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Optimization of Diesel Engine Cylinder Liner Undercut

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Abstract:-Current paper presents the optimization results of diesel engine cylinder liner for marine application engines. The liners have shown cracks at the undercut area near adjustment flange between the liners in the cylinder block. This study includes the optimization liner geometry at undercut area. The paper also presents the results obtained for the distribution of stresses and temperatures in the critical areas of the cylinder liner. For calculation of Liner deformation we have considered assembly forces, Gas Pressure and gas temperature. A 2D finite element mesh is used for this study, using axisymmetric elements with reduced integration and reduces time because it is circular part. We used Abaqus 14.0 for stresses calculation and FEMFAT 5.2a for calculation of factor of safety in critical area.

Keywords:-Cylinder Liner, Cylinder Block, Gas Pressure, Temperature, Abaqus 14.0, FEMFAT.

I. INTRODUCTION

The demands on decreased environmental impact from vehicles from the automotive industry to develop engines with reduced engine oil and fuel consumption. Liner is one of the most important functional parts in engine to guide piston in cylinder block in transverse direction and protect piston compression ring and oil ring. The bore in which an engine piston moves up and down may be an integral part of the crankcase or it may be a separate liner. It depends on size and power of engine. Another factor is the big temperature difference on the outside and inside in wet liner which tends to induce thermal stresses and the liner has to withstand those as well. Liner provides a sealing to the expansion of combustion gases and to provide the heat transfer to the cooling liquid that circulates through the engine blocks galleries (in case of dry and wet cylinders). They also allow the re-use/ salvage of the engine block in certain cases. Due to the assembly of cylinder head, crankcase, high temperature and temperature difference between inner and outer side high amplitude stresses induced in liner flange area. Present study is pre - development project for optimization of liner. In old design factor of safety in flange undercut area less than 1 in same area stress concentration is also very high. We are going to reduce stress concentration by changing geometry so factor of safety will be more that 1.2 as per company standard. We have used Creo 2.0 for geometry design, Hyperwork 14.0 for meshing and Abaqus 14.5 for stress, strain analysis and deflection calculation and FEMFAT 5.2a for calculation of factor of safety, mean stress and amplitude stress.

Competitive automotive world cylinder liners should provide with good hardness and wear resistance properties were best chooses to provide customer satisfaction and lower fuel consumption. It not only provides cylinder liners with good wear resistance but also improves the standards of customer satisfaction and also acts as an important heat treatment process compared to other traditional techniques [1].

The alterations in the geometry of the critical zone of the cooling channel of the liners (modified design of the liners), where stress corrosion pitting and cracking were prematurely observed in service, produced a small improvement in the stress distribution in that zone, as against the distributions obtained for the original design of the liners. However, the values obtained for the radial stress in that zone, using a 2DFE package with axisymmetric elements, are still high for both designs of the liner, which creates a great potential for the development of stress corrosion and corrosion fatigue pitting [2].

II. PROBLEM DEFINATION

This Liner is used for new engine development for marine application having power output bore and stroke has been decided. In first version of Cylinder liner it is observed that factor of safety of liner under flange is less than 1 but as per standards it should be more than 1.2.

This is the water cooling groove near the top load bearing seating zone of the liner with the cylinder block. This groove is a channel where cooling water circulates at very high pressure and speed to keep the water temperature below 90 °C. Cylinder liners in diesel engines are subjected to low cycle fatigue (LCF), mainly due to starts and stops of the engine. In the wet type designs LCF is aggravated by corrosion and, hence, stress corrosion and corrosion fatigue may occur in high stress concentration areas, such as in grooves and assembly notches.

After studying all parameter we have concluded that by optimizing groove geometry we can reduce stress concentration and increase the factor of safety. The liners were assembled to the cylinder block at room temperature. The

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initial tolerance was a sliding fit with manual light pressure belonging to the class h6; j5 in the contact zone of the upper part, and h6; f5 for the bottom contact zone after the second cooling channel.

There is clearance between cylinder liner and crankcase (cylinder block). Also O-Rings are used to seal the oil area.

Engine Specification:

Application	:	Marine
Power	:	1736 KW
No. of Cylinder	:	12
Bore	:	170 mm
Stroke	:	210 mm
Engine Speed	:	1800 rpm
Maximum Back Pressure	:	8.5KPa
Liner Type	:	Top Cooling Wet Liner

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III. METHODOLOGY

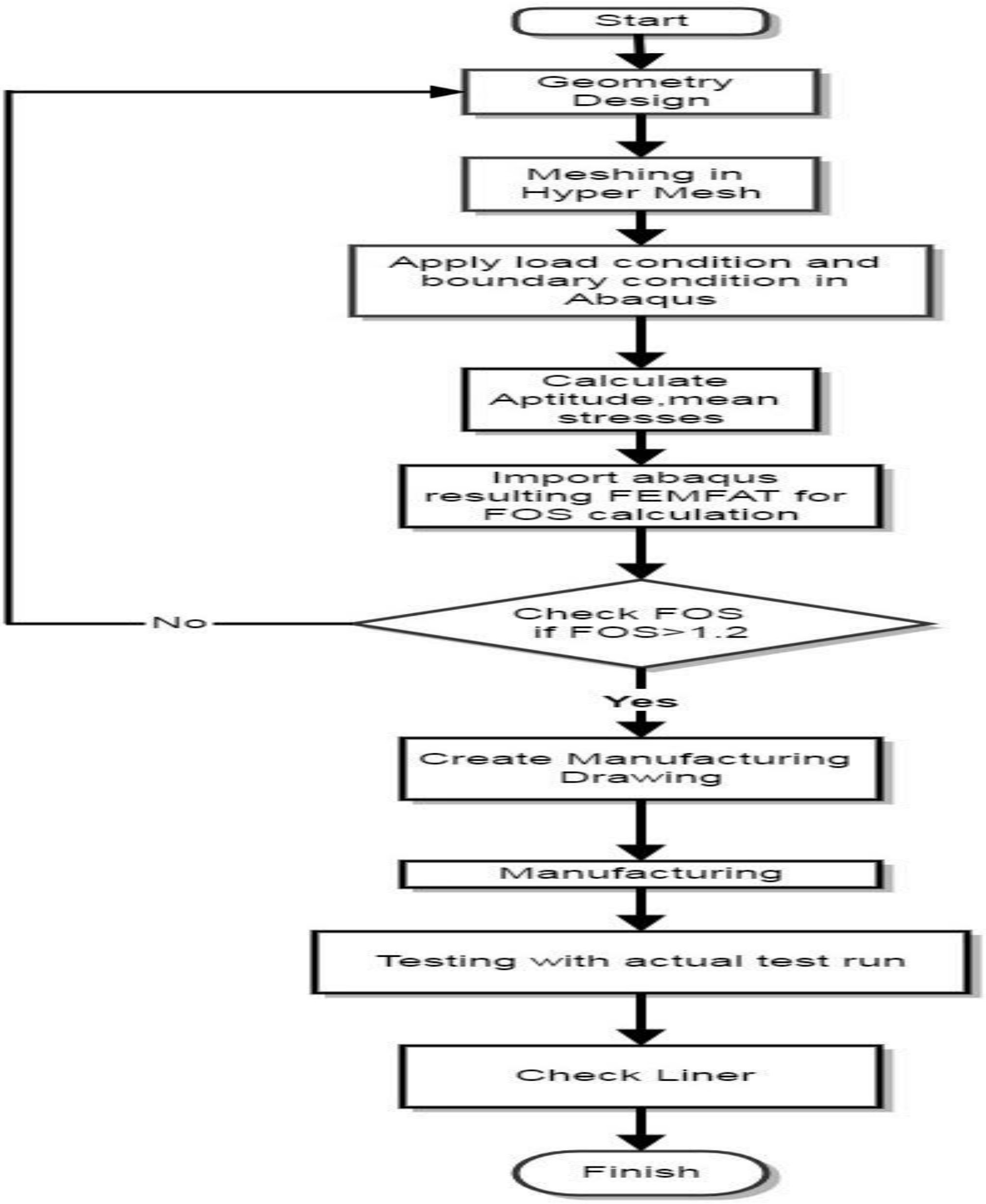


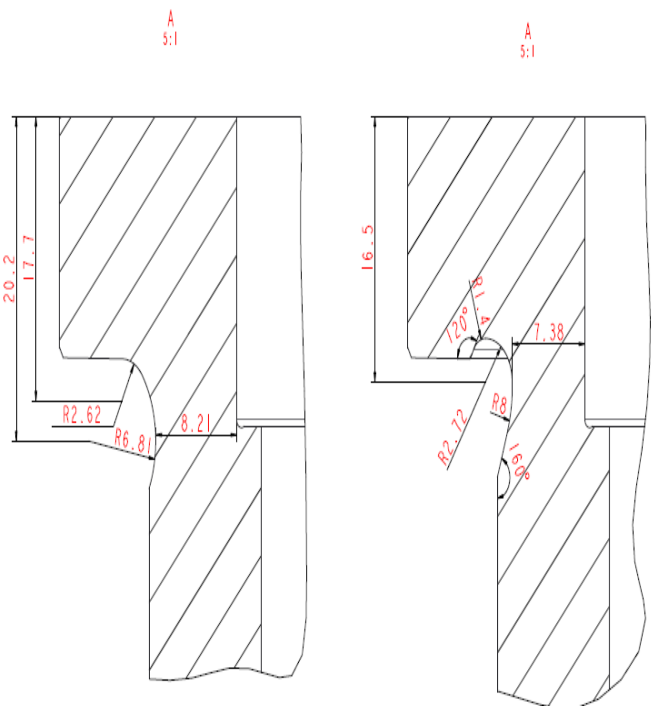
Fig.1. Flowchart

IV. SIMULATION

For simulation of cylinder liner can be assumed to be an axisymmetric body with radial symmetry because it is circular component. The objectives of the simulation of liner is stress analysis were to obtain the stress distributions in the liner and the stress concentration behavior in the critical area at the upper part of liner at flange area of liner. Since the body is axisymmetric, any longitudinal section passing through the longitudinal axis can be analyzed, and the analysis is therefore 2D. For 3D model analysis it consumes more time for iterations so we have decided to use 2D geometry for stress analysis. with three normal stress components: radial stress σ_{rr}, axial or longitudinal stress, σ_{zz} and tangential stress, σ_{yy}, the last normal to the plane of the paper, as shown in Fig. 10. The finite element code ABAQUS was used to obtain the stresses σ_{rr}, σ_{zz} and σ_{yy}, and also the distribution of temperature. 2D axisymmetric elements were used, CAX4 with eight nodes for the computation of temperature, and the elements CAX6, also with eight nodes, with reduced integration, for the stress calculation.

A. Geometry Design

Due low factor of safety in critical area below the liner flange, decided to change liner geometry means changes liner groove. To change liner geometry (groove) Creo Parametric 2 is software used. In below image old geometry and new geometry shown. Liner geometry changed by iteration method by modifying and analyzing several times liner geometry get finalized.



Old Geometry *New Geometry*

Fig.2. Comparison between Old and New Geometry

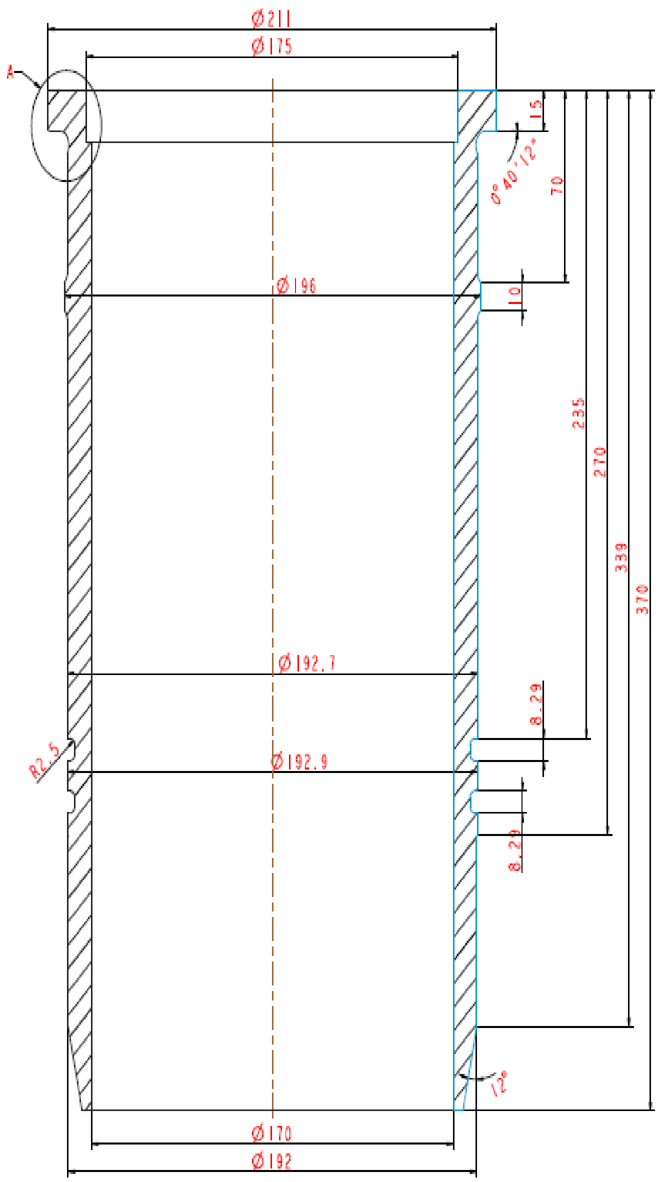


Fig.3. Liner Drawing

B. Liner Material

For marine diesel engine liner special grade cast iron used content are C, Si, Mn, P, S, Cr, Mo, Cu, Ni and Sn etc.

C. Meshing Technique

For meshing cylinder triangular element it will be more effective as compared other element type.

D. Boundary Conditions

Cylinder liner rested on crankcase with edge contact and on upper part of liner cylinder head. At 70mm from top of liner other 1.46mm step for coolant distribution in all around the liner. After this step at 235mm O-ring grooves for sealing and

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after first O-Ring groove 1mm small step for sealing and locking.

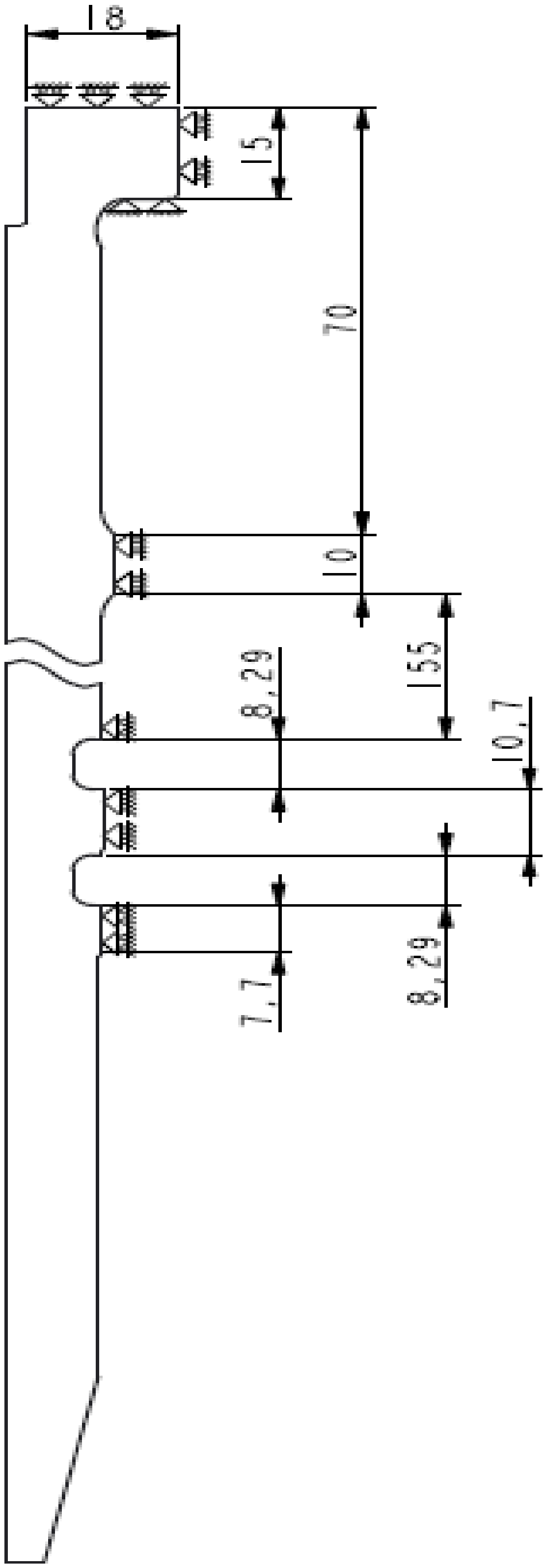

Fig.4. Boundary Condition

E. Forces on Cylinder Liner

Forces on cylinder are applied on 13 step from liner assembly to exhaust stroke.
Forces on liner as below:

1. Bolting with small displacement
2. Full Bolting
3. Bolt forces
   Total 6 bolts used to fix the liner and each bolt applies 260KN force.
   Total Bolt Force = 6*260

   = 1560 KN
4. Assembly forces and temperature in combustion chamber
5. Assembly forces + Temperature + Gas Pressure
6. Assembly forces at cooling after exhaust stroke
7. Assembly forces + Temperature at cooling
8. Assembly forces + Temperature + Gas pressure at cooling
9. Assembly forces after Liner cooled
10. Assembly forces + Temperature after cooled
11. Assembly forces + Temperature + Gas Pressure after cooled
12. Assembly at cool
13. Assembly + Gas Pressure

V. RESULT AND DISCUSSION

Due to abrupt change in geometry stress concentration is high at undercut area. After optimizing critical area of liner geometry stress concentration reduced and amplitude stresses also optimized. In below image amplitude stresses have been showed.

Actual loading applications usually involve a mean stress on which the oscillatory stress is superimposed. In below image mean stresses showed in optimised liner at critical area. In below image mean stresses showed at critical area. Maximum mean stress is 44MPa, minimum mean stress is -40MPa in transition are mean stress is 6MPa.

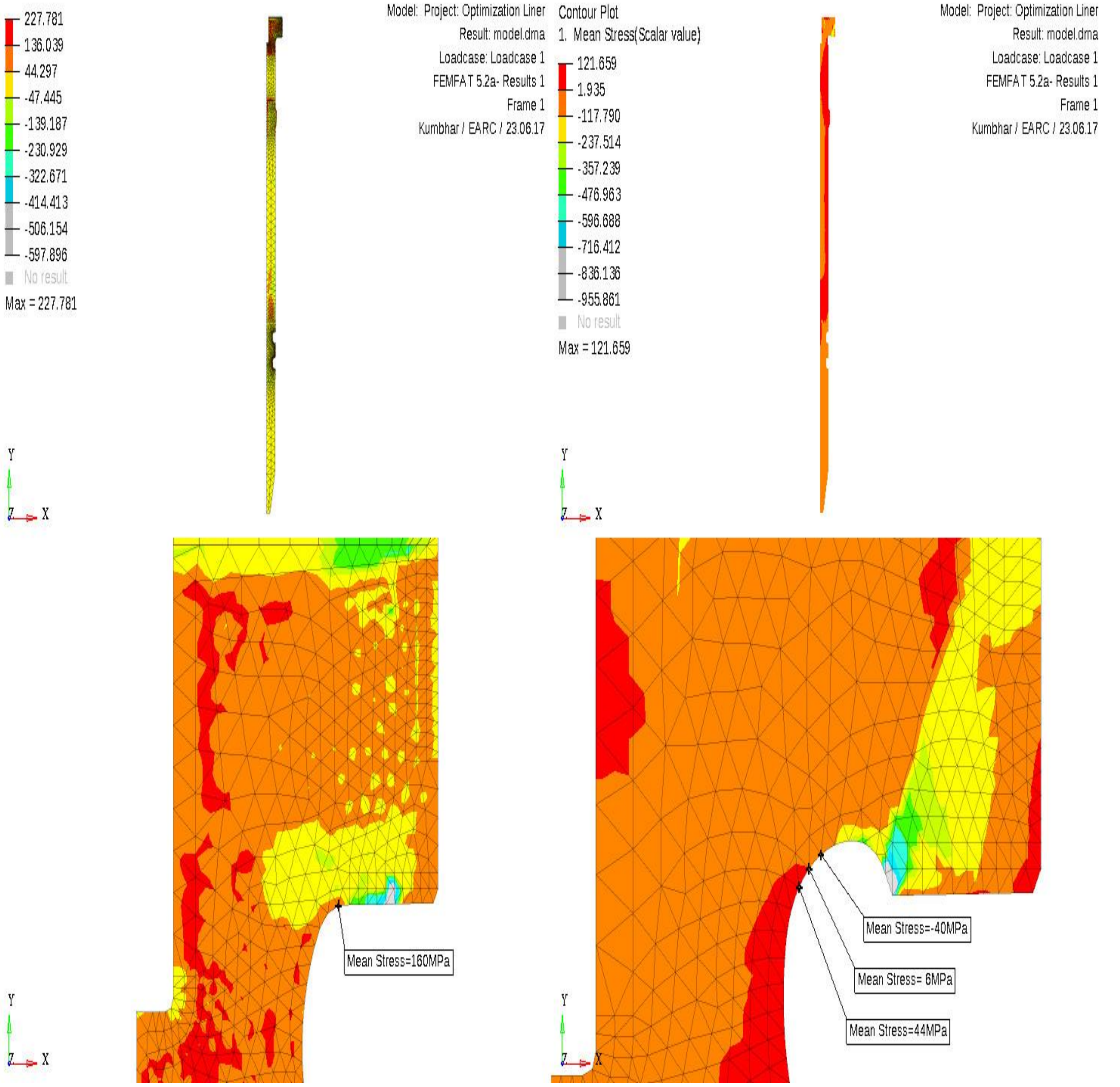

Fig.5. Old and New liner Mean Stresses

Amplitude stresses in old liner more than new liner. Due to the abrupt change in geometry mean stresses and amplitude stresses are higher in old liner design. In new Liner stresses get distributed in undercut area. In old liner amplitude stresses in critical area are 136MPa, 131MPa and 30MPa. In critical area amplitude stress vary certainly from 136 MPa to 30 MPa but in new design this variation is not much it varies from 118MPa to 94MPa.

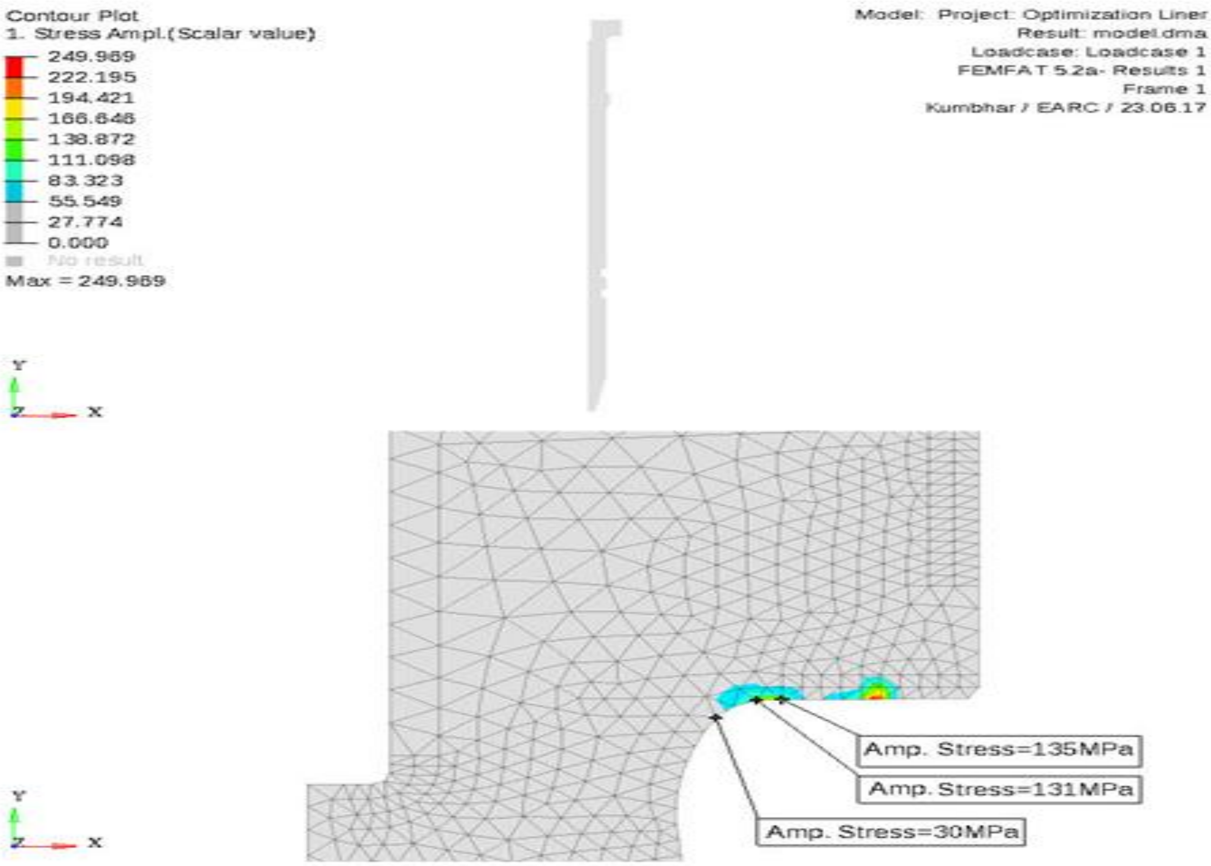

Fig.6. Old and New liner Amplitude Stresses

Factor of safety can be defined as the ratio of ultimate strength to the design strength. It is a constant factor that is considered for designing of machine components or structure beyond its working strength. After optimizing geometry in critical factor of safety gets increased from 0.7 to 1.2.this is because of low stress concentration. Stress concentration has been optimized by changing radius from single radius 2.62mm to 2.72mm and 8mm.

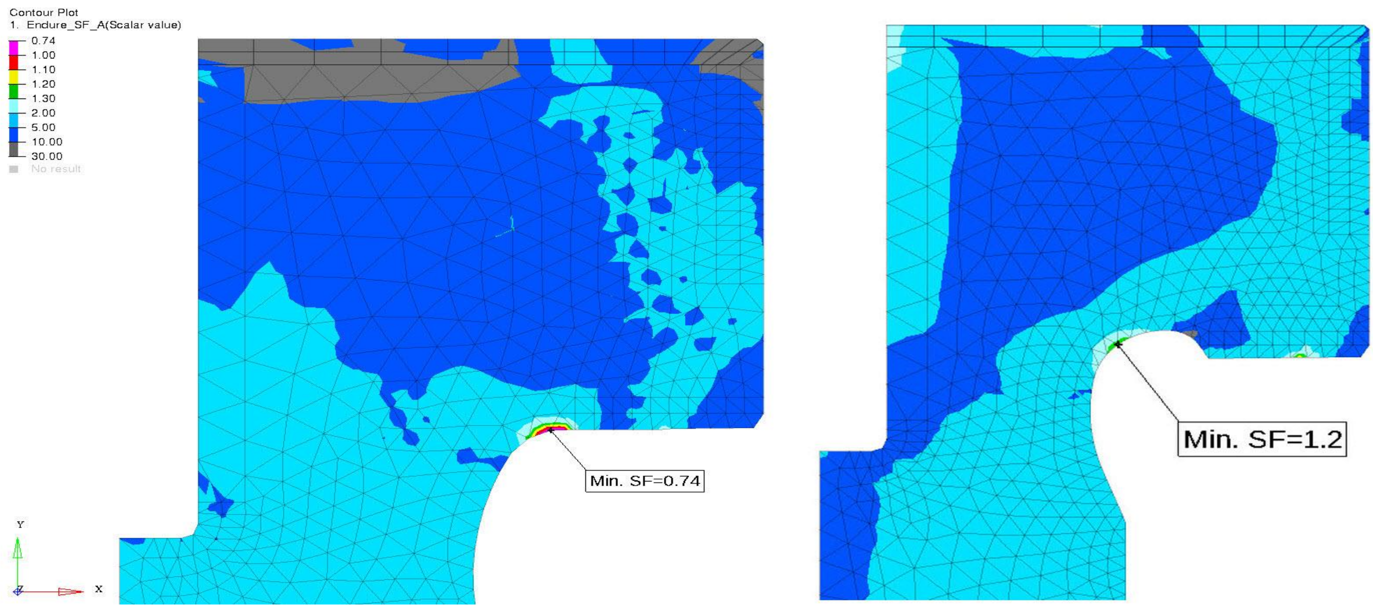

Fig.7. Old and New Factor of Safety

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VI. CONCLUSION

Hence, after optimizing liner geometry and improving factor of safety of liner for rated power engine. Initially factor of safety was 0.7 and after changing geometry it is 1.2 so this is safe.. Also by changes some more feature we can use it high power engine and for other applications as well.

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