FATIGUE BEHAVIOUR OF Al-Mg-Zr ALLOY AND MODIFICATION OF MICROSTRUCTURE BY USING FRICTION STIR PROCESSING.

PAMPADE SATISH KUMAR[1], NISHANI YASHWANTH K[2], NAGESH[3],

VISHAL KUMAR B[4].

[1] *Student, Mechanical Engineering, Rajarajeswari college of Engineering, Karnataka, India.*

[2] *Student, Mechanical Engineering, Rajarajeswari college of Engineering, Karnataka, India.*

[3] *Student, Mechanical Engineering, Rajarajeswari college of Engineering, Karnataka, India.*

[4] *Student, Mechanical Engineering, Rajarajeswari college of Engineering, Karnataka, India.*

ABSTRACT

Al-Mg-Zr alloy plays a virtual at the present modern industrial sectors. Preparation of Al-Mg-Zr Alloy is light in weighted, high strength, extremely hard materials which are useful for every industrious like Aerospace, Motor vehicles, mechanical tools manufacturing industries due to its advantageous properties like the light in weight, high strength, flexibility, hardness, simplicity and easily applicable and so on. At the centre of research and growth of these sectors, this project emphasizes understanding the fatigue behavior of Al-Mg-Zr alloy and modification by using friction stir processing. This sample was tested under fatigue properties. According to the ASTM (American society for testing and materials) standard testing procedure.

KEYWORD: - *Composite materials of Al-Mg-Zr alloy, Casting process, Friction stir processing, SEM (scanning electron microscope), Fatigue test.*

---

1. INTRODUCTION:

In material science, Fatigue is a weakening of a material caused by repeatedly applied loads. It is a progressive and localized structural material due to cyclic load. The nominal maximum stress value that causes such damage may be less than the ultimate tensile strength of the material.

Repeated loading and unloading material leads to fatigue. If loads are above a certain threshold microscopic cracks will be beginning to format the stress concentrators such as surface, PCB (Persistence Band Slip), grain interfaces in some of the metals. When the crack reaches critical sizes, the crack propagates suddenly and the structure will fracture. Due to mechanical causes, the estimated fatigue accounts for ~90 % service failures. Fatigue failure data is usually initiated at a site of stress concentration. The term fatigue is borrowed human reaction of 'tiredness' due to repetitive work. Engineering fatigue data is usually plotted as S-N curve. Here S is the stress and N is the number of cycles to failure.

1.1 FACTOR OF EFFECTING FATIGUE FAILURE:

Geometry and microstructural aspects also play an important role in determining fatigue life. Fatigue can be classified in 2 ways are based on load and their environment. On basic of load, fatigue can be divided into two types of High cycle fatigue and low cycle fatigue. On the basis of their environment, a different type of fatigue failure is corrosion fatigue, thermal fatigue, etc. Stress concentration from both these sources has a deleterious effect. Residual play the same role. A corrosion environment can have a deleterious interplay with fatigue**.**

1.2 THE PROCESS OF FATIGUE CONSISTS OF THREE KEY STAGES:

Component that can fail by fatigue are usually subjected to different stages of crack growths. Initial fatigue damage, crack propagation, sudden fracture.

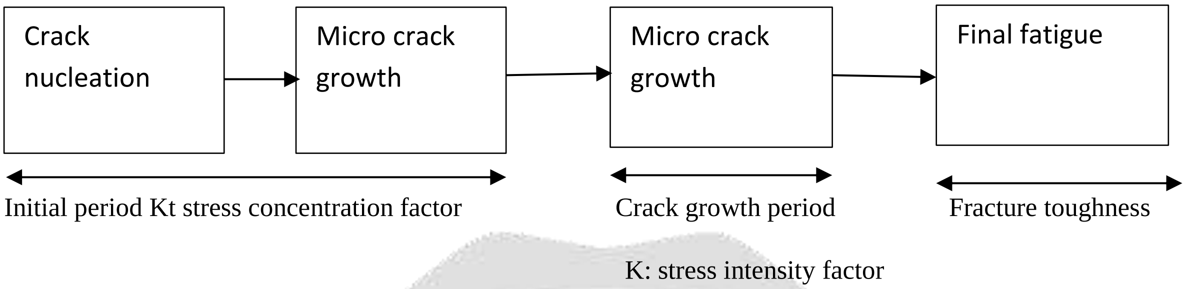

Fig 1 stages of fracture

1.3 COMPOSITE OF MATERIALS Al-Mg-Zr ALLOY:

In the fatigue test, in the composite material of Aluminium alloy is magnesium, zirconium materials. These materials having their own physical, chemical, and thermal properties. In aluminium, it is a 1xx.x series alloy. It is like steel, brass, copper, lead, or titanium. It can be melted, cast, formed and machined much like these metals and it conducts electric current. Aluminium is very light metal with a specific weight of 2.7g/cm^3. Aluminium is good corrosion resistance, it naturally generates a protective oxides coating and high corrosion resistant. and aluminium is a good electrical and thermal conductivity. In magnesium is a gray-white lightweight metal, two-thirds the density of aluminium and it is a 5xx.x series alloy. It is highly flammable, it is relatively soft compared to aluminium material, it is a strong activities corrosion. In zirconium material, it is greyish-white, soft, ductile, malleable metal and Zirconium is a 9xx.x series alloy material.

Table 1 mixture of alloys

Alloy	Aluminum	Iron	Copper	Manganese	Magnesium	Zinc	Zirconium
Casted alloy	96%	-	-	-	4-5%	-	0.04%
5xxx	95.85-98.56%	0.7%	0.4%	0.15%	0.8%	0.25%	0.05%

2 OBJECTIVES

As we know the aluminium alloys commonly used in aircraft structures is high strength alloys and high strength aluminium alloys in convention lack some important properties such as weldability, fatigue life, corrosion resistance…etc. Due to which alternatives has to be made to overcome their inabilities and the alternatives have their own disadvantages. For example, due to poor weldability, fasteners take the role and since stronger material has to be used as fastener the due to metal-metal interaction corrosion may occur and if the material lacks corrosion resistance the material has to be coated with corrosion resistance coating which may increase the weight of the structure. Hence we decided to cast aluminium alloy which has high strength as well as other important properties mechanical properties.

- To prepare specimen of Al-Mg-Zr alloy plate or rod through processing.
- Microstructure of different pre-forms is studied by standard metallographic Procedures.
- To conduct fatigue test through welded Al-Mg-Zr alloy plate on RR more experiment.
- The results are to be plotted in the form of S-N curve.
- Proctographic studies would be performed by revealing the worn-out surface by Scanning Electron Microscope.

3 EXPERIMENTAL PROCEDURE:

3.1 SAND CASTING: Sand casting is the most versatile method for producing aluminium cast products. The process starts with a pattern that is the same as that of the finished cast product. In this process, the pattern is pressed into fine sand mixed with binders to form a mold in which liquid alloy is poured. The melt is poured into the cavity and allowed to solidify. Compared to permanent die or mold casting, sand casting is a slow process but more economical for small quantities. As a result of low thermal conductivity of sand, the cooling rate is very low resulting in casting of less strength. Complex shapes could not be cast using sand casting. We are getting material of 270mm*70mm* 5mm of length, width and thickness respectively.


Fig.2 Casting process of Al alloy

3.2 MILLING:

The removal of material from a workpiece to obtain a required object is called as machining. Any machining will be conducting this procedure but grinding machine procedure is too costly and good finishing will occur in the result. But we selecting the milling procedure because its cost is less and also good finishing. The Milling procedure is used to cut off the unwanted materials from the workpiece with cutting blades. Milling is carried out by moving the workpiece toward a fixed rotating blade and the work pieced is shaped to desired shapes. Milling can be also used to smoothening of the surface by replacing cutting blades with blades having an abrasive surface.

Fig3.1 milling operation

3.3 FRICTION STIR PROCESSING

The permanent joining of two materials by liberating an enormous amount of heat energy is called as welding. Friction stir welding uses in our project, it is a rotating cylindrical, shouldered tool with a profiled probe penetrates into the material until the tool shoulder contact with the upper surface of the plates. Frictional heat generated between the wear resistant welding tool and the material of the workpiece. This is mainly focused on optical speed (1200-1500) rpm, feed rate (40-100) mm/sec.

Fig 3.2. Friction stir processing

4 MICROSTRUCTURE:

SCANNING ELECTRON MICROSCOPE:

A scanning electron microscope (SEM) is a device by scanning the surface with a focused beam of electrons that produces images of the sample is called a Scanning Electron microscope (SEM).

4.1 PRINCIPLE OF SCANNING ELECTRON MICROSCOPE (SEM):

The scanning the electron microscope was invented by Manfred von Ardenne.It is surface microscope uses the behavior of electrons to create an image. most important the 3D image is formed.

It works based on the principle of scattering of electrons on the surface of the sample when electrons are bombarded from the source either they get reflected or absorbed or through the sample, In these case scanning electron microscope the image is scanned therefore the electrons get reflected from the sample or detected and these are used in this technology. The electron source gets bombarded on the sample and some electrons get passed through the sample which is called as scattered electrons are used in the TEM microscope but here we use the secondary electrons that comes through the reflected source. When these electrons bombarded on the sample are reflected as the secondary electrons, backscattered electrons, X-rays but all the secondary electrons detected are directly used by scanning electron microscope technology. In scanning electron microscopy electron beam scans object in Raster scan pattern i.e., scanned side by side so that the 3D image is formed. The secondary electrons are detected by electron detectors it is the path of microscope which process the secondary electrons and finally the 3D image has created this process is called a scanning electron microscope (SEM).

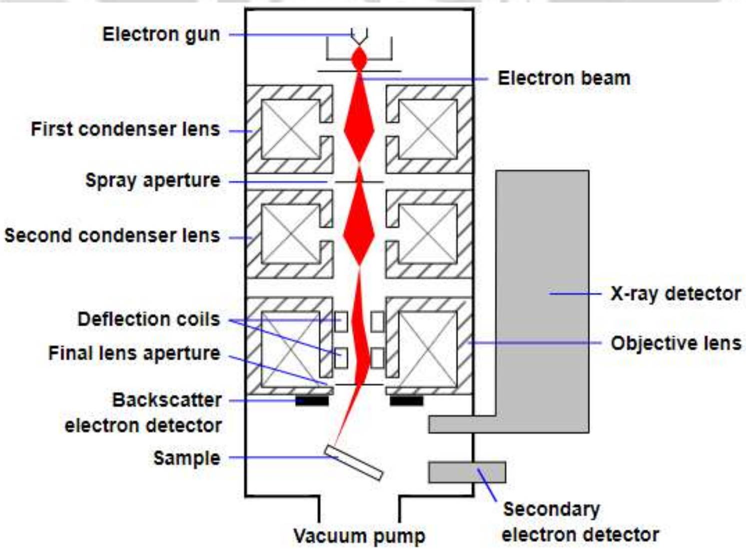

Fig3: Scanning Electron Microscope (SEM)

5 FATIGUE:

It's defined weakening of material caused by repeatedly applied loads is called as fatigue. It is the progressive and localized structural damage in a material due to cyclic loading. The nominal maximum stress values that causes such damage should be much less than the ultimate tensile strength of the material. Repeated loading and unloading of a material results in fatigue.

5.1 FATIGUE LIFE:

Fatigue is defined as the failure of a material due to cyclic loads (lower than its yield strength) applied on the material. Fatigue life is defined as the number of cycle the material can undergo for an applied load and fatigue strength is determined as the amount of load the material can withstand for a given finite number of cycles. Fatigue limit of a material is defined as the margin of load below which the material can withstand infinite number of cycles, only some high strength metals such as aluminium alloys and steel alloys and titanium alloys has fatigue strength.

In tensile fatigue cyclic tensile load is applied and in creep-fatigue cyclic load is applied under elevated temperatures, torsional fatigue involves cyclic torsional loads, fretting fatigue occurs due to wear of the material and in rotating bending load is applied over rotating material.

The type of fatigue testing we have done is rotating bending fatigue. The specimen has been shaped to specimen according to ASTM standard is tested on the rotating bending fatigue testing apparatus to determine the fatigue life of the alloy

Fatigue test is conducted to find the endurance limit of the alloy. Here High Cycle Fatigue (>107 cycles) test of the alloy is done on TEC-SOL INDIA Rotating Beam Bending fatigue testing machine with LAB VIEW software. The fabricated alloy of predetermined chemical composition was utilized to prepare specimens for the fatigue test. The specimens were machined having a total length of 200mm with a gauge length of 100mm. The diameter of the specimen is 11.8mm while the neck diameter is 9mm. The machined samples were mounted on the chucks of the machine. The load chuck consists of a load cell which detects the applied load and sends the data to the software and it is displayed on the screen. The samples are tested at various loads in minimizing order and the number of cycles run by the sample at different load is noted. The test is continued until a sample withstand more than 107 cycles. Then stress Vs. The number of cycle graph is plotted.

6 RESULTS AND GRAPHS

6.1 FATIGUE TEST

Fatigue properties of Al-Mg-Zr alloy depends on various factors, they are mainly microstructural features and casting defects. Microstructural features include primary Si, eutectic Si intermetallic, slip bands and grain size, casting defects include pores and oxides. Pores decrease the time for crack initiation by creating a high stress concentration in the material near to the pores. As a result of this most of fatigue life is spent in crack growth. Single shrinkage pore at the surface or close to the surface is considered to be more critical than the gas pore. Presence of impurities as inclusions can also affect the fatigue properties

S-N GRAPH

Fig.6.1 Fracture specimen

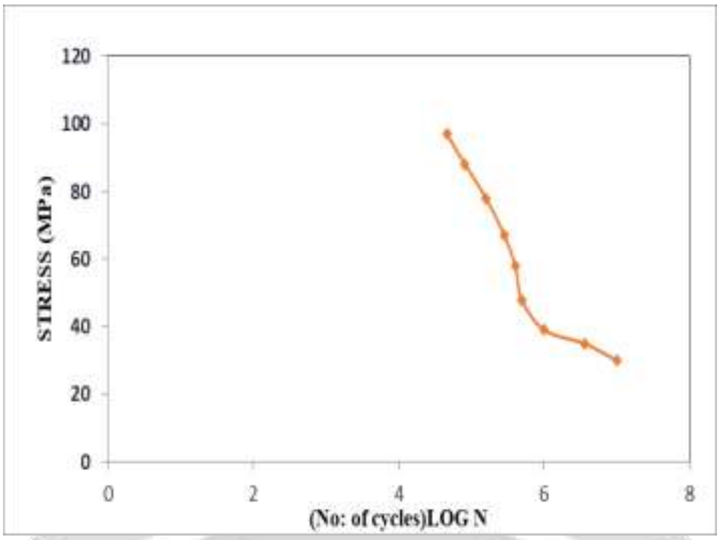

Fig.6.2 S-N graph for fabricated alloy

LOAD TO NUMBER OF CYCLES FOR FABRICATED ALLOY:

Sl. No.	Stress(MPa)	No: of cycles
1	97	47,689
2	88	82733
3	78	161568
4	67	290969
5	58	400052
6	48	481714
7	39	925684
8	35	10000734
9	30	13000958(continued)

Table5: Load to number of cycles on fabricated all

5.2 MICROSTRUCTURE:

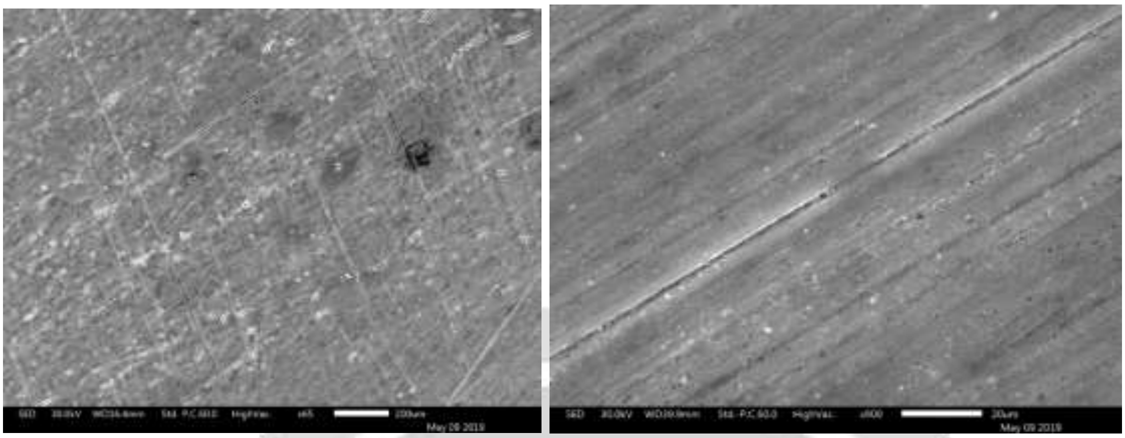

Fig5.3 With friction stir processing

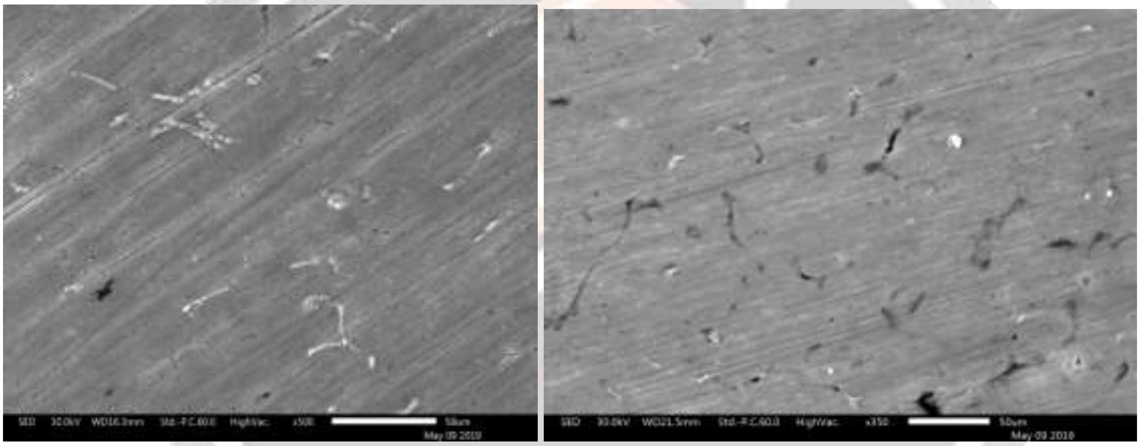

Fig5.4 Without friction stir processing

7 CONCLUSIONS:

Due to the wealth of materials on fatigue available on fatigue failure for research works, it was quite challenging to sieve through these useful materials and come up with the most relevant ones to the task at hand. Despite this fact, tremendous effort was put into this work to select the most relevant information necessary for designers and researcher.

Perhaps, works such as this will inspire young engineers to design structures that can withstand fatigue loading. Although numerous work has been done on fatigue failure and testing methods, much still need to be done perhaps in a new dimension, I observed that engineering students are introduce to the principle of fatigue towards the end of their bachelor studies or early masters' studies. I strongly suggest that students should be introduce to the principle of fatigue failure right from their first year alongside other testing (tensile test, hardness test and the rest) and also much more collaboration between engineers and materialist is needed so as to tackle the problem of fatigue failure.

8 AKNOLEDGEMENT

We feel immense pleasure in showing my gratitude to all the people who have made this work possible, by offering help and guidance whenever required. The people whom we list below are deeply acknowledged for their contribution and support. It brings a sense of privilege to associate this work with the name of my guide

Associate Professor Mr. Suresh D working under whom has been a precious opportunity. We are grateful to **Dr. Ramesh C**, **Head of Department** for providing me this opportunity to work. special thanks to **Dr. Balakrishna Rayanki**, Principal Rajarajeswari college of Engineering for leading a helping hand in completion of our project.

7 REFERENCES

[1 R. Lee, “The Outlook for Population Growth,” Science, vol. 333, no. November, pp. 569–573, 2011.

[2] P. Livieri and P. Lazzarin, “Fatigue strength of steel and aluminum welded joints based on generalized stress intensity factors and local strain energy values,” International Journal of Fracture, vol. 133, no. 3, pp. 247–276, 2005.

[3] I. A. Ashcroft and A. D. Crocombe, “Modelling Fatigue in Adhesively Bonded Joints,” in Modelling of Adhesively Bonded Joints (L. F. M. da Silva and A. Öchsner, eds.), ch. 7, pp. 183–223, Springer-Verlag Berlin Heidelberg, 1 ed., 2008.

[4] N. E. Dowling, “Fatigue of Materials: Introduction and Stress-Based Approach,” in Mechanical Behaviour of Materials, ch. 9, pp. 468–470, Pearson Education Limited,4 ed., 2013.

[5] E. Oberg, F. D. Jones, H. L. Horton, and H. H. Ryffel, “Welding,” in Machinery’s Handbook, ch. 57, pp. 1496–1549, Industrial Press, Inc., 30 ed., 2016.

[6] D. Kaplan and G. Murry, “Thermal, Metallurgical and Mechanical Phenomena in the Heat Affected Zone,” in Metallurgy and Mechanics of Welding (R. Blondeau, ed.), pp. 89–131, London, UK: ISTE, 2010.

[7] E. Halmøy, “Introduksjon,” in Sveiseteknikk, pp. 1–14, Institutt For Produktutviklingog Produksjon, Norwegian University of Science and Technology,2007.