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Fingers Structure Impact on Load-Deformation Characteristic of Diaphragm Spring

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***Abstract*:- The aim of this project is to observe the load-deformation characteristics of diaphragm spring used in clutch systems according to the surroundings. In this thesis we establish a finite element model of six diaphragm springs with different cases and simulate the load- deformation characteristic for diaphragm spring based on nonlinear finite element method (FEM), then research the fingers structure's effect on the characteristics of spring. The result shows that the finger structures are the key factors which affect the characteristic of diaphragm spring.**

The dimensions which are used for modeling the diaphragm spring are almost same except the height of spring. Here we used four different cases of height thickness ratio (H/t), the thickness of spring is constant and the height of spring increases from 1.6 to2.2.

Creo-parametric (version 2.0) is used in the design and the solid modeling of the springs in the project. Numerical simulations or static structural analysis is done by using ANSYS Workbench (Version 14).the material of spring 50CrV4 is used. The numerical and test results are observed for each diaphragm spring with different cases. These results are compared with theoretical test results which were derived by Almen-Lazlo. The general evaluation of the project is given in the conclusion.

Keywords:* *Diaphragm spring, ANSYS, Load Analysis, Thermal Stress, Deflection, Simulation

1.DIAPHRAGM SPRING

The slotted cone-shaped disc spring is a modification of the regular conical disc spring or Belleville spring in as much as it has regularly arranged slots extending from the inside diameter. A diaphragm spring undergoes a larger deflection at a smaller load comparing with a regular disc spring or Belleville spring of comparable dimensions, thereby combining some of the advantages of the disc spring and the cantilever type spring in a single unit. It is used, wherever stacking is unsuitable, a relatively large outside diameter of the spring is acceptable, and a regressive load-deflection characteristic curve is desired, like in clutch applications.

Diaphragm springs are often divided into a cone disc spring and a variety of lever arm segments. The organized slots of the lever arm segments allow this sort of spring to nonlinearly endure a bigger deflection at a smaller load than a cone disc spring. This sort of diaphragm spring is widely used as part of machine elements whenever area or space is restricted significantly within the presence of high force. Thus, the employment of this sort of spring in such small space is greatly important.

The importance of the nonlinearity can be seen in a friction clutch system. Instead of allowing continuous increasing load acts in an assembled machines system, a slotted disc spring has the ability to tune the increasing load into a considerably constant load within an intermediate deflection range. This is often helpful to avoid unexpected overload which might cause damage in machinery.

To improve the performance of the nonlinear load-displacement, several analytical works have been developed especially to prolong the constant applied load within the load-displacement. This can be done by varying the thickness profile of a disc spring cross-section. By preserving the constant applied load within the intermediate load-displacement region, fast increasing load exposure can be avoided.

It is commercially used for cars and light commercial vehicles. This type of spring is very compact, it has a few working parts and a spring that is particularly suited to light vehicles. In this report, we use a diaphragm spring clutch load--Deformation characteristics generally adopt the approximate formula proposed by Almen-Laszlo.

2.LOAD DEFLECTION CHARACTERISTICS OF DIAPHRAGM SPRING

The performance of diaphragm spring depends on the ratio of height to thickness. Typical load- deflection curves for various height-thickness ratios are shown in Fig.1.1 Note that the curve for a small H/*t* ratio is nearly a straight line. At H/*t* = .04 the curve shows a nearly constant load for approximately the last 50 percent of deflection before the flat position. Above H/*t* = 1.41 the load decreases after reaching a peak. When H/*t* is 2.83 or more, the load will go negative at some point beyond flat and will require some force to be restored to its free position. In other words, the washer will turn insideout.

H	4.20
t	2.63
R	115
r	87
e	88

δ_1	4
δ_2	12
r_f	24
r_e	77
r_p	27

L	113
H/t	1.6

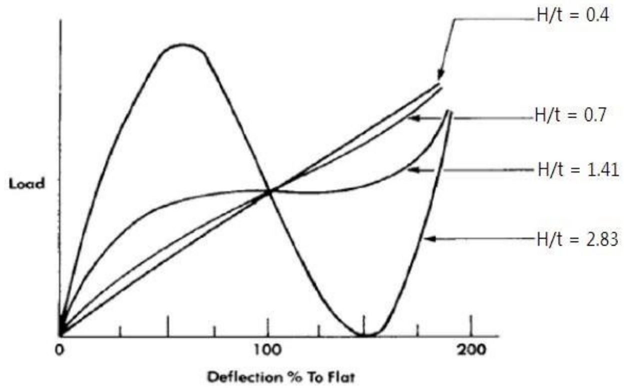

Fig1. Load deflection characteristics of diaphragm spring [13]

3.OBJECTIVE

The objective of the present work is to study the load deflection characteristics of the diaphragm spring with various H/t ratios. In this study, the spring characteristics of a standard spring are solved and compared by using theoretical and FEA results. Theoretical results are calculated by using Almen-Lazlo formula, and for FEA results we use Creo for designing and Ansys for analysis.

4.APPROACH

This project will provide step by step direction to model a diaphragm spring in CREO PTC and load-deflection test specimen in FEA ANSYS and investigate various loadings and different height conditions. The fully elastic material properties are loaded into FEA ANSYS and the 50CrV4 test specimen is loaded in tension. The end results of this project will investigate how FEA ANSYS reacts to high loading conditions for fully elastic deformation, especially beyond the yield point

5.MODELING

Models have long been utilized as a part of the advancement of complex frameworks. Their utilization is getting to be more pervasive in the product improvement space as displaying procedures and apparatuses adult. Notwithstanding this, there are numerous testing issues that the demonstrating examination group must address if programming displaying practices are to wind up standard. Moreover programming and frameworks get to be more entwined and the displaying systems utilized for frameworks building need to be orchestrated with programming models.

Models are utilized to investigate and find out about the issue to be tackled, where the "issue" can be, for instance, necessities distinguishing proof, framework determination, framework or part plan, complex convention or calculation outline. Quite compelling is the utilization of models to empower "consider the possibility that?" examination and prognostics (e.g., expectation, for example, by means of models of 'huge information.

The essential objective of this report is to cultivate trade of creative thoughts on the utilization of models in clutch designing. An alternate objective of this workshop is to further advance cross-treatment between the model-driven design (MDE) groups (e.g., MODELS) and programming building groups.

6.DESIGN DATA:-

For case 1

Table 1Dimensions of Diaphragm spring

And for other three cases only H/t ratio changes in which thickness is constant

Case – 2	H/t	1.9
Case – 3	H/t	2.125
Case – 4	H/t	2.2

The design of the following diaphragm spring is listed in the figure 3.1. CREO is used for designing and assembling the Diaphragm spring and fulcrum ring. . Rotationally symmetrical, this portion may be circumferentially divided into eighteen co-frames. Therefore analysis of the pattern used in the broadcast to all the solid instead of a single slice and the necessary analyzes were performed on the identification of symmetry boundary conditions. Thereby using less number of components to save time and computer system resources are needed.

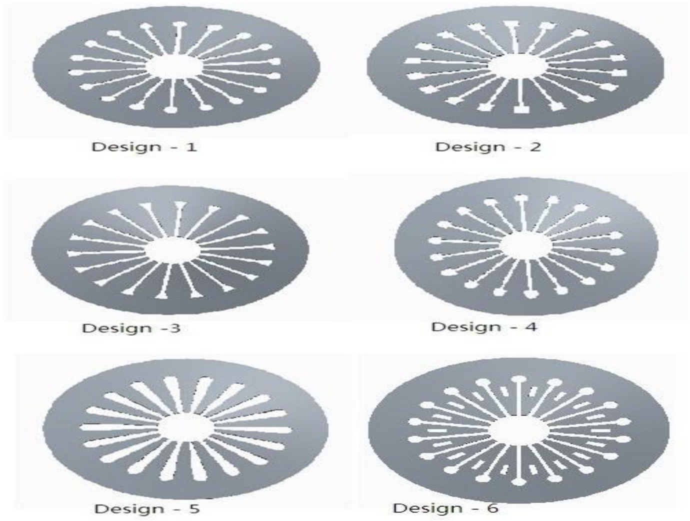

Figure2. Diaphragm spring designs

Diaphragm springs are shallow conical rings that are subjected to axial loads (Fig.3.1). Normally the ring thickness is constant and the applied load is evenly distributed over the upper, inside, and the lower outside edges. Diaphragm springs are generally manufactured from spring steel and can be subjected to static loads and dynamic loads.

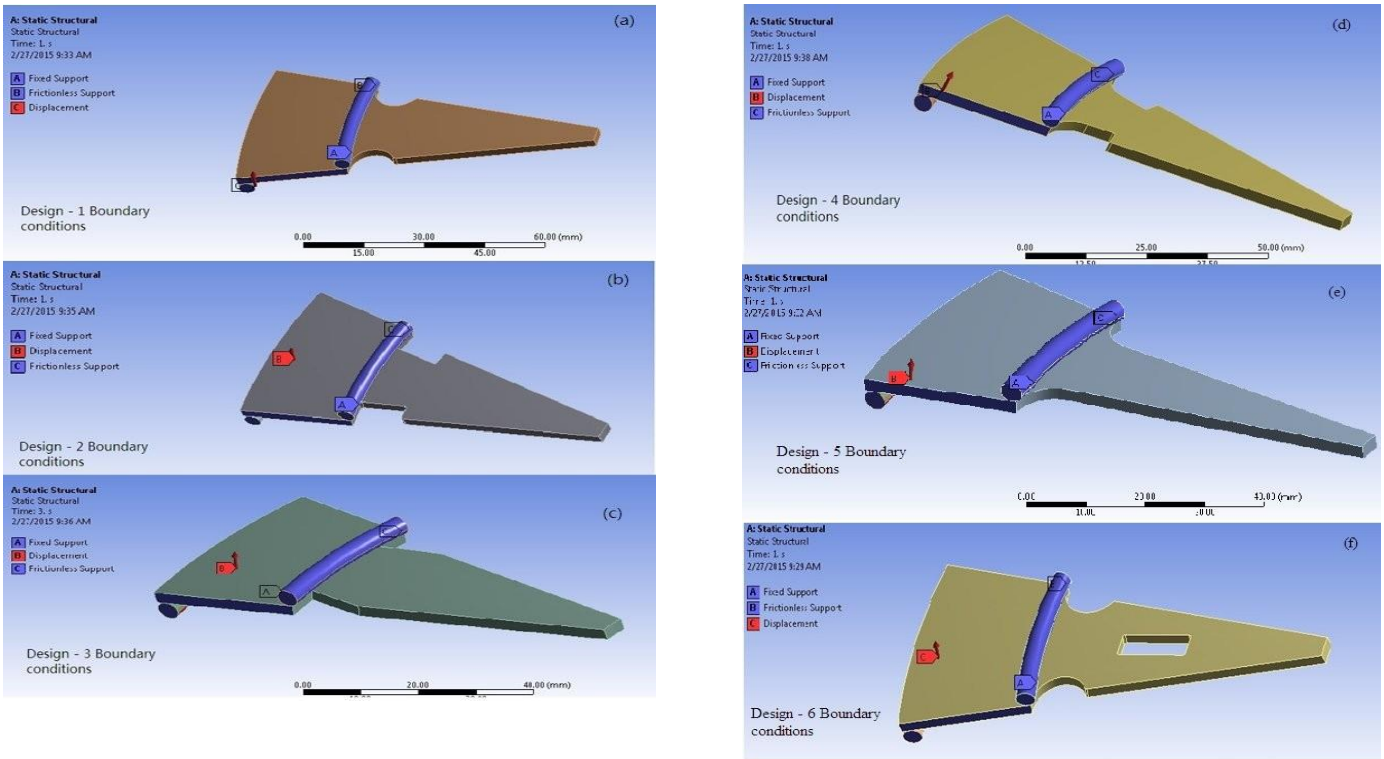

Figure 3.Loads and Boundary conditions,
(1) Design-1,(2) Design-2, (3) Design-3,
(4) Design-4, (5) Design-5, (6) Design-6

7.FEA RESULTS

The FEA results include Von Misses stress, displacement, and load-deflection curves from the FEA ANSYS program. The results will include analysis for the fully elastic tensile loading condition, elastic-plastic material properties under the various loading conditions.

FEA results of design 1 with different H/tratios

Table 2 FEA results of P_1-λ_1 design 1 with different H/t ratios

λ_1(1.6)	1	2	3	4	5	6	7	8
P_1(1.6)	2717.1	3870.18	4056.84	3739.14	3532.32	4121.28	6163.92	10288.44
λ_1(1.9)	1	2	3	4	5	6	7	8
P_1(1.9)	3653.28	5299.56	5622.84	5019.48	4060.08	3377.34	3695.76	5667.84
λ_1(2.125)	1	2	3	4	5	6	7	8
P_1(2.125)	4419	6613.38	7138.62	6495.48	5139.36	3695.4	2835	3300.12
λ_1(2.4)	1	2	3	4	5	6	7	8
P_1(2.4)	5523.12	8411.58	9475.02	8936.82	7303.32	5096.34	2985.12	1729.782

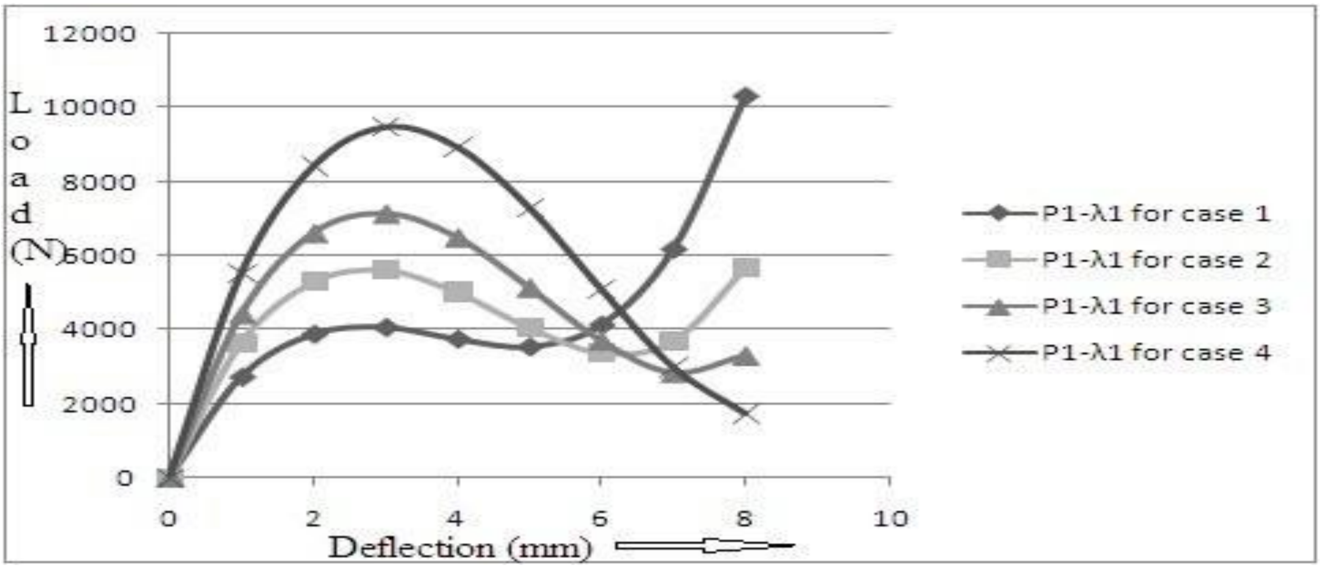

Fig.4. FEA calculation of P1-λ1 design 1 for different cases

Now as comparing these four cases according to FEM from design1 case 1 shows more variation comparing to other cases. The advantage of more variation has been seen in friction clutches because of ability to tune the increasing load into a considerably constant load.

FEA results of design 2 with different H/tratios

Table 3 FEA results of P_1-λ_1 design 2 with different H/t ratios

λ_1(1.6)	1	2	3	4	5	6	7	8
P_1(1.6)	2485.08	3573.54	3805.02	3574.8	3440.52	4017.06	5873.4	9578.34
λ_1(1.9)	1	2	3	4	5	6	7	8
P_1(1.9)	3328.92	4850.46	5196.06	4726.44	3928.32	3368.7	3695.76	5485.68
λ_1(2.125)	1	2	3	4	5	6	7	8
P_1(2.125)	4007.88	6022.8	6561	6046.38	4899.06	3660.84	2935.8	3380.22
λ_1(2.4)	1	2	3	4	5	6	7	8
P_1(2.4)	4994.64	7640.82	8658	8238.42	6795.9	4928.04	3089.88	1997.64

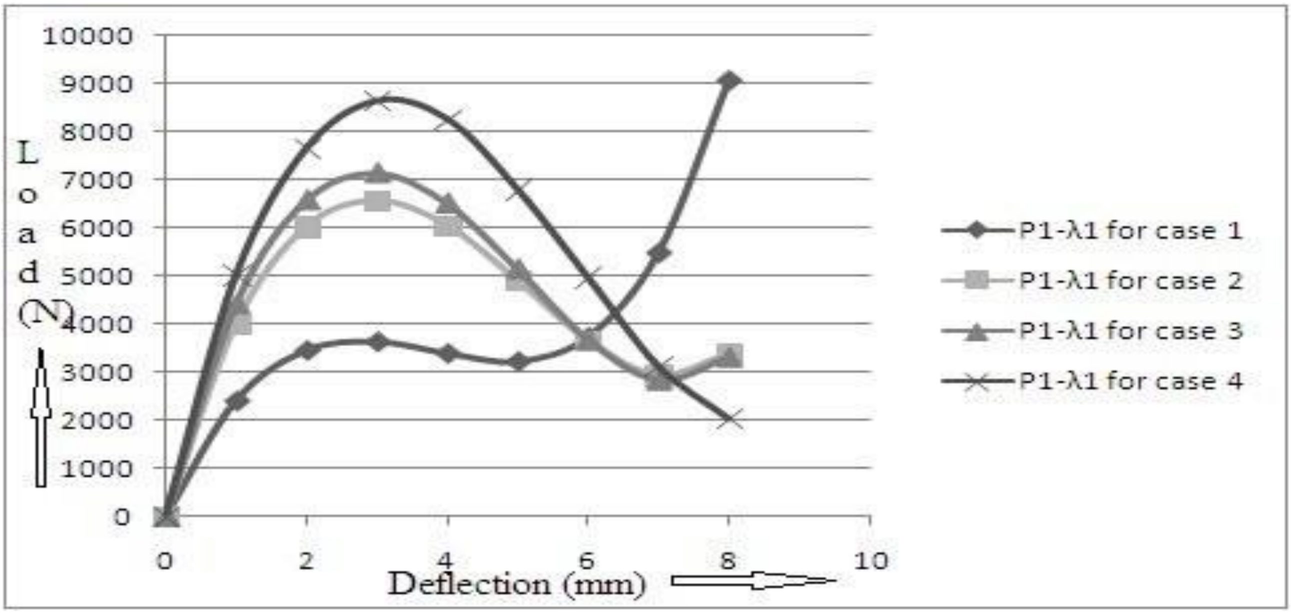

Fig.5. FEA calculation of P1-λ1 design 2 for different cases

From the same figure, it is observed that FEM analysis results almost approach the three numerical formulations in the early quarter displacement but tends to contribute to large error in the following displacement region. One possible explanation is that, the 3-dimensional FEM model allows the deflection in the radial direction. However, the 2-dimensional numerical formulations completely ignored such deflection as assumed in Almen formulation. This is considered as a factor that contributes to such error.

FEA results of design 3 with different H/tratios

Table 4 FEA results of P_1-λ_1 design 3 with different H/t ratios

λ_1(1.6)	1	2	3	4	5	6	7	8
P_1 (1.6)	2406.96	3456.72	3635.46	3394.98	3224.34	3734.82	5485.68	9068.58
λ_1(1.9)	1	2	3	4	5	6	7	8
P_1(1.9)	4007.88	6022.8	6561	6046.38	4899.06	3660.84	2935.8	3380.22
λ_1(2.125)	1	2	3	4	5	6	7	8
P_1(2.125)	4417.02	6581.16	7145.28	6520.32	5152.14	3682.08	2838.42	3314.52
λ_1(2.4)	1	2	3	4	5	6	7	8
P_1(2.4)	5024.88	7667.1	8654.76	8282.16	6814.26	4980.24	3123.36	2032.38

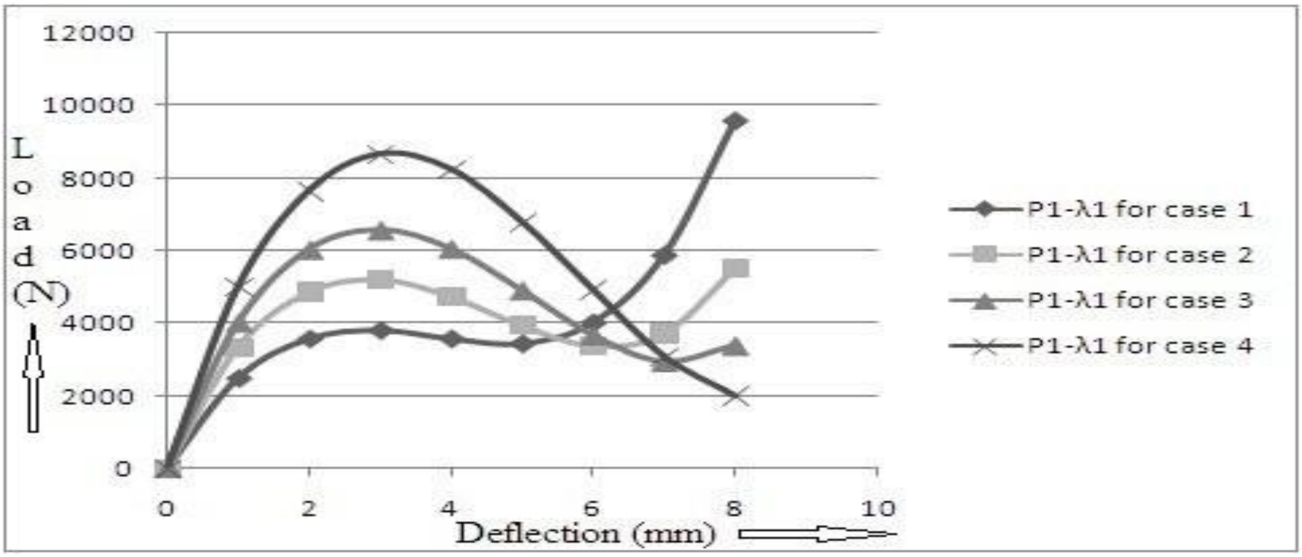

Fig.6.FEA calculation of P1-λ1 design 3 for different cases

Now as comparing these four cases according to
FEM from design 3 case 2 and 3 shows more variation comparing to other cases. The advantage of more variation has been seen in friction clutches because of ability to tune the increasing load into a considerably constant load.

FEA results of design 4 with different H/tratios

Table 5 FEA of P_1-λ_1 design 4 with different H/t ratios

λ_1(1.6)	1	2	3	4	5	6	7	8
P_1 (1.6)	2716.56	3868.74	4051.62	3733.38	3523.68	4112.46	6152.58	10275.3
λ_1(1.9)	1	2	3	4	5	6	7	8
P_1(1.9)	4994.1	7640.28	8657.82	8238.42	6795.9	4928.04	3089.88	1997.64
λ_1(2.125)	1	2	3	4	5	6	7	8
P_1(2.125)	4419.36	6606	7132.14	6491.7	5136.66	3689.64	2828.52	3291.66
λ_1(2.4)	1	2	3	4	5	6	7	8
P_1(2.4)	5527.26	8412.12	9479.7	8936.46	7297.56	5087.88	2972.16	1709.658

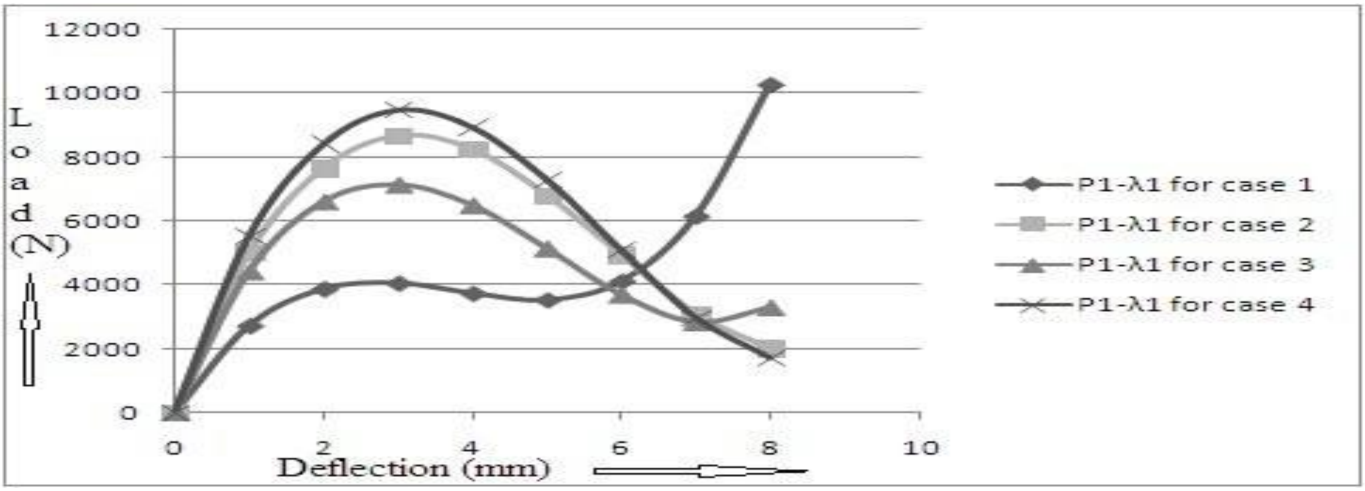

Fig.7.FEA calculation of P1-λ1 design 4 for different cases

Comparing this design for different cases, case 2, and 4 is almost same and case 1 the load deflection curve rapidly increases within a range .

FEA results of design 5 with different H/t ratios

Table 6 FEA results of P_1-λ_1 design 5 with different H/t ratios

λ_1(1.6)	1	2	3	4	5	6	7	8
P_1 (1.6)	2717.28	3873.6	4060.44	3743.46	3535.02	4127.4	6170.4	10296.36
λ_1(1.9)	1	2	3	4	5	6	7	8
P_1(1.9)	3657.06	4062.06	5618.88	5023.8	4062.78	3379.68	3697.2	5669.82
λ_1(2.125)	1	2	3	4	5	6	7	8
P_1(2.125)	4421.7	6613.02	7137.54	6499.08	5138.1	3696.3	2835.72	3301.02
λ_1(2.4)	1	2	3	4	5	6	7	8
P_1(2.4)	5522.58	8405.64	9481.14	8936.82	7302.6	5101.38	2986.92	1729.08

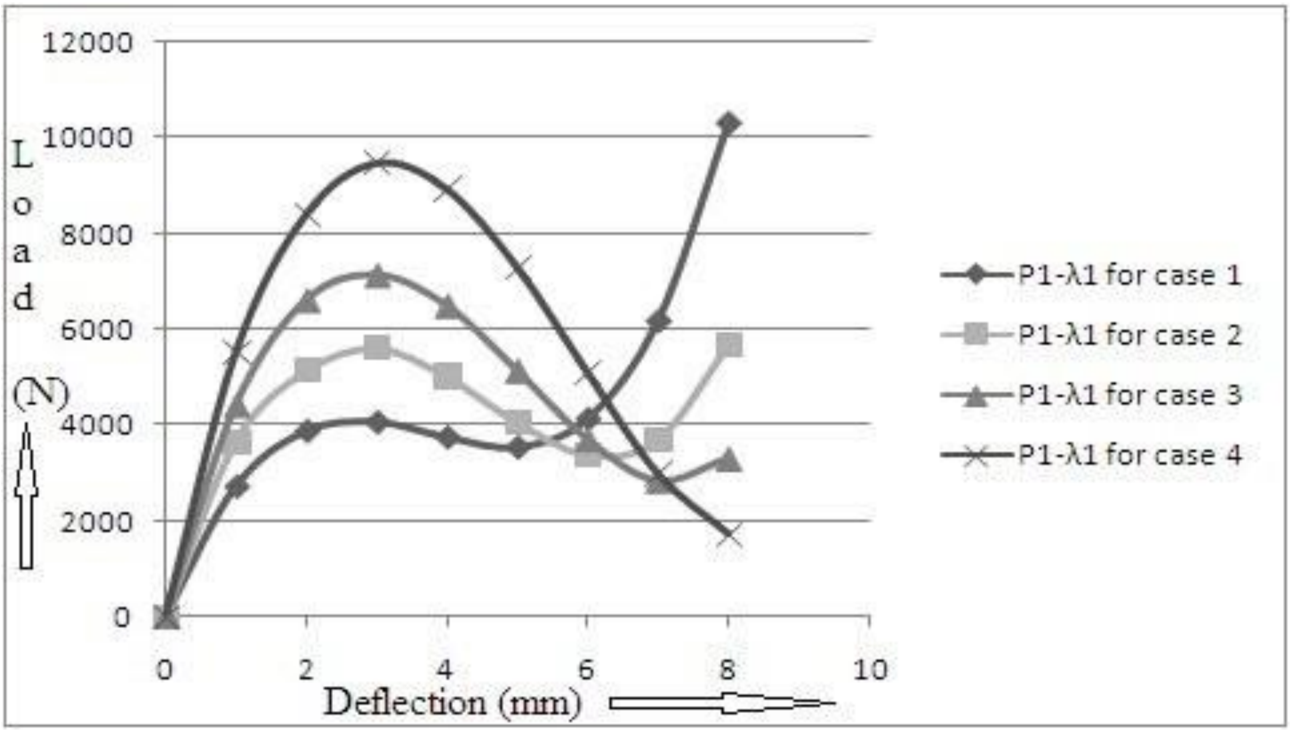

Fig.8. FEA calculation of P1-λ1 design 5 for different cases

above graphs show the curves obtained by the Ansys software for 4 different cases with height thickness ratio of 1.6 mm, 1.9 mm, .15 mm and 2.2 mm by considering the four different cases. The least variations is in case 4.

FEA results of design 6 with different H/tratios

Table 7 FEA results of P_1-λ_1 design 6 with different H/t ratios

λ_1(1.6)	1	2	3	4	5	6	7	8
P_1 (1.6)	2716.74	3869.1	4054.68	3736.44	3528.72	4117.32	6158.34	10281.06
λ_1(1.9)	1	2	3	4	5	6	7	8
P_1(1.9)	3648.24	5273.64	5607.18	5003.1	4049.46	3362.22	3664.62	5628.6
λ_1(2.125)	1	2	3	4	5	6	7	8
P_1(2.125)	4424.4	6626.34	7162.92	6538.32	5155.38	3713.76	2860.74	3335.22
λ_1(2.4)	1	2	3	4	5	6	7	8
P_1(2.4)	5517.36	8409.96	9466.38	8909.82	7213.32	5090.4	2973.96	1715.796

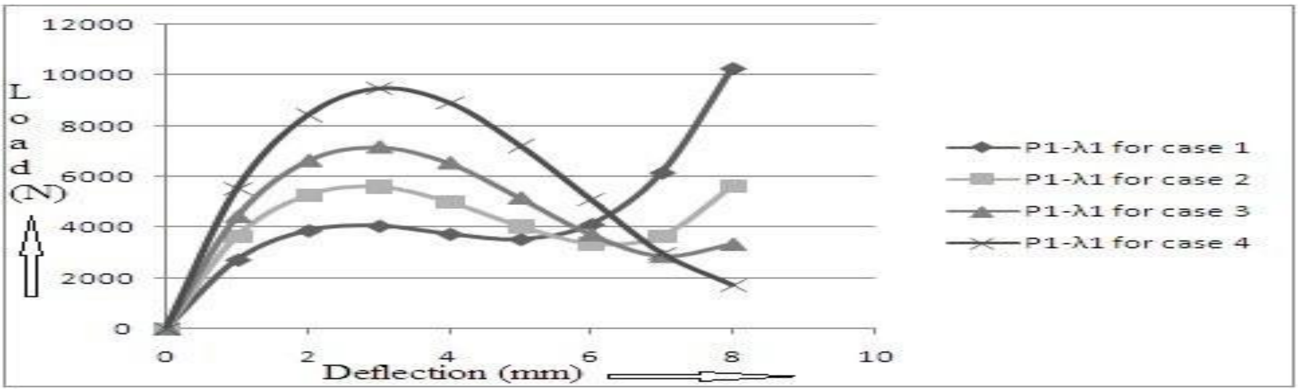

Fig.9. FEA calculation of P1-λ1 design 6 for different cases

Case 4 when height thickness ratio is 2.2 the load deflection curve diaphragm spring reaches maximum with an increase of displacement, it decreases and reaches minimum.

8. THEORETICAL RESULTS

The theoretical results include Reaction force, displacement, and load deflection curves from the Alman-Lazlo calculation equations. The results will include analysis for the fully elastic tensile loading condition, under the various loading conditions. In this theoretical analysis there are six different models of diaphragm spring with different height thickness ratio. The results are shown intables

Table 4.1 Theoretical results of P_1-λ_1-λ2 of design 1-6 with different H/t ratios

λ_1(1.6)	1	2	3	4	5	6	7	8
λ_2(1.6)	2.475761	4.931099	7.373441	9.810213	12.24884	14.69675	17.16138	19.65013
P_1(1.6)	2520.626	3601.753	3766.835	3539.326	3442.68	4000.353	5735.798	9172.469
λ_1(1.9)	1	2	3	4	5	6	7	8
λ_2(1.9)	2.487584	4.94946	7.393056	9.825797	12.25511	14.68842	17.13316	19.59674
P_1(1.9)	3353.97	4895.948	5149.386	4637.739	3884.463	3413.01	3746.836	5409.394
λ_1(2.125)	1	2	3	4	5	6	7	8
λ_2(2.125)	2.498007	4.966375	7.41253	9.843898	12.26791	14.69198	17.12355	19.57003
P_1(2.125)	4088.666	6088.189	6522.022	5913.621	4786.439	3663.93	3069.55	3526.751
λ_1(2.4)	1	2	3	4	5	6	7	8
λ_2(2.4)	2.512571	4.990716	7.441861	9.873432	12.29285	14.70756	17.12496	19.5525
P_1(2.4)	5115.251	7803.916	8589.452	7995.311	6544.949	4761.819	3169.376	2291.074

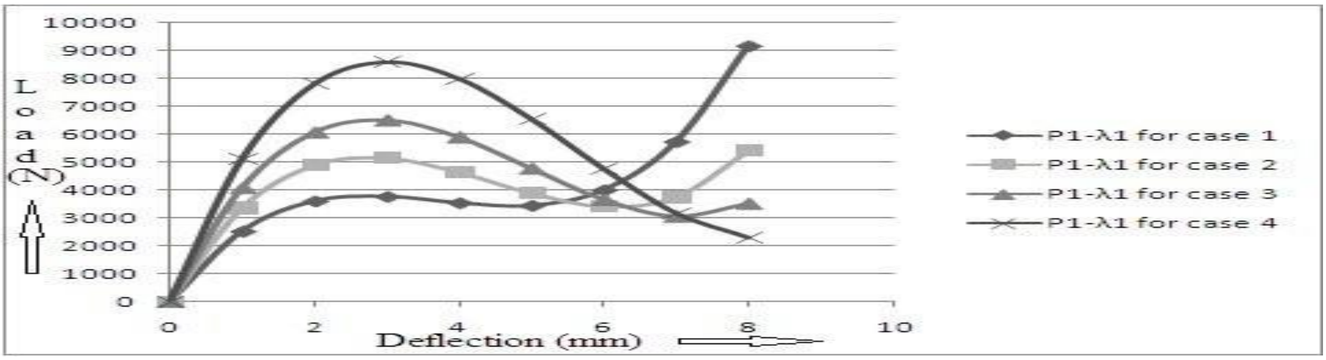

Figure 10.Theoretical calculation of diaphragm spring P1-λ1for case 1-4

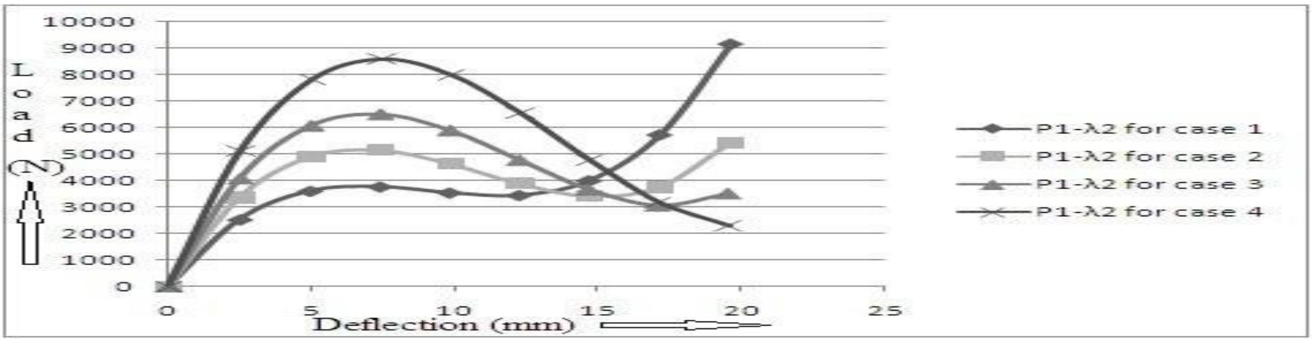

Figure 11.Theoretical calculation of diaphragm spring P1-λ1for case 1-4

Now as comparing these four cases according to Almen-Lazlo, for case 2 when h/t=1.9 shows more variation as comparing to the other cases. In this study the variation of h/t is identified as important design stage to identify the force deflection curve and meet the nonlinear properties.

9. CONCLUSION

Our main objective is to address this problem by analyzing the design of a spring by changing H/t parameters in a way that requires a minimum of knowledge and experience from the user. This saves time and allows the designer to eliminate many designs that would not work and reduces design time. It produces a design that satisfies all major design criteria and constraints and is a robust starting point to a final customizing process. This process allows the engineer a greater flexibility in designing a spring and allows greater customization than currently available.
The comparison between Finite Element Analysis using Ansys 14.0 and theoretical results of Diaphragm spring are similar at conical end, but at inner end where big deformation occurs there are some deviations. The shapes of the curve in load vs. deflection curve is nearly similar and having small amount variations. The behavior of curves are nonlinear and follow the same paths so the Finite Element results using Ansys 14.0 are verified by theoretical results which is calculated using Almen-Lazlorelationship.

Variation in load deflection curve obtained through FEM a, as compared to theoretical results is substantial. Therefore, FEM based estimation of load deflection curve results into significant errors and should be used with due care. Furthermore, it should be noted that if FEM simulation is performed using the actual experimental conditions of Diaphragm spring, the deviation in results can be small. The diaphragm spring has nonlinear behavior so it can be analyzed by ‘Static Structural ‘using large deformation theory.

These observations indicate that FEM based modeling of Diaphragm spring can be used effectively a simulation of the load deflection curve. However, the accuracy of results is different in terms of theoretical results. Still the deviations in results are not very large except for design 5 case 2 and may be used to obtain very close estimates on load deflection curves of Diaphragm spring.

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