Sept. 4, 1962 M. R. BOTHWELL 3,052,331

JOINT

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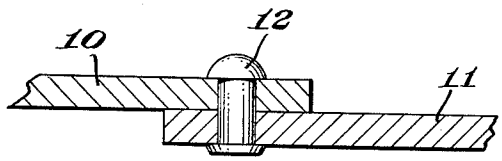


Fig. 1

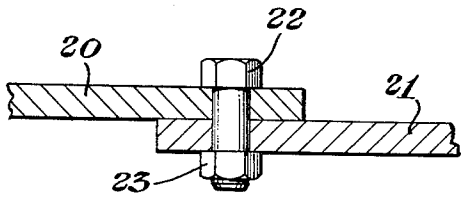


Fig. 2

INVENTOR.
Marvin R. Bothwell
BY
Edward E. Schilling
AGENT

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Marvin R. Bothwell, Midland, Mich., assignor to The Dow Chemical Company, Midland, Mich., a corporation of Delaware

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This invention relates to an improved mechanically connected joint having at least one part formed of magnesium or magnesium-base alloy containing at least 75 weight percent of magnesium (hereinafter referred to as a magnesium metal) and more particularly concerns an improved corrosion resistant joint consisting exclusively of one or more parts formed of magnesium metal and of aluminum or aluminum-base alloy containing at least 75 weight percent of aluminum (hereinafter referred to as an aluminum metal).

This application is a continuation-in-part of my copending applications Serial No. 696,673 and Serial No. 696,678, both filed November 15, 1957, and now abandoned.

For the purposes of the specification and claims such terms as galvanically compatible, or galvanically incompatible, are to be understood to be with reference to magnesium metal.

A magnesium metal article may suffer severe galvanic corrosion when incorporated in a composite metal structure consisting of dissimilar metal parts and exposed to a corrosive environment. Parts formed of certain metals and alloys, such as steel, aluminum of commercial purity (99.0 to 99.9 percent aluminum) and its alloys, copper and brass, have heretofore caused severe preferential galvanic attack on magnesium metal articles to which they were joined. This preferential attack on a magnesium metal article occurs when the magnesium metal has a more active solution potential than that of the dissimilar metal or alloy article with which it is in electrical contact whereby galvanic action may be set up between the two metals when in contact with a liquid corroding medium, thus causing a flow of electric current which tends to promote dissolution of the magnesium metal. The resulting corrosion of the magnesium metal article takes place more rapidly than it would in the absence of contact between the dissimilar and incompatible metals. If the galvanically incomportible metal article joined to a magnesium metal article in a composite structure is formed of aluminum metal, the problem is compounded due to the fact that the aluminum metal is in turn readily attacked by the alkaline products formed during the corrosion of a magnesium metal.

It is therefore an object of the present invention to provide an improved corrosion resistant joint containing at least one part formed of a magnesium metal.

It is another object of the invention to provide an improved joint containing exclusively at least one part formed of magnesium metal and at least one part formed of a galvanically compatible aluminum metal.

Another object is to provide an improved corrosion resistant joint having at least one magnesium metal part and at least one aluminum metal part which does not require a special fabrication technique to assemble.

Still a further object is to provide an improved corrosion resistant joint having at least one magnesium metal part and at least one aluminum metal part which is suitable for use under conditions of great mechanical stress and at elevated temperature.

The invention is based on the discovery that by forming a mechanically connected joint consisting exclusively of at least one magnesium metal part and at least one galvanically compatible aluminum metal part there is obtained a sturdy composite structure which is resistant to a corrosive environment and remains sturdy at elevated temperatures. The aluminum metal is of a special purity grade which is polarizable to substantially the active solution potential of the magnesium metal article in contact therewith upon the passage of a small cathodic current whereby the magnesium metal article is not sacrificially attacked. The special purity grade of aluminum metal is hereinafter more fully described.

In the past rather similar metals, such as two alloys of the same metal base having different solution potentials, have been made galvanically compatible by the inclusion in or exclusion from one of the alloys certain critical alloying metals in order to modify the solution potential of that alloy to match the solution potential of the other alloy.

In contrast to the procedure of modifying the solution potential of one of the metals in a composite structure, the polarization potential of one of the metals may be altered. Thus, the composition of an aluminum metal can be controlled to make it galvanically compatible with a magnesium metal in a composite structure. The criterion for high compatibility is that the aluminum metal should polarize to the solution potential of the magnesium metal it contacts at a very low cathodic current density since this current determines the rate of galvanic corrosion of the magnesium metal. Normally active magnesium metal will not be sacrificial to the more noble aluminum metal with which it is in contact if galvanic action is soon arrested by polarization of the aluminum metal surface. If cathodic current flow is thus substantially stopped, galvanic corrosion of the magnesium metal is substantially prevented.

Polarizability of the surface of an aluminum metal is closely related to the concentration levels therein of certain critical alloying metals and metal impurities. Common impurities in commercial grade aluminum are iron, copper and silicon. It has been found that polarization of aluminum metal will more readily occur if the iron content of the aluminum metal is below 0.05 percent by weight, the copper content below 0.1 percent, the nickel content below 0.1 percent and the combined total of iron plus copper plus nickel content below 0.1 percent. It is to be preferred that the aluminum metal contain less than 0.05 percent combined total iron plus copper plus nickel content. The content of lead, bismuth, chromium and titanium should also be below about 0.5 percent. On the other hand, up to 1 percent of manganese, 15 percent of magnesium and 3 percent of silicon, singly or in combination, do not adversely affect the polarizability of aluminum metal when alloyed therewith. The presence of zinc is less markedly detrimental than the presence of iron so that up to 2.5 percent of zinc can be tolerated, in the absence of magnesium, in the aluminum metal. In the presence of magnesium in the aluminum metal an even greater proportion of zinc may be used equal to, in percent by weight, 2.5 plus 0.5 times the magnesium content in weight percent. In any event it is essential that the aluminum metal employed in the composite structure of the invention have the property of polarizing in a corrosive environment to substantially the solution potential of the magnesium metal article in contact therewith upon the passage of a small cathodic current. For example, on immersing the composite structure in a 3 percent aqueous solution of NaCl, saturated with respect to $Mg(OH)_2$, the aluminum metal should polarize upon being subjected to the action of a cathodic current density of less than 0.5 milliampere per square inch of cathode area and preferably less than 0.2 milliampere per square inch of cathode area.

The simplest joints according to the inventions consist of two structural members mechanically joined by at least one fastener. The structural members may both be

formed of magnesium metal and joined together by a galvanically compatible aluminum metal fastener. Or a structural member formed of a magnesium metal may be joined to a galvanically compatible aluminum metal structural member by means of a fastener formed either of a magnesium metal or of a galvanically compatible aluminum metal. A suitable structural member may be in the form of a panel, angle, channel, rib, bracket and the like, while a suitable fastener may be in the form of a rivet, nut and bolt assembly, sheet metal screw, clip and the like.

In the appended drawing, FIGS. 1 and 2 illustrate specific embodiments of the invention.

FIG. 1 is a transverse cross section through the seam portion of a structure showing one rivet of an assembly having overlapping magnesium parts 10 and 11 such as structural panels mechanically connected by a rivet 12 extending through the overlapped portions of said parts. Rivet 12 is formed of galvanically compatible aluminum metal.

FIG. 2 is a transverse cross section through the seam portion of a structure showing one bolt and nut in a lap joint assembly having overlapping parts 20 and 21, such as structural panels, mechanically connected by bolting. Part 20 is formed of a magnesium metal. Part 21 is formed of an aluminum metal galvanically compatible with the magnesium metal. As shown, bolt 22 extends through the overlapped portions of said parts 20 and 21 and is retained by a nut 23. Bolt 22 and nut 23 are both formed of galvanically compatible aluminum metal.

By way of preparing and testing examples of the invention experimental aluminum alloys were prepared from high purity aluminum (99.9+ percent) and cast into ingots. These ingots were then rolled into 0.020 inch thick sheet. Duplicate specimen joints were prepared and tested as follows in each case:

The aluminum alloy sheet was cut into ½" x ½" squares and pierced and two of these squares were centrally fastened with a high purity aluminum —2 percent magnesium alloy rivet on opposing sides of a pierced and tared 1½" x 1½" x .064" AZ31 B magnesium alloy coupon in such a way as to insure good electrical contact. The resulting assembly was subjected to stagnant immersion in 200 ml. of 3 percent sodium chloride solution at 95° F. for one week. The duplicate assembly was similarly immersed in sea water at 95° F. for one week. Following the exposure the samples were disassembled, the AZ31 B alloy was cleaned of corrosion products in hot 20 percent chromic acid and the loss of weight was measured. The test results of specimen articles according to this invention and of two blanks are shown in the table.

TABLE 8

Corrosion of AZ31 B Magnesium Alloy Coupled to Various Aluminum Alloys

Test	Composition of Al Alloy							Corrosion Rate (mg./cm.²/day)	
	Fe	Cu	Zn	Mn	Si	Mg	Al	3 percent	Seawater
1	.004	.004	------	------	.006	------	balance	0.35	0.24
Blank	.17	.004	------	------	.006	------	---do----	24.8	1.88
2	.01	.004	------	------	.029	4.8	---do----	.42	.23
3	.003	.001	------	------	------	------	---do----	.36	.22
Blank	.035	0.20	------	------	.036	------	---do----	48.7	21.2
4	.01	.004	1.0	------	.031	3.7	---do----	1.42	.35
5	.014	.005	------	------	.27	------	---do----	.78	.33
6	.01	.004	------	.30	.005	------	---do----	.34	.23

What is claimed is:

1. An improved mechanically connected joint consisting of two magnesium metal parts positioned in overlapping relationship and having an aperture formed therethrough the overlapping portion and a galvanic compatible aluminum metal fastener having a shank and retaining means, said aluminum metal fastener extending through said aperture and mechanically connecting said magnesium metal parts, said galvanically aluminum metal containing less than 0.05 percent of iron, less than 0.1 percent of copper, less than 0.1 percent of nickel and less than 0.1 percent combined total iron plus copper plus nickel, up to 1 percent of maganese, up to 15 percent of magnesium, up to 3 percent of silicon and a proportion of zinc which does not exceed 2.5 plus 0.5 times the said magnesium content and the said alumnium metal having the property of assuming substantially the solution potential of the magnesium metal when coexposed to corrosive environment on the passage of a small cathodic current.

2. An improved lap joint comprising a magnesium metal part and a part formed of a galvanically compatible aluminum metal positioned in overlapping relationship and having an aperture formed therethrough the overlapping portion and a metallic fastener formed of a galvanically compatible aluminum metal and having a shank and retaining means, said metallic fastener extending through said aperture and mechanically connecting said magnesium metal and galvanically compatible aluminum metal parts, said galvanically compatible aluminum metal containing less than 0.05 percent of iron, less than 0.1 percent of copper, less than 0.1 percent of nickel and less than a combined total of 0.1 percent of iron plus copper plus nickel, up to 1 percent of manganese, up to 15 percent of magnesium, up to 3 percent of silicon and a proportion of zinc which does not exceed 2.5 percent plus 0.5 times the said magnesium content and the said galvanically compatible aluminum having the property of being polarizable to substantially the active solution potential of said magnesium metal part upon the passage of a small cathodic current.

3. In a joint having as its component parts at least two overlapping structural members mechanically connected by at least one mechanical fastener, said component parts being formed exclusively and respectively of magnesium metal and of aluminum metal, at least one of said component parts being formed of magnesium metal and at least one of said component parts being formed of aluminum metal, the improvement which comprises: that each said part formed of aluminum metal contains less than 0.05 percent of iron, less than 0.1 percent of copper, less than 0.1 percent of nickel, and less than 0.1 percent of iron plus copper plus nickel, and has the property of being polarizable to substantially the active solution potential of magnesium metal when said aluminum metal is coexposed with the magnesium metal to a corrosive environment, upon the passage of a small cathodic current.

4. An improved joint having as its component parts at least two overlapping structural members mechanically connected by at least one mechanical fastener, said component parts being formed exclusively and respectively of magnesuim metal and of galvanically compatible aluminum metal, at least one of said component parts being formed of magnesium metal and at least one of said com-

ponent parts being formed of galvanically compatible aluminum metal part being formed of an aluminum metal containing less than 0.05 percent of iron, less than 0.1 percent of copper, less than 0.1 percent of nickel and less than a combined total of 0.1 percent of iron plus copper plus nickel and having the property of being polarizable to substantially the active solution potential of magnesium metal when said aluminum metal is coexposed with the magnesium metal to a corrosive environment upon the passage of a small cathodic current.

5. An improved joint having as its component parts at least two overlapping structural members mechanically connected by at least one mechanical fastener, said component parts being formed exclusively and respectively of magnesium metal and of galvanically compatible aluminum metal, at least one of said component parts being formed of magnesium metal and at least one of said component parts being formed of galvanically compatible aluminum metal part, said aluminum metal containing less than 0.05 percent of iron, less than 0.1 percent of copper,

less than 0.1 percent of nickel and less than the combined total of 0.1 percent of iron plus copper plus nickel, up to 1 percent of manganese, up to 15 percent of magnesium, up to 3 percent of silicon, a proportion of zinc which does not exceed 2.5 percent plus 0.5 times the said magnesium content and the said aluminum metal having the property of assuming substantially the solution potential of the magnesium metal on being coexposed to a corrosive environment on the passage of a small cathodic current.

6. The joint as in claim 4 in which the said galvanically compatible aluminum metal part contains a combined total of less than 0.05 percent of iron plus copper plus nickel.

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