Dec. 26, 1967 H. SCHREINER 3,360,348

COMPOSITE STRUCTURE OF INTER-BONDED METALS
FOR HEAVY-DUTY ELECTRICAL SWITCH CONTACTS

Filed May 11, 1965 2 Sheets-Sheet 1

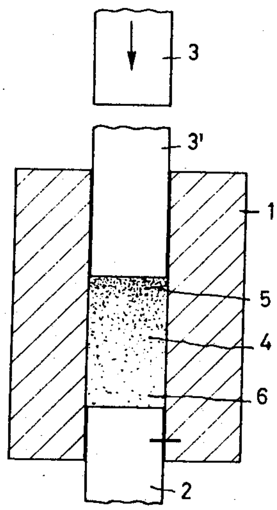

Fig. 1

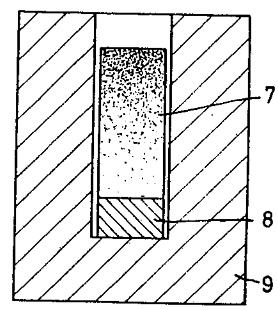

Fig. 2

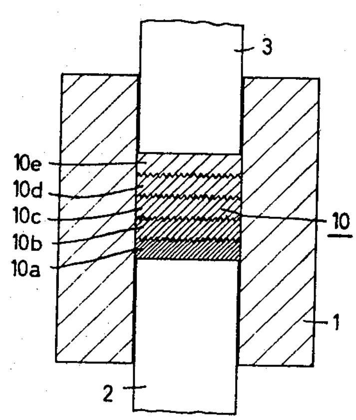

Fig. 3

Dec. 26, 1967 H. SCHREINER 3,360,348
COMPOSITE STRUCTURE OF INTER-BONDED METALS
FOR HEAVY-DUTY ELECTRICAL SWITCH CONTACTS
Filed May 11, 1965 2 Sheets-Sheet 2

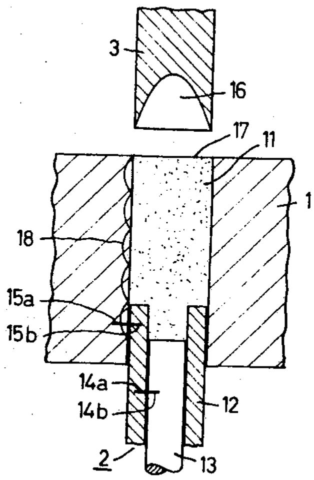

Fig. 4

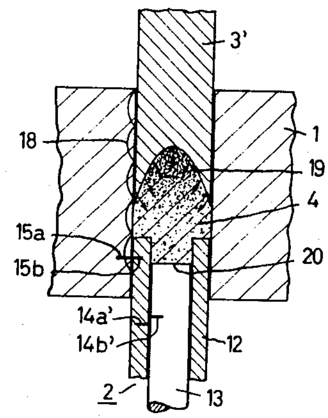

Fig. 5

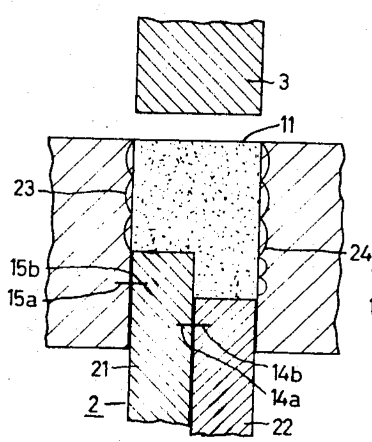

Fig. 6

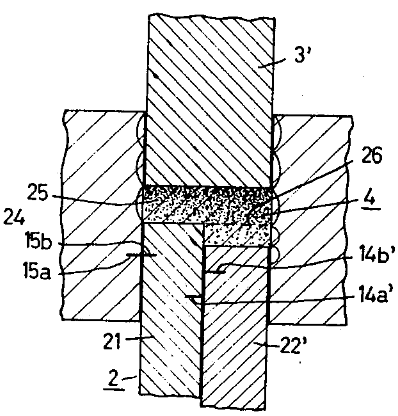

Fig. 7

United States Patent Office

3,360,348

Patented Dec. 26, 1967

1

3,360,348
COMPOSITE STRUCTURE OF INTER-BONDED METALS FOR HEAVY-DUTY ELECTRICAL SWITCH CONTACTS

Horst Schreiner, Nurnberg, Germany, assignor to Siemens-Schuckertwerke Aktiengesellschaft, Berlin-Siemensstadt, Germany, a corporation of Germany

Filed May 11, 1965, Ser. No. 454,921
Claims priority, application Germany, May 15, 1964, S 91,084
4 Claims. (Cl. 29—182.1)

My invention relates to composite and internally bonded structures of metal for heavy-duty electrical switch contacts and to methods of producing such contact structures.

Electrical switch contacts for high current-interrupting duties are required to be highly resistant to burn-off when subjected to switching arcs and to also possess good electrical conductivity. It has been attempted to attain this combination of properties with the aid of bonded composite materials, for example combinations of tungsten and copper or tungsten and silver. Composite contacts have long since been used in which the localities endangered by burn-off are clad with refractory material spacially separated from a good conducting material which, when the switch contacts are closed, conducts the flow of continuous current. Also proposed for high-duty electrical switch contacts have been multi-layer bonded structures of tungsten and silver in which the content of one of the components increases from layer to layer. In such a laminated structure, the hardness, density and refractory quality increase from layer to layer as the tungsten content increases, with a simultaneous decrease in electrical and thermal conductance. Thus, for example, a laminated contact of tungsten and silver can be produced from W/Ag compositions whose respective ratios from layer to layer are 90/10, 80/20, 70/30 and 60/40. The individual layers are produced from pulverulent mixtures which are filled into a die and pressed, each following layer being densified at a higher pressure. Ultimately all of the layers are pressed conjointly at a given maximum of compression. After sintering the four-layer pressed body for 2½ hours at 905° C., it is subjected to cold pressing at 14 metric tons per cm.^{2}. This method has the following shortcomings:

The required high shaping and densifying pressure and the extreme pressure required for subsequent cold pressing, result in extreme wear of the pressing tools. Despite the high ultimate pressure applied, these composite metal structures still retain a residual porosity of a few percent and consequently do not secure the highest feasible resistance to burn-off.

It is an object of my invention to provide a composite metal structure for high-duty electrical contacts, for example arc contacts for high-voltage circuit breakers, which overcomes the above-mentioned difficulties and obviates the deficiencies of the composition contact materials heretofore available.

According to the invention, a metal body for electrical contacts comprises a compressed and sintered porous skeleton structure of refractory metal and an impregnation of good-conductance metal premeating the pores of the skeleton structure, and the composite body has in the direction of compression a progressively different ratio of the percentile shares of the skeleton material and the impregnation respectively, but without concentration jumps, the concentration of the impregnation increasing gradually in the mentioned direction in complementary, i.e. inverse relation to the concentration of the skeleton structure.

2

The body is produced by first pressing a pulverulent mass of the refractory material to the desired shape and in the manner required to obtain a progressively different density without concentration jump. The shaped body is then sintered and thereafter fully impregnated. The impregnating metal then forms a structural component which penetrates into the pores of the sintered skeleton and whose concentration increases in the pressing direction continuously at a rate complementary to the concentration of the sintered skeleton structure.

For economical manufacture, it is particularly favorable to form the pressed body of several layers of pulverulent material, all consisting of the same materials. If the impregnation-penetrated skeleton structure of a contact body according to the invention is to have its largest dimension in the direction of the pressing operation, it is preferable to compress the mass of pulverulent material from only one side. The pressure drop then occurring along the height of the pressed body in the pressing direction can then be utilized for obtaining continuously merging layers of respectively different ratios of composition. This method of the invention is predicated upon the recognition that when metal powder is subjected to unilateral pressing, the mixture of metal powder is subjected to a higher amount of densification at the side of the moving press plunger, than at the opposite side, so that the density of the pressed material decreases toward the fixed support or plunger. After pressing, the resulting shaped body is sintered and is subsequently impregnated with a liquid metal or alloy.

If the body is to have its smallest dimension in the pressing direction and/or if larger differences in density within the body are to be achieved, the following method according to the invention is preferable. According to this method, the same powder composition is pressed in several layers, but different respective pressures are applied to the individual layers. When proceeding in this manner, the first layer of powder material, placed into a die or the like, is pressed at the highest pressure. Thereafter the second layer of powder material is filled onto the pressed first layer and subjected to pressing at a somewhat lower pressure. Analogously, each further layer is filled on top of the previously pressed layer and is pressed at a lower pressure than the preceding layer. As a result, the previously deposited layers, virtually, are not further compressed when pressing the subsequent layers, and the shaping and densifying pressure is effective to cause the boundary faces to merge by intermeshing and coalescing.

If impregnated composition structures of metal according to the invention are produced by multi-layer pressing of metal powder having respectively different compositions, then the above-explained intermeshing and coalescing, as well as the required concentration differences, also result if the same amount of pressure is applied to each of the layers, but larger differences in density are obtainable by utilizing the effect of the pressure drop resulting from unilateral pressing in the above-described manner. The mechanical intermeshing and coalescing of the individual layers can also be improved by loosening the surface of each layer upon which another layer is to be filled into the die. Such loosening is effected, for example, with the aid of a wire brush or the like.

It is desirable, in principle, to attain highest feasible pre-densification during the pressing operation preceding the sintering process, because sintering requires heat and time, and the amount of shrinkage during sintering is larger with a smaller space filling degree of the pressed body. I have found, however, that the objections existing in this respect against unilateral pressing and densification, are overcome by properly selecting the composition of the powder mixture to be pressed, as well as the pressing and sintering conditions. That is, the resulting sintered skeleton structure should exhibit high mechanical strength without appreciable sintering shrinkage, preferably also good wettability. From these viewpoints it is advantageous to form the contact structure according to the invention from a unilaterally pressed and densified sinter structure from a material which, when being sintered, develops a liquid phase. For this reason, it is preferable to form the skeleton material predominantly of tungsten, the residual constituents being copper and nickel, and to use as impregnation either copper or silver or an alloy of the latter two metals.

It has been found that with composite and metal-impregnated contact structures of this kind those localities which contain a minimum amount of the sinter-skeleton material need be subjected to only such a minimal specific pressure that the resulting pressed and shaped contact body has just enough mechanical strength at the edges to permit being handled and transported for sintering purposes.

In this respect, the invention takes advantage of the observation that the sinter skeleton of such an impregnated body will assume high mechanical strength without requiring sintering to perfect density, and will exhibit good wettability, if a sinter skeleton is formed, with the occurrence of a liquid phase, from a tungsten-copper-nickel alloy containing about 1 to about 5% copper and about 0.5 to about 2% nickel, the balance being substantially all tungsten. The wettability can be further increased by adding to the impregnating metal an admixture of other metals, for example zinc or tin, in a small amount such as from traces up to 1%.

Such an impregnation-penetrated and bonded contact structure is produced, for example, by employing a powder mixture of 98.5 to 93% tungsten, 1 to 5% copper, the remainder being 0.5 to 2% nickel. This composition is pressed to a skeleton structure having the desired shape of the contact. The pressed body is then sintered at a sufficiently high temperature, preferably between 1150 and 1350° C. Thereafter the resulting skeleton structure is impregnated with the impregnating metal. The sintering of the skeleton is effected in a reducing or inert atmosphere or in vacuum. The impregnation may be performed by placing the skeleton structure upon the molten impregnating metal, depositing the molten metal upon the skeleton structure, or immersing the skeleton structure in the molten impregnating metal. If desired, an excess amount of impregnating metal may be used for the purpose of forming readily solderable coatings on the resulting contact body.

As mentioned, the layers in a structure made according to the invention merge continuously with each other with increasing or decreasing concentration. For thus obtaining the required mechanical strength, as well as the desired porosity and wettability of the sintered skeleton, the mixing proportions of tungsten, copper and nickel may be chosen within wide limits, as is also the case with the known bonded composition and metal in which the concentration of the individual constituents does not virtually change along its spacial coordinates. Thus, for example, the copper content in the skeleton structure of a contact body according to the invention may be increased up to about 15%.

Embodiments of bonded and integrated contact structures as well as methods of their production according to the invention will be further described with reference to specific examples and with reference to the accompanying drawing in which:

FIG. 1 shows schematically and in section a unilaterally operating die press during an initial stage of a process according to the invention.

FIG. 2 shows schematically and in section an impregnating device used in a subsequent processing stage for impregnating the contact body initially prepared according to FIG. 1.

FIG. 3 shows a die during production of a five-layer contact according to the invention.

FIGS. 4 and 5 relate to still another manufacturing device during different stages respectively of the production process.

FIGS. 6 and 7 show in section still another pressing device, used for the manufacture of a contact shoe also in respectively different stages of the process.

Functionally corresponding parts are denoted by the same respective reference characters in all illustrations.

FIG. 1 illustrates the unilateral pressing of the powder material in a die **1** with a fixed lower plunger **2** and a downwardly displaceable upper plunger **3**, the ultimate pressing position of the upper plunger being shown at **3'**. The pressed body **4** has a higher density in its upper portion **5** than in the lower portion 6.

FIG. 2 illustrates the impregnating process. The pressed and subsequently sintered body **7** is placed upon a disc **8** of copper. The assembly is heated in a container **9**. After impregnation, the copper is completely absorbed in the porous body **7**. By employing an excessive quantity of copper, the contact body **7** receives a coating of copper on its side of lower density and consequently higher electrical conductance.

Described presently is an example of a process performed with the aid of devices as shown in FIGS. 1 and 2.

Tungsten powder in an amount of 89% by weight, produced from WO_3 and having a grain size smaller than 0.06 mm., is mixed with 10% electrolysis copper powder of a grain size less than 0.06 mm., and 1% carbonyl nickel powder of less than 0.01 mm. grain size. A quantity of 152 g. powder is filled into a die of cylindrical shape having a diameter of 25.1 mm. (FIG. 1). The mass of powder is then unilaterally densified under a pressure of 4.3 tons (metric). The compressed cylindrical body has an axial height of 32.7 mm.

The shaped body is removed from the die and sintered at 1200° C. for one hour in hydrogen. During sintering there occurs a liquid phase which results in high mechanical strength of the sinter skeleton. The density in sintered condition is virtually equal to the density in the pressed, not yet sintered condition, namely about 9.3 g./cm.^{3}.

After sintering, the body is impregnated with copper at 1200° C. in pure hydrogen. The impregnation is completed within one minute. The sinter body is either immersed in liquid copper or the calculated quantity of copper required for completly filling the pores of the skeleton structure, is deposited upon or placed beneath the sintered body (FIG. 2).

The resulting pore-free impregnated body has a density of 13.6 g./cm.^{3}. At the side of the moved pressure plunger employed during the preceding pressure shaping, the tungsten content and consequently the density are higher than on the opposite side where the fixed bottom plunger was located during pressing. The contact structure thus produced is employed as a high-duty switch contact so located that the burn-off resistant, tungsten-rich side constitutes the electrical contact surface. The copper-rich opposite side of the contact structure possesses good soldering qualities and can be soldered or brazed with hard solder or brazing material upon conventional carrier metals.

For producing relatively low contact bodies, that is bodies whose axial height is smaller than the diameter on the edge length, and for obtaining larger differences in the density within the body than attainable by utilizing the pressure drop of unilateral pressing, the pressing is effected in several stages. In this case the effect of a higher difference in density, if required, can be further increased by giving the individual layers of powder respectively different compositions.

FIG. 3 shows a die **1** with a pressed body **10** composed of five layers. These layers are produced by individually pressing the layers **10**a, **10**b, **10**c, **10**d and **10**e. The lowermost layer **10**a is first pressed at the highest pressure. Each following layer, filled on top of the preceding layer, is then pressed at a lower pressure, the uppermost layer **10***e* thus being compressed at the lowest pressure. For good intermeshing and coalescing of the individual layers, the individual surface of each layer is first loosened by brushing with a steel wire brush before the next layer of powder is filled into the die. The resulting multi-layer body is removed, sintered and the resulting sintered skeleton structure impregnated with metal. The lowermost layer **10***a* has the highest content of skeleton-forming metal, for example tungsten, and the smallest content of impregnating metal such as copper; the uppermost layer **10***e* which was pressed at the lowest pressure, has the lowest content of tungsten and the highest content of impregnating metal. The surface of the layer **10***e* is ultimately soldered upon a body of impregnating metal. If the impregnation is effected from the side of the layer **10***e*, using an excess amount of impregnating metal, a coating of this metal remains on top of the layer **10***e*.

In the same manner as described in the foregoing example, impregnated contact structures according to the invention can be produced of the metal systems Me_1–Me_2 and Me_1–Me_2–Me_3, in which Me_1 denotes W, Re, Mo or the like refractory metals; Me_2 denotes Cu, Ag or their alloys; and Me_3 denotes Ni, Co or Cr.

FIG. 4 shows the open position and FIG. 5 the ultimate pressing position of a device which comprises a die **1**, a fixed lower plunger **2** and a vertically movable upper plunger **3**, the lowermost position of the upper plunger being shown at **3′** in FIG. 5. A powder mixture **4**, filled into the die **1**, is pressed and shaped into a body **4**. The lower plunger is composed of a fixed tubular portion **12** in which a piston **13** is displaceable. In the filling position according to FIG. 4, two markers **14***a* and **14***b* between parts **12** and **13** are adjacent to each other, and two corresponding markers **15***a* and **15***b* on die **1** and part **12** are likewise adjacent to each other.

The pressure plunger **3** has a cavity **16** which determines the shape of a switch pin to be pressed. The cavity **16** is lowered onto the originally planar surface **17** of the powder mass **11**. Due to the different shapes of the active face on plunger **3** and the mass of powder **11**, there results a continuous variation in density, not only in the travel direction of the pressing plunger but also in other directions. The filling factor f, which in the present case is defined by the relation $f=h_F/h_P$, wherein h_F denotes the height of the powder mass in the filled-in condition and h_P the height in compressed condition, varies between the values 4 and 1.5. This is indicated by a scale marking **18** entered in FIG. 5 for explanatory purposes. The vectors **19** of the compressing forces extending in the direction normal to the boundary faces result in good densification of the material at the surface.

It is desirable to increase the strength of the edges at the lower surfaces **20** and to secure a minimal compressing density P_{min} resulting in a body of sufficient edge strength. For this purpose, the position **13** may be lifted a slight amount, as indicated by the markers **14***a′*, **14***b′*, toward the upper plunger **3** without moving the tubular part **12** of the lower plunger, so that the markers **15***a* and **15***b* retain in FIG. 5 the relative position as shown in FIG. 4.

FIGS. 6 and 7 show the filling position and pressing position respectively with respect to the production of a contact shoe by a process and in a manner corresponding to FIGS. 4 and 5 respectively. The lower plunger **2** is subdivided into a fixed portion **21** and a displaceable portion **22**. During pressing operation, the portion **22** is lifted slightly toward the upper plunger **3′** whose ultimate pressing position is denoted by **3′** in FIG. 7. The lower plunger thus moves from the position of FIG. 6, in which the markers **14***a* and **14***b* coincide, to the position **22′** in FIG. 7 where the marker **14***b′* is slightly above the marker **14***a′*. As is shown by the explanatory scales **23** and **24**, the filling factor in the left-hand portion **25** of the compressed body **4** has the value 3, whereas in the right-hand portion the filling factor is smaller than 3. The movable portion **22** of the lower plunger, therefore, can be used not only for securing the desired edge strength but also for controlling the differences in density in directions departing from the travel direction of the compressing tool.

To those skilled in the art, it will be obvious upon a study of this disclosure that, with respect to composition, materials and auxiliaries used, my invention permits of various modifications and hence may be given embodiments other than particularly illustrated and described herein, without departing from the essential features of my invention and within the scope of the claims annexed hereto.

I claim:

1. In a composite and internally bonded body with a plurality of layers for electrical switch contacts comprising a body one side of which is most compressed and has the highest content of spark-resistant high-melting metal and the smallest content of impregnating metal, the remote side of said body being least compressed and having the lowest content of high-melting metal and the highest content of impregnating metal, said spark-resistant high-melting metal consisting of an alloy formed preponderantly of tungsten with a remainder substantially of copper and nickel, and said impregnating metal being formed substantially by metal selected from the group consisting of copper and silver and their alloys, the concentration of the high-melting metal and of the impregnating metal which fully impregnates the intermediate layers gradually merging into each other at values between the border layers without a concentration leap and the concentration varying in the direction of compression.

2. In a switch contact body according to claim **1**, said sinter skeleton structure consisting substantially of tungsten with 1 to 15% by weight of copper and 0.5 to 2% of nickel.

3. In a switch contact body according to claim **1**, said sinter skeleton structure consisting substantially of 28.5 to 93% by weight of tungsten, 1 to 5% copper and 0.5 to 2% nickel.

4. In a switch contact body according to claim **1**, said impregnation containing a minor amount of additional metal from the group consisting of zinc and tin.

References Cited

UNITED STATES PATENTS

2,464,517 3/1949 Kurtz -------------- 75—208

FOREIGN PATENTS

252,531 6/1964 Australia.
544,969 5/1942 Great Britain.

OTHER REFERENCES

Goetzel: "Treatise on Powder Metallurgy," vol. I, pp. 287–297; 1949, Interscience Publishers.

L. DEWAYNE RUTLEDGE, *Primary Examiner.*

CARL D. QUARFORTH, BENJAMIN R. PADGETT, *Examiners.*

A. J. STEINER, *Assistant Examiner.*