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ANALYSIS OF REPLACING MAGNESIUM OVER ALUMINIUM IN INDUSTRY

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Abstract— for a long time in our vastly developing Automobile industry Aviation industry etc. we are using Aluminium. Studies are there which shows that Magnesium is more versatile than Aluminium. The difference between aluminium and magnesium is based upon many factors, such as brittleness, heat dissipation, tool life, die casting and cost. Remarkable fact about Magnesium is that when compared to aluminium it is lightweight. Automotive parts can be easily formed from magnesium, and companies like Ford are running tests to substitute aluminium with magnesium. The die casting cycle of aluminium versus magnesium has more advantages, since the magnesium injected speed should be very fast due to its rapid solidification rate, whereas magnesium die casting's eject time is shorter than the amount of time required for aluminium. Magnesium die casting needs a shorter dwelling and lubrication time, with faster shot speed, when compared to aluminium.

Metallic composites containing nano particles could offer distinct benefit over polymeric composites due to the inherent high temperature stability, high strength, high modulus, and wear resistance, thermal and electrical conductivity of the metal matrix. Using Magnesium nano materials is much more useful than regular kind.

In this paper we are trying to suggest how Magnesium can be replaced with Aluminium as base metal in composites in aerospace and automobile industries and its various uses. Since magnesium and its alloys are the lightest structural metallic materials having highest specific strength. However magnesium shows high potential to substitute conventional materials. Magnesium alloys should be used in applications where low mass and high definite properties are required. According to the combination of specific Young's modulus and high specific strength magnesium alloys show similar or even better values than aluminium and many commercial steels.

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I. INTRODUCTION

The density of magnesium is only 65% of the density of commonly used aluminium alloys in the aerospace industry. Therefore can be a breakthrough technology if used for low weight airframe structures. However to use this low weight material several mechanical properties have to be increased and the technological behavior must be improved.

the technical focus of this project is the modification of existing and the development of new magnesium wrought products (sheets and extrusions), that provide significantly improved static and fatigue strength properties for lightweight fuselage applications. the specific strength properties of these innovative materials are required to be higher than aa2024 for structural applications (secondary structure) and higher than aa5083 for non-structural applications.

the technological objective is a weight reduction of fuselage structure, system and interior components of machines up to 30 %. the strategic objectives are the rise in the operational capacity of 10 %, a reduction in the direct operating cost up to 10 % and finally a reduction in the fuel consumption of 10 % and therefore a reduced environmental impact with regard to emissions and noise.

II. DESCRIPTION OF OBJECTIVES

The aluminium 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 only small progress in aluminium material development.

Due to the fact that weight reduction is a very important objective for strengthening the competitiveness of the whole European aeronautic industry, several alternatives to obtain weight reduction have to be investigated. One alternative can be the use of new design principles like welded or bonded airframes or the use of laminates such as Glare® or Metal Laminates. Another alternative could be the application of low density structural plastics or fibre reinforced composites. But the application of non-metallic materials is in some areas not possible due to limited properties under low or elevated temperatures, missing electric conductivity or low damage tolerance. Fibre reinforced plastics are a rather costly material only used for primary structure applications with highest requirements.

The family of magnesium alloys and especially magnesium wrought materials can be an excellent alternative because of their low density, good mechanical properties, moderate 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 activities on magnesium wrought products like sheets, extrusions or forged parts. The alloy spectrum of magnesium wrought alloys is still very limited. Aeronautic requirements and applications of wrought products have been evaluated only in some subtasks of a few projects.

Increasing the research on magnesium wrought alloys will promote a new class of metallic materials for aeronautical applications to win the competition against plastics and fibre reinforced plastics. Therefore, the spectrum of available metallic materials will be enlarged, not only for aircrafts, but also for space, military and satellites applications. Thus, as a consequence, it will also stimulate the research in the field of other engineering materials.

Within this project the overall objective is to demonstrate that Magnesium is a suitable engineering material which can be applied for weight savings up to 35 % compared to aluminium. To reach this goal magnesium has to deliver significantly higher weight specific mechanical properties compared to Aluminium. The targets for replacement of aluminium can be divided into two different steps in respect of time scale and risk:

Replacement of medium strength 5xxx aluminium alloys for cockpit and cabin applications

Replacement of medium to high strength 2xxx aluminium alloys for secondary structure or non-pressurized fuselage applications

Corrosion is one of the most important problems to be solved with newly adapted and environmentally friendly surface protection systems according to aerospace requirements. Advanced design concepts are requested to prevent any galvanic corrosion within joinings of components made from dissimilar materials. Additional topics in that area are the needs for grounding and local surface protection technologies for damages which have to be realized for nearly all aeronautic components.

Flammability will be evaluated and addressed with addition of chemical elements, special surface treatments and comparative investigations to reference aluminium alloys. The fire worthiness requirements (FAR/JAR) for the different areas of aircraft will be the base for the assessment of efficiency of the selected protection systems.

The technical focus of the university driven proposal, AEROMAG which has been prepared in close collaboration to the Network of Universities "EASN" is the 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.

At first new alloys will be developed and existing alloys will be tested. Appropriate manufacturing (rolling, extrusion), forming and joining technologies require development, simulation and validation for the innovative material and application. Corrosion is a problem to be solved with newly adapted and environmentally friendly surface protection systems and advanced design concepts. Flammability will be addressed with addition of chemical elements and special surface treatments. A further essential task is the development of material models and failure criteria for the prediction of forming processes, plastic deformation and failure behaviour of components. Finally material adapted design and the evaluation of structural behaviour will be investigated to close the process and development chain for aeronautic components.

Property	Temperature	Requirements of new Mg alloys for	
		systems application	structural application
Tensile Ultimate Strength	RT	275-350 MPa	450 MPa
Tensile Yield Strength	RT	200-300 MPa	350 MPa
Elongation to fracture	RT	12-16 %	16-18 %
Yield Strength	150°C	- 10% of YTS	-10% of YTS
Compressive Yield Strength	RT	± 10% of YTS	± 10% of YTS
Failure under compression	RT	comparable Al 5083	comparable Al 2024 T3
Specific Weight	RT	1,75	1,75
Residual Strength	RT	n.a.	comparable to 2024 T3
Fatigue Crack Growth	RT	n.a.	comparable to 2024 T3
Fatigue limit (K_t=1.0, R=0.1)	RT	160 MPa	140 MPa

Table 1: Requirements for magnesium alloys for aeronautic applications.

III. RESULTS

The Russian Institutes VILS and VIAM proposed some new alloys and made a comprehensive review about available magnesium alloys and magnesium applications in aerospace in past and present products. The Technion also contributed with a new rapid solidified, interesting alloy. Magnesium Elektron joined the consortium to support the material processing step by feedstock supply and knowledge transfer of rolling specialty alloys.

The most promising alloy systems (fig. 1) which were selected due to corrosion behaviour, environmental friendliness and mechanical performance for further investigation as wrought products in the project, were Mg-Al-Zn, Mg-Zn-Zr-Re and Mg-Y-Re.

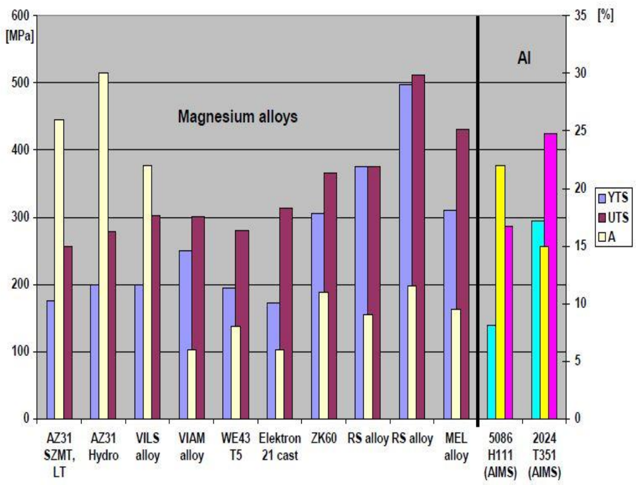


Fig. 1: Static properties of commercially available and new alloys.

Investigation of forming processes

INPG has done the full characterization of deformation behaviour at room and elevated temperatures by microstructural analysis and mechanical testing. The objective is to define the forming windows for different alloys and processes. University of Savoie in Annecy performed some forming tests at room temperature with specific devices to study strain localisation effect by image correlation technique

Surface protection

Existing and commercially available, environmentally friendly surface treatment technologies are investigated and tested in accordance with aircraft and aerospace standards. The specifications have been defined by the end-users.

The main focus of work comprises the definition of pre-cleaning technology, the development of sol-gel technology (TU Vienna), comparison of commercial surface treatment technologies, testing of bare corrosion protection and testing of multilayer coating. Conversion coatings, anodizing treatments and hard and wear resistant coatings suitable for Mg substrates will be tested, evaluated and rated. AMT&S Alonim, Eurocopter and external companies are providing the surface protection systems.

The magnesium sheet shall be pre-cleaned for maximum corrosion protection. Investigating the corrosion resistance of anodizing treatments, the corrosion resistance was quantitatively estimated thanks to pitting depth measurements on metallographic sections. For each specimen, the pitting depth has been measured on 3 different metallographic sections. All the specimens corroded only by pitting, no intergranular corrosion, no filiform corrosion appeared under the protective layers. No particular influence of the scratch (depth/corrosion morphology) has been evidenced on the micrographs. The metallographic sections confirm the visual observations. Currently only HAE with varnish and unsealed Tagnite coated specimens fulfilled the requirements in terms of corrosion resistance.

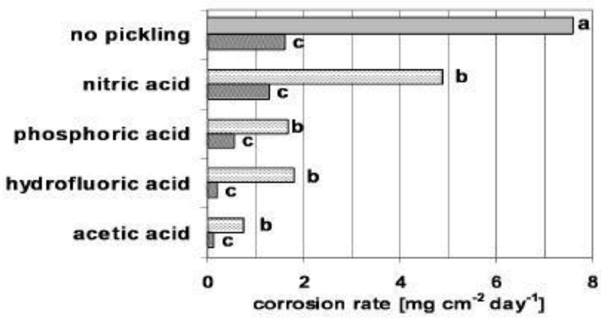
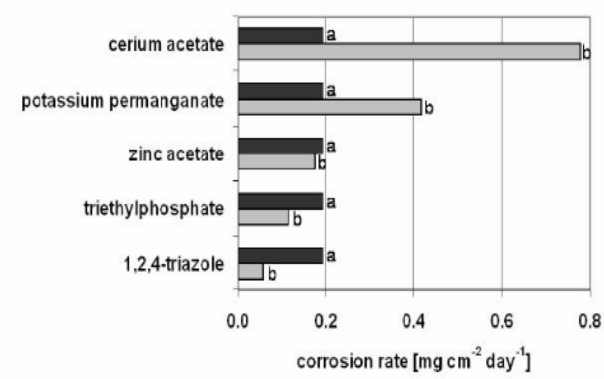


Figure 2: Anticorrosive performance of samples with different treatments: a) untreated sample, b) after acid pickling and c) after acid pickling and sol gel coating

The additional influence of potential corrosion inhibitors was also investigated. The amount of the additives was calculated to be 5 % of the total mass of the nonvolatile compounds in the sol. The films were deposited on samples pretreated with hydrofluoric acid. The results of the corrosion test are summarized in Fig 5. The anticorrosive effect of manganese and cerium is outweighted by the negative influence on the barrier properties of the sol gel coating in this system. Zinc acetate showed only a minor effect. Triethylphosphate and 1,2,4-triazole proved to be efficient inhibitors, decreasing the corrosion rate by a factor of 1.7 and 3.3 respectively.



Some tests to determine the auto-ignition temperature of magnesium alloys have been carried out by the Technion. First the mechanism of auto-ignition was studied to understand the problem of flammability and to conclude on the influence of different alloy compositions. Eutectic phases ignite first (low melting temperature) Homogeneity of bulk increases auto-ignition temperature (no low-temperature melting phases) Highly dependent on geometry (powder, bulk) No standard for solid materials available (the closest standard is ASTM standard E659-78) Dependent on atmosphere and reactions

Airbus and Technion have carried out some first measurements to compare the general flammability behaviour of aluminium and magnesium sheets and real magnesium components. First it has to be stated that all tests which were carried out passed without any problem the JAR/FAR, Part 25, § 25.853(a) requirements. The reason for that is that the specification was made for non-metallic materials which are often used in the cabin of an aircraft. Airbus found that the time to melting for AZ31B, 2 mm sheet was about half as for comparable AA2024. Without external heat the Mg sheet did not continue burning. But to learn more about the flammability of magnesium, the Technion performed additional tests close to a catastrophic scenario. Different magnesium components were directly placed within a burning jet fuel with a temperature of 600 to 800°C. It needed 240 seconds until the components were melted and other 10-20 seconds until they ignited. Coated components could increase the time to only partial ignition up to 10 min. After 1 min when the fuel was fading out, the coated components self extinguished. In comparison to that the Al case melted 350 seconds after the full ignition of the fuel. No ignition of the

Al case was observed in this test. But for all cases there was no ignition observed till melting of the magnesium material.

Joining technologies

Different joining techniques were applied to magnesium wrought semi-finished products, in order to promote their introduction on aeronautical structures. Airbus has performed some first tests to join magnesium sheets by friction stir welding. ENSAM has performed some initial tests to define the parameter window for friction stir welding of magnesium. PALBAM has been working on TIG welding. They performed several welding trials and did some microstructural (fig. 4) and mechanical characterization (fig. 5).

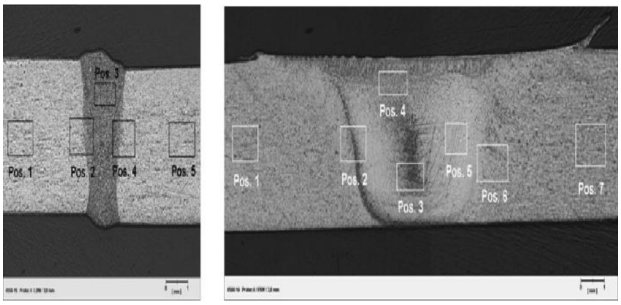


Fig. 4: Welded AZ31B joints a) laser beam welded, b) friction stir welded

III. CONCLUSION

Within all these advantages magnesium has one major disadvantage: it's costlier than aluminium. But studies shows that the pricing predict is that the magnesium expense will decrease from 2300 US $/ton in 2001 down to 1800 US $/ton in 2005 leading to a drop of the magnesium to aluminium price ratio from 1.5 to 1.2.

Magnesium alloys have two major disadvantages for the use in automotive functions; they exhibit low high temperature strength and a relatively poor corrosion resistance. The major step for developing the corrosion resistance of magnesium alloys was the introduction of high purity alloys. Alloying can further improve the general corrosion behaviour, but it does not change galvanic corrosion dilemma if magnesium is in contact with another metal and an electrolyte. And also imparting nanoparticles to pure magnesium or magnesium alloy could bring up a remarkable change in its strength, corrosion, creep and wear resistance, even though studies with nano ceramic composites is rarer in the industries. The ongoing developments should be able to generate alloys with tolerable properties and also a suitable coating technology for corrosion protection to fulfil all automotive requirements. Developing new and perfecting old casting and manufacturing technologies will help to reduce the costs for components and help to increase the area of applications.

Although there is increasing interest in using magnesium the definite applications are still limited in comparison to their major competitors' steel, aluminium and plastics. This increase of magnesium in automotive applications is considered as possible if we increased in house-recycling to reduce costs, secondary material flow.

Considering aerospace applications, the main objective is to reduce weight of the fuselage structure, system and interior components up to 30, an increase in the operational capacity of 10 %, a reduction in the direct operating cost of 10 % and finally a reduction in the fuel. Magnesium for Aerospace Applications consumption of 10 % and therefore a reduced environmental impact with regard to emissions and noise. Increasing the research on magnesium alloys will promote a new class of metallic materials for aeronautical applications to win the competition against plastics and fibre reinforced plastics.

So far from this study we can conclude that magnesium can be used as the base metal in composites instead of aluminium. And for the future society development, this change will bring economic benefits and moreover we can enhance production efficiency and thereby supporting technological innovations.

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