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COMPOSITE METAL STRUCTURAL COMPONENTS

Peter Joseph Forsyth, Farnham, Surrey, and Ronald Walter George, Dennis Arthur Ryder, and Robin Edwin Vian, Farnborough, England, assignors to National Research Development Corporation, London, England, a British corporation

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This invention relates to composite manufactured metallic structural materials. It is particularly but not exclusively applicable to sheet material.

It is commonly if not usually the case that such structural material is designed and made with special regard to the loads which it will have to bear in use. However, with conventional homogeneous materials, the various inter-related factors affecting the desired performance of the material cannot all be taken simultaneously fully into account because of the physical problems which would arise. As a simple example, dimensional and weight requirements will necessarily limit other properties of a given component made of a given material. The deficiencies of homogeneous materials are particularly apparent when considering the fatigue resistance properties of metallic sheet materials.

In order to try and overcome these deficiencies composite metallic materials having special properties have previously been proposed. Thus, for example the use of sandwich sheet materials in which the centre layer has the greatest ductility has been described in the provisional specification of copending patent application No. 44,226/60, now U.S. Patent No. 996,387, as a means of improving the fatigue resistance of sheet material.

According to the present invention a composite metallic structural material comprises a metallic matrix and a relatively higher strength reinforcing component unalloyed with but embedded in the matrix and in the form of fine wires or filaments of higher tensile strength than the matrix.

The matrix may be a sheet and the reinforcing wires are preferably generally in the plane of the sheet and preferably have a specific predetermined orientation.

The wires or filaments of the reinforcing component may be made up as a woven or knitted mesh.

The wires of the reinforcing component are preferably as thin as possible and their proportion of and arrangement in the composite material is initially calculated in accordance with the desired strength and weight properties of the material.

Advantageously the woven type reinforcing component is made with higher strength wires arranged in preferred predetermined positions or directions. Thus, for example, the warp or weft threads, or some only of the warp or weft threads, or some of both warp and weft threads, may be of higher strength wire and the remainder of lower strength wire. In one such arrangement which has given good results, the whole of the warp threads were of higher strength wire and the whole of the weft threads were of a lower strength soft metal wire capable of alloying with the metal of the sheet component under hot manufacturing or heat treatment conditions. In a particular example the weft threads were of soft aluminium and the sheet component was an aluminium alloy, the aluminium wires becoming alloyed with the alloy sheet component during a solution heat treatment process.

For some composite materials it may be essential to increase the proportion or density of distribution of the higher strength wires. This may be achieved by interposing two or more contiguous layers of the wire reinforcing component between any two of the sheet components.

In the case of aluminium alloy sheet materials, a percentage of stainless steel wires as low as 1% by volume of about 0.015 in. diameter has resulted in a very great improvement of fatigue properties.

Other high strength wires which have conferred excellent properties on the composite material are made of cobalt and cobalt alloys, tungsten and tungsten alloy. In each case these wires have been combined with lower strength wires in woven or knitted mesh as has been described.

In general, the methods of manufacture involve the cleansing of the components by suitable pickling or other chemical methods, stacking the sheet and wire components in suitable manner and hot working the stack, e.g. by pressing or hot rolling to bond the components together and embed the reinforcing component in the sheet matrix component

Regarding hot rolling, the stack may be passed through the rolls in any direction in relation to the orientation of the individual wires of the reinforcing component but if, for example, heavy reductions of thickness during rolling are to be made it is preferred that rolling should take place with the high strength wires parallel with the axis of the rolls so that longitudinal breakage of these wires by excessive extension during rolling is obviated

In one method of manufacturing the composite sheets of the invention a sheet component is wrapped in the wire reinforcing component, the latter being in mesh form if desired, and the assembly is sandwiched between two further sheets of the lower strength metal sheet and the whole hot rolled to give a single composite sheet.

In another method a woven mesh of wire is sandwiched between two sheets of the lower strength metal sheet and the assembly hot rolled as before to give a single composite sheet.

In yet another method a wire mesh of metal is used as a core or matrix on which lower strength metal is deposited, the composite sheet thereafter being cold or hot rolled to final form. The deposition process may be a hot spraying or electro-chemical process.

In the case of aluminium or aluminium alloy sheet materials, a typical hot rolling temperature range is 400 to 450° C. Where such alloys are reinforced with a wire mesh component including high strength wires and soft aluminium wires, a subsequent solution heat treatment at 500° C. followed by quenching may be employed, in which step the aluminium wires lose their separate identity becoming alloyed with the sheet matrix material. After rolling, the composite sheets may be stretched straightened in the usual way and age hardened at about 165° C., or a similar temperature as is appropriate to the nature of the material of the sheet matrix component.

The above mentioned methods all permit the construction of a composite sheet in which the elements of the reinforcing wire component are strategically arranged with respect to the expected nature and directions of application of working loads.

Several examples of the invention will now be described. The examples relate to the three methods of construction briefly described above and include experimental results of physical tests to which the products were put. The tests results will be shown in tabular form.

The materials employed were high strength aluminium alloy sheet material to specifications *a*, D.T.D. 687; nominal composition Cu 0.4, Mn 0.5, Mg 2.7, Zn 5.3, Al balance, *b*, L. 73 nominal composition Cu 4.4, Mn 0.6, Mg 0.6, Si 0.7, Al balance of thickness in the range 0.012

to 0.030 inch and stainless steel and tungsten wire of diameter in the range 0.002 to 0.015 inch.

The methods employed were:

(a) Wrapping an aluminium or aluminium alloy sheet with wire then placing it between two additional alloy sheets and hot rolling the assembly at a temperature in the range 400 to 450° C. to give a single composite sheet,

(b) Hot rolling a sheet of wire mesh between two sheets of aluminium alloy the rolling being performed in some cases along and some cases across the length of the high strength wires,

(c) Hot rolling a composite stack including outer sheet matrix layers of thickness 0.030 inch and several interleaved alternate inner layers of sheet matrix material of thickness 0.012 inch and meshes of woven stainless steel wires and soft aluminium wires of diameter 0.007 inch,

(d) Filling the interstices of a piece of wire mesh by aluminium spraying before rolling it between alloy sheets.

In general the hot rolling was continued to reduce the thickness of the composite material to 0.063 inch.

The composite wire reinforced sheets of (a), (b), (c) and (d) were solution heat treated, stretched and aged in accordance with the appropriate specifications of the sheet matrix material. Microsections from each sheet were also examined and wire reinforced sheets were always radiographed. Tensile test pieces were taken from each batch of material produced and these were tested in the usual manner. Fatigue crack propagation tests were carried out on 10" x 6½" x 0.064" panels tested in fluctuating tension at a stress of 18,000±2000 p.s.i. Each specimen had a central slot normal to the axis of tension so that a crack grew from each of its ends towards the edges of the sheet. The crack length and the number of stress cycles applied were recorded on the same frame of a ciné film at suitable intervals throughout the test.

The test results on specimens of the materials produced were as follows:

TABLE I

Material	0.1% proof stress, tons/sq. in.	U.T.S., tons/sq. in.	Elongation, percent	Fatigue life (cycles to failure at 18,000±2,000 p.s.i.)
(9) DTD 687A (Clad)	29.2	33.7	12.5	120,000
(10) Wire wound pure aluminium sheet rolled between two DTD 687A sheets	30.4	36.8	12.0	287,000
(11) DTD 687A three-ply material with wire wrapped central sheet	28.4	33.6	13.0	196,000
(12) Two DTD 687A sheets with wire mesh centre	30.3	33.1	1.5	312,000
(13) DTD 687A with aluminium sprayed mesh at centre	25.6	30.1	2.0	289,000
(14) As 13 but mesh laid in at 45° to sheet axis	32.2	36.5	8.0	544,000
(15) 3 ply to L73 specification	25.9	30.2	12.0	1,188,940
(16) Two L73 sheets with wire mesh at centre laid in at 45° to sheet axis	27.9	30.1	5.0	1,940,610

TABLE II

Material	0.1% proof stress, tons/sq. in.	U.T.S., tons/sq. in.	Elongation, percent	Modulus of Elasticity, Ex. 10^6 lb./sq. in.
Room temperature:				
Control specimen, sheet L73	25.6	30.0	10.0	10.3
(i) L73 sheet combined as in (c) above with 6% by volume of stainless steel wires of diameter 0.007 in. cross rolled but tested longitudinally of the wires	33.9	36.0	6.5	11.9
At 200° C.:		18.0		8.4
(ii) Control specimen, sheet L73	22.0	2.6	8	11.2
(iii) As i		6.0		6.0
At 250° C.:				
(iv) Control specimen, sheet L73	14.0	16.5	5.0	11.0
(v) As i		5	5.5	5.0
At 300° C.:	4			
(vi) Control specimen, sheet L73	7.3	13	4.5	8.0
(vii) As i				
Room temperature:				
(viii) As i but with 12% by volume of stainless steel wires	39.2	40.5	3.5	12.8
(ix) As i but with 8% by volume tungsten wires, dia. 0.007"			44.5	14.0
(x) As (ix), 200° C			29.0	13.0
(xi) As (ix), 250° C			19.0	12.0
(xii) As (ix), 300° C			16.0	11.0

The improvement in the properties of the composite sheet materials compared with the sheet matrix materials may also be expressed in terms of specific strength and specific modulus of elasticity which take into account the specific gravity of the composite material. The following data illustrate this feature of the composite materials.

TABLE III

Material	Temperature	Specific Strength	Specific Modulus
L73 (control specimen)	Room temp	10.75	3.6
	200° C	6.5	3.0
	300° C	1.7	2.0
As ix	Room temp	10.7	3.3
	200° C	7.3	3.2
	300° C	4.0	2.7
As i	Room temp	11.7	3.8
	200° C	8.5	3.7
	300° C	4.2	3.2

It will be seen that there is a marked improvement in the fatigue life of the specimens with but slight yet tolerable decreases in isolated instances of some of the other properties.

We claim:

1. A method of producing a composite metallic material comprising assembling in a stack at least two matrix layers of relatively low strength metal and at least one in-

tervening reinforcing layer of fine wires, which layer includes at least a proportion of relatively high strength fine wires wound on a matrix layer in sheet form, the wire wound matrix layer being interposed between two matrix layers, compacting the stack thus formed to embed the wires in the matrix layers, and treating the compacted stack to convert the compact to a substantially homogeneous composite material including the embedded high strength wires.

2. A method of producing a composite metallic material comprising assembling in a stack at least two matrix layers of relatively low strength metal and at least one intervening reinforcing layer of fine wires, which layer is a knitted fabric and includes at least a porportion of relatively high strength fine wire, compacting the stack to embed the wires in the matrix layers and treating the compacted stack to convert the compact to a substantially homogeneous composite material including the embedded high strength wires.

3. A method of producing a composite metallic material comprising assembling in a stack at least two matrix layers of relatively low strength metal and at least one intervening reinforcing layer of fine wires, which layer is a woven mesh of wire and includes at least a proportion of relatively high strength fine wire, compacting the stack to embed the wires in the matrix layers, and treating the compacted stack to convert the compact to a substantially homogeneous composite material including the embedded high strength wires.

4. A method as claimed in claim 1 in which compacting is done by hot rolling.

5. A method as claimed in claim 2 in which compacting is done by hot rolling.

6. A method as claimed in claim 3 in which the woven mesh includes warp threads of relatively high strength and weft threads of relatively low strength.

7. A method as claimed in claim 6 in which the weft threads are of a material which will alloy with the material of the matrix during a process step subsequent to the assembly of the stack.

8. A method as claimed in claim 7 in which compacting is done by hot rolling the stack.

9. A method as claimed in claim 8 in which the hot rolling is done so that the direction in which the stack passes through the rolls is such that the high strength wires are substantially parallel with the axes of the rolls.

10. A method as claimed in claim 6 in which a plurality of wire reinforcing layers are stacked one on the other and then collectively stacked between the external matrix layers.

11. A method as claimed in claim 10 in which compacting is done by hot rolling the stack.

12. A method as claimed in claim 11 in which the direction in which the stack passed though the rolls is such as to maintain the high strength wires substantially parallel with the axes of the rolls.

13. A method of producing a composite material of a high strength aluminium alloy and a reinforcement of another metal comprising assembling in a stack external relatively thicker sheet matrix layers of the aluminium alloy and sandwiched between the external layers at least one reinforcing layer including at least a proportion of relatively higher strength substantially parallel fine wires selected from the group consisting of stainless steel, tungsten and cobalt alloy wires, which proportion constitutes from 1 to 20% by volume of the composite material, hot rolling the assembled stack at a temperature in the range 400 to 450° C. with the higher strength wires parallel with the roll axes to convert the stack into composite substantially homogeneous sheet material containing the embedded high strength wires and solution heat treating and age hardening the composite sheet at temperatures appropriate to the treatment of the matrix material.

14. A method as claimed in claim 13 in which a plurality of separate reinforcing wire layers are initially separated from one another by sheets of the matrix material substantially thinner than the external layers.

15. A method as claimed in claim 13 in which the reinforcing wire layer is of woven construction including warp threads of the relatively high strength wires and weft threads of soft aluminium wire whereby during heat treatment the aluminium wires become homogeneous with the matrix sheet material.

16. A method as claimed in claim 15 in which the reinforcing wire layer is of woven construction including warp threads of the relatively high strength wires and weft threads of soft aluminium wire whereby during heat treatment the aluminium wires become homogeneous with the matrix sheet material.

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HYLAND BIZOT, *Primary Examiner.*

DAVID L. RECK, *Examiner.*

H. F. SAITO, *Assistant Examiner.*