COMPOSITE METAL STRIPS

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FIG. 1

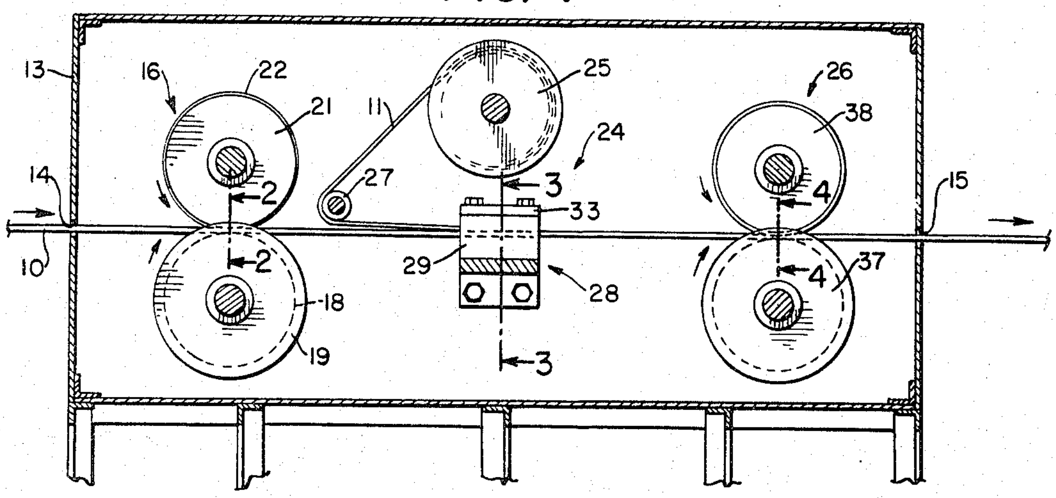


FIG. 2

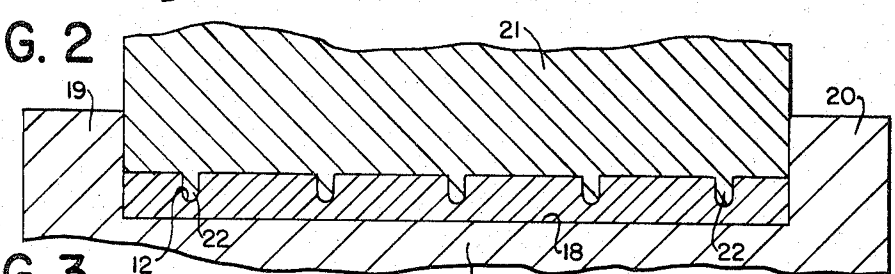


FIG. 3

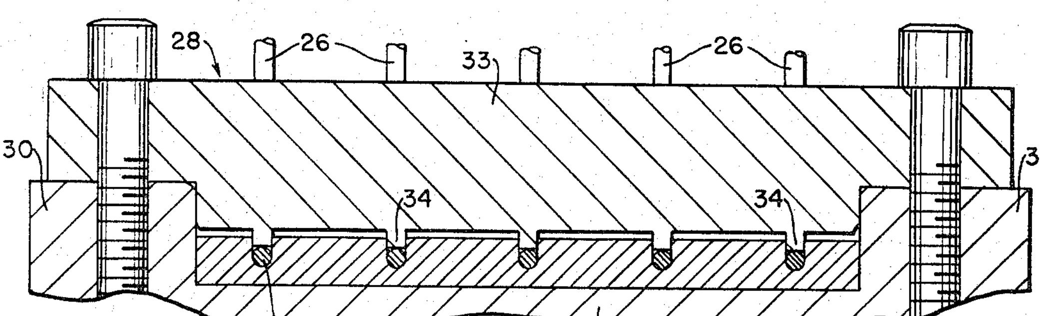


FIG. 4

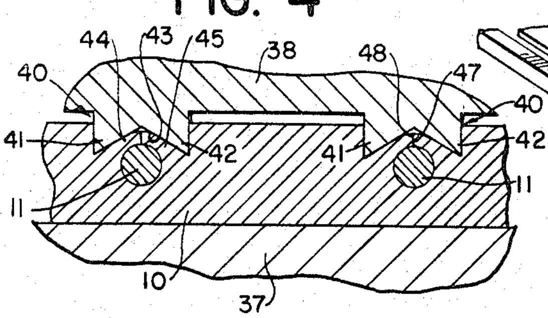
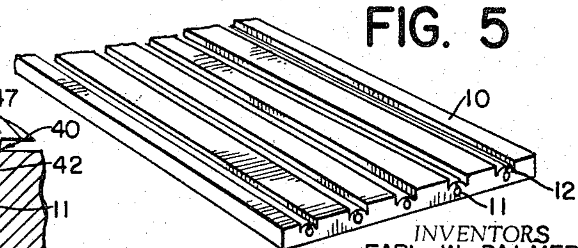


FIG. 5



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COMPOSITE METAL STRIPS

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This invention relates to composite metal strips and more particularly it relates to the manufacture of metal strips which have elongated wires interlocked within the body of the metal strip. The invention consists of a method and apparatus for manufacturing these metal strips and to the composite metal strip per se.

In the fabrication of metal goods, particularly strip metal, the properties of the strip metal can be improved by forming a composite metal structure from separate and often very dissimilar metal members. This is particularly true when it is desirable to retain the basic strip form structure and improve its structural or physical properties.

For example, the mechanical strength of a metal strip can be improved considerably by interlocking at least one and preferably a plurality of elongated laterally spaced wires within the body of the metal strip without destroying the basic structure of the metal strip itself. In this way a normally softer metal can be reinforced by incorporating wires made from a metal which might have for example, greater hardness or spring than the metal strip. For a further example, metal strips which have superconducting wires interlocked within the body of a metal strip which is not superconducting at the temperatures at which the wires are superconductive are particularly useful in many practical applications of superconductivity.

The composite metal strip of the invention is comprised of a metal strip having at least one and advantageously a plurality of elongated laterally spaced grooves formed into one broad face of the strip. A wire, having a smaller diameter than the depth of the groove, is positioned in each groove in flush contact therewith. Integral strip or flap portions partially cut or severed from the metal strip along opposite sides of the groove adjacent the broad face of the strip are infolded relative to each other and are clinched about the wire to interlock the wire to the strip. It has been found that composite metal strips formed in this way can be characterized as being reinforced in that they generally have more elastic properties than the metal strip alone and are more resistant to bending along the plane of the metal strip. Of course the choice of metal wire influences the properties of the composite strip. In one useful application the metal wires are formed from a superconducting metal and the metal strip is formed from a metal which has normal conductivity but is not superconducting at the low temperatures at which the wire is a superconductor. It is preferable in this application that the metal strip have good conductive properties, both thermal and electrical, at this low temperature.

In a magnet coil formed of superconducting wire alone, if for any reason any part of the wire reaches a temperature above the critical point where superconductivity is lost, the resistance introduced causes an abrupt decrease in the high current flowing in the coil, creating forces that may destroy the coil. With the superconductive wire embedded in strip of good electrical and thermal conductivity, however, the wire may be loaded much more heavily because it is efficiently cooled by the strip, and if a "normal" spot does occur, it is shunted by a relatively large mass of material of excellent conductivity, avoiding catastrophic changes in current. In fact, a coil

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made from the composite strip may be deliberately overloaded to the point where appreciable resistance is indicated, and brought back to normal fully superconductive operation, without sudden drastic changes in current flow.

The method of forming these composite strips also offers certain advantages both in its simplicity and in the improved product it forms. The method consists of forming a plurality of elongated laterally spaced grooves into one broad face of the strip and positioning a wire in each groove so that it is in flush contact with the metal strip defining the grooves. Integral strip portions are separated by partially cutting them away from opposite sides of the groove adjacent the broad face of the strip and these integral strip portions are then infolded toward each other and clinched about the wire to interlock the wire to the strip. This method is also preferably formed in a continuous operation.

While simple in general principle, the method of forming these composite strips required finding and applying new concepts before successful operation was achieved. For example, repeated attempts to roll grooves of the desired configuration into strip of the desired thickness were unsuccessful; the upper corners of the groove were always rounded off at precisely the point where a maximum amount of metal was needed for clinching. The idea of over-filling the roll pass, by feeding in strip thicker than desired on the exit side, finally gave satisfactory groove configuration. For grooved strip 0.040 inch thick, the roll should be fed with strip thicker than 0.040 inch, up to as much as 0.050 inch thick. Likewise, in clinching the wire, it is essential that no elongation of the strip be permitted to result from this operation, or the embedded wire may be deformed or unduly stressed. The proportion of the cross section displaced in clinching must be carefully related to the residual cross section to obtain satisfactory results.

The apparatus for performing the method of the invention consists of means for forming elongated grooves into one broad face of the strip as it is fed therethrough. It further includes wire positioning means located adjacent the groove forming means which serves to position the wire within the groove so that it is in flush contact with the portion of the metal strip. Additionally, means are provided for separating the integral strip portions on opposite sides of the grooves and infolding the strip portions toward each other and clinching them about the wire to interlock the wire to the strip. This apparatus is also preferably formed to perform the operation on a continuous basis.

A preferred embodiment of the invention is described hereinbelow with reference to the drawing wherein:

FIG. 1 is a side elevation partly in section of apparatus for performing the method of the invention;

FIG. 2 is an enlarged section taken along the lines 2—2 of FIG. 1;

FIG. 3 is an enlarged section taken along the lines 3—3 of FIG. 1;

FIG. 4 is a greatly enlarged section taken along the lines 4—4 of FIG. 1; and

FIG. 5 is a fragmentary perspective of the composite metal strip of the invention.

Referring now to the drawings, apparatus is shown for manufacture of a composite metal strip which is shown in FIG. 5 consists of a metal strip **10** and a plurality of laterally spaced elongated wires **11** which are positioned within grooves **12** formed in the body of the metal strip. In order to understand the small size of the strips which are used in this application it is to be noted that the wire in one application had a diameter of 0.012 inch and the width of the groove was essentially the same size as the wire. The metal strip had a width of 0.50 inch and the thickness of the strip was 0.040 inch with the depth of the groove being 0.020 inch. Five such wires were provided and they were spaced apart about 0.087 inch.

In another application the wire and strip sizes were the same as above, but nine wires were embedded with a spacing of about 0.050 inch. This represents the maximum number of 0.013 inch diameter wires that can be embedded in a 0.500 inch wide strip, since a greater number leaves insufficient strip between wires for reliable and proper clinching action.

The composite metal strip can be constructed so as to produce a composite metal structure which increases the strength of the metal strip. For example piano wire has been used in a relatively soft copper strip and it has been found that the physical properties of the composite strip, particularly in its resistance to bending and its elastic memory upon bending is greatly increased.

It is also intended to use the composite metal strip constructed as shown and described in superconductor applications. In such an application the wires are made from a superconductive material, the choice of which, from among those that can be fabricated as wire, depends chiefly on the superconductivity characteristics. Niobium-zirconium alloys have been used. Copper and aluminum have been used successfully as the strip metal; both metals are easily and economically formed into metal strips.

As shown in FIG. 1 the strip **10** is continuously fed in a linear path into a chamber **13** which is substantially closed with the exception of an inlet opening **14** at one end of the chamber and an outlet opening **15** at the opposite end of the chamber through which the strip is allowed to pass. The chamber is shown because in some applications, for example if the metal strip was formed of aluminum, it would be desirable to maintain the strip within an inert atmosphere while the strip is being worked on in order to prevent oxidation of the strip metal surface within the grooves prior to confining the wire within the body of the strip. Any inert gas which will prevent oxidation of the aluminum can be used, or alternatively the chamber could be filled with an oil bath or some other liquid which will accomplish the same effect.

Positioned within the chamber **13** are a pair of groove forming rollers **16**. The groove forming rollers consist of a bottom roll **17** which has a flat annular surface **18**, as shown in FIG. 2 and flange portions **19** and **20** extending along opposite sides of the flat annular surface **18**. A top roll **21** has a width substantially equal to the opening defined between the flange portions **19** and **20** and fits closely therebetween. The top roll **21** has a plurality of laterally spaced annular ribs **22** formed thereabout. The space between the top roll **21** and the flat surface **18** of the bottom roll **17** defines a groove forming station through which the metal strip is fed and grooves are formed by the annular ribs **22** of the top roll **21**. The grooves are formed into one broad surface of the strip, usually approximately half way into the body of the strip and have a depth greater at least than the diameter of the wire which is to be fed into the grooves. The thickness of the grooves, however, should be substantially equal to the diameter of this wire so that there is flush contact therebetween. Immediately upon emerging from the groove forming rolls **16** the strip **10** is fed to a wire feeding station **24**. A supply roll **25** containing as many strands of wire **11** as there are grooves is stripped from the roll and is passed around a guide roll **27** with the wires being fed into a wire positioning device **28**. The wire positioning device **28** consists of a base member **29**, shown in FIG. 3 which has upwardly extending flange portions **30** and **31**. Secured to the flange portions **30** and **31** is a top plate **33**. The top plate has a plurality of laterally spaced finger portions **34** which are of a width which permits them to be inserted into the grooves **11** to wipe the wires **12** into the base of the grooves **11**. Alternatively, the fingers may be replaced with narrow wheels serving the same function.

The metal strip **10** with the wires in flush contact with the base and side portions of the metal strip defining the grooves **11** is then fed to a wire interlocking station **26**. The interlocking station **26** is comprised of a bottom roll **37** which is of essentially the same construction as the bottom roll **17** of the groove forming rolls and has a top roll **38** which fits into the bottom roll **37** in the same manner as the top roll **21** of the grooving apparatus. Here, however, a plurality of laterally spaced annular cutting and clinching dies **40** are formed on the top roll **38**. These clinching dies consist of a pair of sharp marginal cutting edges **41** and **42** which have an angular recess **43** therebetween. The cutting edges **41** and **42** are defined by surfaces which meet at an angle less than 90°, and preferably at about 60° as shown in FIG. 4, and are spaced about a distance slightly larger than the width of the groove **12**. As shown in FIG. 4 when the metal strip **10** with the wire **11** contained inthe groove **12** is fed through the clinching rolls **36** the sharp edges **41** and **42** cut through and into the board surface of the metal strip. This cutting forms separate integral strip or flap portions **44** and **45** on opposite sides of the grooves which are displaced by the top roll **38** with the integral strip portions riding in the recess **43** and are simultaneously infolded toward each other. The edges **47** and **48** of the integral strip portions which once defined the marginal edge of the broad surface adjacent the grooves are joined together in substantially abutting relationship as the integral strip portions are clinched about the wire to interlock the wire to the strip.

The integral strip portions remain securely and integrally attached to the strip in the middle of the body of the strip and it is only the portion adjacent the broad face through which the grooves are cut that is infolded about the wire. By this interlocking, the basic structure of the metal strip remains the same in that there is no bending or distortion of the strip. Only portions of the strip are modified by being grooved and portions adjacent the groove are infolded to lock the wire in the strip; but even this grooving and interlocking does not destroy the basic continuity of the structure, rather it simply permits wires to be interlocked within the strip such that they are embedded substantially midway between the broad faces of the strip.

Although it is not essential that the edges **47** and **48** be in abutting relationship, this is desirable in many applications particularly if the metal strip material is aluminum and the inner wall surfaces which are in contact with the wire must be preserved from the formation of an oxidic layer. In this instance it would be desirable to cold weld the edges together to get a true seal. If, however, the metal strip were formed from copper, which is not susceptible to oxidation, the wire could be interlocked and clinched within the metal strip without abutting these edge portions.

We claim:

1. A composite strip comprising:

(a) a metal strip,

(b) at least one elongated groove formed into one broad face of the strip,

(c) a wire positioned in the groove in flush contact therewith, said wire having a smaller diameter than the depth of said groove, and

(d) integral strip portions partially cut from the metal strip along opposite sides of the groove adjacent the broad face of the strip infolded relative to each other and clinched about the wire to interlock the wire to the strip.

2. A composite strip according to claim **1** in which a plurality of elongated laterally spaced grooves are formed into one broad face of the strip, and a wire is positioned in each groove in flush contact therewith.

3. A composite strip according to claim **1** in which the wire is formed of a superconductive metal and the strip is formed of a metal which has normal conductivity at the low temperatures at which the wire is superconductive.

4. A composite strip according to claim **1** in which the metal strip is copper.

5. A composite strip according to claim **1** in which the metal strip is aluminum.

6. A composite strip according to claim **1** in which the integral strip portions cut from the opposite sides of the grooves adjacent the broad face of the strip and clinched about the wire are folded down with the edge surface which once defined a portion of the broad face of the strip substantially abutting each other.

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U.S. Cl. X.R.

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