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Figure 1

Figure 1: Figure 1

Abstract

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RELATIONSHIP BETWEEN THE STRUCTURE OF A MAGNESIUM ALLOY AND ITS TENDENCY TO STRESS CORROSION

(Presented by Academician A. A. Bochvar on 6 VI 1957)

Among known magnesium alloys, high-strength alloys of the Mg—Al—Zn—Mn system exhibit a great tendency toward stress corrosion. Up to the present time the mechanism of the process of corrosion cracking of high-strength magnesium alloys had not been developed, and therefore numerous searches for radical methods of treating these alloys that would prevent corrosion cracking were not crowned with success ($^{1-4}$).

Our work on the mechanism of corrosion cracking established the following:

1. The principal alloying component that leads magnesium alloys of the Mg—Al—Zn—Mn system to a tendency toward corrosion cracking is aluminum; moreover, the tendency of alloys of this system to corrosion cracking in the natural atmosphere begins to appear only at such an aluminum content at which supersaturated solid solutions are formed, i.e., at an aluminum content above 2—3%. With an increase in the aluminum content in the alloy, the strength of the alloy increases, but its resistance to stress corrosion decreases.

Fig. 1. Effect of aluminum on the tendency to stress corrosion of an alloy of the Mg—Al system

In Fig. 1 the influence of aluminum on the corrosion cracking of the binary alloy Mg—Al is shown.

2. Corrosion cracking of magnesium alloys is caused by selective dissolution of the supersaturated solid solution or of the intermetallic compound Mg_4Al_3, as a result of which micro-notches are formed.

Fig. 2

Figure 2: Fig. 2

Proceeding from these concepts, we come to the conclusion that an alloy should not crack only in the case when the alloy contains no continuous chains of precipitates of the intermetallic compound Mg_4Al_3 or of supersaturated solid solution, along the zones of which the alloy cracks.

The structure of a magnesium alloy not prone to corrosion cracking must consist of a solid solution depleted in aluminum and uniformly precipitated intermetallic compounds in the form of particles not connected with one another.

We made an attempt to obtain such a structure of a magnesium alloy by selecting a method of heat treatment leading to complete decomposition within the grain. Complete decomposition within the grain is achieved by prolonged holding in the temperature range 175–250° (^{5}). At a lower temperature the decomposition of the supersaturated

of the solid solution proceeds at a very low rate. For simplicity of the investigation, an extruded binary alloy, Mg + 8% Al, was taken.

From the phase diagram it follows that at a temperature of 175° a solid solution with an aluminum content of 2.9% is formed, at 185°–3%, and at 250°–3.8%.

To obtain the required decomposition, we carried out prolonged heat treatment of the alloy at a temperature of 185° for 5 days. In addition, an additional treatment was given at low temperatures from 60-100° for 15-30 days in order to deplete the solid solution still further in aluminum, i.e., to bring the aluminum content down to 2%.

Heat treatment according to various regimes was applied to the alloy in specimens. After heat treatment, the surface of the specimens was cleaned with glass paper and washed with ethyl alcohol. Specimens of variable cross section were used for the tests (^{6}).

The load was produced on a Schopper machine, on the basis of a specified stress equal to 90% of the value $\sigma_{0.2}$. The load was calculated according to the formula $P = \frac{\sigma b h}{6x}$, where P is the force required to create the specified stresses, σ is the stress, b is the width of the specimen in the given section, h is the thickness of the specimen, and x is the distance from the point of application of the force to the given section. Corrosion tests were carried out under variable loading of the specimens in a 0.001% NaCl solution. The time at which the first crack appeared was recorded.

Fig. 2. Microstructure of alloy Mg + 8% Al in the hot-extruded condition. 200×

Fig. 3. Microstructure of alloy Mg + 8% Al in the hardened condition (quenched in air from 420° for 24 hours) with subsequent aging at a temperature of 175°

Fig. 3

Figure 3: Fig. 3

for 10 hours. 200×

In Figs. 2, 3, and 4 the microstructures of the alloy after various types of heat treatment are presented. On examining the microstructures, the following may be noted: the alloy in the hot-extruded condition (Fig. 2) consists of a supersaturated solid solution of aluminum in magnesium and of the intermetallic compound Mg_4Al_3, located along the grain boundaries (thickened boundaries). The alloy in the ha-

in the quenched state (homogenized), is a "microscopically" homogeneous supersaturated solid solution. A large grain growth is observed, evidently due to recrystallization during quenching.

With short-term aging of the quenched alloy, partial decomposition of the supersaturated solid solution occurs, mainly at the grain boundaries (Fig. 3). With prolonged heating for 30 days at a temperature of 80° without preliminary homogenization of the alloy, no visible decomposition is observed. With prolonged aging for 5 days at a temperature of 185°, decomposition takes place inside the grain (Fig. 4).

It should be noted that additional treatment at a temperature of 60–100° for 15–30 days after heating at a temperature of 185° for 5 days produces no visible changes.

Thus, with prolonged treatment at a temperature of 185° we evidently already have a sufficiently complete decomposition of the supersaturated solid solution. After such treatment the alloy should consist of a solid solution containing 3% Al, which under the given conditions does not undergo corrosion cracking, and of separate, mutually unconnected particles of intermetallic compounds.

Fig. 4. Microstructure of the alloy Mg + 8% Al in the aged state at a temperature of 185° for 5 days. 200×

The results of the corrosion tests were as follows:

Treatment-regime No.	1	2	3	4	5	6	7	8	9	10	11
Heating temperature, °C	Without heat treatment (hot-pressed)	420	420; 175	80	185	185	60; 185	60; 185	80; 185	80; 185	100; 180; 100

Treatment-regime No.	1	2	3	4	5	6	7	8	9	10	11
Duration of heating, days	–	1	1; 0.4	30	5	5	15; 5	30; 5	15; 5	30; 5	15; 5; 30
Time to cracking of specimen, days (average for 5 specimens)	18	10	15	50	Did not undergo cracking for 1 year	Did not undergo cracking for 1 year	Did not undergo cracking for 1 year	Did not undergo cracking for 1 year	Did not undergo cracking for 1 year	Did not undergo cracking for 1 year	Did not undergo cracking for 1 year

Consideration of the data obtained shows that the alloy in the hot-pressed, quenched, and aged (incomplete decomposition) states undergoes corrosion under stress in a comparatively short time. Prolonged heating at a temperature of 80° does not lead to microscopically visible decomposition, and corrosion cracking is not prevented.

Prolonged heating at a temperature of 185°, leading to decomposition inside the grain and to the precipitation of intermetallides in the form of mutually unconnected particles, prevents corrosion cracking. The specimens did not under –

were subjected to corrosion cracking for 360 days. The tests were discontinued because of substantial general corrosion of the specimens. It should also be noted that the heat treatment we used at a temperature of 185° does not reduce the mechanical properties of the alloy. To solve practical problems of eliminating the susceptibility of magnesium alloys to corrosion cracking, it is necessary to determine the minimum heating time at which complete decomposition of the supersaturated solid solution will be ensured at the given temperature. It is quite possible that the duration of heating will be considerably less than the 5 days established in our experiment.

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REFERENCES

1. E. G. Perryman, *J. Inst. Metals*, **78**, 6, 621 (1951).
2. M. Hunter, *Am. Soc. Met. Metals, Handbook*, Cleveland, 1948, p. 234.
3. D. R. Priest, F. N. Buk, M. G. Fontano, *Trans. Am. Soc. Met.*, **47**, 473 (1955).
4. E. M. Zaretskii, in: *Corrosion of Metals*, Collected Papers, 1955, p. 239.
5. W. Bulian, *Zs. f. Metallkunde*, **41**, No. 10, 392 (1950).
6. S. E. Pavlov, *Zav. lab.*, **13**, No. 10 (1947).

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