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NATIONAL DEFENSE RESEARCH COMMITTEE

of

OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

WAR METALLURGY DIVISION

Advisory Report

on

"SUGGESTED RESEARCH TOPICS ON MAGNESIUM AND MAGNESIUM ALLOYS"

by

THE WAR METALLURGY COMMITTEE

of the

NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL

OSRD No. 6599

Serial No. M-652

Copy No. 134

February 25, 1946

February 25, 1946

To: Dr. James B. Conant, Chairman
National Defense Research Committee of the
Office of Scientific Research and Development

From: War Metallurgy Division (Div. 18), NDRC

Subject: Advisory Report on "Suggested Research Topics on Magnesium and Magnesium Alloys"

A special advisory committee of the War Metallurgy Committee prepared this report as a result of a request from the Committee on Materials Research Coordination of the National Advisory Committee for Aeronautics, for a review of a previous War Metallurgy Committee advisory report on a "Survey of Research on Magnesium and Magnesium Alloys Being Conducted by Government Agencies, Branches of the Armed Services, and Producers and Fabricators of Magnesium", OSRD No. 5400, Serial No. M-553.

The attached report reviews this previous report, pointing out where additional research might be warranted, and where the scope of existing research projects might be expanded advantageously.

Acceptance as an advisory report under Contract OEMsr-307 with the National Academy of Sciences is recommended.

Respectfully submitted,

Louis Jordan
Technical Aide to the Chief
War Metallurgy Division, NDRC

Enclosure

PREFACE

This report is pertinent to the project designated by the War Metallurgy Committee as NDRC Survey Project SP-28.

The distribution of this report is as follows:

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SUGGESTED RESEARCH TOPICS

MAGNESIUM AND MAGNESIUM ALLOYS

At the request of the National Advisory Committee for Aeronautice, a special advieory committee of the War Metallurgy Committee has reviewed the current research projects on magnesium as reported by the armed services, government agencies, and the producers and fabricators of magnesium. The purpose of this review was to list the current research projects in this field in order to make possible some degree of correlation, to avoid undesirable duplication of effort, and to point out where additional research might be warranted or where the scope of existing research projects might be expanded to advantage.

The current research program includes projects which are concerned with many fields of interest to the producers and users of magnesium and magnesium alloys. While it is apparent that more extended investigations of certain broad topics may be desirable, it is not the purpose of this report to recommend research projects or to outline definite programs of research. In the opinion of the committee, consideration should be given to the desirability of additional work in the following fields of interest. The scope of the individual projects and the type of research program which might be developed depends on factors which are not within the province of this committee.

Investigations of Structures Employing Magnesium Alloys

There is need for the engineering development of experimental structural units employing magnesium to be used in evaluating the

serviceability of magnesium construction and to serve as a source of engineering information for those interested in the use of the metal. Such work will bring out the weak points which may need further research or development work, and. at the same time, will demonstrate the types of application for which magnesium is ready to be used to advantage. No amount of laboratory work can substitute for practical service experience. The availability of the results of extensive service tests will be most useful to the intelligent direction of individual research projects. Typical parts which might be used for service tests include the following:

Fairings
Passenger, cargo, and bomb-bay doors
Horizontal stabilizers
Wheel doors
Bulkheads and partitions
Dorsal fins
Miscellaneous panels in cockpit
Trailing portions of control surfaces
Trim tabs
Furniture, cabin parts and fittings, and similar accessories
Turret- and gun-mount housings, framinge, and similar items
Miscellaneous housings and covers
Spacers
Selected ducts
Selected radio and electrical parts
Selected panel stiffsners
Air induction system components
Brackets
Containers
Map cases
Wheels
Brakes
Miscellaneous engine and supercharger parts
Rudder pedals
Dive brakes
Tail cones

Research to Develop Improved Magnesium Alloys

(a) For Use as Forgings at Elevated Temperatures

Extensive investigations of the use of presently available alloys for use as forgings and of the variables encountered in different forging and pressing operations have been conducted. There is need, however, for improved alloys for use as forgings at elevated temperatures. This is of interest to the aircraft industry in connection with the development and use of impellers and blades for centrifugal and axial flow compressors. The new 18,000 ton press to be operated by the Wyman-Gordon Company might be made available to study the forging characteristics of new alloys which might be developed in the laboratory. It is suggested that additional work in this field should be undertaken at an early date.

(b) For Use as Sheet Material.

The Bureau of Aeronautics, Navy Department, and the Air Service Technical Command, A.A.F., are supporting research projects to develop superior wrought magnesium alloys. Continued research in this field is also supported by the producing companies. It is suggested that, if additional research in this field is considered, attention might be given to the observed effects of small quantities of impurities on the properties of the alloys. Methods for the control or elimination of such impurities as H_2, O_2, Cl_2, C, Na, and P during the melting operation should be investigated. For aircraft applications, alloys with improved mechanical properties, particularly better tensile and compressive yield strengths,

greater toughness and lower notch sensitivity are desired. Better cold-forming propsrties and a better understanding of hot-forming processes are of widsspread industrial intsrest. For commercial applications, other than aircraft, the great need appears to be for a cheaper sheet, more competitive on a volume basis with aluminum alloys.

(c) For Use as Extrusions.

Extrueions are important,not only in themselves, but as the stock used for producing sheet and forgings. Problems concerned with the production of ingots of consistant and uniform grain size and conetituent distribution need study. Ingot quality should be correlated with ths effects of extrusion speeds, temperatures, and with the gsometry of ths piece and the design of the extrusion dies.

(d) For Use as Castings.

Castings constitute about 85% of the end uee of magnesium alloys. A great deal of effort has been devoted to the production of eatisfactory castings and a high level of psrformance has been attained. Nevertheless, more work remains to be done and a number of investigations to complement or to extend current research projects on magnesium castings appear warranted. These include:

Sand Castings and Foundry Techniques

(a) Further study of melting, fluxing, and refining practices to improve casting and ingot quality.

(b) Further study of methods for the production of high-purity alloys.

(c) The development of improvsd surface protection agents for molten magnesium alloys.

(d) Fundamental study of the effects of gating and risering on the quality and properties of castings.

(e) Further study to determine safe limits for metallic impurities that may be introduced by the use of secondary metal.

Permanent and Semi-Permanent Mold Castings and Techniques

There appears to be considerable interest in the development of materials suitable for use as semi-permanent molds for the production of short runs of magnesium castings.

Die Castings

The use of magnesium die castings shows promise when advantage can be taken of the light weight of magnesium alloys to compete with other die casting alloys on a volume basis. More study to improve die casting techniques and possibly to develop special alloys for die casting appears justified.

Research to Develop Composite Materials to Gain Improvements in Rigidity, Strength, and Corrosion Resistance

The so-called sandwich materials show considerable promise, particularly for aircraft applications. Investigation of the use of magnesium alloys as components in this type of construction needs further study. The development of clad materials and the properties of these materials could be further investigated.

Research to Develop Means for Decreasing the Flammability of Sheet Magnesium

This is of particular interest to the Engineer Corps, U.S.A. The effects of procedures used to decrease flammability of magnesium sheet on the properties of the alloys and on production techniques should be investigated. The possibility of developing satisfactory alloys with inherently better non-flammability characteristics needs additional study.

Further Study of Inspection Methods and the Relations Between Casting Defects and Service Performance

Magnesium castings have been faced with stringent inspection. This has resulted in an average high standard of quality, but the cost has been excessive. A better understanding of the relation between inspection results and service is needed. Extension of current investigations to develop satisfactory fluoroscopic inspection and other non-destructive tests appears warranted.

Basic, Long-Range Research Projects

The following specific subjects have been suggested for university research. These topics suggest many research projects which would be suitable for graduate and undergraduate research. In this type of work, it is important to take into account the newer commercial alloys and modifications of present alloys so that the results can be correlated with current engineering development.

(1) Determination of the modes of plastic deformation in magnesium as a function of temperature, rate of deformation, alloy composition, mode of stressing.

(2) Properties and metallography of sheet as a function of amount of cold work, annealing conditions, and alloy composition. This would include consideration of the degree of anisotropy in properties and the relation of the same to the metallography.

(3) A systematic determination of the phase diagrams of all binary alloys of magnesium and of the important ternary alloys. With this, might be incorporated a study of the hardness and strength of the single-phase alloys as a function of the atomic percentage of alloying agent. It could also include a study of the strength and hardness of the two-phase alloys produced by precipitation of the second phase from the supersaturated single phase.

(4) Determination of the diffusion constants of various metals in magnesium.

(5) Determination of the fundamental laws governing the rupture characteristics of magnesium alloys.

(6) Find methods of reducing the inherent tendency of molten magnesium to burn.

(7) Properties of magnesium and its alloys in the molten state; e.g., density, viscosity, vapor pressure. Interpret data in terms of thermodynamic quantities.

(8) Determination of various physical constants of magnesium and its alloys and their dependence on temperature; e.g., thermal expansion, electrooonductivity.

(9) Brazing techniques for magnesium alloys.

(10) Fundamental study of film-forming behavior as a function of alloy environment and radiation.

(11) Anodic oxidation of magnesium alloys.

(12) Electroplating of magnesium alloys.

(13) Development of other methods of applying metallic coatings; e.g., spraying.

(14) Electrolytic polishing for brightening and deburring.

(15) Fundamental study of the electrochemical behavior of magnesium.

(16) Development of wet and dry cells and rectifiers which depend on the basic electrochemical nature of magnesium for their operation.

(17) The use of magnesium as a bearing material.

(18) Coating of steel with magnesium.

(19) Use of magnesium as a modifying or alloying agent in other base metals.

(20) Use of magnesium as a catalyst or agent in chemical reactions.

(21) Use of magnesium for gettering.

ADDENDUM

The following listed topics were subjects of research projects under the sponsorship of governmental agencies or industry, during World War II. Some of these projects were brought to a close before completion, while others are still in progress.

Corrosion and Surface Treatments

(a) The corrosion resistance of magnesium alloys in various atmospheres, and the effects of old and newly developed anodic and chemical treatments.

(b) The galvanic corrosion of magnesium alloys in contact with various unlike metals.

(c) The stress-corrosion properties of magnesium alloys.

(d) The effects of shot peening on the properties of magnesium alloys.

(e) Chemical methods for the preparation of magnesium-alloy sheet, prior to spot welding.

Fabrication

(a) Forming magnesium alloys by stretching, Guerin press, and deep drawing, at room and elevated temperatures.

(b) Machinability of cast and wrought products.

(c) Joining magnesium alloys by riveting, cementing, and by gas, arc, and spot welding.

(d) Deformation characteristics of magnesium.

General

(a) The development of improved cast and wrought magnesium alloys.

(b) The properties and aircraft applications of magnesium alloys.

Heat Treatment

(a) Investigations of the optimum heat-treating practices for cast and wrought magnesium alloys.

Flammability

(a) The effects of various additives and coatings on the flammability of magnesium alloys.

Metallography

(a) Improved polishing and etching methods.

(b) Metallographic characteristics of fractures caused in magnesium alloys by different types of stresses.

(c) Examination of impurities and heterogeneities in pure magnesium and its alloys.

Properties (General)

(a) Creep strength of magnesium alloys at room and elevated temperatures.

(b) The size effect, notch sensitivity, and damping capacity of magnesium alloys.

(c) Shear, compression, torsion, and bearing strengths of magnesium alloys.

(d) Lattice parameters and equilibrium diagrams of magnesium alloys of the system, Mg-Al-Zn.

(e) Stress-strain curves in tension and compression for the commercial alloys.

(f) Effects of minor constituents on the mechanical and physical properties of magnesium alloys.

Properties (Fatigue)

(a) Bending and tension fatigue properties of wrought and cast magnesium alloys.

Properties (High Temperature)

(a) A determination of the elevated temperature properties of commercial cast and wrought magnesium alloys.

(b) The development of cast magnesium alloys for service at elevated temperatures.

Properties (Structural)

(a) Column tests, and a general evaluation of formed and fabricated magnesium-alloy sections.

Cast

(a) Investigations of foundry techniques and casting methods.

Wrought

(a) Methods for producing magnesium-alloy press and hammer forgings.

Structures

(a) The application and service testing of commercial magnesium alloys for aircraft structures, such as fuel tanks, flaps, ailerons, wing panels, fins, and stabilizers.

(b) The application and service testing of commercial magnesium alloys for material.

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TSDIO FORM 69 (13 MAR 47)

U. S. Office of Scientific Research and Development

AUTHOR(S)

DIVISION: ~~Materials (6)~~

SECTION: Magnesium and ~~Alloys (11)~~

CROSS REFERENCES: Magnesium alloys (58420)

ATI- 6173

ORIG. AGENCY NUMBER

O.S.R.D.-6599

REVISION

AMER. TITLE: Advisory report on suggested research topics on magnesium and magnesium alloys

U

FORG'N. TITLE: Aerospace Industry

ORIGINATING AGENCY: O.S.R.D., N.D.R.C., Washington, D.C.

TRANSLATION:

COUNTRY	LANGUAGE	FORG'N.CLASS	U. S.CLASS.	DATE	PAGES	ILLUS.	FEATURES
U. S.	Eng.		Unclass.	Feb'46	11		

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265650

TSDIO FORM CO (13 NO 47)

U. S. Office of Scientific Research and Development

AUTHOR(S)

DIVISION: Materiels (8)
SECTION: Magnesium and Alloys (11)
CROSS REFERENCES: Magnesium alloys (58420)

ATI- 6173

ORIG. AGENCY NUMBER

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FORG'N. TITLE:

ORIGINATING AGENCY: O.S.R.D., N.D.R.C., Washington, D. C.

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