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Study on Groove Shape in Park Lock System

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***Abstract:** In order to reduce the stress concentration in Pawl grooves with different shapes or tips with variable radii geometry are studied and are compared to the samples without any grooves, the shape that offers the best stress reduction is studied and optimised further.*
***Keywords:** Park Lock System, Grooves, Finite Element Analysis, Stress Concentration, bending stress.*

I. INTRODUCTION

Park Lock System (PLS) is a part in the e- Axle of the Electric vehicle that is placed in the output shaft of the transmission system of the vehicle to stop the vehicle from un-intentional roll over or sudden transfer of the power from motor to the wheel due to some malfunction.

A PLS majorly consists of Park Lock System Wheel (PLS Wheel) which is connected to the output shaft directly, pawl this part is designed to mess with the PLS wheel itself and stop any further movement of the vehicle. Further in the assembly cone and connecting rod are placed along with the actuator for the rotation and locking.

In a Park Lock System, the parts that are subjected to the stress are Park Lock System Wheel (PLS Wheel) and Pawl. The pawl and the PLS Wheel are subjected to tensile and compressive load, depending on the vehicle parking orientation during its working condition. In the park position both the parts develop a severe stress concentration in the base of their tooth. To avoid any failure in the parts, groves have been introduced since long time in the industry. Traditionally circular arcs [1] were used but after years of research and inspiration from nature [2,3], researchers have observed that circular arc may serve the purpose but are not the optimal groove shape for distributing the stress in the sample and in case of parts with tight constraints for orientation or material.

II. GROOVE IMPROVEMENT FUNDAMENTAL

Peterson [8] says human have been intuitively been using fillets in design, along with this Baud [8] came with a fillet design for tensile load that are inspired by laminar stream of frictionless fluid that is flowing from an orifice at the bottom of a tank. Making a profile like this is easy using a CNC Lathe. Peterson's [7] provides other method for the shaft notches where the fillets were made at an angle of 15^{o} to 20^{o} with smooth ends as proposed by Morgenbrod, here another graphical idea was proposed by Grodzinski's where the two edges of the shafts shoulders was divided into equal spaced interval and larger interval in the side of smaller diameter of the shaft as shown in the figure and the kinks between the joins should be smoothed out.

Mattheck came up with a new concept that is inspired by self-growth of branches, in this type of fillets "Method of tensile triangle" are used, in this the sharp corners are replaced by a 45^{o} notch which generates two new less dangerous notches with larger angle then these adding more obtuse angle to each notch as shown in the figure as follows to the notches. Many such methods were proposed one of them is Preiss et.al. [5] idea of using a complex groove shape using a chamfer, circular arc and groove height to design a groove so that the stress concentration can be distributed among the three different geometries.

III. PROBLEM STATEMENT

A pawl must be developed that can withstand a tensile and compressive force of 13627.45 N on the pawl Tooth from both the sides, so that the over all length can be reduced from the existing limit of 90 mm. The permissible yield stress for the pawl is Re = 910.6 MPa. Without a groove the Von Misses Stress that is effective at the corner is1218M Pa which is significantly more than the permissible limit Re. The given constraint on the groove is that the height width and length should be less than 10mm each respectively. The factor of safety should be 1.53 and the steel used is EN 654512.

To make this possible the chosen method is as discussed in Preiss et.al [5] (1998) paper where it is applied for a pressure vessel.

IV. GROOVE GEOMETRY USED IN THE PAWL

The Groove comprise of three basis parameters as presented in figure -1. Here chamfer angle is denoted by α, r denotes the arc radius and h denotes the groove height.

The chamfer of the groove starts right at the corner where the pawl tooth meets the pawl shaft. The chamfer is designed to be tangent to the circular arc, the groove height 'h' starts from the quadrant point and continue till the end of the pawl.

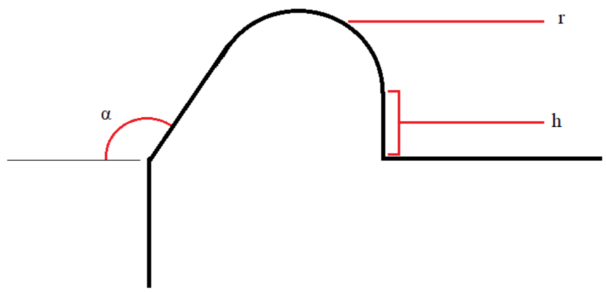

Figure – 1

The admissible values of the following parameters should be as follows

1) $90^o \leq \alpha \leq 180^o$
2) 0 mm ≤ r ≤ 6 mm.
3) 0 mm ≤ h ≤ 5 mm.

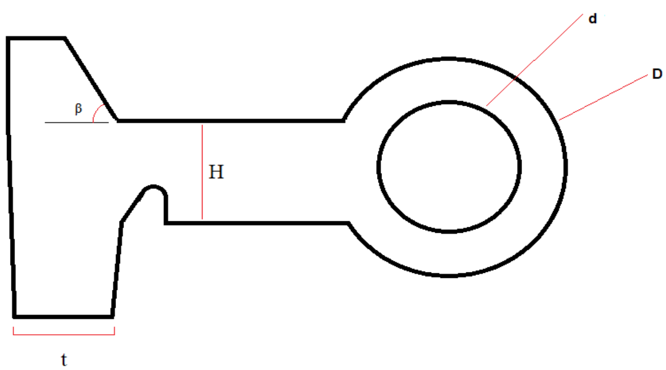

Figure – 2

In the pawl the β depicts angle of ramp, H is the width if the pawl, t is the thickness of tooth, D is the outer diameter of the pawl ring and d denoted internal diameter. After the designing of the pawl the safe values of H=20mm, t = 180 mm, $\beta = 47.52^o$, the draft angle of the tooth is 5^o, by the industry standards the thickness of the pawl must be 10mm at least, but for added safety it is kept 11 mm and the total length is kept mandatorily under 90 mm.

V. FINITE ELEMENT METHOD

All the numerical and analytical calculation are done using ANSYS. The pawl is analysed using the tetragonal elements, this suits in irregular meshing. The considered structure is divided into sub-regions in order to ease the mesh generation of regular finite elements. The size of element chosen is 0.001mm, this size increases the number of elements which in turns increases the smoothness of the elements in and around the groove which increases the accuracy in calculation. Further some refinement is done in the meshing of the pawl on the two adjacent sides of the concerned edge as shown in figure - 3.

Such assumption in meshing is valid for all the stress relief groove parameters and enabled for automatic mesh adjustment. This type of mesh generation produces sufficiently dense mesh in the groove area good mesh distribution in the region where the stress concentration in not critical and not an area of interest.

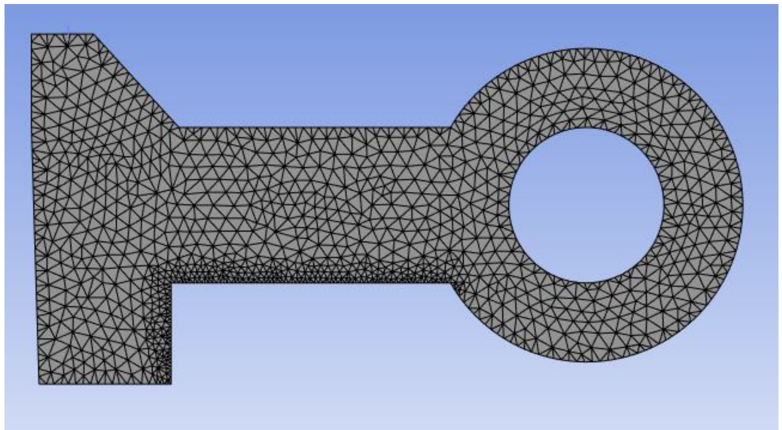

Figure – 3

VI. FORMULATION OF OPTIMIZATION PROBLEM

To optimize the groove of the pawl ANSYS in built optimization tool was used it, the optimization method used by the software is topology optimization. The groove is optimized in four different steps, in the first three steps the groove is optimized in each single parameters of arc radius(r), groove height (h) and chamfer angle (α) individually. Among the most suitable data points those data points are chosen where the equivalent stress is less than the Re. In the fourth and the final step the groove is optimised using the data points of all the three parameter that are in the optimum range of the equivalent stress.

After the execution of the fourth step the most suitable and the manufacturable dimension are chosen for the pawl.

VII. RESULTS OF OPTIMIZATION

A. Chamfer Angle(α)

Value of α is between 90^{o} and 180^{o}. As shown in the figure – 4 the stress concentration in the groove remains less than 800Mpa when the α is increasing. A slight increase in stress can be seen in the end at a range of 168 o to 180 o, however it still in the range of permissible stress limit. For further optimization the value of α will be in between 132.75^{o} to 180^{o}.

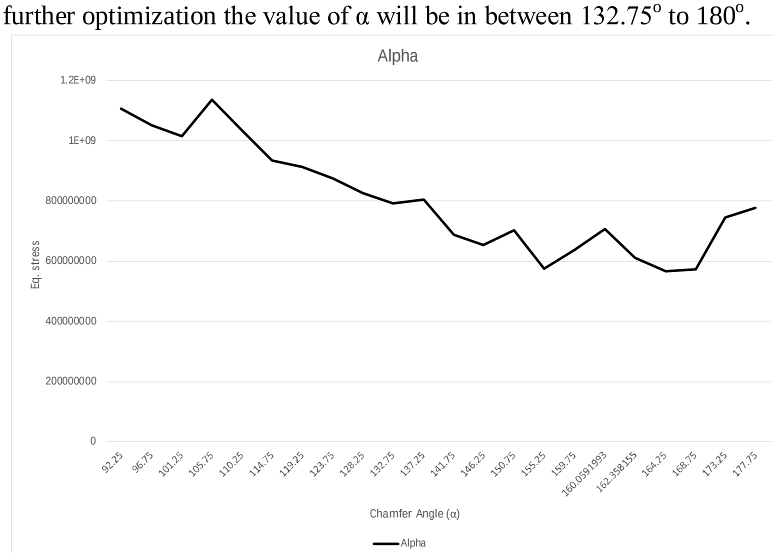

Figure - 4

B. Arc Radius(r).

The admissible value of arc radius (r) is 0 mm to 6 mm. After plotting the data from ANSYS. The stress concentration in the groove decreases as the radius of the arc (r) increases, as can be seen in the figure – 5 . The aim is to maintain the concentration of the stress as low as possible in the groove region and the limit is 901.6 MPa. From the plot it is quite evident that stress concentration reaches and maintains a value of 800MPa in between 4.7mm to 6mm, when arc radius (r) treated individually.

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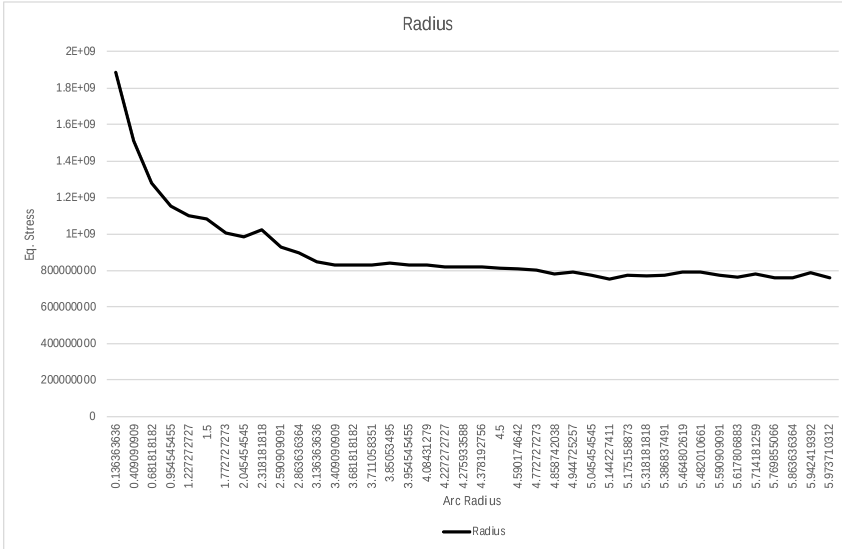

Figure – 5

C. Groove Height(h)

The values of groove height (h) are in the range of 0mm to 4mm. With increase in groove height the stress concentration increases and remain above the permissible yield limit (Re) as can be seen in figure - 6. The Eq. Stress is at the lowest when the h is in the range of 0mm to 0.10 mm. In this range the approximate Eq. stress is 900Mpa. As the effective value is relatively small in comparison to the other two parameters of the groove and the effect are negligible. So, the best option is to eliminate this para meter in the final step.

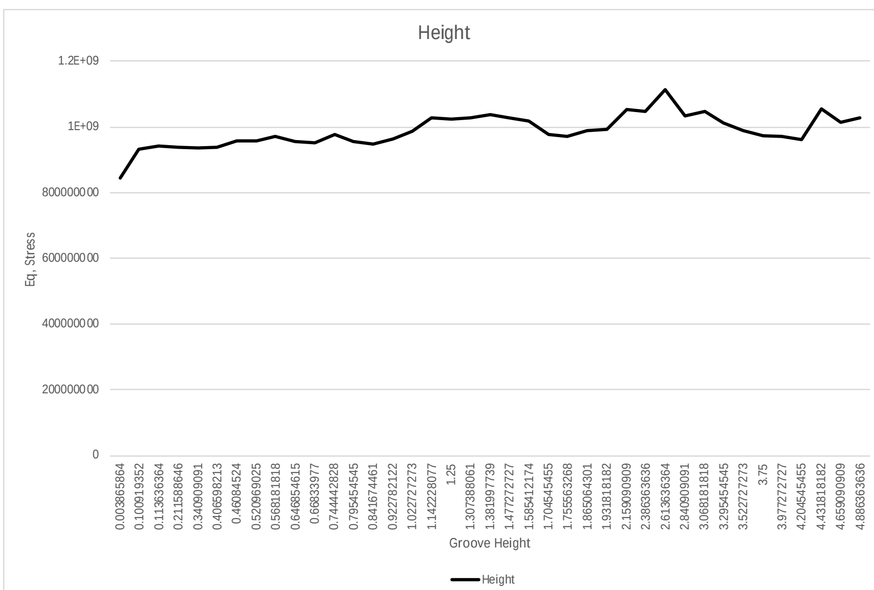

Figure – 6

D. Optimization of Groove on arc Radius (r) and Chamfer Angle(α)

By using the value range of α and r as received in the previous results and plotting them for the corresponding values of eq. stress as shown in figure – 7. In the following figure the red line represents the data plot of chamfer angle (α) and the black represent arc radius (r).

After applying Preiss Method in the pawl groove and setting it for optimization it turns out that the by the influence of both the factor the eq. stress concentration drops even further to the range of 500 Mpa and the max is in the range of 800 Mpa. The range of favourable r is 5mm to 5.5mm and for α it is in between 140^{o} to 170^{o}.

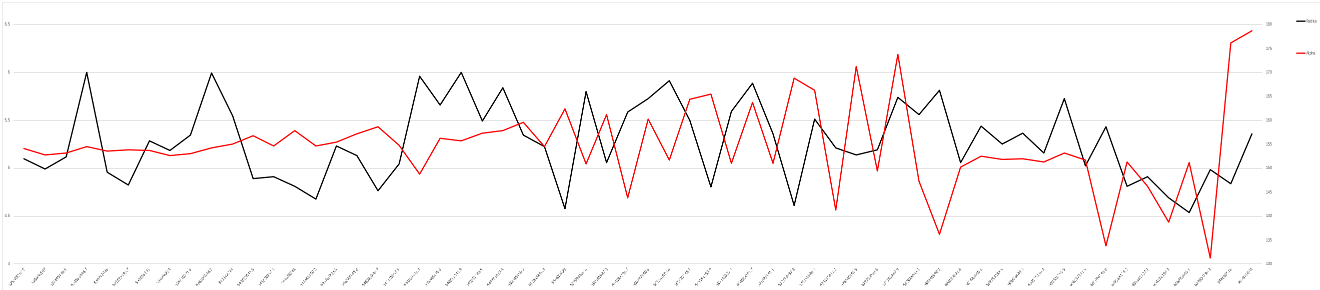

Figure - 7

VIII. CONCLUSION

The results of the study of stress concentration in the pawl tooth base shows the stress concentration decreases as the chamfer angle increases. The increase in arc radius also decreases the eq. stress concentration around the groove. The Groove height does not make a positive effect on the maximum eq. Stress, for better and safe design elimination of groove height is better. The eq. stress concentration decreases even further by the combined effect of chamfer angle (α) and arc radius (r) making the design of the groove even safer. The stress concentration is lowest around the groove when the Chamfer angle is in the range of 140o to 170o and the arc radius is in between 5mm to 5.5 mm. So, it can be said the groove designed by Preiss et. al. method for the pawl in park lock system. Is safe and can be applied in the practice.

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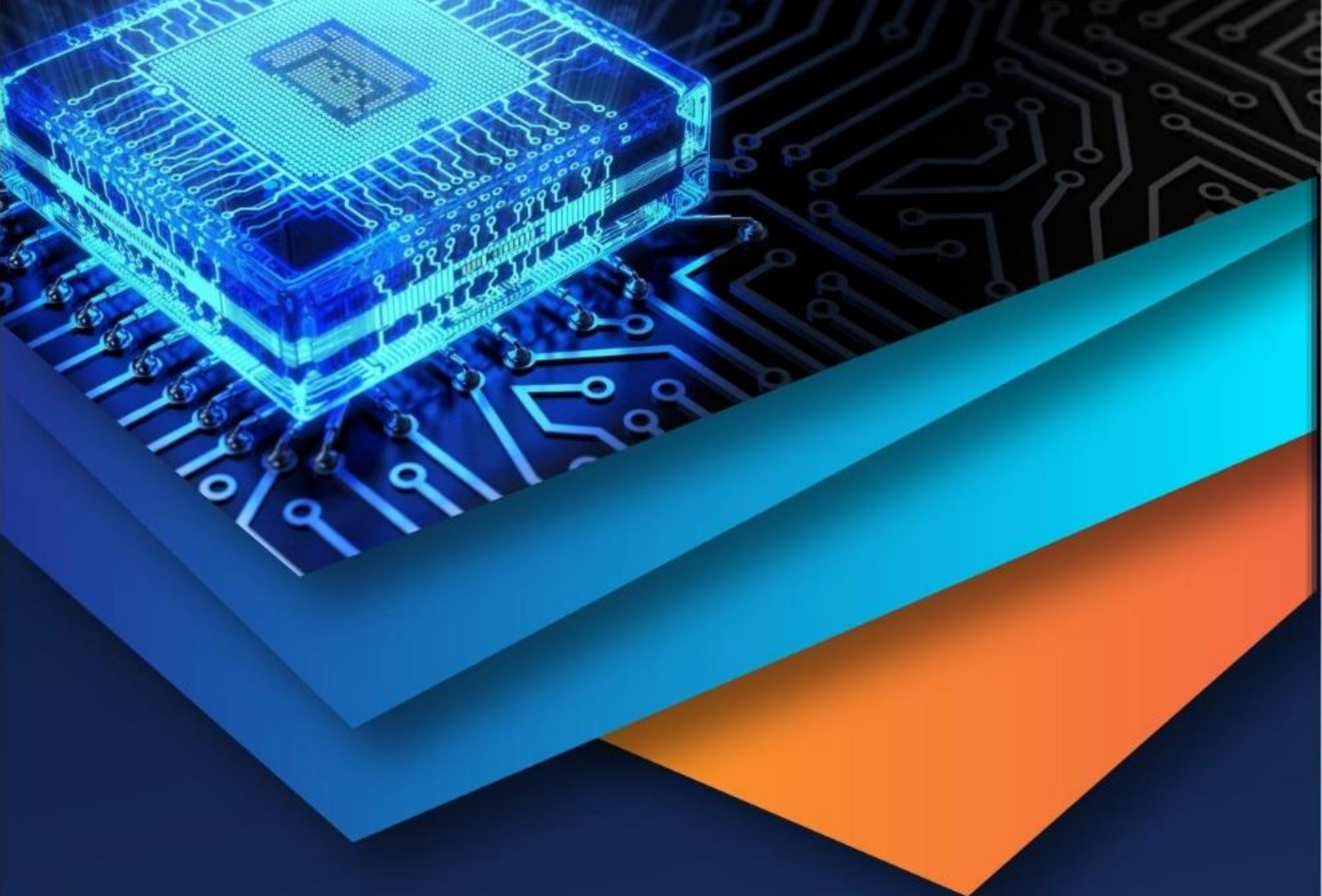

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