

EFFECT OF LASER SHOCK PEENING ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF ZE41 Mg ALLOY

*Report submitted to the SASTRA Deemed to be University
as the requirement for the course*

MEC 300 MINI PROJECT WORK

Submitted by

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December 2021



SCHOOL OF MECHANICAL ENGINEERING

THANJAVUR, TAMIL NADU, INDIA – 613 401



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Bonafide Certificate

This is to certify that the report titled “**Effect of LASER Shock Peening on Microstructure and Mechanical Properties of ZE41 Mg Alloy**” submitted as a requirement for the course, **MEC 300 Mini-project Work** for B.Tech. Mechanical Engineering, is a bonafide record of the work done by **Mr. Dinesh Kumar B (Reg. No.122009050)**, **Mr. Moulish Kumar R (Reg. No.122009146)** and **Mr. Praveen S (Reg. No.122009183)** during the academic year 2021-22, in the School of Mechanical Engineering, under my supervision.

Signature of Project Supervisor

: 

Name with Affiliation

: Dr. P. Dinesh Babu

Associate Professor – School of Mechanical
Engineering

Date

: 23-December-2021

Mini-project Viva-voce held on _____

Examiner 1

Examiner 2



SCHOOL OF MECHANICAL ENGINEERING

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Declaration

We declare that the report titled “**Effect of LASER Shock Peening on Microstructure and Mechanical Properties of ZE41 Mg Alloy**” submitted by us is an original work done by us under the guidance of **Dr. Dinesh Babu P, Senior Associate Professor, School of Mechanical Engineering, SASTRA Deemed to be University** during the final semester of the academic year 2021-22, in the **School of Mechanical Engineering**. The work is original and wherever We have used materials from other sources, We have given due credit and cited them in the text of the report. This report has not formed the basis for the award of any degree, diploma, associate-ship, fellowship or other similar title to any candidate of any University.

Signature of the candidate(s) : 



Name of the candidate(s) : Dinesh Kumar B
Moulish Kumar R
Praveen S

Date : 23-December-2021

Acknowledgement

At the very outset of this report, we would like to extend our sincere and heartfelt obligation towards all the personages who have helped us to complete the Project. Without their active guidance, help, cooperation and encouragement, we would not have made headway in the project work.

It is our pleasant duty to express deep sense of gratitude to our Honourable Vice chancellor **Dr. S. Vaidhyasubramaniam**, SASTRA Deemed to be University the paramount of the institution, for his patronage and **Prof. R. Chandaramouli**, The Registrar, SASTRA Deemed to be University for providing us the necessary facilities to carry out this work in our university campus.

Foremost, we would like to express our sincere gratitude to our project guide **Dr. P. Dinesh Babu** for his continuous support towards our project work, with patience, motivation, enthusiasm, and immense knowledge. We are ineffably indebted to him for the conscientious guidance and encouragement to accomplish this project work successfully.

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Abstract

Name: Dinesh Kumar B

ZE41 Mg amalgam has as of late been proposed for car, hardware, biomedical and aviation applications. The ZE41 combination has exceptionally moo thickness, tall particular quality, and great castability and weldability characteristics compared to aluminium and steel-based combinations. Be that as it may, the uncontrolled erosion is the most impediment of Mg which is being tended to by a few courses such as alloying, creating composites, surface coatings and microstructural alteration. Within the show ponder, ZE41 Mg combination has been treated by LASER stun peening prepare to attain grain refinement. At that point the impact of adjusted microstructure on mechanical properties will be dissected by hardness, malleable test.

Specific Contribution

- Literature survey
- Derivation of suitable method to overcome the drawback of the metal
- Results, Presentation and Final report

Specific Learning

- Complete understanding of Tensile property of ZE41 Mg alloy
- Microstructure change caused by LASER Shock Peening method on any specimen

Abstract

Name: Moulish Kumar R

ZE41 Mg alloy has recently been proposed for automotive, electronics, biomedical and aerospace applications. The ZE41 alloy possesses very low density, high specific strength, and good castability and weldability characteristics compared to aluminum and steel-based alloys. However, the uncontrolled corrosion is the main limitation of Mg which is being addressed by several routes such as alloying, developing composites, surface coatings and microstructural modification. In the present study, ZE41 Mg alloy has been treated by LASER shock peening process to achieve grain refinement. Then the effect of modified microstructure on mechanical properties will be analysed by hardness, tensile test.

Specific Contribution

- Literature survey
- Derivation of suitable method to overcome the drawback of the metal
- Results, Presentation and Final report

Specific Learning

- Complete understanding of Tensile property of ZE41 Mg alloy
- Microstructure change caused by LASER Shock Peening method on any specimen

Abstract

Name: Praveen S

ZE41 Mg alloy has lately been proposed for automotive, electronics, biomedical, and aerospace programs. The ZE41 alloy possesses very low density, high particular strength, and exact castability and weldability characteristics compared to aluminium and steel-based totally alloys. but uncontrolled corrosion is the main difficulty of Mg which is being dressed by using several routes which include alloying, developing composites, surface coatings, and microstructural amendment. inside the present study, ZE41 Mg alloy has been treated by using the LASER shock peening technique to attain grain refinement. Then the impact of modified microstructure on mechanical houses could be analysed by using hardness, tensile take a look at.

Specific Contribution

- Literature survey
- Derivation of suitable method to overcome the drawback of the metal
- Results, Presentation and Final report

Specific Learning

- Complete understanding of Tensile property of ZE41 Mg alloy
- Microstructure change caused by LASER Shock Peening method on any specimen

CHAPTER 1

INTRODUCTION

1.1 Overview:

ZE41 a Magnesium alloy a steel-based alloy recently proposed for automobile, aerospace and industrial application and widely used in all the major industries in the world where reduction of weight is important, ZE41 proposed as the substitution for aluminum in automobile and aerospace industries.

ZE41 possesses a very low density, high castability as it suited for high integrity casting high weldability and high specific strength, and possesses a great physical property and has all the required qualities to replace aluminum [3]

1.2 Manufacturing Process:

Using conventional method ZE41 is formed by casting process. Heat treated from 177-343°C for 10 to 16 hours, followed by water quenching and welded by TGI process with filler rod

1.3 Drawbacks:

Despite of having good usage in industries and adaptability, the main drawback is uncontrolled corrosion of Mg alloy and physical properties in compared with aluminium alloy, which can be addressed by various method such as alloying, developing composites, surface coating and microstructural modification.

1.4 Motivation:

As there are enormous usage of aluminium in the industries it will be an interesting task to find a better replacement and make it accessible to all kind of industries and finding the better way to eradicate the common physical problems faced in automobiles due to aluminium.

CHAPTER 2

OBJECTIVE

Firstly, the main objective is to increase the tensile properties of ZE41 by adapting required methodology by increasing residual and microstructure refinement.

Adapting required methodology to increase the compressibility stress of the microstructure and thereby increasing the hardness of the ZE41 and comparing with the base metal configuration.

And concluding with microstructure analysis with Scanning Electron Microscope (SEM) and comparing with the base metal configuration, and providing the final result based on the observations made.

CHAPTER 3

METHODOLOGY

3.1 Metal Cutting:

ZE41 a delicate steel-based metal used in aerospace application need a careful consideration when cutting into desired shape for further testing, after considering many cutting technologies the **Electric Discharge Machining (EDM)** with iridium wire is used for cutting. This method is also commonly known as Electro Discharge erosion.

The workpiece is immersed in dielectric fluid, the tool acts as cathode and the workpiece acts as anode, both the electrodes is immersed in the dielectric fluid.

The electric spark is created between the electrode and workpiece, this evidence the flow of electric current. Due to continuous flow of the current heat is developed in workpiece which will ranges from **8000 to 1200 degree Celsius** and due to the heat melting of the surface of workpiece where the electric spark is pointed.

The dielectric fluid of deionized water acts as the coolant and also flushes the eroded additional material off the surface.



Fig 3.1 ZE41 before cutting

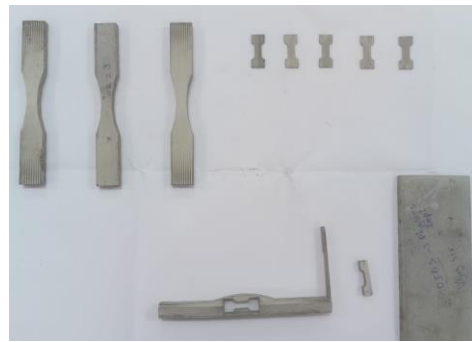


Fig 3.2 ZE41 after cutting

3.2 LASER Shock Peening:

LASER Shock Peening is proved to be one of the best surface treatments to improve the physical properties of metal by increasing the compressibility strength by increasing residual strength and **grain refinement** and **microstructure modification**.

LASER Shock Peening uses a high energy LASER beam hits the metal surface, the plasma waves apply pressure to the metal surface then alter the microstructure shaping and arrangement.

Due to the pressure applied the microstructure volume decrease thence increasing the compressive residual stress in the microstructure, due to the increase in the volume the microstructure pushes the surrounding microstructure grid which is not affected by the LASER Shock Peening and thus the surrounding metallic grid adapt to the enlarged volume of the metallic grid.

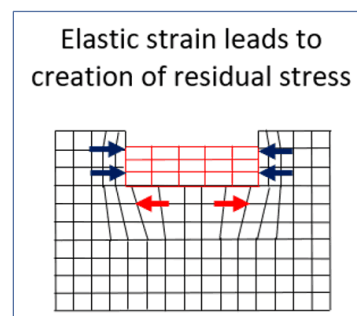


Fig 3.3 Effect of LASER Shock Peening on Microstructure Grid

The affected area tries to push outwards the grid whereas the not affected grid try to recover the original shape, the sum of the opposing forces comprises the total comprises residual stress in the metal which helps in improve the physical properties.

In our case we tend to increase the tensile strength of the specimen by following the LASER Shock peening on the marked region in the middle of the tensile specimen with the following specification.,

Table 3.1 LASER Shock Peening specification

LASER Shot diameter	2 mm
Energy	3 Joules
Number of passes	Single Pass
Total Shots	4
Area	4 mm x 4 mm
Sides	Both sides

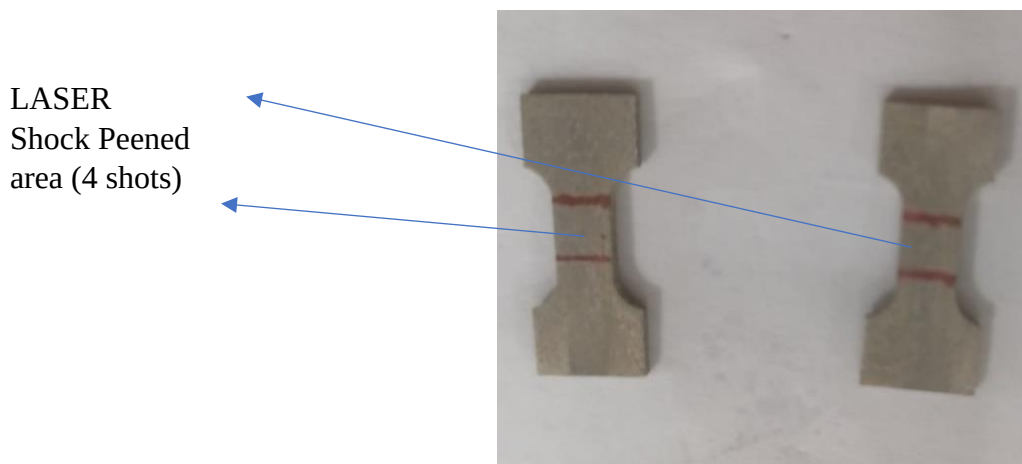


Fig 3.4 LASER Shock Peened area in the Tensile Specimen

3.3 Tensile Testing:

Tensile test is done to determine the various mechanical properties of the material in the universal tensile testing machine under tensile load. The material to be tested is hold firmly in the two jaws upper and lower jaws, the former pulls the specimen in positive Y direction and the later holds the specimen firmly in the static position.

The metal deforms and breaks at a position where all the required properties like **tensile strength, yield strength and elongation** are obtained.

In our cases we tested two tensile specimens in base metal configuration and two tensile specimens after LASER Shock Peened configuration, the changes in value are discussed in upcoming topic.

3.4 Vickers Micro Hardness Testing:

Vickers hardness is also known as micro hardness testing, it uses diamond intender tip to make the rhombus indentation and the hardness is calculated using the measurement of the diagonal of the rhombus using,

$$\mathbf{HV = 1.854(F/D^2)}$$

F – Force being applied.

D – Area of the indentation.

For Vickers hardness testing the specimen need to be polished so the surface will be disturbance free to calculate the indentation, for polishing the surface polished using different grade sheets and disk polishing is done and mirror finish is obtained and the polished surface is tested for hardness in Vickers.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Effect of LASER Shock Peening on Tensile Properties:

Tensile test is done on two tensile specimens in base metal configuration the average value of the ultimate force, ultimate stress and percentage of elongation. Tensile test is done on two Shock Peened metal and the average results are obtained.

The results are distinguished and discussed below.,

Table 4.1 Comparison of physical properties of Base metal and LASER Shock Peened metal

Sl. No:	Properties	Base metal	LASER Shock Peened
1.	Ultimate Stress	134 MPa	168 MPa
2.	Ultimate Force	587 N	692 N
3.	Elongation	9.85 %	11.8%

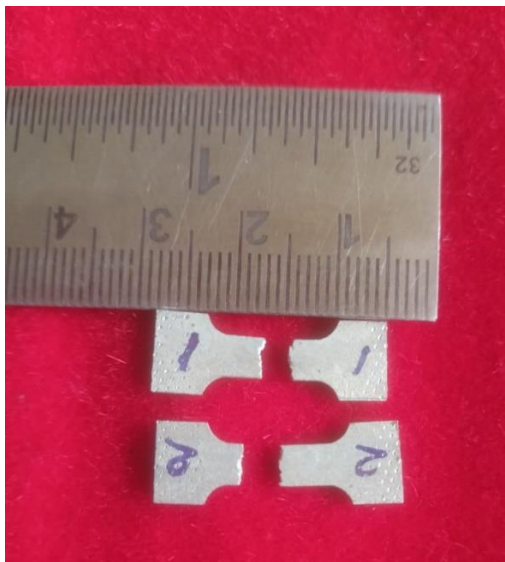


Fig 4.1 Base metal fractured Micro-Tensile Specimen



Fig 4.2 Shock Peened fractured Micro-Tensile Specimen

As comparing Fig 4.1 and 4.2 given above it clearly proves that the LASER Shock Peening is effective surface treatment to improve the physical properties of the metal. In the base metal configuration, the breakage occurs approximately in middle of the specimen whereas in the processed metal the breakage occurs in the area where the LASER Shock peening is not done. And also, the Table 4.1 shows that there is observable change in the physical properties of LASER Shock Peened metal in compared with the base metal.

This proves that LASER Shock Peening alter the microstructure and increase the residual stress by increasing the compressive stress in the metal and provides an enormous improvement in the physical properties.

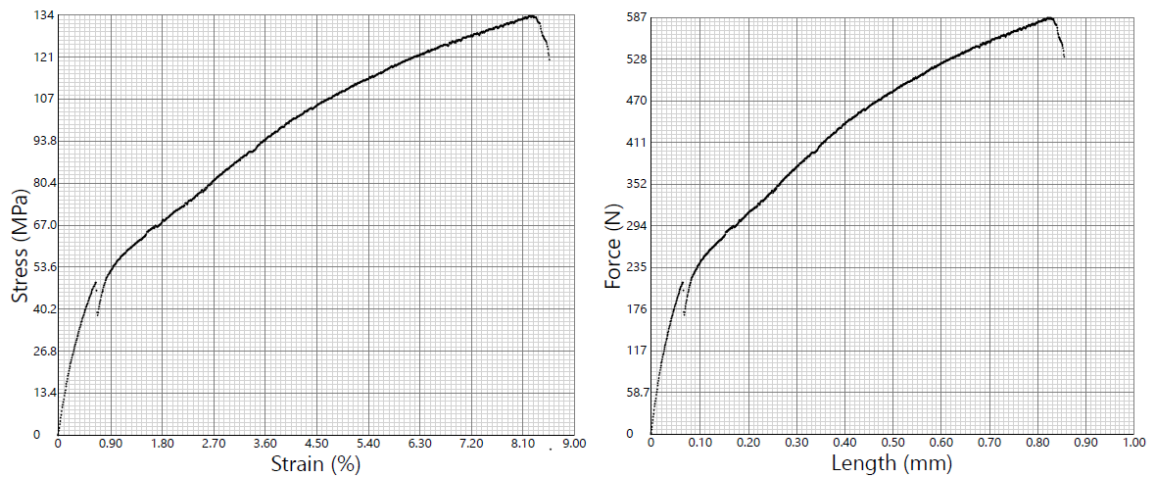


Fig 4.3 Stress - Strain curve and Length - Force curve of Base metal configuration of ZE41

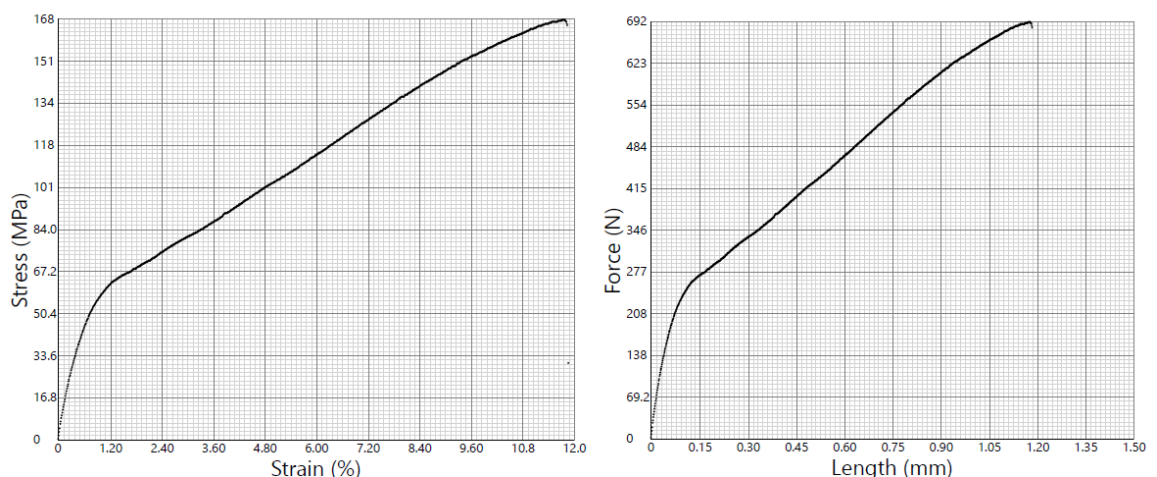


Fig 4.4 Stress - Strain curve and Length - Force curve of LASER Shock Peened metal configuration of ZE41

Fig 4.3 and Fig 4.4 shows the comparison between the base metal and LSP metal in stress-strain graph and force-length graph and shows the improvement in the tensile stress.

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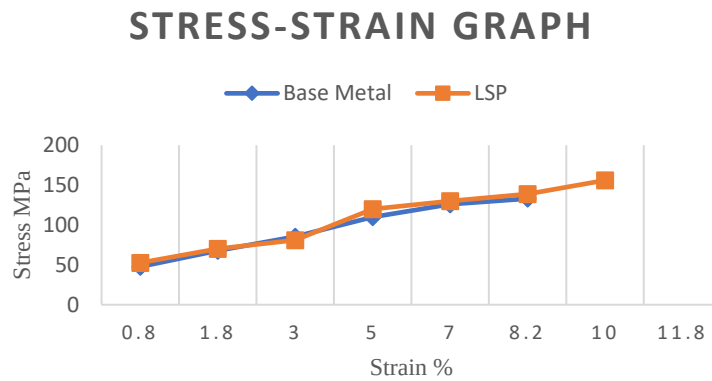


Fig 4.5 Stress – Strain graph comparing base metal and Shock Peened ZE41

Fig 4.5 shows the distribution of the stress and strain comparison between base metal and LSP metal,

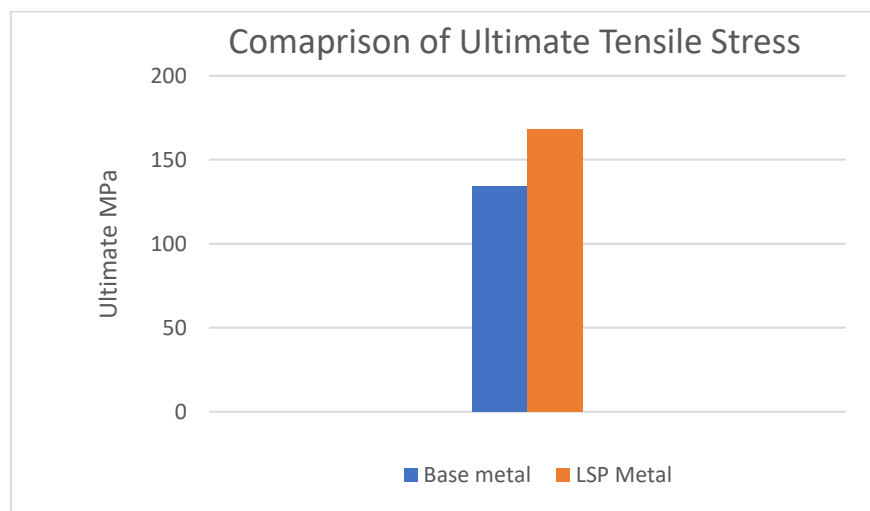


Fig 4.6 Bar comparing Ultimate Tensile Stress of base metal and Shock Peened ZE41

Fig 4.6 shows the bar distribution of Ultimate Tensile Stress of base metal and LSP metal and it is proved that the LSP metal shows an increased Ultimate Tensile Stress in compared with the base metal.

9

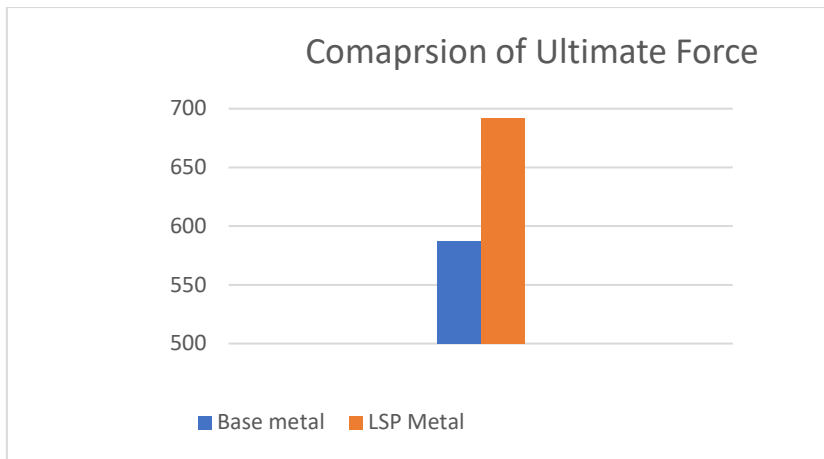


Fig 4.7 Bar comparing Ultimate Force of base metal and Shock Peened ZE41

Fig 4.7 shows the bar distribution of Ultimate force of base metal and LSP metal and it is proved that the LSP metal shows an increased Ultimate force in compared with the base metal.

4.2 Effect of LASER Shock Peening on Hardness:

Vickers hardness test is done on the polished surface and the result is obtained,

Table 4.2 Comparison of base metal hardness and Shock peened metal

Base metal Hardness value	65 HV
LASER Shock Peened Hardness value	78 HV

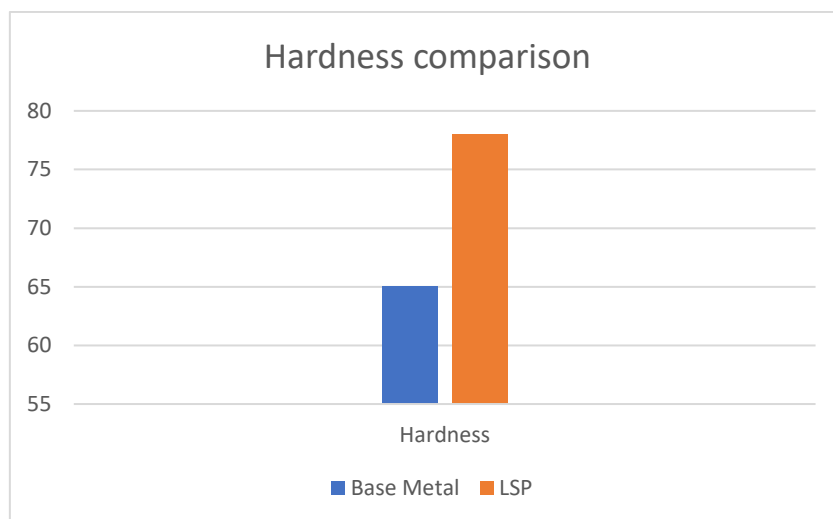


Fig 4.8 Bar comparing hardness of base metal and Shock Peened ZE41

Fig 4.8 shows the bar distribution of Hardness of base metal and LSP metal and it is proved that the LSP metal shows an increased Hardness in compared with the base metal.

4.3 Effect of LASER Shock Peening on Fracture Region:

The SEM image of the fracture region of base metal configuration and LASER Shock Peened metal during tensile test in various magnification is presented below,

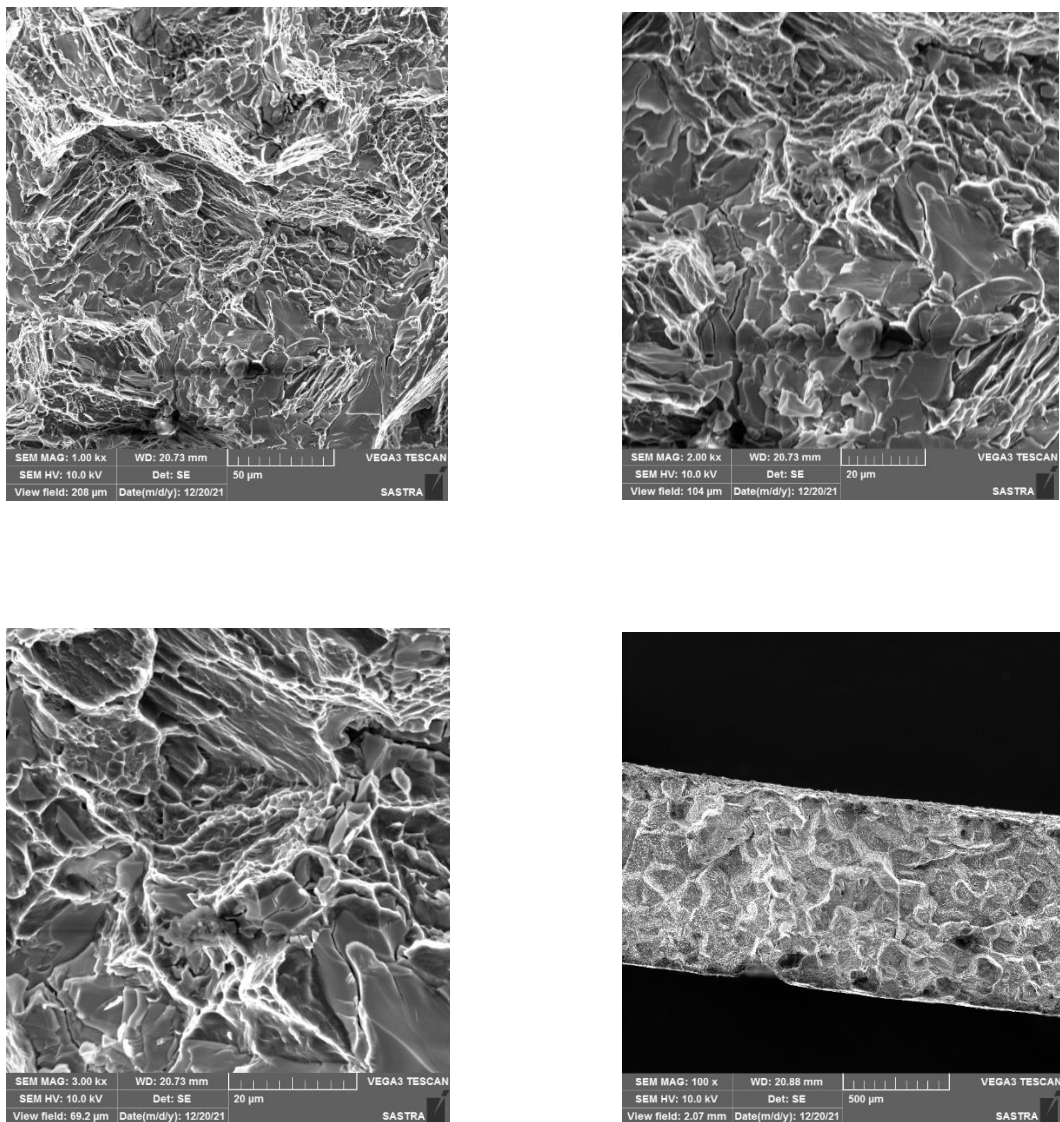


Fig 4.9 SEM images of base metal configuration in different magnification

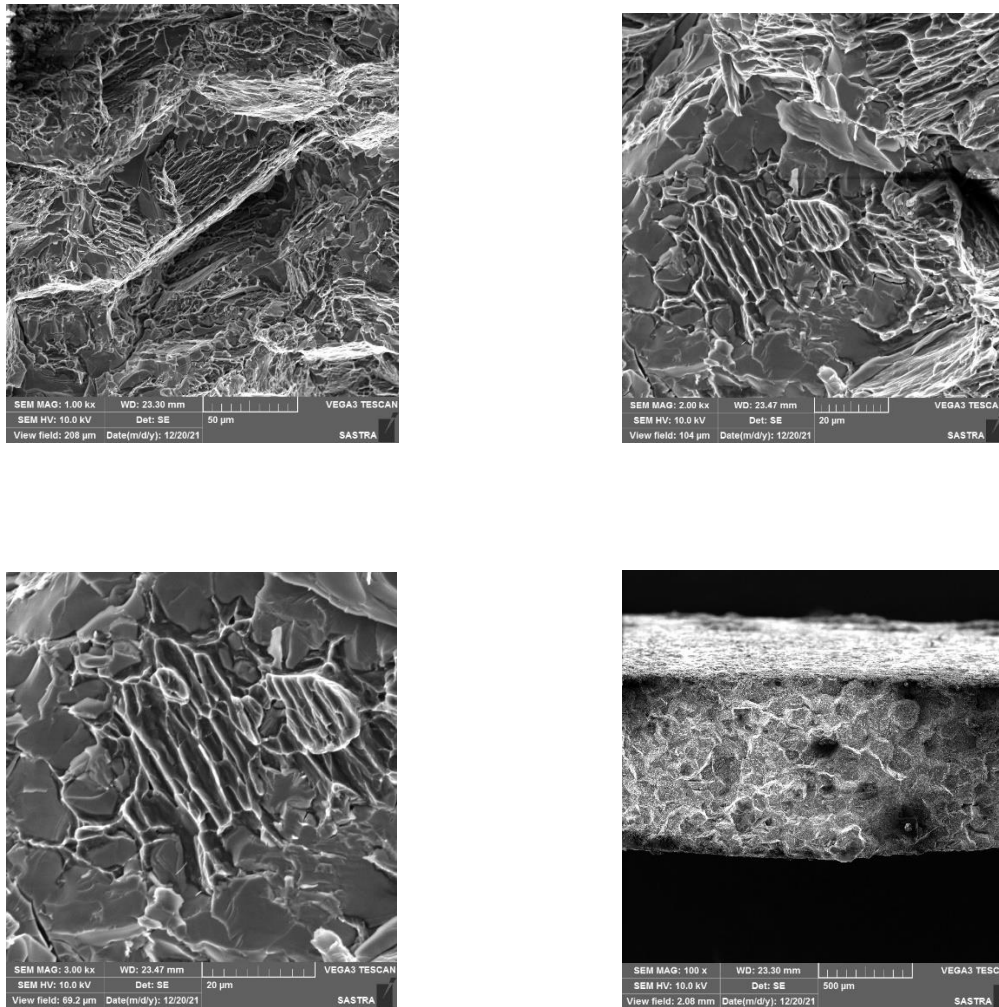
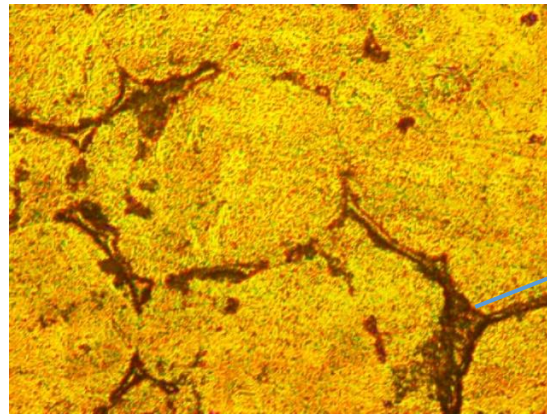


Fig 4.10 SEM images of Shock Peened metal configuration in different magnification

Fig 4.9 and Fig 4.10 shows the Scanning Electron Microscope (SEM) Images of the fracture region of the base metal and LSP metal.

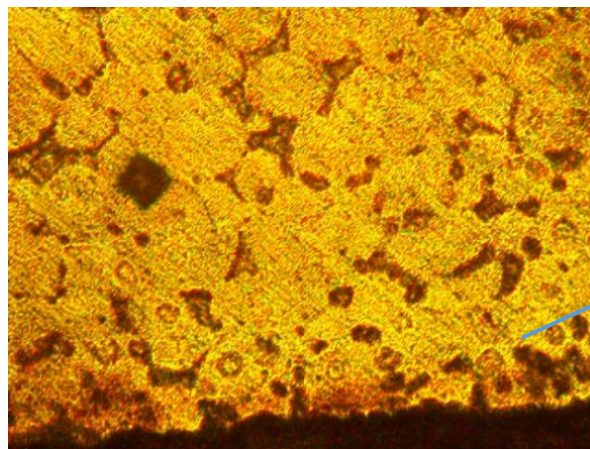
4.4 Effect of LASER Shock Peening on Microstructure:

Microstructure of the ZE41 on the both the base metal and LSP metal is obtained in different magnification and compared and found that the Zirconium ions in the base metal structure is spread across the grain structure and no inferred with the grain boundary of magnesium, whereas in the LSP area the Zirconium is attached to the broken grain boundaries of the magnesium grain which in turn creates residual stress and increases the hardness of the metal as shown in the



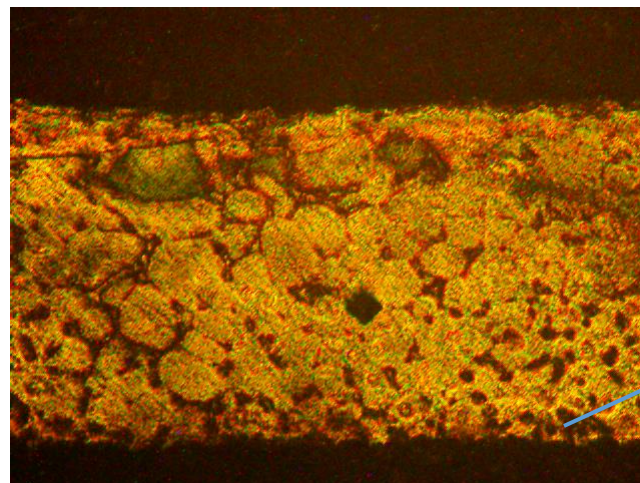
Zirconium on grain boundaries

Fig 4.11 Microstructure of LSP area in 200x Magnification



Zirconium Ions

Fig 4.12 Microstructure of LSP area in 100x Magnification



More compressed grains in the LSP region

Fig 4.13 Microstructure of LSP area in 50x Magnification

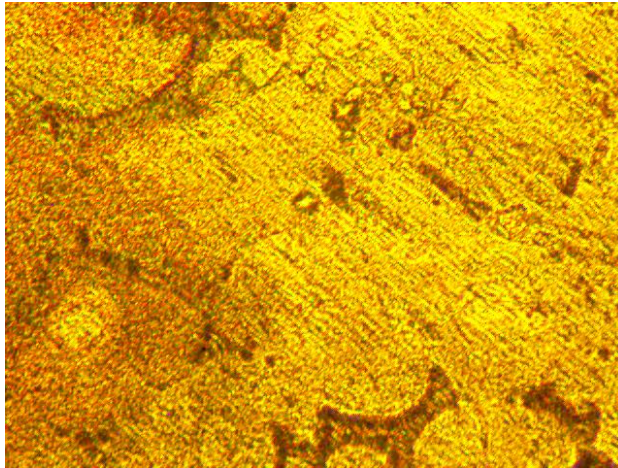


Fig 4.14 Microstructure of base metal in 200x Magnification

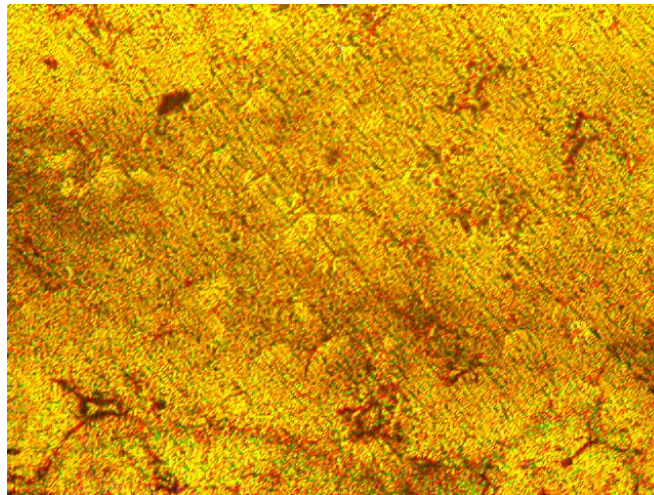


Fig 4.15 Microstructure of base metal in 100x Magnification

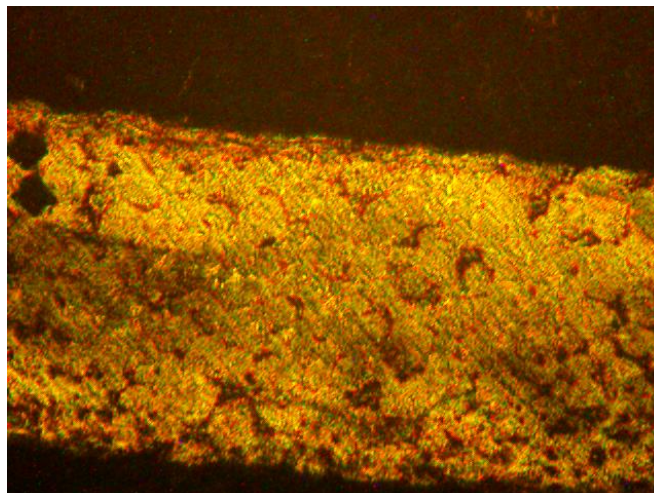


Fig 4.16 Microstructure of base metal in 50x Magnification

Comparing Fig 4.13 and Fig 4.16, LSP [Fig 4.13] has more compressed grains in the 50x magnification and proves that the compressibility stress increase in LSP metal and thus increases the hardness and physical properties.

CHAPTER 5

CONCLUSION AND FURTHER WORK

From the studies done above and the results obtained and comparisons made, it is made clear that the LASER Shock Peening is one of the best surface treatments for improvising the physical properties.

As it shown that the tensile properties and microstructure and grain refinement are improved in the affected metal rather in the base metal configuration.

Further the work can be continued by finding the fatigue resistance value for both base metal and LASER Shock peening of ZE41 and comparing the value and publishing result. Then the corrosion problems can be tested with before and after LASER Shock Peening and further microstructure analysis can be done.

The final conclusion and conclusion are tabulated.,

Table 5.1 Final comparison table

SI No.	Properties	Base Metal	LSP
1.	Ultimate Tensile Stress	134 (MPa)	168 (MPa)
2.	Ultimate Force	587 N	692 N
3.	Elongation	9.8 %	11.8 %
4.	Hardness	65	78

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Junak G (2020) Fatigue properties of AZ31 and WE43 magnesium alloys DOI 10.24425/amm.2020 132811

Parthiban K, Mohan Kumar S, Rajesh Kannan A, Siva Shanmugam N and Sankaranarayananasamy N Microstructure and fatigue behaviour of spin-arc welded AISI C1018 low carbon steel *sagepub.com/journals-permissions* DOI: 10.1177/09544089211027786 *journals.sagepub.com/home/pie*

Allan H. Clauer (1996) LASER Shock Peening for fatigue resistance *LSP Technologies, Inc.* 6145 B Scherers Place Dublin, OH 43016-1272

Grade ZE41 Magnesium Alloy Manufacturing of ZE41

<https://www.azom.com/article.aspx?ArticleID=9966>

How Laser Peening Works, Step by Step <https://www.lsptechnologies.com/how-laser-peening-works/>

Peer Evaluation Form for Group Work

Your name: Dinesh Kumar R

Write the name of each of your group members in a separate column. For each person, indicate the extent to which you agree with the statement on the left, using a scale of 1-4 (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree). Total the numbers in each column.

Evaluation Criteria	Group member: Praveen S	Group member: Moulish Kumar R
Attends group meetings regularly and arrives on time.	4	4
Contributes meaningfully to group discussions.	4	4
Completes group assignments on time.	4	4
Prepares work in a quality manner.	4	4
Demonstrates a cooperative and supportive attitude.	4	4
Contributes significantly to the success of the mini-project.	4	4
Total	24	24

Feedback on team dynamics

1) How effectively did your group work?

Everyone in the group is actively participated in the group meet and pretty helpful in all the activities carried out in the project and everyone supported everyone and all fulfilled their own part.

2) Were the behaviors of any of your team members particularly valuable or detrimental to the team? Explain.

My team mates are very valuable they took part in creating ppt for review when I had class and exams and they supported me in the process.

3) What did you learn about working in a group from this mini-project that you will carry into your next group experience?

Idea sharing and supportive when ideas ran out.

Peer Evaluation Form for Group Work

Your name: Moulish Kumar R

Write the name of each of your group members in a separate column. For each person, indicate the extent to which you agree with the statement on the left, using a scale of 1-4 (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree). Total the numbers in each column.

Evaluation Criteria	Group member: Praveen S	Group member: Dinesh Kumar R
Attends group meetings regularly and arrives on time.	4	4
Contributes meaningfully to group discussions.	4	4
Completes group assignments on time.	4	4
Prepares work in a quality manner.	4	4
Demonstrates a cooperative and supportive attitude.	4	4
Contributes significantly to the success of the mini-project.	4	4
Total	24	24

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Idea sharing and supportive when ideas ran out.

Peer Evaluation Form for Group Work

Your name: Praveen S

Write the name of each of your group members in a separate column. For each person, indicate the extent to which you agree with the statement on the left, using a scale of 1-4 (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree). Total the numbers in each column.

Evaluation Criteria	Group member: Dinesh Kumar B	Group member: Moulish Kumar R
Attends group meetings regularly and arrives on time.	4	4
Contributes meaningfully to group discussions.	4	4
Completes group assignments on time.	4	4
Prepares work in a quality manner.	4	4
Demonstrates a cooperative and supportive attitude.	4	4
Contributes significantly to the success of the mini-project.	4	4
Total	24	24

Feedback on team dynamics

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Idea sharing and supportive when ideas ran out.

Sample Self-Evaluation Form for Group Work

Your name: Moulish Kumar R

	Seldom	Sometimes	Often
Contributed good ideas			Yes
Listened to and respected the ideas of others			Yes
Compromised and Cooperated			Yes
Took initiative where needed			Yes
Came to meetings prepared			Yes
Communicated effectively with teammates			Yes
Did my share of the work			Yes

My greatest strengths as a team member are:

1. Planning of the work which is to be carried out.
2. Ensuring stable work flow at any situation.

The group work skills I plan to work to improve are:

1. Communicating with team mates much more often.
2. Analyse the availability of facilities before starting the process.

Sample Self-Evaluation Form for Group Work

Your name: Dinesh Kumar B

	Seldom	Sometimes	Often
Contributed good ideas			Yes
Listened to and respected the ideas of others			Yes
Compromised and Cooperated			Yes
Took initiative where needed			Yes
Came to meetings prepared			Yes
Communicated effectively with teammates			Yes
Did my share of the work			Yes

My greatest strengths as a team member are:

1. Planning of the work which is to be carried out.
2. Ensuring stable work flow at any situation.

The group work skills I plan to work to improve are:

1. Communicating with team mates much more often.
2. Analyze the availability of facilities before starting the process

Sample Self-Evaluation Form for Group Work

Your name: Praveen S

	Seldom	Sometimes	Often
Contributed good ideas			Yes
Listened to and respected the ideas of others			Yes
Compromised and Cooperated			Yes
Took initiative where needed			Yes
Came to meetings prepared			Yes
Communicated effectively with teammates			Yes
Did my share of the work			Yes

My greatest strengths as a team member are:

1. Planning of the work which is to be carried out.
2. Ensuring stable work flow at any situation.

The group work skills I plan to work to improve are:

1. Communicating with team mates much more often.
2. Analyse the availability of facilities before starting the process

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