the spraying process is carried out for protecting the surface of the support material against scaling, for example in the case of a steel support, the layers applied to the surface are subsequently heat treated.

Cylinder liners, pistons, shafts and axles are prepared by rough turning or rough sand blasting before spraying in order to improve adherence of the sprayed material.

It is well known that if a layer is to be bonded to the surface of a support material, the surface is first carefully prepared by degreasing and then making it rough by projection of steel shot or by brushing, to provide a firm bond. It is also known to improve the bond between the support material and sprayed metal by applying an interlayer by flame spraying or plating. The interlayers are usually of materials such as molybdenum and nickel-aluminium (see German Specification No. 1,923,030). In such a process, a cleaned, rubbed down strip of steel is first preheated. An interlayer of NiAl is applied, and AlSn in the form of a composite wire is then sprayed on the interlayer under melting conditions, rolled and subsequently heat treated at 300 to 350°C for approximately 1 hour.

The processes described for the manufacture of laminated materials using highly adhesive interlayers such as molybdenum and nickel-aluminium have, however, the disadvantage that the materials obtained must not be subjected to any stress concentrated at a point or any impact or rolling because the covering layer would become detached from the support material under these conditions and a component which has been treated in this way would break down in use.

In order to strengthen a weak bond between layers it has been proposed, for example, to carry out a melt treatment after the spraying process (German Specification No. 23 60 547), using powders of a special composition (British Specification No. 867,455) but even layers treated in this way are not suitable for the types of stresses mentioned above.

In German Specification No. 23,60,523, there has been described a process for the manufacture of a laminated material in which the support material used is aluminium or an aluminium alloy. The layer of oxide on the surface of the support material prevents sufficiently firm adherence of a metal layer sprayed on it so that the sprayed metal layer tends to peel off. To overcome this disadvantage, it has been proposed to spray a thin interlayer of a highly adhesive material such as NiAl or Mo on the support material.

The disadvantage of this process in that the adhesive material is sprayed on through the oxide layer of the support material so that the bond is again insufficiently strong to withstand the stresses mentioned above.

German Specification No. 2,360,523 also describes a process for removing the skin of oxide inevitably present on the support material. Tin is substituted in the surface zone of the support material or precipitated on the surface and the materials which are to form the surface layers on the support material are sprayed as layers on this layer of tin.

Owing to the lengthy and difficult preliminary treatment required, this process also does not provide a rational solution to the manufacture of a laminated material since it can only be applied to workpieces which are not to undergo further shaping and it is unsuitable for a continuous production process.

It is also known to improve the bond of sprayed surface layers to their support by subsequently sintering them (see "HOESCH Berichte aus Forschung und Entwicklung unseres Werkes", (1973), 3, pages 109 to 116).

When casting an AlSnZn bearing alloy on light metal bodies, it is known to anchor the alloy firmly to the light metal support by a process of diffusion and subsequently to reinforce the effect by an additional process of homogenizing (diffusion-annealing) (German Specification No. 868,789).

In German Specification No. 2,130;421, it is proposed to improve the bond between a steel support and a coating alloy by first applying a metal coating which is compatible with the subsequently applied coating alloy proper and does not form a thick, brittle interlayer with the steel. It is applied by immersion of the steel support in aluminium or an aluminium alloy, by application of a powder or by spraying a very thin layer of aluminium on the steel.

The production of a bi-metal of steel with aluminium or a hardenable aluminium alloy which is sprayed on in the molten state and then subjected to a process of compression has been described in German Specification No. 745,961. When homogenizing by diffusion annealing is subsequently carried out, the excessive heat treatment gives rise to the known disadvantages such as the formation of iron aluminides at the steel/aluminium interfaces.

In German Specification No. 1,400,039, there is described a composite material in which the layer applied by spraying consists of aluminium and low melting constituents which are insoluble or only slightly soluble in aluminium. The layer applied by spraying and the support material are subsequently treated by a mechanical process of hot forming. Interlayers applied either by spraying or by cladding or electroplating may be used to improve the bond between the layers.

One disadvantage of this process is that the material must be rolled in several passes and preheated to around 500°C before each pass.

For the production of a steel/AlPb laminated material to be used in the manufacture of bearings, it is also known to produce the AlPb material by a process of powder rolling in which a stream of powder consisting of three layers of different compositions are run into a rolling mill to produce a semi-finished band, a so-called "Green band" (German Specification No. 1,775,322). The disadvantage of this process is that due to mixing as the powder runs into the nip between the rollers, the three layers are not clearly separated from each other. The operations of sintering and rolling which must subsequently be carried out are therefore accompanied by uncontrolled processes of diffusion which may lead to the formation of brittle phases which impair the bond. Moreover, as a result of the high degree of deformation, the spherical lead particles become stretched so that when bearing elements manufactured from such laminated materials are subjected to continuous wear in operation, they break down due to the internal notch effect of the lead filaments.

It is known that such coatings still have serious shortcomings, ("Jahrbuch d. Oberflächentechnik", (1956), pages 291 to 306). The main disadvantages are that an after-treatment by heat must be carried out in addition to production of the inter-layers to improve the bond, and that, in spite of this, the surface layer is liable to split away, either partly or completely, when the material is used for the manufacture of the workpieces. This splitting away is due partly to the formation of brittle inter-metallic phases.

It is an object of this invention to provide a laminated material comprising a support layer and a surface layer of a suspension of different alloy components, which material is characterised by firm bonding between the layers and advantageous properties for shaping, so that the material can be used for the manufacture of workpieces such as sliding bearing components, without having first to be subjected to an additional heat treatment, e.g. sintering.

According to this invention, there is provided a laminated material comprising a support layer, a surface layer and an interface between the support and surface layers, the interface being formed either on or by an intermediate layer or on a surface of the support layer, and the surface layer comprising a suspension of different alloy components substantially insoluble in one another at least in a temperature range in which the alloy components are in the solid state, wherein:- a) the surface layer is applied to the interface by thermal metal spraying of particles of the alloy components; b) the properties of the interface being such that the sprayed alloy particles will penetrate it and will bond to it, the interface either i) being a roughened surface on the support layer or on the intermediate layer or ii) comprising aluminium or aluminium alloy surface-activated by heating to a temperature above 450°C but below the melting point of the aluminium or the aluminium alloy; and c) the surface layer has a substantially solid layer structure and is pressed into intimate contact with the interface by mechanical pressure with accompanying reduction in thickness, the pressure being applied simultaneously to the support and surface layers.

Although the information of a porous metal layer as a rough surface for fixing a third layer to a solid steel support layer is known (see Metall, June 1975, No. 6, pages 581 to 585), such rough surfaces have hitherto been impregnated by casting with liquid lead or liquid babbitt metal (see U.S. Specification Nos. 2,189,253 and 2,198,240). The disadvantage of this material is that when hemispherical indentations or lubrication grooves are stamped into it, severe cracking and information of fissures can occur, which may be attributed to the coarse accumulation of lead in the sintered structure. By contrast, the present invention affords the advantage that since the suspension of alloy components is applied to the interface by thermal metal spraying, a better structure is obtained in the surface layer. Thus in the case of lead-containing suspensions such as Cu + Pb or Al + Pb applied to the interface in accordance with the invention, the lead is in a finely divided form in the metallic matrix so that the formation of cracks is unlikely to occur.

In cases where the rough surface is formed on an intermediate layer, this intermediate layer may be so formed that the suspension of alloy components subsequently applied, which tends to separate, is bonded exclusively to the rough surface. The thickness of such a rough surface should be within the range of 0.05 mm to 0.3 mm and is preferably 0.2 mm.

A rough surface may be formed on a porous intermediate layer in the form of a porous sintered structure comprising a copper material such as brass or bronze, and preferably tin-bronze containing 90% by weight of Cu and 10% by weight of Sn. In such a sintered structure, the sintered particles are preferably spherical because they provide a firmer bond and better response to shaping than a scattered sinter grain. The tin-bronze particles are sintered on a support layer which is preferably electroplated with copper, in order to improve the bond. When a scattered sinter structure is used, e.g. in the case of relatively thick support materials, the electroplated layer may be dispensed with. Both faces of the support layer may be covered with electroplated layers.

If the sintered particles are spherical, they have a relatively large surface area and consequently the heat conditions of the thermal metal spraying are so advantageous that, as has been found, a pronounced zone of diffusion, for example of copper in aluminium with partial fusion of the AlPb particles with the porous interlayer, extends over the whole cross-section of the material, and this may explain the excellent bond and its ability to withstand stresses.

The invention also includes a process of forming a laminated material which includes a support layer, a surface layer and an interface between the support and surface layers, the interface being formed either on or by an intermediate layer or on a surface of the support layer and the surface layer comprising a suspension of different alloy components substantially insoluble in one another at least in a temperature range in which the alloy components are in the solid state, the process comprising the steps of:- providing a support layer; applying on to the support layer an intermediate layer which has a rough surface constituting the interface, the latter having bonding properties with respect to the surface layer; applying the surface layer to the rough surface by thermal metal spraying of particles of the alloy components so as to form a substantially solid surface layer structure; and pressing the surface layer into intimate contact with the interface by mechanical pressure with accompanying reduction in thickness, the pressure being applied simultaneously to the support and surface layers. The intermediate layer may be formed by sintering a copper material, e.g. brass or bronze powder (preferably tin-bronze containing 90% by weight of copper and 10% by weight of tin) on the support layer to form a porous sintered structure. The brass or bronze powder preferably comprises spherical particles.

It therefore constitutes an advantageous embodiment of the invention to use a porous layer, e.g. of tin-bronze (CuSn 10), as an intermediate layer. In this embodiment, a good bond is obtained by the grain form of the intermediate layer, the material used for it, and the conditions employed for flame spraying.

Contrary to the widely held view found in the literature, this excellent bond is due to a pronounced diffusion layer and welding of the surface layer to the rough surface.

Since the metallic reactions between the sprayed metal and the material of the rough surface, which bring about the bond between them, are the more numerous the higher the interface temperature, this temperature is important. However, the possibility of improving the adherence of the sprayed surface layer by increasing the surface temperature of the workpiece is limited by the formation of oxide which inevitably occurs.

Furthermore, the use of a porous sintered layer of tin-bronze has the advantage that good compression strength is obtained. In addition, the sintered structure ensures efficient removal of the heat of friction.

The combination of metal support layer and sintered structure intermediate layer may be pre-heated before the spraying operation. The pre-heating temperature may range from 100 to 500°C.

If instead of using the rough surface for receiving the surface layer there is used an aluminium layer or aluminium alloy layer which has been surface activated by briefly heating it to a temperature between 450°C and the melting temperature of the aluminium or aluminium alloy, the laminated material can generally be produced at a lower cost, although the surface layer can be applied equally well to such an interface as to a rough surface and the strength of the bond is virtually the same.

The interface of aluminium or aluminium alloy provided to receive the surface layer may be formed by, for example, a material plated with aluminium or aluminium alloy, or by aluminium or aluminium alloy alone.

The support layer, or plating on the support layer may be virtually pure aluminium, for example Al 99.5, or an aluminium alloy.

The manufacture of aluminium-plated steel has long been known. For manufacturing laminated metal materials comprising lead-containing suspension alloys, the intermediate material, e.g. aluminium or aluminium alloy, serves to improve the bond to the support material (see German Specification No. 1,400,039). The disadvantage of using a support or intermediate layer based on aluminium is that the temperature employed for applying the surface layer by flame spraying does not break down the layer of oxide on the material below, so that when the resulting laminated material is subsequently processed to shape it and is subjected to high dynamic stresses, the layer sprayed on the surface becomes detached and causes breakdown of the workpiece. It has now been found that with the material of the invention the oxide skin on the aluminium layer is destroyed by the surface activation by heat and appropriate thermal conditions during spraying, so that a good laminated material capable of withstanding the necessary stresses is obtained without further after-treatment such as, for example, diffusion annealing. If destruction of the aluminium oxide skin is to be achieved, as is necessary, the temperatures employed for surface activation must reach 450°C within a short time but may be slightly below the melting point of aluminium.

Surface activation by heat may be carried out with any known apparatus such as gas heated or electric continuous furnaces and should peferably be carried out in a protective gas in order to prevent fresh formation of oxide on the surface.

By appropriate adjustment of the spraying conditions, preferably using a reducing atmosphere of C_2H_2/O_2 combustion gas mixture, the oxide skin on the aluminium-containing support layer is destroyed and the droplets of molten suspension alloy reaching the surface form an excellent bond with the preheated support layer, and this bond is not destroyed by subsequent shaping and stress. The suspension alloy components applied as the surface layer, which has been melted or highly plasticised by the combustion gas, may be, for example, an AlPb mixture in which the aluminium component contains additional alloying constituents such as Si, Cu, Fe and Mg. The lead which constitutes the second component of the mixture may contain tin as alloying constituent. Instead of such AlPb powder mixtures, there may also be used an AlPb alloy containing approximately 5% to 20%, preferably 8%, of lead in aluminium. It may in addition contain Sn, Si or Cu as alloying constituents. The constituents of the mechanical mixture of AlPb or of the alloyed powder are regarded as highly heated if they have been converted into the plastic or molten state by heat. The molten material is finely divided by the stream of carrier gas and carried along with the gas at high speed. On encountering the support layer which has been preheated under a protective gas, the finely divided, molten spray particles become rapidly cooled.

The AlPb mixture or alloyed powder used for spraying may be, for example, approximately 20% by weight of lead and 80% by weight of aluminium.

The invention is not limited to this composition but also covers other proportions of components in the mixture and other alloying compositions. The shape of the particles of the mixture or alloy used for thermal metal spraying in accordance with the invention is preferably spherical ather than spattered or club shaped. The proportion of particles having a shape other than spherical should as far as possible not exceed 20%, for example, in an aluminium/lead mixture.

It is known that part of the material being sprayed, e.g. aluminium or lead, evaporates at the high temperatures employed for flame spraying because the sprayed metal particles usually vary in size. Due to these differences in the sizes of the particles, the smaller particles heat up more quickly, since the surface area increases with the square of the size of the particles while the mass increases with the third power. Smaller particles therefore evaporate more quickly and become even smaller.

When using AlPb mixtures, it is therefore recommended to use aluminium particles which are smaller than 60 µm but preferably between 40 and 60 µm. The size of the lead particles should preferably be between 80 and 100 µm in order to eliminate the undesirable effect of evaporation. The particle size of the AlPb alloy is preferably 100 µm.

Spraying may be carried out with the usual powder spray guns although any other thermokinetic application devices designed to apply metallic or non-metallic coatings may be employed.

If the layer (in the form of a band, bar or strip) which is to be coated is so wide that it is impossible to obtain uniform coating over its whole width with a single spray device, several spray devices may be arranged side by side or above one another to ensure uniform coating.

Continuous coating may also be carried out by a wide jet spray nozzle designed so that aluminium and lead can be supplied separately. The separate components leave the nozzle at an angle to each other so that they become mixed together just above the rough surface.

The coating may also be improved by arranging a device such as a spray rosette, for example, in front of the nozzle of the powder spraying device in order to convert or deflect the spray cone into a jet of uniform width and thickness.

The apparatus may, for example, comprise two spray nozzles adjustable in position and arranged opposite each other, each nozzle having apertures arranged in a row and being supplied with air or an inert gas such as nitrogen or helium, or a mixture thereof.

The combustion gas for the powder spraying apparatus may be either an acetylene/oxygen mixture or a hydrogen/oxygen mixture. Although a somewhat more porous layer of suspension alloy is obtained when using the acetylene/oxygen mixture, a hydrogen/oxygen combustion gas is preferred for economic reasons.

If it is intended to spray the suspension of alloy material onto an interface having a rough surface the distance between the nozzle and the support layer to be coated should be 210 ± 10 mm since it has surprisingly been found that even small deviations from this distance produce such changes in the thermal conditions that as the distance increases, a poorer bond is obtained, whereas if the distance is reduced, lead evaporates due to the heat being reflected.

If it is intended to spray the suspension alloy material onto an acitvated aluminium surface the distance between the nozzle from which the powder is sprayed and the surface on which it is to be sprayed should be 170 mm ± 10 mm both for an AlPb powder mixture and for AlPb alloy powder. Even slight deviations from this distance lead to changes in the thermal conditions. The invention provides good bonding of the sprayed surface layer to the support layer which has been preheated under protective gas, due to destruction of the aluminium oxide skin by empirically determined surface activation and optimum spraying conditions.

Continuous coating of the support layer is carried out by feeding the fixed spray device with a mixture of alloy suspension constituents or suspension alloy and moving the support layer to be coated, which has been preheated under protective gas, past the spray device. The process may be varied, in that sections of strips or bars preheated under protective gas may be coated in the manner described above.

The laminated material produced in this way is compressed after the coating operation. This compression may be produced by rolling or by static application of pressure. The degree of deformation of AlPb coatings, based on the total thickness of the material, should not be so great that the Pb particles are stretched. It should therefore be between 5% and 20%, preferably between 11% and 14%. The laminated material produced in this way requires no further finishing operations, for example annealing, and can be used directly for the manufacture of bearing linings, bearings boxes and so on without risk of the layers splitting off.

Some examples of the invention are explained below with reference to the drawing, in which:-

Figure 1 is an enlarged section through a laminated material in accordance with the invention, and comprising a solid support layer, an intermediate layer, and surface layer;

Figure 2 is an enlarged section through a laminated material in accordance with the invention, and comprising a sintered structure as the support layer having on each side a rough surface and surface layers; and

Figure 3 is an enlarged section through a laminated material in accordance with the invention, and comprising aluminium plated steel as the support layer and AlPb as a suspension forming the surface layer.

Example I

Referring to Figure 1, there is seen a support layer in the form of a steel strip 4 which is copper plated on both sides at 5 and is covered on one side with a sintered structure 3 of substantially spherical tin-bronze powder. This structure 3 constitutes an interface and it has a rough surface on which a surface layer of an alloy of aluminium and lead is applied by thermal spraying, for example flame spraying, electric arc spraying or plasma spraying. The aluminium particles are indicated by 1 and the lead particles by 2. The sprip of laminated material produced in this way is compressed by rolling to reduce its thickness of about 12%.

Example II

A laminated material (not shown) comprises a support layer in the form of a steel strip which is not copper plated. It carries a sintered structure which constitutes an interface and is of spherical tin-bronze. The support layer with the interface have a total thickness of 1.7 mm. The surface layer is applied by flame plating, and the whole then compressed by rolling.

A steel strip 1.5 mm in thickness conforming to DIN 1623 is used as the support layer. The sintered structure which forms the interface with a porous rough surface has a composition corresponding to CuSn 10 and a thickness of 0.2 mm. The AlPb mixture forming the surface layer comprises 80% by weight of aluminium and 20% by weight of lead. The aluminium component used is a powder of spherical particles measuring 40 to 60 microns and containing Si and Fe as alloying constituents. The second component of the mixture comprises spherical particles of PbSn containing 1% of Sn. 100% of the particles measured between 80 and 100 micron.

The combustion gas used is an H_2/O_2 mixture. A spray nozzle unit is used to restrict the cone of the flame.

The strip is continuously moved past the flame spraying device at a rate of 1 metre per minute while the spraying device is fed with the AlPb mixture. With the given spray data, which is preadjusted, the thickness of the AlPb surface layer obtained is 0.4 mm.

The whole structure after application of the surface layer is compressed by rollers. The degree of deformation, based on the total thickness of 0.1 mm, was 14%, which corresponds to a final thickness of the finished laminated material of 1.8 mm.

Example III

Referring to Figure 2 a sintered structure 3 of tin-bronze composed of mainly spherical particles is preformed as a strip 0.5 mm in thickness which constitutes a support layer. Both faces of the sintered structure 3 have a roughened configuration as shown, and each constitutes an interface. A suspension alloy of 80 parts by weight of aluminium and 20 parts by weight of lead is applied to both interfaces of this strip of sintered structure 3 by thermal metal spraying, for example flame spraying, electric arc spraying or plasma spraying. The aluminium constituents of the suspension alloy are indicated by 1 and the lead constituents by 2. The material of the suspension alloy may be the same as that used in Example II. After the thermal spraying, the strip of laminated material was compressed to reduce its thickness of about 14%.

Example IV

Referring to Figure 3, a steel strip 14, forming the support layer, is roller plated with aluminium 13 on one side to form the interface. After this has been preheated under protective gas in a continuous furnace, an alloy of aluminium and lead is applied on to the interface by a thermal metal spraying process, for example flame spraying, electric arc spraying, plasma spraying, or flame plating. Reference numeral 11 indicates mainly the aluminium particles and reference numeral 12 the lead particles. The composite material thus formed is compressed by rolling to reduce its thickness by about 14%. The support layer strip 14 is a steel conforming to DIN 1623 and is 1.5 mm in thickness. The roller plated aluminium interface is of Al 99.5 or Al 99.0 and has a thickness of 0.2 mm. The AlPb mixture is 80% by weight aluminium and 20% by weight lead. The aluminium component used is a powder of spherical particles ranging from 40 to 60 micron containing Si and Fe as alloying constituents. The second component of the mixture comprises spherical PbSn particles containing 1% of Sn. 100% of the particles are from 80 to 100 μm in size.

The combustion gas used in an H_2/O_2 mixture. A spray nozzle unit is used to limit the cone of the flame. The strip 13, 14, preheated under protective gas in a continous furnace, is continosly moved past the thermal metal spraying device at a predetermined speed of 1 metre per minute while the spraying device is fed with the AlPb mixture. The thickness of the AlPb surface layer obtained with the preadjusted spray data was 0.4 mm. After application of the surface layer, the laminated material is cooled and then compressed by rollers in the same continuous run. The degree of deformation is 14%, based on a total thickness of 2.1 mm, which corresponds to a final thickness for the finished laminated product of 1.8 mm.

Example V

A support layer (not shown) comprising an aluminium strip containing 99% Al of thickness 0.5 mm is quickly heated to above 450°C but below the melting point of the strip so as to cause surface-activation of both its faces. The strip is then coated on both its faces with a suspension alloy of 80 parts by weight of aluminium and 20 parts by weight of lead by thermal metal spraying, for example flame spraying, electric arc spraying, plasma spraying, or flame plating, under operating conditions similar to those employed in Example IV. The material of the suspension alloy used for coating may be the same as that used in Example IV. After the thermal metal spraying, the laminated material is compressed so that its thickness is reduced by about 14%.

WHAT WE CLAIM IS:-

1. A laminated material comprising a support layer, a surface layer and an interface between the support and surface layers, the interface being formed either on or by an intermediate layer or on a surface of the support layer, and the surface layer comprising a suspension of different alloy components substantially insoluble in one another at least in a temperature range in which the alloy components are in the solid state, wherein:- a) the surface layer is applied to the interface by thermal metal spraying of particles of the alloy components; b) the properties of the interface being such that the sprayed alloy particles will penetrate it and will bond to it, the interface either i) being a roughened surface on the support layer or on the intermediate layer or ii) comprising aluminium or aluminium alloy surface-activated by heating to a temperature above 450°C but below the melting point of the aluminium or the aluminium alloy; and c) the surface layer has a substantially solid layer structure and is pressed into intimate contact with the interface by mechanical pressure with accompanying reduction in thickness, the pressure being applied simultaneously to the support and surface layers.

2. A material according to claim 1 wherein the support layer comprises aluminium, copper, tin or iron, or alloys thereof.

3. A material according to claim 2 wherein the support layer is of low carbon steel.

4. A material according to any preceding claim wherein the support layer is copper plated on one or both sides.

5. A material according to claims 1 to 3 wherein the rough surface is on an intermediate layer comprising a porous sintered structure of brass or bronze.

6. A material according to claim 5 wherein the bronze is tin-bronze containing 90% by weight of copper and 10% by weight of tin (CuSn 10).

7. A material according to claim 5 wherein the porous sintered structure is formed by sintering substantially spherical particles onto the support layer.

8. A material according to claim 1 wherein the support layer comprises a porous sintered structure.

9. A material according to claim 8 wherein the support layer is sintered from a brass or bronze powder.

10. A material according to claim 9 wherein the bronze powder is of tin-bronze (CuSn 10).

11. A material according to claim 2 wherein the support layer is plated with aluminium or aluminium alloy.

12. A material according to claim 11 wherein the support layer is plated on one or both sides.

13. A material according to claim 11 or claim 12 wherein the support layer is plated with Al 99.5 conforming to DIN 1712.

14. A material according to claim 2 wherein the support layer is of Al 99.5 conforming to DIN 1712, or of an Al Alloy.

15. A material according to any preceding claim wherein the surface layer is of an anti-friction material.

16. A material according to claim 15 wherein the anti-friction material is an aluminium/lead alloy.

17. A material according to claim 16 wherein the anti-friction material comprises from 75 to 94% by weight of aluminium and from 6 to 25% by weight of lead.

18. A material according to claim 17 containing from 10 to 20% by weight of lead.

19. A material according to claim 17 or claim 18 wherein the aluminium component contains Si, Cu, Mg, Fe or other alloying constituents and the lead component contains at least 90% of lead and Sn, Sb or Li.

20. A material according to claim 19 wherein the lead component is PbSn with a tin content of 1%.

21. A material according to claim 1

wherein the interface is aluminium or aluminium alloy plated on the intermediate layer whose thickness is in the range of from 0.05 mm to 0.3 mm.

22. A material according to claim 21 wherein the said thickness is 0.2 mm.

23. A process of forming a laminated material which includes a support layer, a surface layer and an interface between the support and surface layers, the interface being formed either on or by an intermediate layer or on a surface of the support layer and the surface layer comprising a suspension of different alloy components substantially insoluble in one another at least in a temperature range in which the alloy components are in the solid state, the process comprising the steps of:-

providing a support layer;

applying on to the support layer an intermediate layer which has a rough surface constituting the interface, the latter having bonding properties with respect to the surface layer;

applying the surface layer to the rough surface by thermal metal spraying of particles of the alloy components so as to form a substantially solid surface layer structure; and

pressing the surface layer into intimate contact with the interface by mechanical pressure with accompanying reduction in thickness, the pressure being applied simultaneously to the support and surface layers.

24. A process of forming a laminated material which includes a support layer, a surface layer and an interface between the support and surface layers, the interface being formed either on or by an intermediate layer or on a surface of the support layer and the surface layer comprising a suspension of different alloy components substantially insoluble in one another at least in a temperature range in which the alloy components are in the solid state, the process comprising the steps of:-

providing a support layer which has a rough surface constituting the interface, the latter having bonding properties with respect to the surface layer;

applying the surface layer to the rough surface by thermal metal spraying of particles of the alloy components so as to form a substantially solid surface layer structure; and

pressing the surface layer into intimate contact with the interface by mechanical pressure with accompanying reduction in thickness, the pressure being applied simultaneously to the support and surface layers.

25. A process of forming a laminated material which includes a support layer, a surface layer and an interface between the support and surface layers, the interface being formed either on or by an intermediate layer or on a surface of the support layer and the surface layer comprising a suspension of different alloy components substantially insoluble in one another at least in a temperature range in which the alloy components are in the solid state, the process comprising the steps of:-

providing a support layer;

applying on the support layer an intermediate layer which has the interface comprising aluminium or aluminium alloy surface-activated by heating to a temperature above 450°C but below the melting point of the aluminium or aluminium alloy;

applying the surface layer to the interface by thermal metal spraying of particles of the alloy components so as to form a substantially solid surface layer structure; and

pressing the surface layer into intimate contact with the interface by mechanical pressure with accompanying reduction in thickness, the pressure being applied simultaneously to the support and surface layers.

26. A process of forming a laminated material which includes a support layer, a surface layer and an interface between the support and surface layers, the interface being formed either on or by an intermediate layer or on a surface of the support layer and the surface layer comprising a suspension of different alloy components substantially insoluble in one another at least in a temperature range in which the alloy components are in the solid state, the process comprising the steps of:-

providing a support layer;

plating on to the support layer aluminium or aluminium alloy;

heating the plated support layer to a temperature above 450°C but below the melting point of the aluminium or aluminium alloy so as to surface-activate the aluminium or aluminium alloy which then constitutes the interface;

applying the surface layer to the interface by thermal metal spraying of particles of the alloy components so as to form a substantially solid surface layer structure; and

pressing the surface layer into intimate contact with the interface by mechanical pressure with accompanying reduction in thickness, the pressure being applied simultaneously to the support and surface layers.

27. A process of forming a laminated material which includes a support layer, a surface layer and an interface between the support and surface layers, the interface being formed either on or by an intermediate layer or on a surface of the support layer and the surface layer comprising a suspension of different alloy components substantially insoluble in one another at least in a temperature range in which the alloy components are in the solid state, the process comprising the steps of:-

providing a support layer of aluminium or an aluminium alloy;

heating the support layer to a temperature above 450°C but below the melting point of the aluminium or aluminium alloy so as to surface-activate the aluminium or aluminium alloy which then constitutes the interface;

applying the surface layer to the interface by thermal metal spraying of particles of the alloy components so as to form a substantially solid surface layer structure; and

pressing the surface layer into intimate contact with the interface by mechanical pressure with accompanying reduction in thickness, the pressure being applied simultaneously to the support and surface layers.

28. A process according to any of claims 23 to 27 wherein the surface layer components include aluminium in the form of a powder of spherical particles in which at least 90 volume percent are of a particles size of between 40 and 60 μm.

29. A process according to claim 28 wherein the surface layer components include lead in the form of a powder of spherical particles in which at least 90 volume percent are of a particle size of between 80 and 100 μm.

30. A process according to any of claims 23 and 27 wherein the surface layer components include at least 80 volume percent of spherical particles and at most 20 volume percent of club-shaped or spatterecd particles.

31. A process according to any of claims 23 and 27 wherein the thermal metal spraying comprises flame spraying, electric arc spraying, plasma spraying or flame plating.

32. A process according to any of claims 23 to 31 wherein a hydrogen/oxygen gas mixture is used in the thermal metal spraying.

33. A process according to any of claims 23 to 31 wherein an excess of hydrogen or of acetylene is used in a hydrogen/oxygen or an acetylene/oxygen combustion gas mixture in the thermal metal spraying.

34. A process according to any of claims 25 to 27 wherein the interface, during application of the surface layer, is kept at a distance of 170 mm ± 10 mm from the nozzle of a spray device.

35. A process according to claim 23 or claim 24 wherein the rough surface, during application of the surface layer, is kept at a distance of 210 mm ± 10 mm from the nozzle of a spray device.

36. A process according to any of claims 23 to 35 wherein a rolling operation is used for the pressing step as part of a continuous process.

37. A process according to any of claims 23 to 35 wherein a static pressing operation is used for the pressing step.

38. A process according to claim 36 or claim 37 wherein the pressing step produces a deformation of from 5 to 20%, and preferably between 11 and 14%.

39. A process according to any of claims 23 to 38 wherein the laminated material is produced continuously in the form of a band, sheet, bar or strip.

40. A process according to any of claims 23 to 39 wherein the spray cone used in the thermal metal spraying is limited in its extent by a limiting device arranged on spray means, so as to obtain a uniform surface layer.

41. A process according to claim 40 wherein an adjustable device for limiting the spray cone is provided, comprising two opposed, elongate sprinklers, each having a row of apertures, which sprinklers are arranged at a given angle to each other and enclose the spray cone.

42. A process according to claim 40 or claim 41 wherein the device for limiting the spray cone is fed with compressed air.

43. A process according to claim 40 or claim 41 wherein the device for limiting the spray cone is fed with nitrogen, helium, argon or hydrogen, or a mixture thereof.

44. A process according to claim 42 or claim 43 wherein the air or gas is fed at a pressure of between 1 and 4 bars.

45. A process according to any of claims 40 to 44 wherein the spray means has a broad jet spray nozzle designed to deliver the components for the surface layer separately.

46. A laminated material substantially as herein described with reference to any of the examples.

47. A process for making a laminated material substantially as herein described with reference to the drawings.

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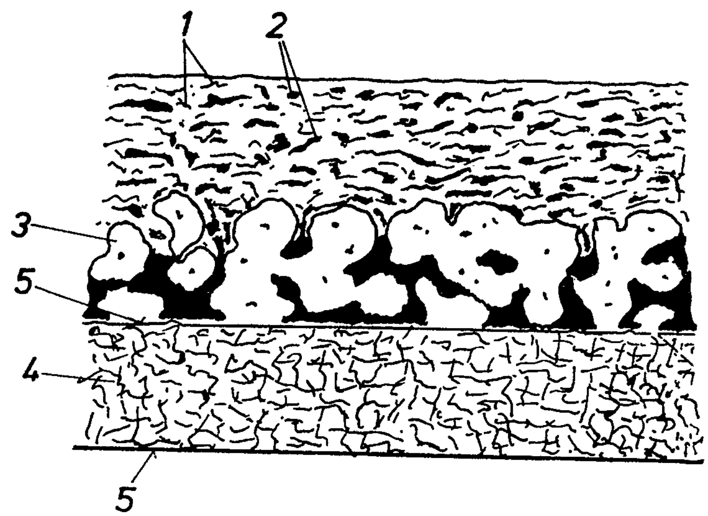
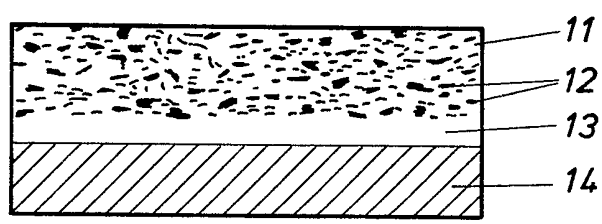


Fig.1

Fig.3



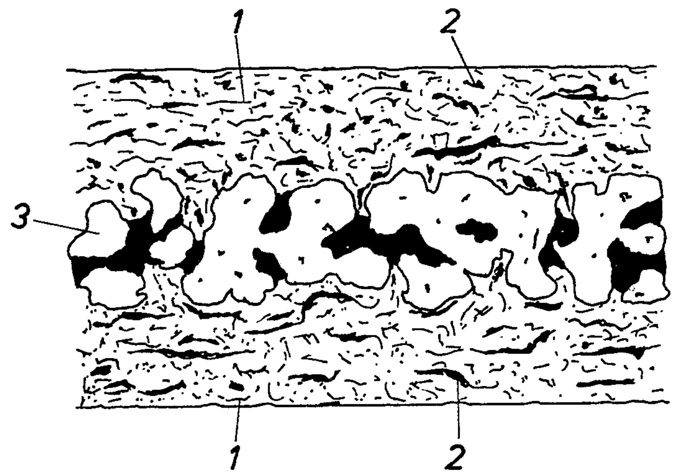


Fig.2