

Optimization of Excavator Sprocket and it's Validation by Test Rig Concept

Mr. Swapnil Ghodake
 Prof. Prashant Deshpande
 Mr. Shrikant Phadatare

Abstract— In an excavator, a sprocket is a toothed wheel that engages with a chain or track to transmit rotary motion. Sprocket, track and idler form an assembly to cause the motion of excavator. Optimization is a methodology of making something (as a design, system, or decision) as fully perfect, functional, or effective as possible to maximize productivity or minimize waste. In this paper, sprocket weight optimization is done with reducing material to get optimized design which can perform well under torque condition keeping same constraints. For this purpose, an FEM tool is used for analyzing existing and optimized sprocket with different types of FEA techniques. Strain Gauging is done for correlation with FEA virtual strain to confirm the loadings. Conceptual Test rig is proposed to validate the optimized sprocket.

Keywords: Excavator Sprocket, Weight Optimization, Test Rig.

I. Introduction

Excavator sprocket is designed for operating at high torque conditions. Excavator sprocket is assembled with the track chain, idlers and carriers rollers. Carrier rollers are located slightly upwards it causes the track chain to get in angular position.

Mr. Swapnil Ghodake
 Mechanical Engineering Department,
 K. E. Society's Rajarambapu Institute of Technology,
 Rajaramnagar, Islampur, Dist. Sangli,
 Maharashtra, India - 415414.

Prof. Prashant Deshpande
 Mechanical Engineering Department,
 K. E. Society's Rajarambapu Institute of Technology,
 Rajaramnagar, Islampur, Dist. Sangli,
 Maharashtra, India - 415414.

Mr. Shrikant Phadatare
 Asst. General Manager,
 India Design Center,
 JCB INDIA LTD, Pune
 Maharashtra, India - 410507

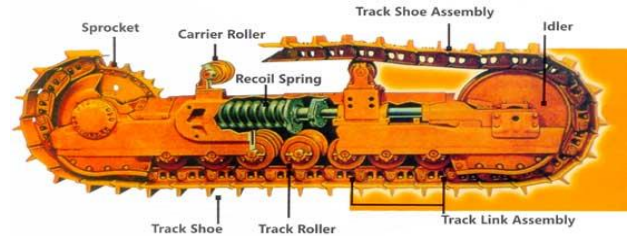


Fig 1. Undercarriage assembly

Also, idler is assembled with the spring which also causes the force development on the chain which ultimately comes on sprocket. For testing, such conditions a finite element analysis tool is used. Using this tool, the loading conditions are applied which on solving gives the stress results. It is important to take a note that the values that we are looking for stress are on the sprocket and not the chain and sprocket assembly. The stress values obtained help us to know the stress area. Taking into account the stress area, strain gauge could be placed at that location so as to compare with the results of FEA.

II. Calculations

$$\text{Torque} = 37500\text{Nm}$$

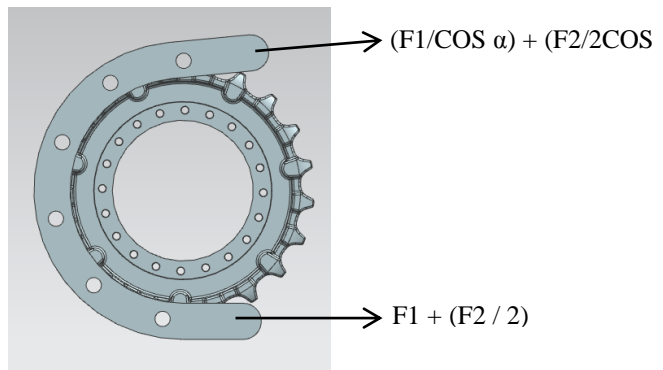
$$\text{PCD of sprocket bolting holes} = 400\text{mm}$$

$$\text{Let } F_1 = \text{Tract Force} = \frac{\text{Torque}}{\text{Radius}} = 187.5\text{KN}$$

$$\text{Radius}$$

$$F_2 = \text{Force due to idler spring} = 0.1404\text{ KN}$$

$$\alpha = \text{Angle made by the track chain with the idlers}$$



$$(F_1/\cos\alpha) + (F_2/2\cos\alpha) = 188.415\text{ KN}$$

$$F_1 + (F_2 / 2) = 187.502\text{ KN}$$

III. Optimization by FEA

A. Material Properties of Sprocket

1. Material: AISI 1045 [1]
2. Yield strength: 241N/mm²
3. UTS: 448N/mm²
4. Poisson Ratio: 0.27 – 3.0
5. Density: 7.8-8.03(x1000 kg/m³)
6. FOS : 2

B. Meshing

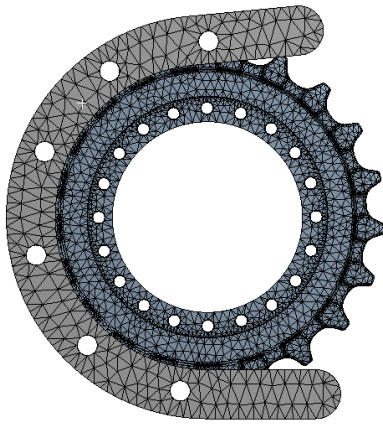


Fig 2. Meshing with 15mm mesh size

- 1) Mesh size : 15mm
- 2) Tetrahedron Reason for not choosing hex type: The geometry contains many intricate corners which could be meshed with tetrahedron and not by hex type.
- 3) Sphere of influence mesh size: 5mm

C. Loading Conditions

1. Earth gravity is applied at the sprocket center.
2. Force is given on one end of the chain.
3. Fixed support is given at the other end of the chain.
4. Remote displacement is given to the sprocket so as to facilitate the rotational motion.

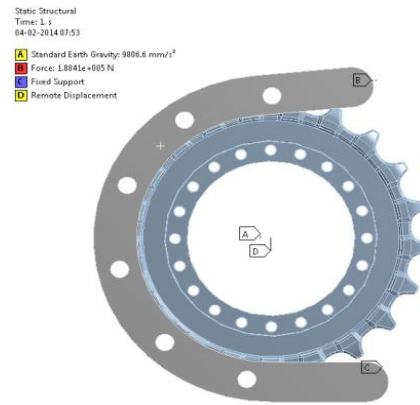


Fig.3 Loading condition

IV. Result

Initially, linear analysis is done so as to check the linear characteristics of behavior. For linear type, contact type is considered as ‘No Separation’ type. Linear analysis gives the following result. Further, nonlinear analysis is carried out by defining actual material properties and contact as ‘Frictional’ with the coefficient of friction as 0.4 for dry & sliding type [2].

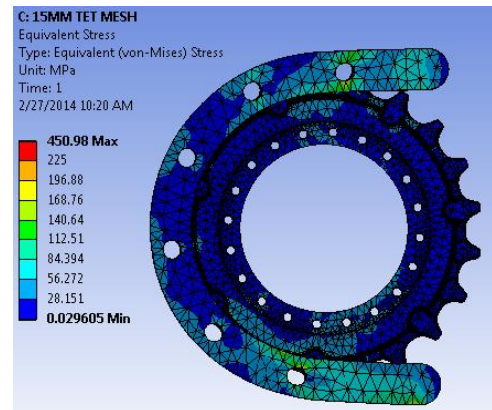


Fig 4.1 Linear FEA of sprocket

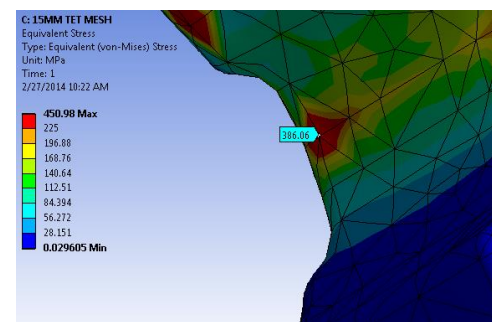


Fig.4.2 Stress on sprocket with linear FEA

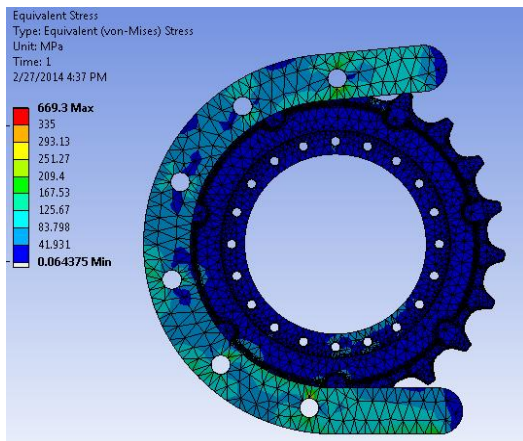


Fig 4.3 Non-linear FEA of sprocket

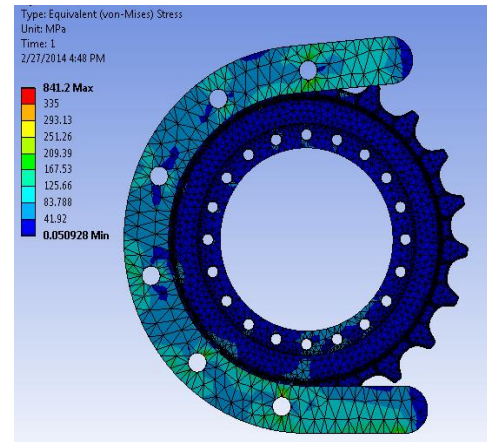


Fig 4.5. Non-linear FEA of weight reduced sprocket

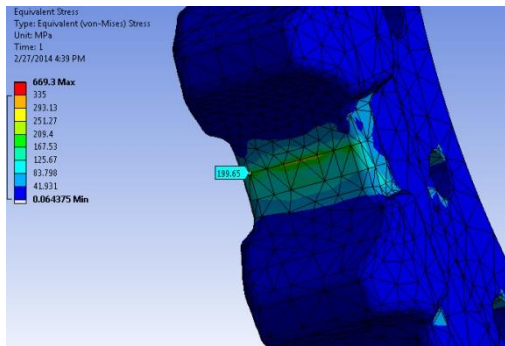


Fig.4.4 Stress on sprocket with Non-Linear FEA

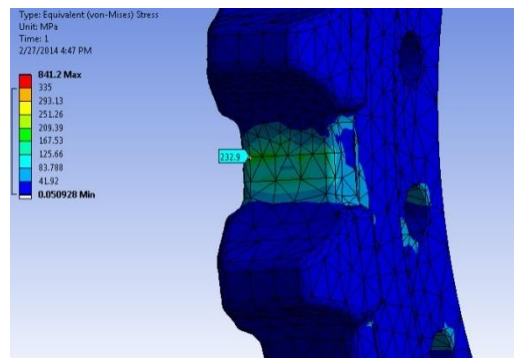


Fig.4.6 Stress on reduced sprocket with Non-linear FEA

Comparing the results of linear from Fig.4.1 & Fig.4.2 and nonlinear analysis from Fig.4.3 & Fig.4.4, a large difference in the stress values is obtained. Nonlinear analysis allows for accurate modeling of structures that undergo large deformation. Hence, nonlinear analysis type is selected for further analysis. It is seen that the stress occurs on the teeth while the rest portion approaching towards the bolting holes is safe. Hence, approach is made such that stress can be directed towards the bolting holes but not on the bolting holes. This can be achieved by reducing the width of the teeth's. Stepwise material reduction is done on teeth's and the results are analyzed at every step. After 4mm tooth reduction from both the sides, i.e. overall 8mm tooth width reduction, weight up to 57.5kg is obtained.

Initial weight of the sprocket was 65.1kg. Results from Fig.4.5 & Fig.4.6 show that the stress was directed towards the bolting holes side but not on the bolting holes. Also, it shows the results obtained are safe i.e. no failure (red spot) is seen on sprocket. Optimization is stopped at this level because of the criterion set. At this stage, 11.67% of weight reduction is seen. Hence, weight optimization is achieved.

TABLE I. Results

Sr.No.	Condition	Result
1	Linear FEA of sprocket	386.06
2	Non-linear FEA of sprocket	199.65
3	Non-linear FEA of weight reduced sprocket	232.9

v. Test Rig Concept

For sprocket to set in motion, torque is required for which hydraulic means would be selected. Two hydraulic cylinders are selected and placed tangential position of the sprocket. The sprocket can rotate about its own axis. Strain gauge is applied at the area where stress occurs. The area of stress could be seen in the analytical data generated to get the idea for placing strain gauges.

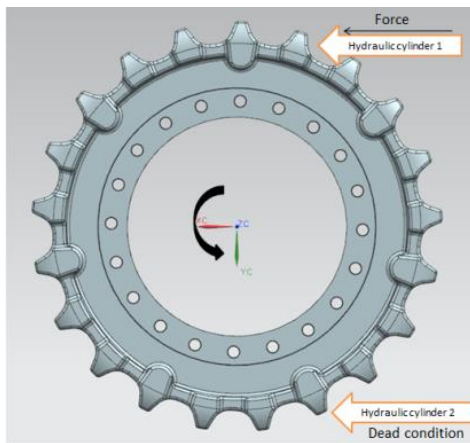


Fig.5.1 Case 1: Hydraulic cyl1 actuated & Hydraulic cyl2 at dead condition

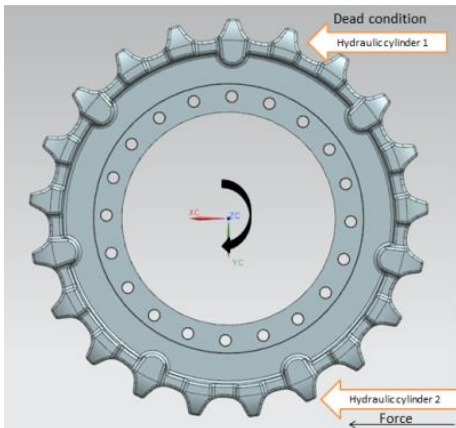


Fig.5.2 Case 2: Hydraulic cyl2 actuated & Hydraulic cyl1 at dead condition

In fig5.1, Hydraulic cylinder1 would be actuated in the first stroke which would apply the traction force on the teeth's that are at tangent. The sprocket would try to rotate about its axis. Hydraulic cylinder2 is kept fixed or at dead condition in

first stroke. Hence, torque is generated with the help of hydraulic cylinder1 by application of force

After the completion of this stroke, hydraulic cylinder1 retracts and stays in dead condition and the hydraulic cylinder2 actuates for next stroke which would then cause the force to impart on the other side of the tooth (fig5.2). Hence, alternately the force is applied on the teeth's for torque generation and results are generated using strain gauge which is connected to the data logger for recording the results which could further be decoded and compared with the analytical data.

VI. Conclusion

The optimization done shows that the values obtained are safe because no failure could be seen even after setting the threshold value to half. This means that the design is safe even with factor of safety as 2. The test rig is put in concept operates on the actual phenomena of torque application in excavator.

Acknowledgement

The authors would like to thank the RIT Institute for the timely and important help in the field of Design & Finite Element Analysis. The authors also wish to thank the reviewers for their very detailed review of the manuscript and for their help in clarifying some aspects of the reported results.

References

- [1] "Handbook of Comparative World Steel Standards" by John E. Bringas.
- [2] "<http://www.engineershandbook.com/Tables/frictioncoefficients.html>