July 3, 1962 H. P. GEORGE ET AL 3,042,555

IMPACT RESISTANT ALUMINUM ALLOY PLATE

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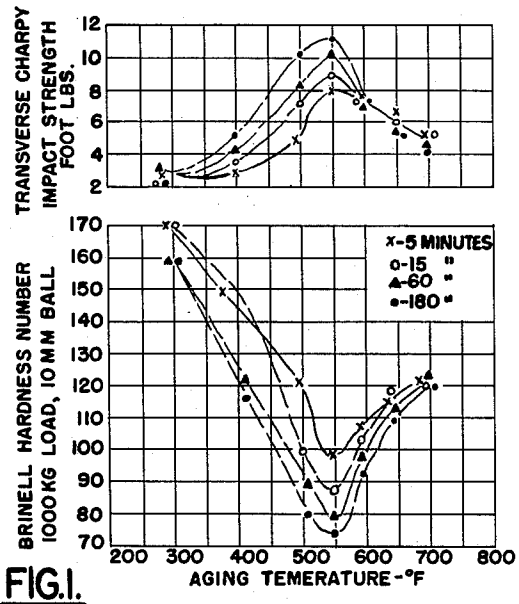


FIG.1.

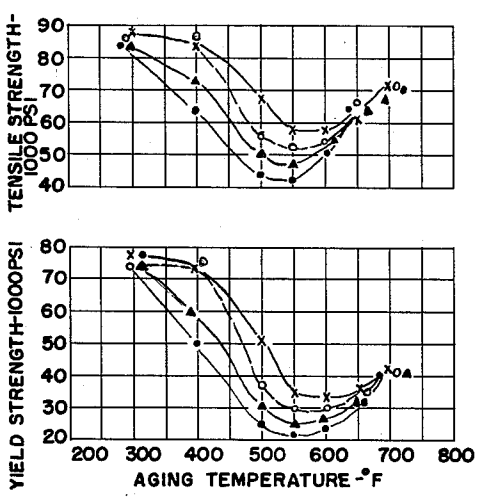


FIG.2.

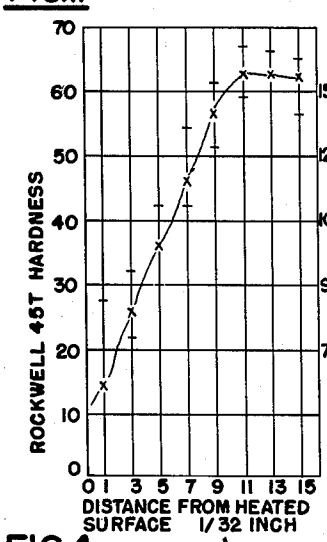


FIG.4.

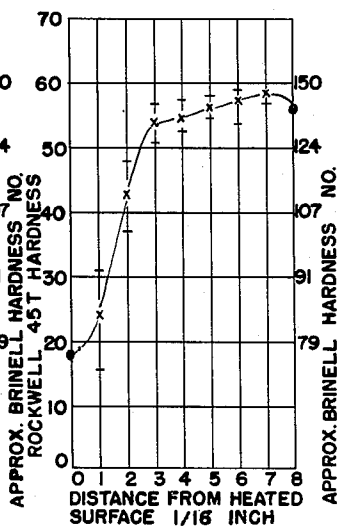


FIG.5.

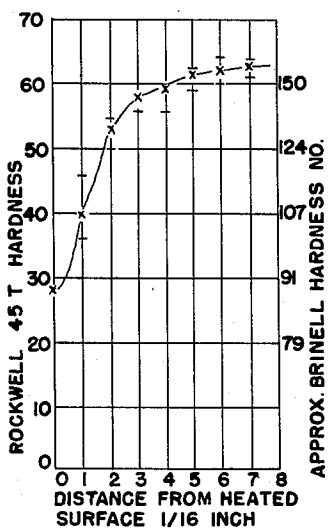


FIG.6.

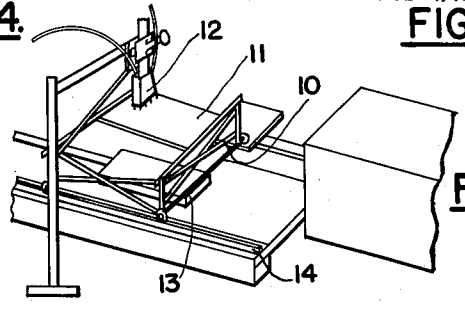


FIG.3.

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IMPACT RESISTANT ALUMINUM ALLOY PLATE

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1 Claim. (Cl. 148—32.5)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment of any royalty thereon.

This invention relates to an aluminum alloy member or plate having a high resistance to penetration and to a process for converting a commercially available high hardness aluminum alloy to such a product. While this product was developed in response to a demand for an armor plate having light weight and high ballistic characteristics, it has applications in other fields where light weight and high impact strength are desirable.

Among the various aluminum alloys now commercially available, two are at present preferred for use in the production of the aluminum alloy member under consideration. The first of these is known as alloy 7075 (formerly 75S) which has a tensile yield strength of 72,000 p.s.i. and an ultimate strength of 82,000 p.s.i. The second is known as alloy 7178 (formerly 78S) which has a tensile yield strength of 75,000 p.s.i. and an ultimate strength of 85,000 p.s.i. Alloys 7075 and 7178 are quite similar in composition, the former consisting of the following weight percentages: 5.1–6.1 zinc, 2.1–2.9 magnesium, 1.2 to 2.0 copper, 0.18–0.40 chromium, 0.30 manganese (maximum), 0.50 silicon (maximum), 0.70 iron (maximum), 0.20 titanium (maximum) and the balance aluminum.

These alloys in their present commercial form possess high hardness and tensile strength. When subjected to ballistic tests in their original form, however, chipping and brittle failure occurs at the rear face of the plate. In accordance with the present invention, this is avoided by establishing across the thickness of the plate a hardness gradient which varies from the original hardness at the front of the plate to a much more ductile condition at the back of the plate. As will appear, this variation in hardness need not always be gradual from one face of the plate to the other but may be largely concentrated near one of the faces.

The invention will be better understood from the following description when considered in connection with the accompanying drawings and its scope is indicated by the appended claims.

Referring to the drawings:

FIGS. 1 and 2 are sets of curves illustrating the effect of aging temperature on various physical characteristics of the aforementioned alloys.

FIG. 3 depicts an apparatus suitable for subjecting a plate to differential heat treatment, and

FIGS. 4, 5, and 6 indicate the hardness distribution produced in three different plates of the aforementioned type by the differential heating process of this invention.

As a result of preliminary tests, data were obtained to the effect that the properties of the aforementioned aluminum plates are virtually unchanged at 300 degrees Fahrenheit for times up to three hours while a substantial increase in ductility and impact properties is produced at temperatures up to 550 degrees Fahrenheit. This fact is depicted by the curves of FIGS. 1 and 2 which show the relation between aging temperature and the various

properties of the plates. For example, in FIG. 2, the yield strength after being aged at 550° F. for 180 minutes was only about 21,000 p.s.i. and the tensile strength under the same conditions was about 42,000 p.s.i.

Guided by these data, the apparatus of FIG. 3 was constructed. It includes a carriage 10 which is arranged to move a plate 11 between a multiple burner torch 12 and a water spray device 13. This carriage is driven along a track 14 by a variable speed motor (not shown). The water spray device 13 is directly under the plate 11 and aligned with torch 12 and has a valve and gage (not shown) for varying the water pressure to obtain the desired temperature on the cold side of the plate 11.

The torch 12 has thirty burners and is so mounted that the space between it and the plate may be adjusted to any desired extent. With this arrangement, a variable heat input is obtained by varying the torch height and gas pressure.

The curves of FIGS. 4, 5 and 6 illustrate the hardness gradient produced in three different plates of the aforementioned type by the operation of the apparatus. In the case of FIG. 4, the torch was spaced $\frac{1}{32}$ inch from the face of a ½ inch plate and there was produced a hardness gradient which varied as illustrated between the back of the plate to a plane spaced $\frac{11}{32}$ of an inch therefrom. In the case of FIG. 5, the torch was spaced from the heated surface by $\frac{1}{16}$ inch and applied at intervals with resultant variation in hardness indicated by the curve of this figure. In the case of FIG. 6, the space between the torch and the heated surface was $\frac{1}{16}$ inch with the resultant variation in hardness indicated by the curve of this figure.

All these plates were ½ inch thick. Obviously less difficulty would be encountered in producing a hardness gradient in a thicker sheet or member. Furthermore, the usefulness of the process herein disclosed is not limited to the production of members having one surface hard and the other soft, but is susceptible of use to soften both sides of the treated member to any desired degree.

We claim:

An armor plate about ½ inch thick composed of an aluminum base alloy consisting of 5.1–6.1% zinc, 2.1–2.9% magnesium, 1.2–2.0% copper, 0.18–0.40% chromium, 0.30% manganese (maximum), 0.50% silicon (maximum), 0.70% iron (maximum), 0.20% titanium (maximum) and balance substantially all aluminum, said plate having a front face and a rear face with varying degrees of hardness therebetween produced by a heat treatment to said rear face of about 550° F. for about 3 hours while simultaneously maintaining the front face at a temperature below about 300° F., and characterized by said front face having a Brinell hardness of the order of 150 and a Rockwell 45T hardness about 20 at the rear face, said front face having a yield strength of at least about 70,000 p.s.i. and a tensile strength of at least about 80,000 p.s.i. and said rear face characterized by a yield strength of about 21,000 p.s.i. and a tensile strength of about 42,000 p.s.i.

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