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IMPROVING FATIGUE LIFE OF ALUMINIUM GEAR THROUGH CAE

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ABSTRACT:

This paper postulates the study of the improvement in fatigue life of gear by purposeful application of the compressive residual stress layer on the surface of gear. The compressive layer introduced at the surface of gear counteract with the tensile residual stresses. The ultimate effect of this leads to increase the resistance of gear material against the initial crack generation in gear. Shot peening process is used for the generaton of compressive layer on the surface of gear. Shot peening is a cold-working process used mainly to improve the fatigue life. Shot Peening allows metal parts to accept higher loads or to endure a longer fatigue life in service without failure. In usual applications shot peening can be done without changing the part design or its material. If you strike a part surface with a rounded object at a velocity, sufficient to leave an impression and continue until you completely cover (cold work) the entire surface then you will have peened that part. In modern usage peening is

applied by throwing tiny cast steel balls or "shot" at high velocity hence the term "shot peening".

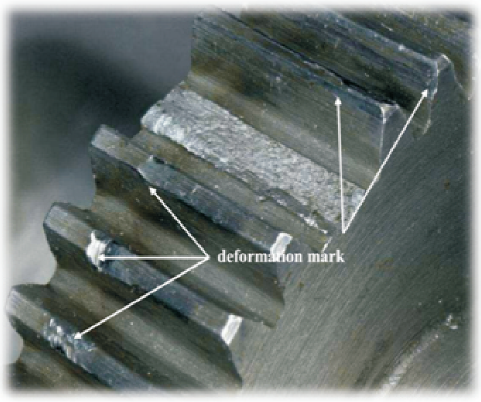
KEYWORDS : Gear, Shot Peening, Residual stress, fatigue.

I. INTRODUCTION:

Gears are used for a wide range of industrial applications. They have varied application starting from textile looms to aviation industries. For many years, gear design has been improved by using improved material, hardening surfaces with heat treatment and carburization, and improves surface finish etc. Few more efforts have been made to improve the durability and strength by altering the pressure angle, using the asymmetric teeth, altering the geometry of root fillet curve and so on.

The gears while transmitting the power develop stresses at the mating positions over the teeth. These stresses are proportional to the amount of power transmitted while the design could offer favorable or adverse conditions for generation of the same. When gears are loaded, they are subjected to forces which are not static but vary in magnitude with respect to time. The stress induced in the gear due to such loading are called as fluctuating stresses. This loading also referred as cyclic loading.

Gear is one of the critically loaded components in industrial area. Gears are commonly used to transmit the power or motion from one source to desired location. Gearing applications range from automotive, to heavy vehicle, to marine transmissions, to axle drive gears, to small gears used in power tools and to very large gears used in transmissions for large ships and mining equipment. The fillets at the root of the gear are usually the areas of high stress and should be shot peened.



Fatigue is a source of major gear damages. Although, traditionally, gears damages are attributed to wear sources, fatigue is responsible for a significant number of gear damages.

Fig.1: Fatigue failure in gear

II. OBJECTIVE

The trend towards smaller, stronger, higher capacity gear transmissions has inevitably increased in all forms of metal hardening and fatigue life extension. The application of the compressive residual stress on the surface of gear is done through the bombardment of small tiny balls using some necessary arrangements. This process is very well known as shot peening process. Shot peening is just one of the applications of shot blasting for increasing the fatigue life of various components subject to fatigue stress. The reduced fatigue failures result in low maintenance and replacement cost for parts like springs, gears, axles and knuckle joints etc. As is well known, the part which fails in fatigue, fails mainly due to its failure in tensile strength. Just as in prestressed concrete at the end of shot peening, the parts are left with residual compressive stress. When the component is subjected to the tensile load, a portion of the tensile stresses set by the load is neutralized by the residual compressive stresses left by the shot peening. Thus the effective load is greatly reduced, resulting in an increased fatigue life even to the extent of 20 per cent, or more. Manufacturers of swords and brass utensils are well known for their denting the surface of the swords or the utensils for better life by round headed hammers called ball peen hammers.

III. MATERIAL AND SPECIFICATION

GEAR SPECIFICATION

Material::Aluminum
Tensile Strength: 180 N /mm2
E= 73 X 105 N/mm2
Poisson Ratio=0.35
Density = 2070 Kg/m3
Outside Diameter = 61.98mm
Pitch Diameter = 58.46mm
Base Circle = 57.174mm
Pressure Angle (α) = 18.63°
Total No. of Teeth = 31

SHOT SPECIFICATIONS:

Material= Steel
E= 2.1 X 10 5 N/mm2
Poisson ratio =0.265
Shot size = 0.5 mm
Density= 7200 Kg /m3

IV. EXPERIMENTATION

FEM

Creating LS-Dyna Model ball Impacting the Plate

Specifications:
Ball: Solid Element, Rigid Material
Plate: Shell Element, Edge Constraint

Parameters to be studied for checking effect of variation

Shot size= 0.5mm, 0.4 mm, 0.30 mm in radius
Shot velocity = 10 to 50 m/Sec
Shot angle= 15° to 90°
Distance between shot & Target = 50 mm, 100 mm, 150 mm, 200 mm

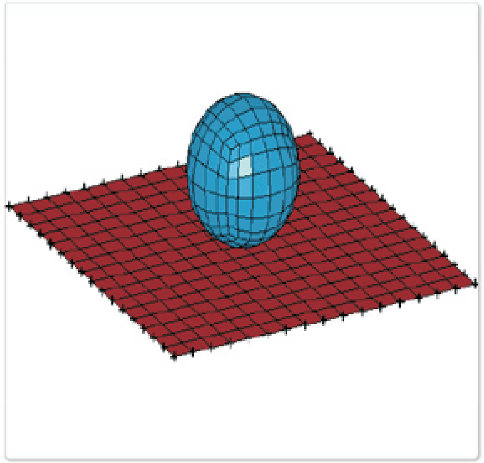
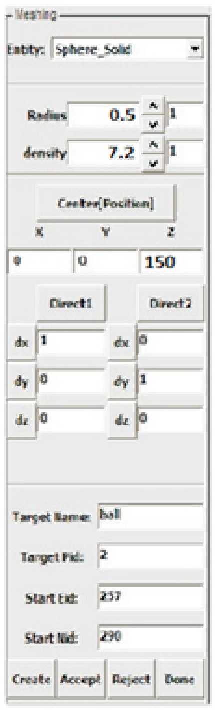


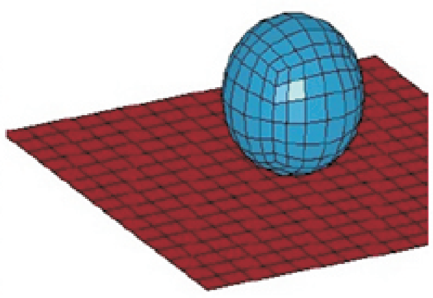
Fig.2: FEA Model

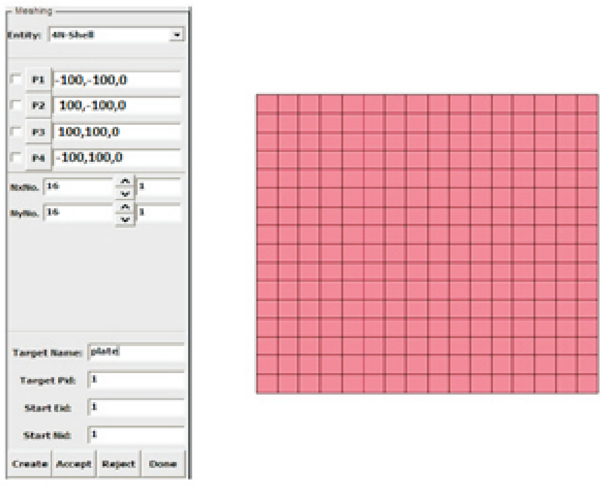
Step 1 Create a Plate

By using Procedure below and defining below properties of plate

Select Entity: 4N Shell
P1=-100,-100,0
P2= 100,-100,0
P3= 100, 100,0
P4=-100, 100,0
NxNo.= 16
NyNo.= 16
Target Name: plate
Click Create
Click Accept
Click Mesh render button







Step 2 Create a Ball

By using Procedure below and defining below properties of ball

Select Entity: Sphere_Solid

Radius= 0.5 mm

Density= 7.2 Kg /m3

Center X=0

Center Y=0

Center Z=50

Target Name: ball

Click Create

Click Accept

Fig.4: Create a Ball

Optimization of parameters

For the optimization of shot peening process done through the FEA moelling through Ls Dyna following factors are taken into consideration.

- Shot Velocity
- Distance between Nozzle and Plate
- Shot Size
- Shot angle

Typical case of inputs for study

Shot size= 0.50 mm

Shot velocity = 25 m/Sec

Shot angle= 90°

Distance between shot & Target = 150 mm

Shot Velocity

Sr. No.	Velocity (m/Sec)
01	10
02	15
03	20
04	25
05	30
06	35
07	40
08	45
09	50

Table1: Iteration with shot velocity

The distance between ball and plate is kept as 150mm. The shot size and angle of shot are kept as 0.5mm and 90° respectively. The output given by Ls Dyna is plotted on the three graphs as follows

• Velocity Vs Residual stress
• Velocity Vs Depth of dent
• Residual stress Vs Depth of dent

Iteration Number	Velocity (m/Sec)	Residual Stress (Mpa)	Depth of dent (mm)
01	10	4.5053463	0.0033136
02	15	6.245002	0.0018954
03	20	7.6566570	0.0014759
04	25	12.124773	0.0018947
05	30	21.900237	0.0031883
06	35	33.444313	0.0042003
07	40	51.205642	0.0050549
08	45	64.198280	0.0056089
09	50	82.818199	0.0061041

Table 2: Results of permanent residual stress and depth with varying velocity

So by considering above factors the optimum velocity can be concluded as iteration number 3 as it produces minimum dent on gear.

For this iteration the value of Velocity is 20m/sec and the residual stress generated is 7.6566570 (Compressive in nature) and depth of dent of 0.0014759 mm.

Distance between Nozzle and Plate

Iteration Number	Distance (mm)	Residual stress (Mpa)	Depth of dent (mm)
01	100	16.23568	0.0010
02	150	15.23695	0.0010
03	200	16.23540	0.0008

Table 3: Permanent residual stress and dent with varying distance between nozzle and target plate

The shot velocity is kept at 20 m/sec. The shot size and angle of shot are kept as 0.5mm and 90° respectively.

In iteration number 3 when the distance from nozzle and plate is 200mm the depth produced is of 0.0008mm. So the iteration number 3 is to be considered as optimized value of distance between nozzle and target.

Shot Size

Sr. No.	Shot size (mm)
01	0.50
02	0.40
03	0.30

Table 4: Iterations with varying size of ball

The size of shot may be selected on various factors such as intensity of peening, available size in the market or percentage of coverage. In this work the size of shot is selected on the behalf of coverage. Larger the size of ball better will be the coverage in less number of shot bombardments. Also a factor is considered that the availability of shot sizes in the market. For current work the optimized value of shot from above consideration is taken as 0.5mm.

Shot angle

Iteration Number	Angle (Degree)	Residual stress (Mpa)	Depth of dent (mm)
01	15	10.112	0.00180
02	25	15.268	0.00200
03	40	9.830	0.00080
04	55	15.226	0.00098
05	65	10.25	0.00100
06	80	5.23	0.00130

Table 5: Permanent residual stress and depth with varying shot angle

The shot velocity is kept at 20 m/sec. The shot size and distance between shot and target are kept as 0.5mm and 200 mm respectively.The results in above table shows that the there is considerable change in the residual stress and depth of dent with varies in angle. Depending on the previous criteria we can optimize the iteration number 3 with 400 angle and 9.83Mpa residual stress with 0.008 mm depth of dent on surface of plate.

By conducting experiments in Ls Dyna we can conclude following optimum values of input parameters,

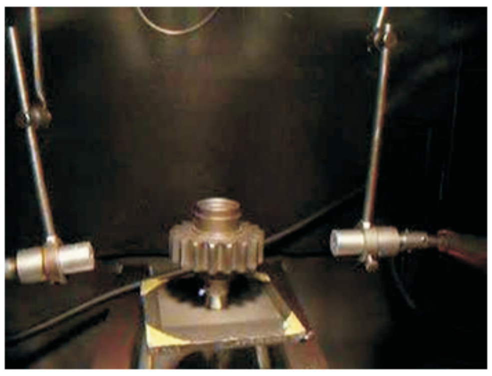
Shot velocity = 20 m/Sec
Distance between shot & Target = 200 mm
Shot size = 0.50 mm
Shot angle = 40°

By giving these input values to Ls Dyna the residual value is calculated as by the procedure explained above we get,

Depth = 0.008505 mm
Residual Stresses = 8.0636 Mpa

EXPERIMENTAL SETUP

The Experimental setup consisting of a table on which the tool holding device is attached to hold toll in proper position as sown. The toll holding device is rotated with help of an electric motor at a constant specified speed. Nozzle arrangement is made in such a way that it is connected to a pressurized chamber through pinch valve. The nozzle can move in horizontal and vertical direction to adjust distance between nozzle and target & peening coverage respectively. The pressurized chamber is filled with appropriate numbers of balls of specified size depending upon applications.



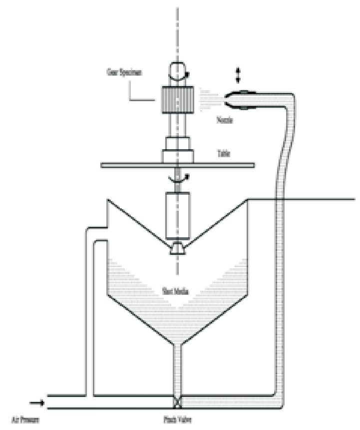


Fig.5: Experimental Set Up

The chamber is connected to a compressor which exerts a pressure of 4.5 Kg/cm2. The diameter of nozzle is 12mm and the table shaft rotates at speed of 11 rpm. Nozzle speed to move horizontally is 2.3 mm/sec.

Testing parameters

Shot velocity	=	20 m/Sec
Distance between shot & Target	=	200 mm
Shot size	=	0.50 mm
Shot angle	=	40°

Fig.6: Shot Peening Setup on Gear Specimen

To calculate residual stresses generated inside the surface we use x–ray diffraction technique (XRD). In x-ray diffraction residual stress measurement, the strain in the crystal lattice is measured, and the residual stress producing the strain is calculated, assuming a linear elastic distortion of the crystal lattice. Although the term stress measurement has come into common usage, stress is an extrinsic property that is not directly measurable. All methods of stress determination require measurement of some intrinsic property, such as strain or force and area, and the calculation of the associated stress.

XRD provides an accurate and well established method of determining the residual stress distributions produced by surface treatments such as machining, grinding and shot peening. XRD methods offer a number of advantages compared to the various mechanical or the non-linear-elastic (ultrasonic or magnetic) methods currently available for the measurement of near-surface stresses. XRD methods are based upon linear elasticity, in which the residual stress in the material is calculated from the strain measured in the crystal lattice, and are not usually significantly affected by material properties such as hardness, degree of cold work or preferred orientation. XRD methods are capable of high spatial resolution, on the order of millimeters, and depth resolution, on the order of microns, and can be applied to a wide variety of sample geometries. The macroscopic residual stress and information related to the degree of cold working can be obtained simultaneously by XRD methods. XRD methods are applicable to most polycrystalline materials, metallic or ceramic, and are non-destructive at the sample surface.

Fig.7: XRD Machine

TEST RESULT

Depth of dent = 0.01 mm
Permanent Residual stress = 9.382 Mpa(Compressive)

IV. RESULT ANALYSIS

Sr. No	Parameter	FEA	EXPT
1	Dept Of Dent (mm)	0.008505	0.01
2	Permanent Residual Stress (Compressive) (Mpa)	8.0636	9.382

Table 6: Result Analysis

V. CONCLUSIONS

Fatigue failure is the main reason that causes the gear to fail at the lower load capacity than it can bear for which they are made. The effect of shot peening on fatigue life of gear was studied, Shot peening introduces the compressive residual stress on the surface of gear. The compressive residual forces improve the fatigue life of gear. The results showed that shot peening can be applied to increase the fatigue life of gear under optimum conditions otherwise we may not get the appropriate results and even it may cause adverse effects. Shot peened gears can be used for carrying high end loads as compared to non peened gears.

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