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PRESENT STATE AND FUTURE OF MAGNESIUM APPLICATION IN AEROSPACE INDUSTRY

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1. Introduction

Weight reduction has always been an important objective for aerospace industry.

Aluminium is a traditional light metal for airborne structures. The alloys used today for aerospace applications are already optimized concerning aeronautic requirements such as strength, fatigue and damage tolerance properties. Therefore weight reduction is more and more difficult to be reached with small advances in aluminium material development.

One alternative could be the use of laminates such as Glare®. Another alternative could be the application of low-density structural plastics or fibre reinforced composites. However, the application of non-metallic materials is not possible in some areas, owing to limited properties under low or elevated temperatures, missing electric conductivity, low impact characteristics and low damage tolerance. In addition, fibre reinforced plastics are rather costly materials when applied to primary structures - applications that are characterised by highest requirements.

Magnesium, as it is well known, is the lightest structural metal available on Earth. Its specific gravity is 1.74 (SP of aluminium is 2.7 and of steel is of 7.9 in average). Therefore it is attractive for building structures that need to be light and strong.

The family of magnesium materials and especially magnesium wrought materials could be an excellent alternative to aluminium because of their low density, rather good mechanical properties and metallic behaviour. In the past decade a lot of research activities and development projects have been carried out working on magnesium cast materials mainly for automotive applications. There were only very few studies on magnesium wrought products like sheets, extrusions or forged parts. Aeronautic requirements and applications have been evaluated only in subtasks of a few projects.

2. Aerospace background of magnesium

Magnesium was commonly defined as the metal of airborne construction. Historically, magnesium has been used in aircraft since the thirties of the last century. In the fifties, magnesium passed a "boom" when it was broadly used in aircraft structures and components.

Military aircrafts and helicopters that were built in that period included hundreds kilograms of magnesium products (Fig.1).

Fig. 1. Sikorsky S-56, Westland Aircraft Ltd. (1950): 115 kg of magnesium

The experimental modification of Lockheed F-80C was fully built from magnesium (Fig. 2)

Fig. 2. Lockheed F-80C: complete magnesium construction

However the real triumph of magnesium in the Western aircraft industry was Convair B-36 Peacemaker with 8600 kg of magnesium (Fig.3).

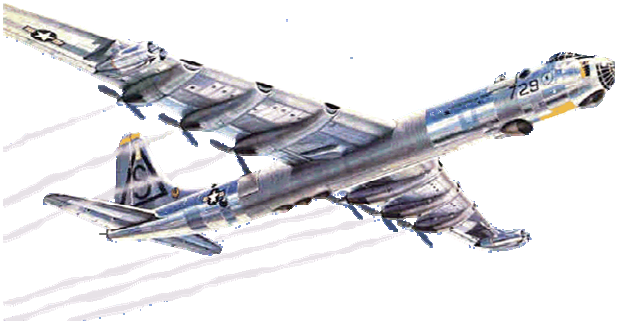

Fig. 3. Convair B-36, total 8600 kg of magnesium: 5555 kg of magnesium sheet, 700 kg of forging

The aerospace industry of former Soviet Union also broadly used magnesium in military aircrafts (Fig. 4).

Fig. 4. TU-95MS: 1550 kg of magnesium

The significant difference of magnesium application in former Soviet Union from the Western countries is the relatively big amount of magnesium components in civil aircrafts. This fact may be explained by utilization of military plane structures for prototyping of civil aeroplanes. For example, if Boeing 737 (start of manufacturing in 1967) had only several small magnesium components in wing structures and door, Tupolev TU-134 (start of manufacturing in 1963) had 1325 magnesium components with total weight 780 kg (Fig. 5).

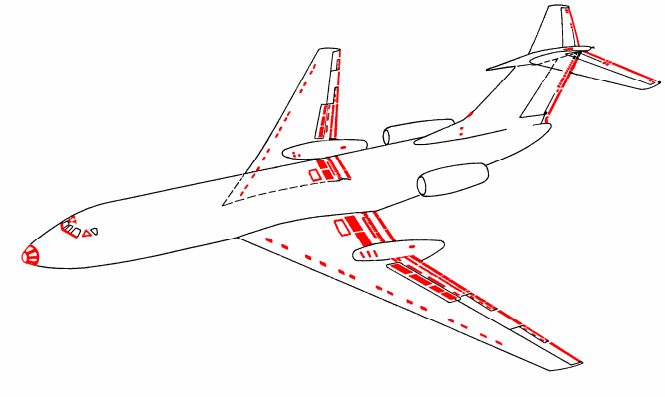

Fig. 5. Location of magnesium components (in red) in TU-134 [1]

3. Present situations with magnesium application in aerospace industry

The amount of magnesium in the former Soviet aircraft reduced on the beginning of 1990th from hundreds to dozens kg per plane (Fig. 6).

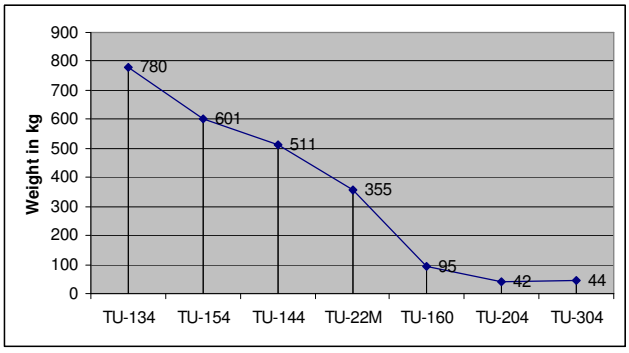

Fig. 6. Tendency of magnesium application in Tupolev aircraft [1]

Regarding the Western aerospace industry, up to now magnesium has not been used in structural applications by major aircraft manufacturers: Airbus, Boeing and Embraer.

The situation is different for helicopter industry where magnesium is used in cast gearboxes and transmissions and some other non-structural elements (Fig. 7).

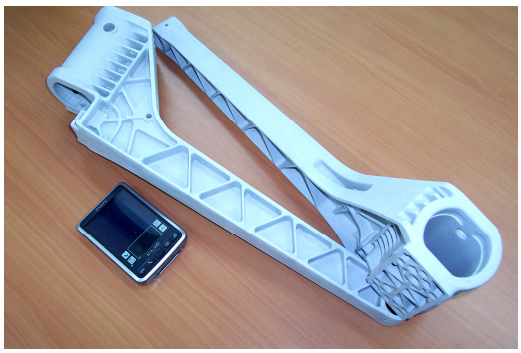

Fig. 7. Magnesium (AM50) die-cast helicopter components (IAI, Israel)

3.1. Reasons for decrease in magnesium applications

Although there is strong public opinion about magnesium flammability as the main reason for restriction of its application, this problem is though more psychological than real. Objectively there have been neither precedents of aircraft accident that occurred because of magnesium ignition, nor facts that application of magnesium in aircraft could reduce fire-safety for passengers. Magnesium meets requirements of all active aerospace standards for material flammability resistance.

Corrosion on magnesium alloys was the real main reason. Generally, most magnesium alloys have higher bare corrosion rate than aluminium. The shortcomings of high-pure alloys and low protection performance of magnesium surface treatments resulted in higher corrosion level of magnesium aerospace components relative to aluminium ones.

The situation has changed with significant improvement of magnesium production technologies, as well as with developments in the last decade, of new magnesium surface treatment technologies such as PGA[1] ALGAN 2M (Fig. 7) and composite coating[2] Gardobond® X4729 (Fig. 8) from Chemetall GmbH; and Magoxide® and Magpass® from AHC Oberflächentechnik.

Fig. 8. Back panel of aircraft door pretreated by Gardobond® X4729 and painted (AZ31B, superplastic forming by AMTS, Israel)

The technologies provide magnesium with similar to aluminum level of protection.

The special interest for aerospace industry is published application of Gardobond® X4729 for

[1] Plasma-Gel Anodizing: new anodizing technology developed by Chemetall GmbH

[2] Composite coatings: new class of surface treatments for magnesium developed by Chemetall GmbH

structural adhesive bonding and for protection of magnesium components in the flame of burning aircraft fuel [2], [3].

The additional reason was lack of high-strength magnesium alloys for structural applications.

Recently Magnesium Elektron Ltd. (UK) developed new high-strength alloys Elektron 21 [4] and Elektron 675 [5] which have mechanical properties comparable to aerospace aluminium structural alloys.

The above mentioned developments, as well as, strong demand for aircraft weight reduction and some dissatisfaction of aerospace industry with composite materials led to the beginning of serious investigation of magnesium comeback to aerospace industry.

4. Future of magnesium in aerospace industry

The future application of magnesium in aerospace industry will be probably based on present running R&D projects. Such kinds of projects are running at the present time in European Union, USA, Israel, France and Austria.

European Framework Program 6th has three magnesium related projects in Aeronautic Priority: IDEA, AEROMAG and MagForming. The two last projects may significantly influence on magnesium future in aerospace industry due to the active participation of major European aerospace companies.

4.1. Aeronautical Application of Wrought Magnesium (FP6 AEROMAG)

The project is coordinated by EADS Innovation Works (Germany). The partners of the consortium are:

- End-users:
  - EADS Innovation Works, Germany;
  - EADS Innovation Works, France;
  - Airbus Deutschland, Germany;
  - Eurocopter, France
  - Alenia, Italy.
- Industrial companies:
  - Palbam-Alonim-AMTS, Israel;
  - Magnesium Elektron, UK;
  - Otto Fuchs, Germany;
  - Salzgitter Magnesium Technologies, Germany;
  - SMW Engineering, Russia.
- Research institutes:
  - VIAM, Russia
  - VILS, Russia
- Universities:
  - ENSAM, France;
  - INPG, France;
  - Naples, Italy;
  - Patras, Greece;
  - Technion, Israel;
  - Thessaly, Greece;
  - TU Vienna, Austria.

Project objectives:

1. Development of new Magnesium wrought products (sheets and extrusions), that provide significantly improved static and fatigue strength properties. The strength properties of these innovative materials are required to be as high as AA5083 for non-structural applications and as high as AA2024 aluminium alloys for secondary structure applications.
2. Simulation and validation of forming and joining technologies for the innovative material and application.
3. Corrosion problem will be solved with newly adapted and environmentally friendly surface protection systems and advanced design concepts.
4. Flammability will be investigated and solved with addition of chemical elements and special surface treatments.
5. Development of material models and failure criteria for the prediction of forming processes, plastic deformation and failure behaviour of components.
6. The technological objective is a weight reduction of fuselage parts, systems and interior components up to 35%. The strategic objectives are an increase in the operational capacity of 10%, a reduction in the direct operating cost of 10% and finally a reduction in the fuel consumption of 10% and therefore a reduced environmental impact

The first results of AEROMAG project were presented by several partners in 2006 on 7th International Conference on Magnesium Alloys and Their Applications in Dresden, Germany and in 2007 on 2nd International Conference and Exhibition „Magnesium – Broad Horizons" in Saint-Petersburg, Russia.

4.2 Forming technologies development for introducing wrought magnesium applications in aeronautics (FP6 MagForming)

The project is coordinated by Palbam-AMTS (Israel). The partners of the consortium are:

- End-users:
  - Airbus Deutschland, Germany;

  - EADS Innovation Works, Germany;
  - Israel Aircraft Industry, Israel;
  - Liebherr Aerospace Toulouse, France;
- Industrial companies:
  - Palbam-AMTS, Israel;
  - Alubin, Israel;
  - Chemetall GmbH, Germany;
  - Magnesium Elektron, UK;
  - SMW Engineering, Russia
  - Ultratech, Poland;
- Universities:
  - Hanover, Germany;
  - Prague, Czech Republic.

Project objectives:

1. Methodologies for the preparation of the raw material for plastic deformation: solidification processes, rolling processes, extrusion and annealing processes, etc.
2. Development of special lubrication technology based on easy-removed, high-temperature stable lubricants.
3. Development of special heated dies that will have the correct temperatures and temperature gradients and will be controlled by special controllers.
4. Development of cooling procedures to attain the best qualities for the manufactured part, as required by the specifications and, at the same time, keeping the press machine far from damage.
5. Development of the exact methodology of applying the press loads: strength of force applied, temperature regime, duration of the application of force, process total speed etc.
6. Modifications of the parts, using modeling software, to make sure that the magnesium part meets the same specifications required by the end users.

Summarizing both projects, we observe that European aerospace industry is developing the clear sequence for application of magnesium in structural components:

1. Production of new advanced magnesium alloys;
2. Production of semi-finished products from new alloys;
3. Forming of components;
4. Assembling;
5. Finishing.

The analysis of preliminary results of both projects demonstrates the perspective of exploiting 10-15% of magnesium components in civil aircrafts in the followimg10 years.

5. Conclusions

Opposite to common opinion about “non-metallic” aeronautic future, major European aerospace industries seriously investigate magnesium as weight-reduction alternative for aluminum.

New high-strength alloys, advanced surface treatment technologies and correct understanding of “magnesium flammability” are the base for magnesium comeback in aerospace industry.

10-15% of magnesium components in civil aircraft in 2015-2020 look like a real target.

6. References

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[4] Magnesium Elektron Ltd., Datasheet 455

[5] Magnesium Elektron Ltd., Datasheet 102