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ALUMINIUM ALLOYS

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This invention relates to a process of improving the resistance to corroding agents as also to deterioration of their mechanical properties when in contact with corroding agents, of aluminium base alloys of the kind hereinafter set forth.

The aluminium base alloys to which the invention relates, contain magnesium in an amount not only sufficient to combine with any further alloying constituents present—whether deliberately added or not—but also in excess of that required to form at room temperature a saturated solid solution with the basic aluminium. The amount of magnesium which is thus in excess of that required for forming a saturated solid solution with the basic aluminium in a state uncombined with any foreign constituents present will be hereinafter referred to as "available magnesium".

A further essential constituent of the alloys to which the invention relates is zinc, the latter metal which combines with magnesium more readily than aluminium, being also present in an amount in excess of that required to form at room temperature a saturated solid solution with the basic aluminium. Such amount is hereinafter referred to as "available zinc". Since the limit of solubility, at room temperature, of the compound Al_3Mg_2 corresponds to a content of about 3% of magnesium of the alloy, and further, since the limit of solubility of the $MgZn_2$ compound at the same temperature is attained with a content of about 0.2% of magnesium and correspondingly about 1.0% of zinc, and since the presence of both compounds simultaneously in an aluminium base alloy only moderately affects their respective solubility limits, this means in effect that the alloys contemplated by the present invention must contain more than about 3.2% of magnesium and more than about 1.0% of zinc, the ratio between these two components being invariably such that there is more than about 3% of magnesium still available for combination with the aluminium base metal after all the zinc present has combined with some of the magnesium present. Thus, when in accordance with the present invention the alloys are subjected to a heat treatment as hereinafter set forth, supersaturated solid solutions of both magnesium and zinc in aluminium are formed by reason of the increased solubility of both these metals in aluminium in the solid state, with rising temperatures, from which both the available magnesium (which is combined with aluminium) and the available zinc (in combination with another part of the magnesium) may be segregated in the form of the compounds, respectively, Al_3Mg_2 and $MgZn_2$. Other metals, such as manganese or silicon may be present in the alloys whether deliberately added or not, their capability of forming compounds with magnesium, however, being taken into account when the quantity of magnesium to be incorporated in the alloy is computed, in order always to ensure the presence of available magnesium in the alloy.

In aluminium base alloys which contain available magnesium and which have been caused to solidify from the molten or fused state by allowing them to cool in the ordinary manner, the micrographic structure is found to consist of two main constituents or phases, namely of large α-crystals which in each case consist of an unsaturated solid solution of the compound Al_3Mg_2 in aluminium, and of a coarse network of smaller particles of β-type crystals surrounding the said α-crystals and probably consisting of a solid solution of minor quantities of aluminium in the compound Al_3Mg_2. However, the texture thus formed is not in phase-equilibrium and it is therefore possible by an annealing process to establish the actual equilibrium by intercrystalline diffusion in a manner known per se and, as applied to alloys of the system Al-Mg. already described by Hansom and Gaylor in the Journal of the Institute of Metals XXIV (1920) pp. 201–232. In this manner, the α-crystals are enabled to take up further quantities of Al_3Mg_2—compound from the intercrystalline network up to their limit of saturation, and, by applying sufficiently high temperatures—ranging between about 250 and about 450° C. and depending on the magnesium content of the alloy—for a sufficient length of time, the whole texture of the alloys is reduced to an entirely homogeneous mass of α-crystals which are more or less saturated with respect to magnesium, according to the percentage of the latter element which is present in the alloy.

As a result of recent and hitherto unpublished research, it has been ascertained that by subjecting the homogeneous alloys consisting of supersaturated α-crystals to an annealing process at temperatures which are lower than those at which they were previously homogenized, but which are at the same time sufficiently high to allow of intracrystalline segregation (i. e. within a moderate temperature range from about 200° C. upwards), the magnesium content of the α-crystals exceeding the limit of saturation at that temperature is caused to segregate from within the α-crystals in a highly dispersed form; that is to say, every individual α-crystal becomes interspersed with a large number of minute particles of the β-type. This texture of course is

again heterogeneous, but is distinguished from the heterogeneous texture of the alloys as cast, in that the β-type constituent is no longer coarsely distributed in a network surrounding the α-crystals, but is highly dispersed in a uniform manner throughout and within the said α-crystals; when viewed with the microscope, a texture of this kind, after the application of suitable etching agents offers the mottled appearance which is well known as characteristic of a segregate in a highly dispersed form.

Further research, upon which the present invention is based, has revealed the fact that the heating and annealing treatment causing first homogenization of the alloys containing only available magnesium, and then segregation of the compound Al_3Mg_2 therefrom in a highly dispersed form, when applied to alloys as defined in the introductory paragraphs of this specification, simultaneously causes also segregation of the available zinc in the form of the compound $MgZn_2$ the resulting products not only exhibiting a very high resistance to corrosion e. g. by sea-water, but also exceptionally high mechanical strength values.

The term "corrosion" as employed above does not only apply to an externally and macroscopically manifest corrosion, for example by discoloration of the surface of the metals, but particularly also to intercrystalline corrosion phenomena which in course of time lead to a decrease in the mechanical strength properties. This intercrystalline corrosion is particularly conspicuous in the alloys after their having been subjected to a plastic deformation in the cold, for instance by a forging or rolling process. According to present day views such intercrystalline corrosion is in fact considered far more dangerous from a technical point of view because of the lowering of the mechanical strength values of the material produced thereby; and its progress is therefore usually followed by determining the progressive decrease in tensile strength etc. after progressively prolonged contact of the alloys with corroding media.

In accordance with the present invention the alloys of the kind described in the introductory paragraphs of this specification are subjected to a thermal treatment which consists in first heating the alloys to temperatures sufficient to cause the alloying elements magnesium and zinc to be incorporated in the aluminium base crystals in the form of a solid solution and maintaining such temperatures until a homogeneous solid solution has been substantially established and then, in a second stage, which may be preceded by a chilling, annealing the alloys at temperatures at which and until segregation of the compound $MgZn_2$ as well as of particles which are rich in magnesium as compared with the basic crystals and probably consist of the compound Al_3Mg_2 takes place in a highly dispersed form. Although the optimum temperatures for achieving segregation, in a highly dispersed form, of the compound $MgZn_2$ and of the aforesaid particles, respectively, are somewhat different, it is notwithstanding possible by suitably selecting an annealing temperature according to the concentration and the ratio of zinc and magnesium present in the alloy, to obtain excellent results in regard to the resistance of the alloys to corrosion and to deterioration of their mechanical properties when in contact with corroding agents.

Example 1

An alloy extruded into sections, and containing 6% of magnesium, 3% of zinc, and 0.5% of manganese and the balance aluminium, and in which consequently about 0.5% of magnesium is required to combine with the zinc so as to form the compound $MgZn_2$, and the available magnesium is about 2.5%, in the original state, had the following strength properties:—

Ultimate tensile strength	kg/sq. mm.	32.9
Elongation	per cent.	26.3
Yield point	kg/sq. mm.	13.2
Contraction	per cent.	42.8

This alloy was subjected to a heating treatment at between about 400° and about 440° C. until a substantially homogeneous distribution in the form of a solid solution, of both components in the aluminium base mass is attained. The alloy is subsequently, if desired after chilling, annealed at about 200° C. during 2 to 10 hours. The mechanical strength values of the thus treated alloy were found to be:

Ultimate tensile strength	kg/sq. mm.	45
Elongation	per cent.	17
Yield point	kg/sq. mm.	28
Contraction	per cent.	50

The resistance to corrosion of the alloy in question was tested by immersing highly polished test rods in seawater for 3 months and then examining their strength properties in the usual manner, the results being that no decline of the original strength values of the test pieces could be ascertained.

Example 2

Another extruded alloy containing about 6% of magnesium, about 4% of zinc and 0.3% of manganese, about 0.7% of magnesium thus being required to combine with the zinc and the available magnesium being about 2.3%, in the original state, had the following strength properties:

Ultimate tensile strength	kg/sq. mm.	39
Elongation	per cent.	12.5
Yield point	kg/sq. mm.	21.2
Contraction	per cent.	24.6

This alloy was subjected to the same thermal treatment as described in Example 1. The strength properties of the improved alloy were found to be:—

Ultimate tensile strength	kg/sq. mm.	54.2
Elongation	per cent.	10.1
Yield point	kg/sq. mm.	51.2
Contraction	per cent.	35.0

This improved alloy also showed no decline in its strength properties when exposed to a 3 months' attack by sea-water and then tested as above.

The alloys according to the invention lend themselves to extruding, sheet rolling and forging. The range of alloys particularly adapted to the treatment according to the invention covers about 4 to 12% of magnesium and 2 to 6% of zinc, while minor percentages of other alloying metals such as manganese may be added. Silicon may also be present in small quantities whether deliberately added or not.

I claim:—

1. The process of increasing the resistance to corrosion as well as the strength properties of an aluminium base alloy containing magnesium

in quantities of between about 3 and about 12 percent and zinc in quantities of between about 2 and about 6 percent, the proportion of magnesium to zinc being such as to leave more than 3 percent of magnesium, after the formation of the compound $MgZn_2$ with all the zinc present, in a state available for combination with aluminium, which comprises subjecting the alloy to an annealing treatment at temperatures between about 400 and about 440° C. for a period of time sufficient to convert the crystalline structure of the alloy substantially into the form of a homogeneous solid solution, and thereafter subjecting the alloy to a lower temperature, but above about 200° C., so as to cause segregation of the compound $MgZn_2$ and of the compound Al_3Mg_2 in a highly dispersed form.

2. The process of increasing the resistance to corrosion as well as the strength properties of an aluminium base alloy containing magnesium in quantities of between about 3 and about 12 percent and zinc in quantities of between about 2 and about 6 percent, the proportion of magnesium to zinc being such as to leave more than 3 percent of magnesium, after the formation of the compound $MgZn_2$ with all the zinc present, in a state available for combination with aluminium, which comprises subjecting the alloy to an annealing treatment at temperatures between about 400 and about 440° C. for a period of time sufficient to convert the crystalline structure of the alloy substantially into the form of a homogeneous solid solution, then chilling the alloy, and thereafter heating the alloy to a lower temperature, but above about 200° C., so as to cause at least partial segregation of the compound $MgZn_2$ and of the compound Al_3Mg_2 in a highly dispersed form.

3. In the art of making alloy articles having aluminium as the principal ingredient and containing magnesium in quantities of between about 3 and about 12 percent and zinc in quantities of between about 2 and about 6 percent, the proportion of magnesium to zinc being such as to leave more than 3 percent of magnesium, after the formation of the compound $MgZn_2$ with all the zinc present, in a state available for combination with aluminium, the steps of subjecting the article to an annealing treatment at temperatures between about 400 and about 440° C. for a period of time sufficient to convert the crystalline structure of the alloy substantially into the form of a homogeneous solid solution, and thereafter subjecting the alloy to a lower temperature, but above about 200° C., so as to cause segregation of the compound $MgZn_2$ and of the compound Al_3Mg_2 in a highly dispersed form.

4. A heat-treated aluminium base metal alloy containing magnesium in quantities of between about 3 and about 12 percent and zinc in quantities of between about 2 and about 6 percent, the proportion of magnesium to zinc being such as to leave more than 3 percent of magnesium, after the formation of the compound $MgZn_2$ with all the zinc present, in a state available for combination with aluminium, the said alloy being characterized by containing a segregate of both $MgZn_2$-compound and Al_3Mg_2-compound in highly dispersed form within the base mass of crystals rich in aluminium.

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