Design of Cupped Spring Washer in Automobile Clutch

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ABSTRACT

In current scenario, in Automotive industry, in clutch division major challenge is to reduce the rattling noise and vibration. Thus, most of the industries are adopting the concept of controlling hysteresis by virtue of introducing the cupped washer design in Clutch Disc assembly. In this project we will model the cupped washer based on the size & geometry of the clutch, carry out calculations of load & deflection to achieve the targeted hysteresis of disc assembly by which vibration and rattling noise in running vehicle can be minimized.

This research paper deals with validation of the calculation to be done in analysis software Abaqus and the result of same is to be compared with actual specimen.

Keywords: *Cupped spring washer, Design, Modeling, Creo, Mathcad, Abaqus, Life*

I. INTRODUCTION

A Cupped spring washer is also known as Coned disc spring, Belleville washer, Conical spring washer, Disc spring or Belleville spring. Cupped spring washer can be loaded along its axis either statically or dynamically and has a shape of conical shell. A Cupped spring washer is a type of spring shaped washer. It has a conical shape which gives spring characteristics to the washer.

Washers are usually nut-shaped disks that serve to increase the area of contact between the two surfaces to serve the application.

Washers are divided into six basic categories based on their configurations: flat, shoulder, tab, lock, countersunk and spring.

Though after years, a lot of different profiles for disc springs have been developed. Today most of the profiles are used with or without contact flats, while some other profiles, like disc springs with trapezoidal cross section, have lost importance.[15]

In this research paper we will find the way to design the cupped spring washer.

II. LITERATURE REVIEW

A technical review paper on our project is made by us and is published in STM Journals by name ‘A Technical Review on Design of Cupped Spring Washer in Automobile Clutch’.[16]

(1) H.K.Dubey et.al discussed about the stress and deflection analysis of a cupped spring washer using FE method. In this research work the analysis of a cupped spring washer has been carried out under axial compressive load. The various geometrical parameters of a cupped spring washer have been varied to investigate the stresses and the deflections induced in the cupped spring washer. The finite element results are compared with the existing analytical equations available for the cupped spring washer and some efforts are made to show the variations in the stresses and deflections with respect to the geometrical parameters and some attempts are made to establish certain relations which will help to evaluate the stresses & deflection for any geometry of a cupped spring washer with accuracy. From this paper it can be concluded that the analytical equation for cupped spring washer estimates the maximum stresses and deflection for certain cases, but FEA is recommended for accurate estimation of maximum stress and deflection in case of cupped spring washer under given loading condition.[1]

(2) H.K.Dubey et.al measured deflection of a Belleville Spring with slots and without slots using finite element method. Vonmisses' stresses have been considered for a particular dimension of its outer diameter and inner diameter, diameter between slots and outer diameter and its Height to thickness in the spring along with the deflections. The results of analysis by finite element analysis are compared with existing analytical results. The comparison of the cupped springs with & without slots reveals that, deflection increases due to the presence of slots. We have concluded that the stresses in slotted cupped spring are very high compared to that of a cupped spring without slots. The reason behind this is the effect of stress concentration at the corner of the slots. Here we can conclude that slotted cupped springs are used for lower load values and greater flexibility.[2]

(3) Abas Manduka et.al has introduces an elastomer at the top and bottom of the cupped spring washer. After that the analysis of the washer is made. The purpose of adding the elastomer is to reduce the washer fracture. The load which is acting is absorbed by the elastomer.[3]

(4) Ganesh S. Pawar et.al carried out optimization in the design of cupped spring washer to reduce the thickness of washer. It also reduces the cost of washer as the material will be reduced. By compromising factors like load, inner diameter, etc. the thickness of the washer is minimized about 2.87mm using MATLAB. As the thickness of washer is reduced the stress induced is less than the permissible value and also the cost of manufacturing is reduced.[4]

(5) Mr. Vishal J. Deshbhratar et.al has given an efficient and reliable analysis technique for the design of the mechanical clutches by using computer modelling and they have developed a numerical method. Here reduction of stresses and forces which are developed in the clutch are done with the help of software. Modelling of clutch is done in pro-e software and the analysis is done in Ansys software. From the analysis on the software the value obtained for loading is less than the allowable stresses. So the design is safe.[5]

(6) L N Gujja et.al made the design of Clutch Test Rig. With the help of operating speed and torque range the design calculations are done. Here the design for Clutch Test Rig is found safe.[6]

(7) Raxit Umretiya and Mohit Lakhwani have done the modelling and analysis of Self Align Clutch is done. Modelling is done in CREO and analysis is done in ANSYS. The results are compared with the existing data.[7]

(8) Gowtham Modepalli has done the study on clutch assembly, modelling is done in PRO E and analysis is done in ANSYS. Stresses and forces for different material are checked and compared. Aluminium is found best for clutch assembly.[8]

(9) May Thin Gyan, Hla Min Htun and Htay Htay Win have done the analysis of single plate clutch for three materials that are Copper, Alloy steel and Cast iron. Here from the stress, strain and displacement values of these materials Cast iron is found to be best.[9]

(10) Waheeduddin Sohaib Mohammad and Hong Zhou showed the systematic design, modelling and analysis of the Wave spring washer. 3D model is prepared considering the parameters: the number of waves, inner and outer diameters, washer thickness and wave height. Analysis is done on this model. Optimization of design and modelling is done with the use of MATLAB and ANSYS.[10]

(11) Sükrü Karakaya showed the modelling of hybrid and different cross sections of disc springs. The load carrying capacity and cost are tried to be optimised. Disc springs are analysed by using ABAQUS. It is found that outer layers of the springs made with carbon/epoxy are more advantageous.[11]

(12) Abhijit Rupnar, Aditya Babar, Akash Karale and Sanket Gundawar have performed the theoretical calculations of design for Diaphragm spring of a single plate dry clutch. Theoretical data is compared with the design and analytical data obtained with the help of software. Here 3d modelling software used is CATIA V5.0. and for analysis HYPERMESH is used.[12]

(13) Sagar Olekar1, Kiran Chaudhary, Anil Jadhav and P. Baskar have designed multiplate clutch by using uniform wear theory. 3D modelling is done in PRO E and structural analysis is done by ANSYS Workbench 14.0. The results are compared for different materials for friction plate. Total deformation, strain energy, shear elastic strain for clutch plate with SF001 as a friction material is less. Therefore, SF001 as friction material will give better performance.[13]

(14) Sonawane Vinod and Kolase Prashant compared the displacement and stresses of slotted cupped spring and cupped spring without slots are compared. It is found that load carrying capacity of slotted springs is less but deflection is more compared to Belleville spring without slot.[14]

III. DESIGN OF CUPPED SPRING WASHER

A. Analytical Method

1. Design Parameters

In design of Cupped spring washer following parameter is used

(1) Outer diameter of Cupped spring washer

(2) Inner diameter of Cupped spring washer

(3) Thickness of washer

(4) Height of washer

These parameters are the most important parameters for the design of cupped spring washer.

2. Design Calculations

The data for the calculations are provided according to the customer requirements where they will share the requirement of the hysteresis and based on it, load of the cupped spring washer is defined.

3. Customer Requirement

In current scenario, in automobile industry, in clutch division major challenge is to reduce the rattling noise and vibrations produced in the clutch. So, for this hysteresis requirement, customer is important factor for clutch design which we have identified and captured in this project.

Customer Input = 111 Nm Hysteresis requirement

Below is the equation by virtue of which load requirement can be found,

Hysteresis = n * μ * r * force

Where,

n = Number of friction faces

μ = Coefficient of friction

r = Mean radii of cupped spring washer

Force = Force of cupped spring washer in disc assembly

4. Selection of Load depends on the following Criteria

(1) Fixing the OD of washer

a. Checking the assembly parameters where the washer is being seated and for fouling of it to other parts.

b. After checking the parameters it was found that OD should be in the range of 96.48 mm.

(2) Fixing the ID of washer

a. Checking the assembly parameters where the washer is being seated and for fouling of it to other parts.

b. After checking the parameters it was found that ID should be in the range of 80.90 mm.

(3) Fixing Thickness

a. It depends upon the force requirement and based on that it can be selected.

(4) Fixing the working Height

a. Checking the assembly stack up and gap between two parts where the cupped spring washer is being seated.

b. It was found from the assembly, it should be 2.855 mm.

(5) Fixing the free Height

a. Free height will be fixed based upon the working deflection, load and stresses on the cupped spring washer.

Based on the provided equation, numbers of iterations are carried out to get target value of 2080N force.

5. Input Parameters

Do = Outer diameter of cupped spring washer

Di = Inner diameter of cupped spring washer

t = Thickness of cupped spring washer

L = Free height of cupped spring washer

Lw= Working height of cupped spring washer

Do = 96.48 mm, Di = 80.90 mm, L = 3.794 mm, Lw = 2.855 mm, t = 1 mm

6. Calculation Equations of Cupped Spring Washer

(1) Mean Diameter

$$Dm = \frac{Do+Di}{2} = 88.69 \text{ mm}$$

(2) Spring Width

$$b = \frac{Do-Di}{2} = 7.79 \text{ mm}$$

(3) Working Deflection

$\delta w = L - Lw$ = 0.939 mm

(4) Force Function

To get the load of the washer, the above working deflection of δw is put into above force function. By performing the above calculations, the load obtained is 2079 N.

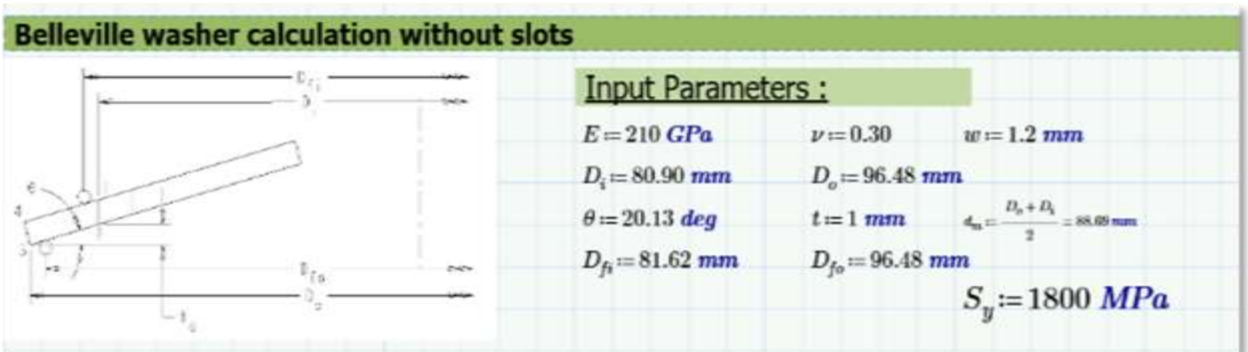

Fig. 1 – MathCad Input Data

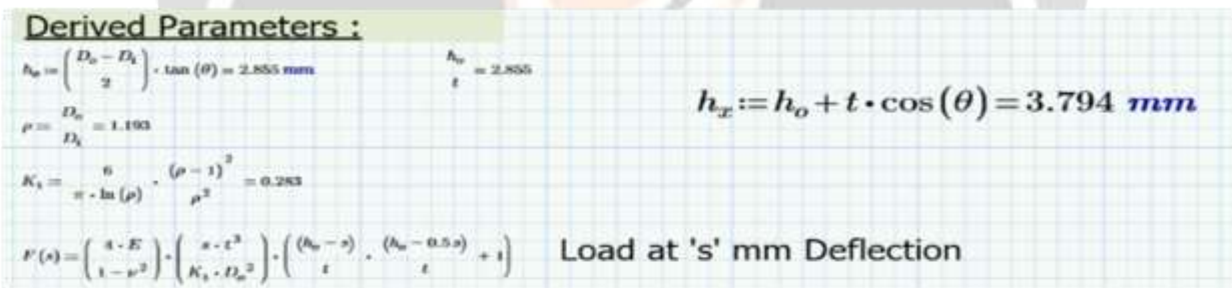

Fig. 2 – MathCad Derived Parameters

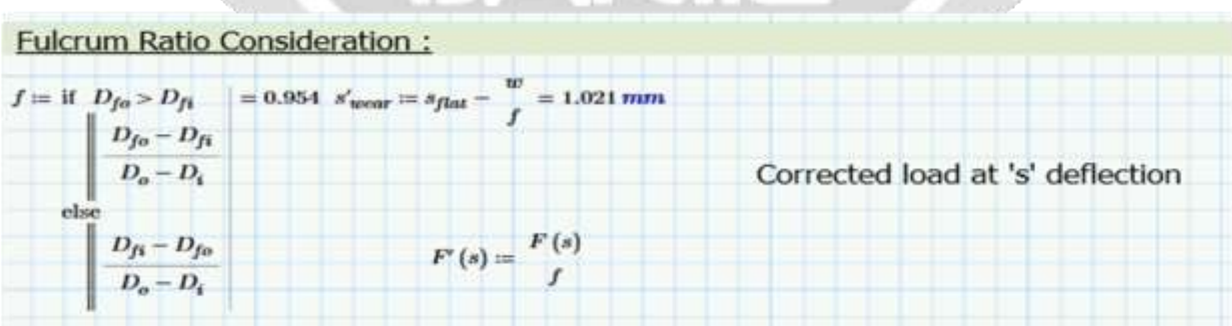

Fig. 3 – MathCad Fulcrum Ratio

B. Modelling of Cupped Spring Washer

In this project we made 3D model of cupped spring washer in Creo 3.0 software.

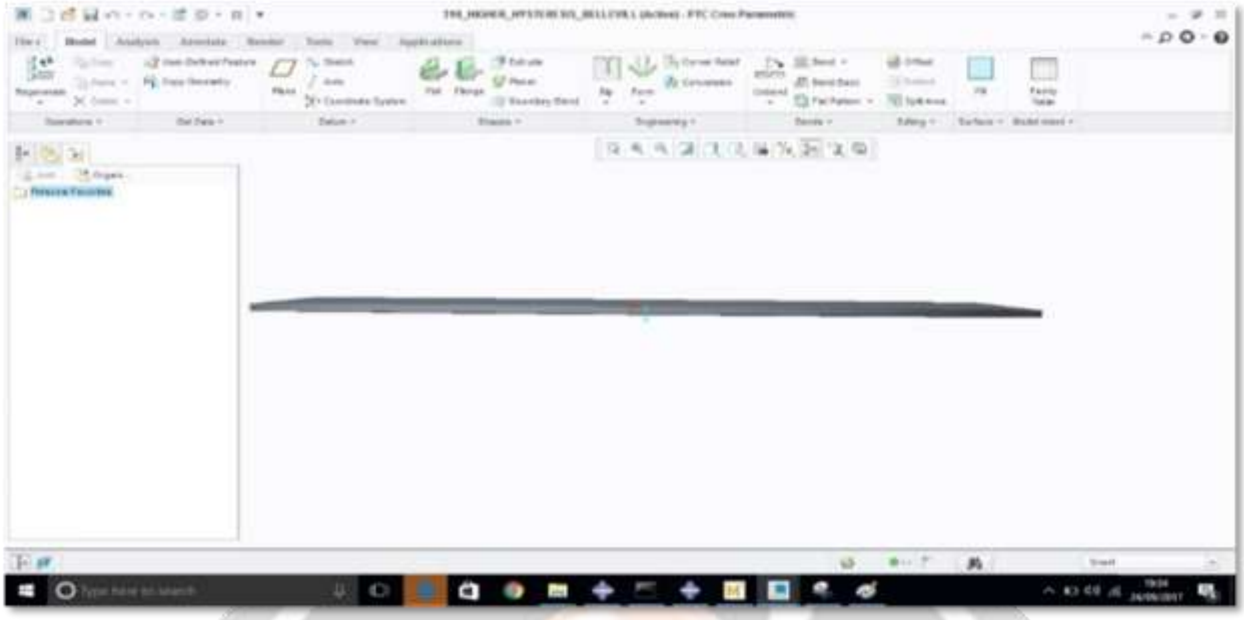

Fig. 4 – 3D Model of Cupped Spring Washer (Front View)

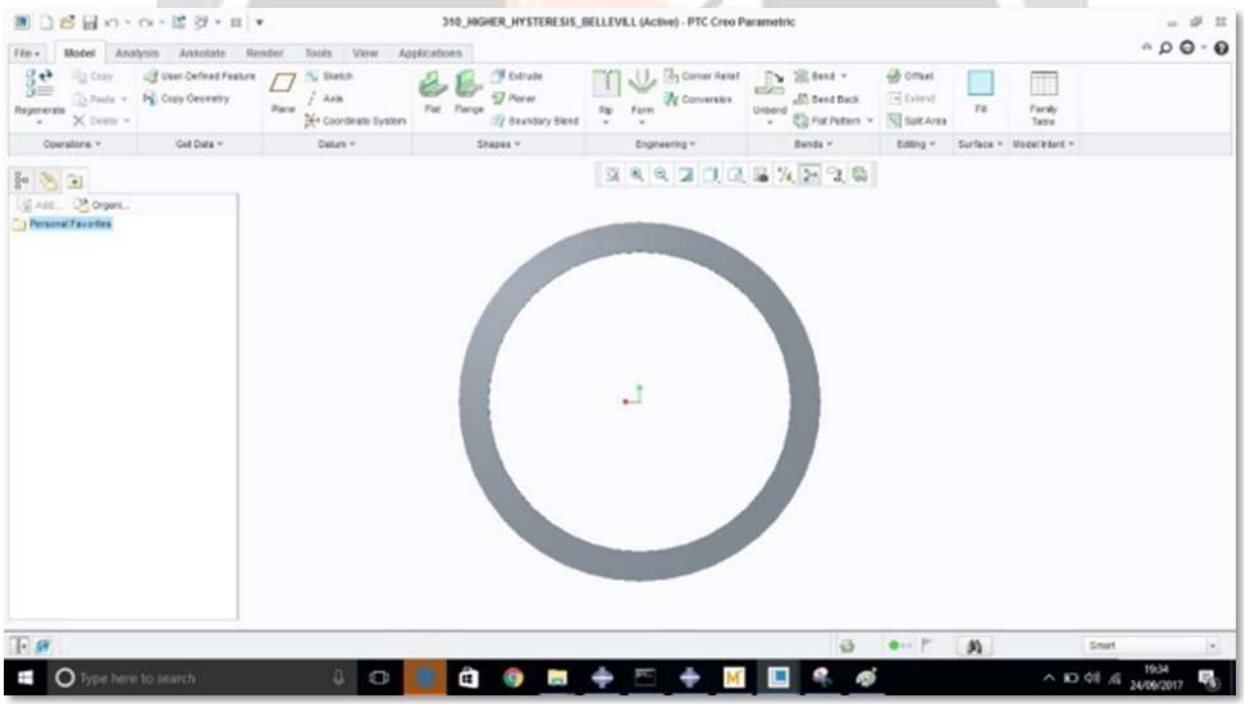

Fig. 5 – 3D Model of Cupped Spring Washer (Top View)

C. Finite Element Analysis

FEA is carried out in Abaqus 6.14.

Both pre-processing and post-processing are done on Abaqus 6.14

1. Pre-Processing

In processing below task carried out,

(1) Importing model of Creo to Abaqus

To import the model from Creo to Abaqus, I have converted the cupped spring washer model from .prt file to .stp file and from Abaqus software "Import" option is selected to import the .stp model of subject problem.

(2) Material assignment

Being the spring steel material, below properties are assigned to model.

a. Strength = 210000 N/mm2

b. Density = 7.8e-09 tonne/mm3

c. Poisson ratio = 0.3

(3) Section Assignment

Analysis is carried out in 3D solid part, so according to that the whole body section is assigned.

(4) Contact Assignment

To compress the washer in Abaqus software to get load, two additional plates are also imported in the Abaqus software.

To provide surface to surface contact to part (cupped spring washer) & plates (both TOP & BOTTOM plate) contact assigned to each part in "Interaction" module of Abaqus system.

(5) Meshing of Model

To mesh the washer, Sweep technique & Element shape as Hex is selected. Global meshing (0.25) is done and at thickness region, local seeding is done where 4 discretization are done.

(6) Boundary condition assignment

a. Fixed the position of bottom plate (All translations & rotations fixed)

b. Washer lateral movement restricted in X & Z direction.

c. Similar way Top plate's lateral movement also restricted in X & Z direction

d. Top plate travels in negative Y direction of 2.5 mm given to get load on each travel displacement as defined in "step" module of Abaqus. (In Step module increment size is defined as 0.01 as Initial and 0.1 as "Maximum")

2. Post-Processing

1. Job creation, in this Job name is given and Job submitted to get results.

2. In Visualization, ODB Field output & Operate on xy data set to get the load vs deflection curve. Once job results achieved, from Visualization tab create “X, Y data” by selecting the force nodes & displacement nodes from model and plotting them on graph. From above “X, Y” plot, load obtained as 1985 N.

Result of Abaqus

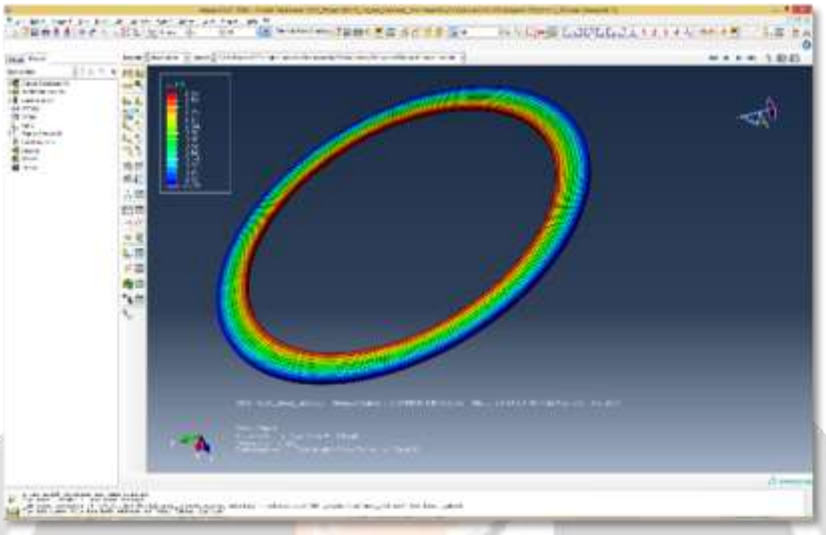

Fig. 6 – Deflection in Washer

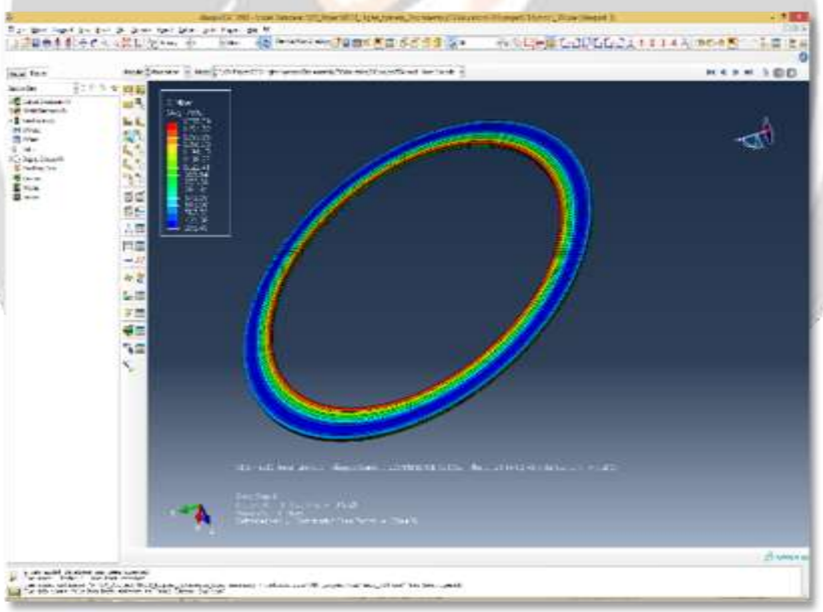

Fig. 7 – Stresses in Washer

D. Load v/s Deflection Data

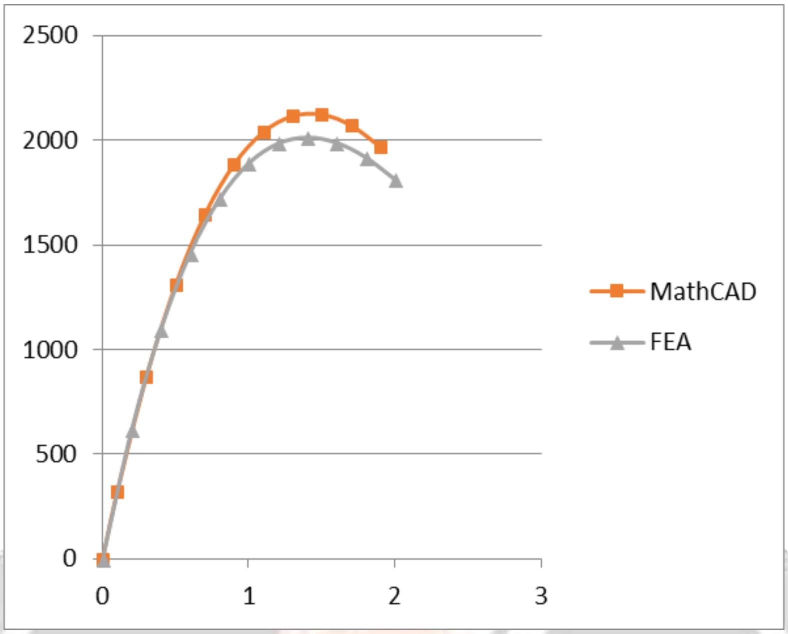

Chart 1– Load vs Deflection Curves

IV. CONCLUSION

To conclude on Hysteresis requirement of customer, load derived from equation **Hysteresis = n * μ * r * force** as 2080 N.

Results of Mathcad and FE analysis compared to conclude

From the Mathcad analytical model load found is 2079 N and from FE analysis load obtained is 1985 N.

In earlier design, stresses were 1455 MPa where as in new design it is 1224 MPa.

As per that new washer will be having 20,00,000 cycles life.

Old design tested for fatigue life in actual machine (testing machine) and it just passed 15,00,000 cycles which means new washer is expected to give better life compared to old one.

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