July 6, 1971 S. HEIMAN 3,591,466

COMPOSITE STRUCTURE PRODUCTION

Filed March 8, 1968

Fig. 1.

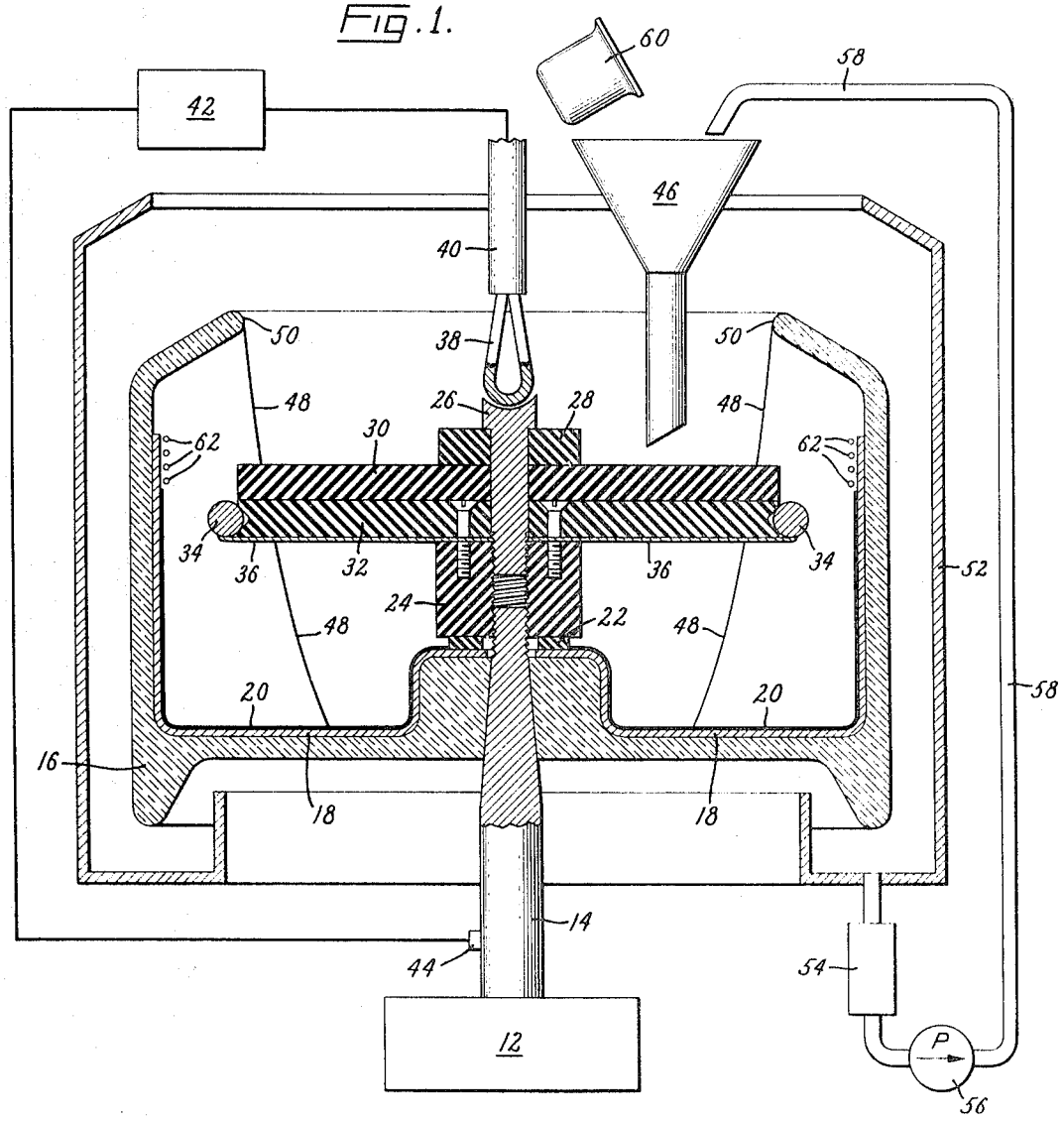


Fig. 2.

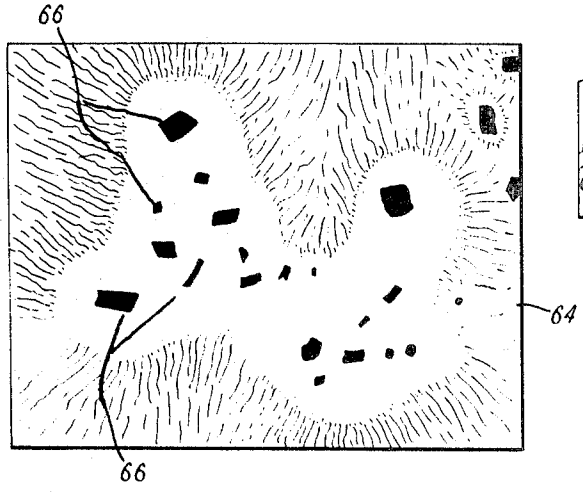
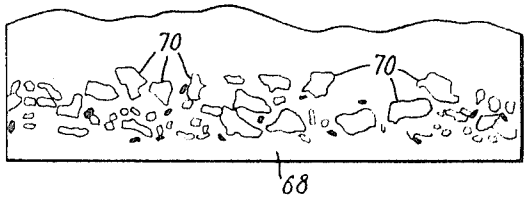


Fig. 3.



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COMPOSITE STRUCTURE PRODUCTION

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U.S. Cl. 204—16 1 Claim

ABSTRACT OF THE DISCLOSURE

Electrodeposition is conducted in rotating cell having rotating deposition electrode. Material to be included (e.g. inorganic fibers) in the electrodeposit is added to the bath, and is held by centrifugal force against workpiece while deposition continues further, firmly investing inclusion in deposit.

BACKGROUND OF INVENTION

Field

This invention pertains to electrodeposition, and more particularly to apparatus and method for including foreign materials, such as reinforcements, in the deposit.

Electrodeposition offers many advantages in the formation of structural products. It may be employed, as in electrotyping and electroforming, in producing particularly complex shapes; it may be used as an economical way to securing a product of a material difficult to extract from its parent compound, such as a tungsten-iron alloy; it may be used to produce a shaped material of great purity, as in aluminum electroforming. However, the very fact that the product is created with a minimum of cold or hot working, and that it is in many instances not only not an alloy but even of higher purity than the differently produced nominally identical metal, tends to cause it to be soft or weak. It is desirable to include reinforcements in the electrodeposit to remedy this. This not only applies to electroplates, but may pertain to electrophoretic deposits, such as latex.

Prior art

The investment of reinforcements in electrodeposits appears easier than it is in fact. For one thing, it is desirable in many instances to orient the reinforcements with respect to a particular dimension of the electrodeposit which is to be subjected to the greatest stress. The prior art has taught the suspension of reinforcements in the bath; but this is in general not conducive to orientation, and it limits the size of the reinforcements. It has been suggested that the workpiece be made horizontal and the reinforcements be dropped upon it in the desired orientation; but this has the disadvantage that sludge will also fall upon it, and that any of the conventional systems for circulating and filtering the bath will disturb the carefully laid out reinforcements, both changing their orientation and creating the danger that their motion during deposition will create voids in the finished piece. Alternatively, bundling reinforcements together and plating upon the fascicle usually coats only the outside of the bundle, leaving the interior uncoated and unbonded.

SUMMARY

I have invented a method of achieving the benefits of droppng reinforcements upon the workpiece without the undesirable consequences of that prior art process. I provide a deposition cell which is mounted upon a vertical shaft and rotated at a speed comparable with that of a centrifuge of the same diameter, producing a radial acceleration a number of times that of gravity. The workpiece is deposited at the part of the cell nearer its periphery, and the counter electrode is located nearer the center. A distributor disk is located centrally in the cell so that reinforcements and bath may be applied to the surface of the disk and be flung off against the workpiece. The very considerable radial acceleration will cause the reinforcements to be held oriented against the workpiece while it is built up by further deposition. Since the reinforcements are held very firmly, it is feasible to circulate the bath without danger of disturbing the reinforcements from their orientation.

DRAWINGS

For the better understanding and explanation of my invention, I have provided figures of drawing in which

FIG. 1 represents schematically apparatus for the practice of my invention;

FIGS. 2 and 3 represent schematically in section typical products of my invention.

EMBODIMENTS

In FIG. 1, a centrifuge **12** is represented by a simple rectangle, being completely conventional. On the centrifuge shaft **14** there is mounted a ceramic centrifuge basket **16**, shown sectioned. Any electrically insulated container will suffice, and a metal basket with solution-resistant insulating coating (such as rubber) may be preferable commercially on grounds of superior strength. Closely fitting inside the basket **16** is a cathode **18**, which in actual use was of stainless steel 0.004 inch thick, covered over most of its surface with a mask **20** (which may be any conventional electroplaters' masking material, such as an inert and adhesive gum or plastic) represented as solid black since it is too thin to permit useful cross-hatching. Cathode **18** is in electrical contact with shaft **14**, being held firmly in place by the pressure of rubber washer **22**. A collar **24** of electrically insulating material, is internally threaded to mate with the threaded end of shaft **14**, and to receive the threaded end of shouldered metal rod **26**, which does not make contact with shaft **14**. Flat insulating plates **28**, **30**, and **32** are stacked concentrically, as represented, and held together by the tension of rod **26**. Collar **24** and plates **28**, **30**, and **32** may conveniently be of any insulating material of enough mechanical strength to withstand rotation, and impervious to the bath to be used. The transparent organic polymer sold commercially under the trade name "Plexiglas" was used for these in the embodiment being described. Plate **32** is grooved at its edge to receive a circular ring anode **34** made by bending ¼-inch nickel rod into a 4-inch diameter circle. A thin sheet **36** of nickel extends from the anode counterelectrode **34** to make contact with rod **26**, passing between collar **24** and plate **32**, which are fastened together by cap screws as represented. A loop **38** of flexible wire extends from a support **40** to make brushing contact with rod **26**. A deposition power supply **42** is connected from support **40** to brush **44**, which makes contact with centrifuge shaft **14**, so that the power supply **42** is effectively connected to anode **34**, and to cathode **18**.

A funnel **46** is located (by support not shown, for simplicity) above distribution plate **30**, so that any material poured through the funnel will, if centrifuge **12** is rotating, be flung off radially. A fluid bath, such as a plating solution, will form a surface partly paraboloidal, like **48**; if excess fluid is added, it will run over the lip **50** of basket **16**, and be caught in non-rotating retainer **52**, which has a drain extending from its gutter-like bottom to a filter and a pump **56**, which discharges via pipe **58** back into funnel **46**. Initial filling may be from container **60**. Desired reinforcements may be suspended in fluid bath in container **60** and poured through funnel **46** to plate **30**, whence they will be flung radially out, the fluid assuming the shape indicated by boundary **48**, the

solid reinforcements being held by centripetal acceleration as the dots **62** (which may be considered as symbolizing elongated reinforcing fibers). Provision of a small excess of fluid bath will suffice to maintain a circulation of bath past lip **50** into retainer **52**, where it will be sent on to be filtered and pumped back into funnel **46**. Thus any of the usual provisions for maintaining electrodeposition baths by recirculation may be duplicated here. The arrangement represented has the further advantage that the continued recirculation provides for the continuing introduction at **46** of a supply of reinforcements as those previously introduced become invested by building up to the deposit.

It is evident that the arrangement described will result in electroplating on the exposed edge of cathode **18**, where insulation **20** does not extend, assuming that the bath provided is one of the conventional electroplating baths which produce a plated deposit at the cathode, which thus becomes the deposition electrode. The reinforcements **62**, being held in position against the cathode **18** (or on the deposit upon it), will be invested in the metal plated out. Nickel plating (conveniently, from a conventional low-stress sulfamate bath) upon alumina single crystals or "whiskers" is a useful combination. The alumina whiskers passing through **46** (if recirculation of the bath is in progress, they will be washed down by it) fall upon the upper surface of **30** and are aligned horizontally before being flung off by centrifugal force against the edge of cathode **18**, so that they are aligned in the direction of the long dimension of the deposit to be formed. The lower orifice of **46** may be flattened somewhat so that the whiskers will be turned broadside to the direction of motion which will be imparted to them when they are flung at the cathode. This manner of applying the reinforcements is not, of course, the only possible one. For example, an air blast from a nozzle suitably located could be employed (with the nozzle flattened for orientation purposes) to blow reinforcements against the cathode. What is required generically is means for orientation and distribution. Clearly, also, in order that the reinforcements be held firmly against the deposition electrode by centrifugal force, the parts of the deposition electrode exposed to receive them should be normal to a common central axis around which the electrode revolves. Thus they will lie on a circle formed by the intersection of the face of the electrode with a plane normal to the common central axis.

The centrifuge readily produces accelerations of several hundred *g*, which suffice to retain the reinforcements even against slight washing by the bath. I have found it perfectly feasible to modify the embodiment here represented by supporting the counterelectrode **34** and its associated assembly upon a ball bearing supported from above and outside the centrifuge, so that there is no direct drive upon the counterelectrode except the drag of the bath **48**, which suffice to bring the counterelectrode (the anode) up to high speed. There is apparently sufficient circulation of electrolyte past the deposition electrode, when nickel plating is being performed, to permit the use of higher current densities than are permissible with stagnant electrolyte; thus the nominal optimum density of 20 a.s.f. for a particular nickel sulfamate bath may be raised to 60 a.s.f. in the practice of my invention.

The stainless steel cathode employed in reinforced nickel deposition is poorly enough adherent so that the tape-like deposit may be pulled off readily. This is evidently not necessary; an adherent deposition electrode (preferably thin) may be used and simply trimmed as desired to produce a reinforced deposit with a thin layer of cathode material on one side.

The principles of my invention are not limited to electroplating. For example, a latex suspension might be deposited by electrophoresis to invest fibers of some other material.

FIG. 2 represents by ink drawing a photomicrograph of a metallographically prepared section, enlarged 1010 diameters, of a nickel deposit or matrix **64** containing oriented aluminum oxide whiskers, **66**, which are viewed in cross section or colloquially "end-on." The striations shown in the matrix **64** are representations of the crystalline structure of the nickel matrix **64** which, viewed under polarized light which was employed for the original micrograph, appeared thus. It is evident that there is a true orientation of the whiskers **66** normal to the plane of the figure; the maximum dimension of a whisker in the plane of the figure is about ⅜ of an inch as magnified, or about a third of an inch-mil in actual size. Since the whiskers were of macroscopically visible length, it is evident that their length is out of the plane of the section.

FIG. 3 represents by ink drawing a photomicrograph, enlarged 245 diameters, of a metallographic section of a nickel deposit 4 inch-mils (0.004 inch) thick which contains, in a matrix **68** of nickel, powdered hard metal particles **70**. The interesting and important characteristic of this particular specimen is that, in the middle portion, roughly two inch-mils thick, it is evident by inspection that there is a very high concentration of the inclusions **70**. While, being a powder, these inclusions are not subject to any benefit by particular orientation, they illustrate that the high inclusion-retentive forces which can be produced by the practice of my invention permit high density of inclusions without any porosities, such as might be expected to occur from accidental movement of the powder if it were simply occluded out of suspension in an electrolyte according to one aspect of the prior art. The benefits of producing a matrix with high density of inclusions, such, for example, as a matrix of a soft metal with carborundum particles in it, for use as a lap, is well known.

What is claimed is:

1. The method of investing inclusions in an electrodeposit which comprises:

providing a deposition electrode rotatable in an electrodeposition bath around a vertical axis outside the electrode;

providing a counterelectrode for immersion in the electrodeposition bath;

providing a distribution plate rotatable around the vertical axis, and located partly above the surface of the electrodeposition bath;

providing the inclusions in the bath by mixing them with the bath and feeding the mixture to the surface of the distribution plate while it is rotating;

rotating the said deposition electrode at a speed sufficient to cause the inclusions to be held by centrifugal force against the deposition electrode and unmoving with respect thereto;

forming an electrodeposit from the bath upon the deposition electrode and around the inclusions to be invested.

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