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Experimental And Finite Element Analysis of Tensile Behavior of Stir Casted Magnesium Alloy Az91

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ABSTRACT

In this present project work the significance of light weight material is discussed. The conventional light weight metal aluminum is replaced by magnesium. In addition magnesium based alloys are superior properties and most widely applicable in automobile and aircraft materials. High-quality samples of magnesium alloy AZ91 is fabricated through stir casting route. The use of wire cut EDM for sample preparation proved to be a reliable and accurate method for creating uniform samples with consistent dimensions. The ultimate tensile strength (UTS) of the magnesium alloy AZ91 obtained through the wire cut EDM tensile test was 174 MPa, indicating that the material is strong and able to withstand high levels of tensile stress. The ANSYS simulation predicted a slightly lower UTS value of 169 MPa, indicating that the simulation method may have made certain assumptions about the material's behavior that did not match the experimental results. The difference of 5 MPa between the experimental and simulated UTS values suggests that there may be some room for improvement in the simulation methods used in ANSYS software. The results of this study provide valuable information for engineers and materials scientists working with magnesium alloy AZ91, as they demonstrate the material's behavior under tensile loading and highlight potential areas for improvement. Hence the fabricated material is tested experimentally and numerically for its tensile properties. Hence the present work is significant for need of light weight material in automobile and aircraft applications.
Keywords: Aluminum, Zinc, Magnesium, Stir Casting, Wire Cut EDM, Tensile Test, Wear Resistance

I. INTRODUCTION

Light weighting is useful where there is any motion associated with a product. All motion needs energy, whether exerted by an engine, a person, or an actuator — the less energy required to generate the appropriate motion, the more efficient the product. Automobiles, trains, rockets, and planes are the most obvious light weighting use cases, but light weighting also applies to consumer products, medical devices, and various other products. Lightweight components typically offer performance advantages. The most obvious example of this is in the automotive industry. The vehicle light weighting process can improve maneuverability, acceleration, and carrying and mileage capacity. Lighter vehicles also experience reduced component wear and tear, and usually offer better fuel economy. For instance, a 10% reduction in vehicle weight can result in a 6%-8% improvement in fuel economy. In aerospace, reducing the structural weight of an aircraft can improve efficiency. The Boeing 787, for example, was made 20% lighter, which increased fuel economy by 10-12%. In the case of the Boeing 787-9, which burns approximately 5,400 liters of fuel per hour, a 10-12% improvement in fuel economy amounts to 540-650 liters saved per hour? Light weighting allows engineers to design products of a certain weight but with expanded functionality. For instance, there is significant demand in the automotive industry for modern vehicles to be made with larger cabins without increasing their weight.

II. MAGNESIUM BASED MATERIALS

Magnesium is the lightest of all the engineering metals, having a density of 1.74 g/cm3. It is 35% lighter than aluminum (2.7 g/cm3) and over four times lighter than steel (7.86 g/cm3). The physical properties of Mg, Al and Fe are given in Table 1. Magnesium is the eighth most common element. It is produced through either the metallothermic reduction of magnesium oxide with silicon or the electrolysis of magnesium chloride melts from seawater. Each cubic metre of the sea water contains approximately 1.3 kg (0.3%) magnesium. It has a good ductility, better noise and vibration dampening characteristics than aluminum and excellent castability. Alloying magnesium with aluminum, manganese, rare earths, thorium, zinc or zirconium increases the strength to weight ratio making them important materials for applications where weight reduction is important, and where it is imperative to reduce inertial forces. Because of this property, denser material, not only steels, cast iron and copper base alloys, but even aluminum alloys are replaced by magnesium-based alloys. The requirement to reduce the weight of car components as a result of legislation limiting emission has created renewed interest in magnesium.

Auto manufacturing companies have made the most of research and development on Mg and its alloys. Volkswagen was the first to apply magnesium in the automotive industry on its Beetle model, which used 22 kg magnesium in each car of this model. Porsche first worked with a magnesium engine in 1928. Magnesium average usage and projected usage growth per car are given as 3 kg, 20 kg, and 50 kg for 2005, 2010 and 2015, respectively. In the past aluminum and some plastic have been used as the preferred material for some auto parts. In recent years magnesium applications in the auto sector have been increasing. Recent research and development studies of magnesium and magnesium alloys have focused on weight reduction, energy saving and limiting environmental impact. Global trends force the automotive industry to manufacture lighter, more environmentally friendly, safer and cheaper cars. The leading automakers are concentrating on the reduction of car weight and limiting the amount of exhaust emissions due to legislative and consumers' requirements for safer, cleaner vehicles. As CO2 emission is in direct proportion to fuel consumption, car weight has become the most critical criterion of design efficiency assessments.

Weight reduction not only saves energy but it also reduces greenhouse gas emissions. Reducing the automotive weights by a certain amount will result in a similar percentage of improvement in fuel economy. Fuel efficiency leads to extensive evaluation of the potential use of magnesium components. Weight reduction of 100 kilograms represents a fuel saving of about 0.5 litres per 100 kilometers for a vehicle. High-strength steels, aluminum (Al) and composites are already being used to reduce weight, but additional reductions could be achieved by greater use of low-density magnesium and its alloys. Reduction in weight can be obtained by a combination of innovative structural design and increased use of lightweight materials. Currently, the average vehicle in North America uses 0.25 % (3.8 kg) magnesium and 8% (120 kg) aluminum.

Significant research is still needed on magnesium processing, alloy development, joining, surface treatment, corrosion resistance and mechanical properties improvement. Environmental conservation is one of the principal reasons for the focus of attention on Mg and its alloys. Environment conservation depends, to a great extent, on transportation industry, particularly CO2 emissions produced by transport vehicles. Weight reduction is the most cost effective option for significantly decreasing of fuel consumption and CO2 emissions. European and North American car producers have planned to reduce fuel consumption by 25%, thereby achieving a 30% CO2 emission reduction by the year 2010. The consumption of magnesium has shown a broad increase in the last 20 years. North America is the main consumer followed by the Western Europe and Japan. Most of the available magnesium is still used for alloying aluminum and only about 34% is directly used for magnesium parts, which can be divided into casting applications (33.5%) and wrought materials (0.5%). A lightweight part made of magnesium on a car may cost more than that of aluminum, but Mg cost compensates for Al cost due to reduction in fuel and CO2 emission.

III. MATERIAL PREPARATION

Stir casting is one of the most popular and widely used method in which material formation (mainly Metal Alloys and Metal Matrix Composites) is done by melting metals and casting them into suitable shapes and sizes by pouring them into cavities. It is also called as liquid metallurgy.

RAW MATERIALS FOR MAGNESIUM ALLOY

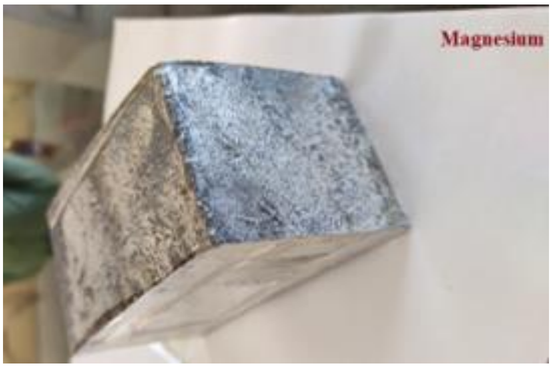

Fig 1. Magnesium metal

Magnesium is a chemical element with the symbol mg and atomic number 12. it is a shiny gray metal having a low density, low melting point and high chemical reactivity. like the other alkaline earth metals (group 2 of the periodic table) it occurs naturally only in combination with other elements and it almost always has an oxidation state of +2. it reacts readily with air to form a thin passivation coating of magnesium oxide that inhibits further corrosion of the metal. the free metal burns with a brilliant-white light. The metal is obtained mainly by electrolysis of magnesium salts obtained from brine. It is less dense than aluminum and is used primarily as a component in strong and lightweight alloys that contain aluminum.

IV. ALUMINUM METAL

Aluminium is a chemical element with the symbol Al and atomic number 13. Aluminium has a density lower than those of other common metals; about one-third that of steel. It has a great affinity towards oxygen, forming a protective layer of oxide on the surface when exposed to air. Aluminium visually resembles silver, both in its color and in its great ability to reflect light. It is soft, nonmagnetic and ductile. It has one stable isotope: 27Al, which is highly abundant, making aluminium the twelfth-most common element in the universe. The radioactivity of 26Al is used in radiometric dating.

Fig 2. Zinc metal

Zinc is a chemical element with the symbol Zn and atomic number 30. Zinc is a slightly brittle metal at room temperature and has a shiny-greyish appearance when oxidation is removed. It is the first element in group 12 (IIB) of the periodic table. In some respects, zinc is chemically similar to magnesium: both elements exhibit only one normal oxidation state (+2), and the Zn2+ and Mg2+ ions are of similar size. Zinc is the 24th most abundant element in Earth's crust and has five stable isotopes. The most common zinc ore is sphalerite (zinc blende), a zinc sulfidemineral. The largest workable lodes are in Australia, Asia, and the United States. Zinc is refined by froth flotation of the ore, roasting, and final extraction using electricity.

4.2 Casting is a manufacturing process in which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting materials are usually metals or various time setting materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods. Heavy equipment like machine tool beds, ships' propellers, etc. can be cast easily in the required size, rather than fabricating by joining several small pieces. Casting is a 7,000-year-old process. The oldest surviving casting is a copper frog from 3200 BC.

Figure 4.4 Stir casting experimental setup

Figure 4.5 Stir-casted sample

TENSILE TEST – EXPERIMENTAL

Figure UTM Tensile testing machine

Tensile test Sample CAD Model (ASTM E8)

A universal testing machine (UTM), also known as a universal tester,[1]materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. An earlier name for a tensile testing machine is a tensometer. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures (in other words, that it is versatile).

Tensile results of magnesium alloy AZ91

Sl.No	Strength	Experimental Result (MPa)
1	Ultimate Tensile Strength (UTS)	174
2	Yield strength (0.2%)	70
3	Elongation (%)	8.5

Finite Elements Analysis (FEA) is a method for solving complex mechanical problems using the power of modern computers. Choosing sound boundary conditions and loads, the engineer is able to simulate reality whatever the situation or complexity. The mechanical behavior of products and constructions can be analyzed and optimized without the necessity of prototyping. Direct results are profits with respect to time and cost in the design phase. It also adds to the reliability of your product.

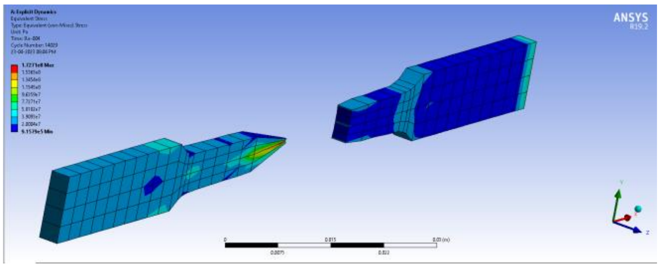

Figure-Equivalent Von – mises stress

V. COMPARISON OF EXPERIMENTAL AND FEA RESULTS

The ultimate tensile strength (UTS) is an important material property that determines the maximum stress a material can withstand before it fails under tensile loading. In this study, the UTS of a material was measured experimentally and compared with the UTS predicted by ANSYS software.

The experimental UTS value was found to be 174 MPa, while the UTS predicted by ANSYS software was 169 MPa. This indicates that there is a difference of 5 MPa between the experimental and simulated results.

There are several possible reasons for this discrepancy. One possible explanation is that the material used in the experiment may not have been identical to the material used in the ANSYS simulation. This could lead to differences in the material's behavior under load, resulting in different UTS values.

Another possible reason for the difference in UTS values is the assumptions made in the ANSYS simulation. ANSYS software uses numerical methods to simulate the behavior of materials under load, and these methods rely on certain assumptions about the material's properties and behavior. If these assumptions are not accurate, the simulation results may not match the experimental results.

Despite the difference between the experimental and simulated UTS values, the results of this study still provide useful information about the behavior of the material under tensile loading. The experimental UTS value of 174 MPa indicates that the material is strong and able to withstand high levels of tensile stress. The simulated UTS value of 169 MPa provides additional information about the material's behavior under different loading conditions.

In conclusion, while there was a difference of 5 MPa between the experimental and simulated UTS values, the results of this study still provide valuable information about the behavior of the material under tensile loading. Further research could be conducted to identify the factors that contributed to the difference in UTS values and to refine the simulation methods used in ANSYS software.

Comparison of Tensile Properties

Sl. No	Tensile Properties	Experimental	Numerical	% deviation
		MPa	MPa	(%)
1	Ultimate Tensile Strength	175	169	8.62%
2	Yield Strength	117	-	-
3	Ductility	8.63	9	4.28

VI. CONCLUSION

Based on the results of this study on the stir casting of magnesium alloy AZ91 and subsequent tensile testing using wire cut EDM, and comparing these results with the ANSYS software simulation, the following conclusions can be drawn:

1. The stir casting process used in this study was effective in producing high-quality samples of magnesium alloy AZ91 for testing.
2. The use of wire cut EDM for sample preparation proved to be a reliable and accurate method for creating uniform samples with consistent dimensions.
3. The ultimate tensile strength (UTS) of the magnesium alloy AZ91 obtained through the wire cut EDM tensile test was 174 MPa, indicating that the material is strong and able to withstand high levels of tensile stress.
4. The ANSYS simulation predicted a slightly lower UTS value of 169 MPa, indicating that the simulation method may have made certain assumptions about the material's behavior that did not match the experimental results.
5. The difference of 5 MPa between the experimental and simulated UTS values suggests that there may be some room for improvement in the simulation methods used in ANSYS software.
6. However, both the experimental and simulated UTS values fall within the typical range of UTS values for magnesium alloy AZ91, indicating that the material behaves in a predictable and consistent manner under tensile loading.
7. The stir casting process used in this study could be further optimized to produce even higher-quality samples with more consistent mechanical properties.
8. The wire cut EDM method used for sample preparation could also be refined to improve the accuracy and precision of sample dimensions.
9. The results of this study provide valuable information for engineers and materials scientists working with magnesium alloy AZ91, as they demonstrate the material's behavior under tensile loading and highlight potential areas for improvement.

10. Further research could be conducted to investigate the factors that contribute to the difference between the experimental and simulated UTS values, and to develop more accurate simulation methods for predicting the mechanical properties of magnesium alloy AZ91.

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