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Probabilistic design of composite leaf spring by using finite element method

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Abstract. A parametric model is created in ANSYS workbench, FEA method is used to carry out probabilistic design in ANSYS workbench. Mono leaf spring is considered for analysis purpose and analysis is carried out. Composite material is applied to parametric model. Boundary conditions are applied to mono leaf spring, both ends are fixed and load (force) is applied to mono leaf spring. Meshing is carried out. The geometric parameters (thickness, width, etc.) are used as input parameter and Von-Mises stress considered as output parameter. For any further uncertainty in analysis, parametric co-relation function is used in ANSYS. The relation in geometric parameter and output parameter is achieved by correlation coefficients

1. Introduction

The leaf spring mainly provides flexibility between two mating parts subjected to fluctuated loads. Research shows when the composite material is used in leaf spring, its weight reduces and ultimately efficiency is increased. Most of the researchers focused on investigating the static behaviour of the leaf spring under loading condition with finite element analysis. The general process is to design spring in modelling software and then the model is exported to some neutral format and importing cad file for analysis in simulation software but this is a very tedious process. This work gives an idea about designing the parametric leaf spring in ANSYS workbench which reduces the time of designing.

The conventional material can be replaced by composite material so as to get better strength, many researchers are carried out analysis of leaf spring by using composite material to achieve better results as compared to conventional material [1-7]. By considering composite material for analysis the weight of vehicle is reduced and efficiency gets increased [1,3].The commercial vehicles leaf spring is used for analysis purpose to achieve the best solution for existing problems, the results calculated for the leaf spring are displacement, principal stress and energy [2-3].

It is observed from a literature survey that the probabilistic approach for the design of composite leaf spring by using FEA (ANSYS) is not taken into consideration. Also uncertainty in Von-Mises stress by considering various geometrical parameters is not focused by anyone in past years. Also, the results of probabilistic design are to be optimized. The result will provide a new approach.

2. Material selection

Carbon/epoxy composite materials have good strength as well as they have better absorption capacity and store more amount of energy. It has good modulus comparatively to conventional material.

Therefore, carbon/epoxy is used for designing of leaf spring and orthotropic material properties are considered [1].

3. Probabilistic Design

This technique is used to understand the effect of uncertain input and the assumptions on the model. This technique provides to determine the extent to which uncertainties in model effect on output parameter. An uncertainty random quantity of a parameter whose value is impossible to determine at a given point.

The uncertainty analysis of leaf spring can be classified into two parameters,

3.1 Input parameters

- Geometric parameters: chamber height (h), length of leaf spring (l), width (w) and thickness (t)
- Load parameters: Force (fy)

3.2. Output parameter

- Von-Mises stress (σMax)

Using these parameter, the probabilistic design is carried out in ANSYS to understand the sensitivity of input parameter on Von-Mises stress. Probabilistic design can be used to determine the effect of one or more these input variables variations on the outcome (Von-Mises Stress) of the analysis.

4. Finite element analysis

4.1 Parametric model

The parametric modelling of mono leaf spring is carried out in ANSYS workbench by taking various parameters length of leaf spring, width of leaf spring, thickness of leaf spring etc. Figure 1 shows the parametric model of mono leaf spring. The dimension commercial vehicle are considered [2].

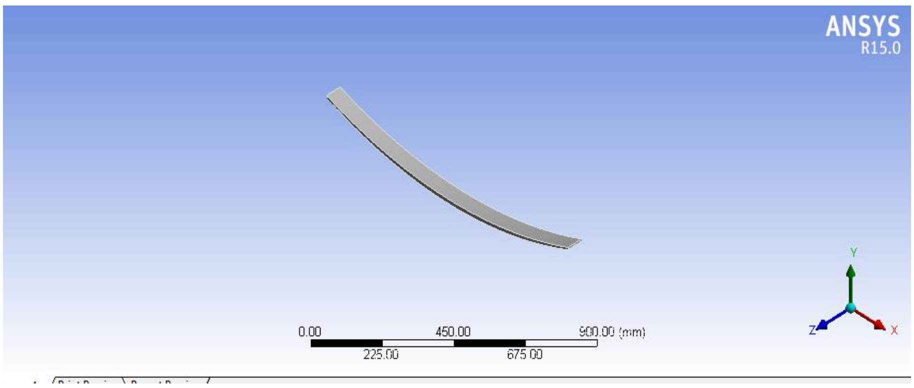

Figure 1. Parametric model of mono leaf spring

4.2 Meshing

Meshing is a process of dividing a model into a small number of pieces. The mono leaf spring has meshed, number of nodes 4577 and number of elements are 552 with element size 16 mm Figure 2.

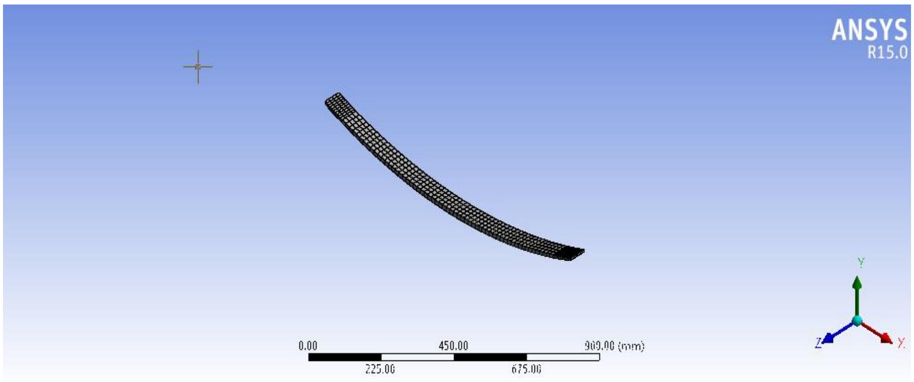

Figure 2. Meshed mono leaf spring

4.3 Boundary conditions

A finite element model with a segment of one mono leaf spring is considered for analysis. The mono leaf spring is considered as a fixed beam during analysis. Both ends of the leaf springs are fixed and a point load is applied on mono leaf spring Figure 3.

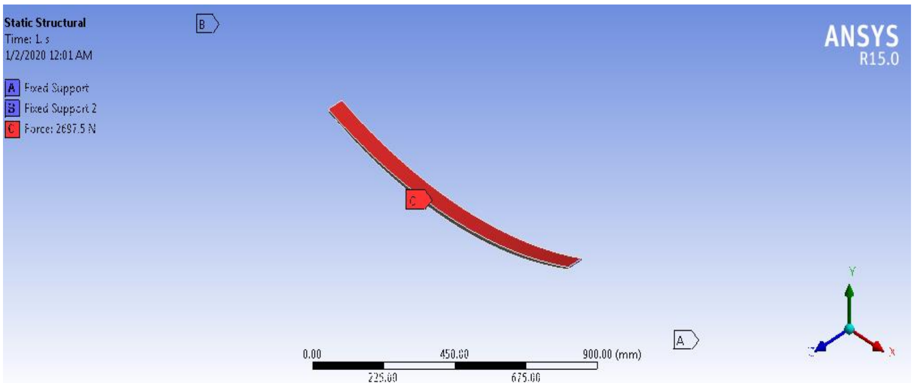

Figure 3. Mono leaf spring with boundary condition

4.4 Finite element analysis

After applying boundary condition to leaf spring, result is obtained as Von-Mises stress. The variation of the Von-Mises stress is shown in the Figure 4. The stress is maximum at fixed end and its minimum at a centre.

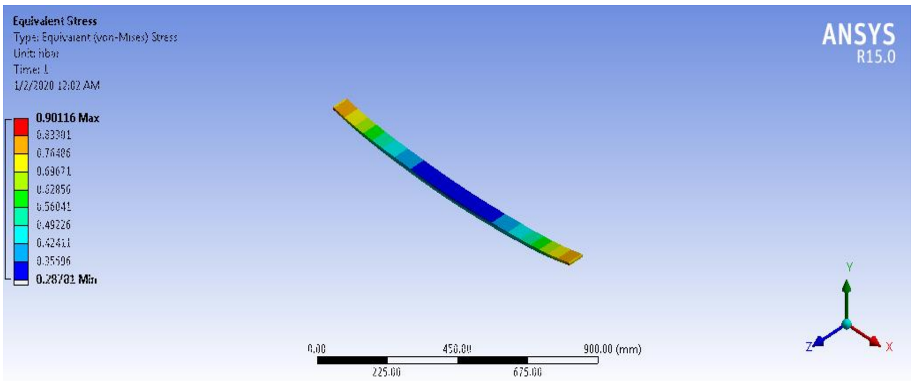

Figure 4. Representation of stress in ansys

Table shows various parameters used for probabilistic design and analysis of leaf spring.

Table 1. Dimensions for leaf spring

Length (mm) P1	Chamber height (mm) P2	Thickness (mm) P3	Width (mm) P4	Force (N) P5	Von-Mises Stress (hbar) P6
1072	95.4	8	60	2697.5	11.099

Each input parameter from its base dimension is varied by 5% in upper bound and lower bound to get the parameter set within that range Table 2.

5 Results

5.1 Probabilistic design

The probabilistic design of composite leaf spring is carried out and the results are obtained in Ansys as Von-Mises stress as objective function. From this study we can able to decide better parameter set to design the leaf spring, for parameter set in Table 2. From the study, the parameter set 15 is best amongst the all parameter set.

5.2 Correlation between input and output parameter

Correlation gives the process of design of experiments and it provides correlation in input and output parameter. Figure 5 shows about linear correlation between the input parameter and the output parameter. For the correlation matrix above twenty set of parameters are considered. The degree colour of the matrix shows the correlation between parameters. The correlation value for the input-output parameter is given in below Table 3.

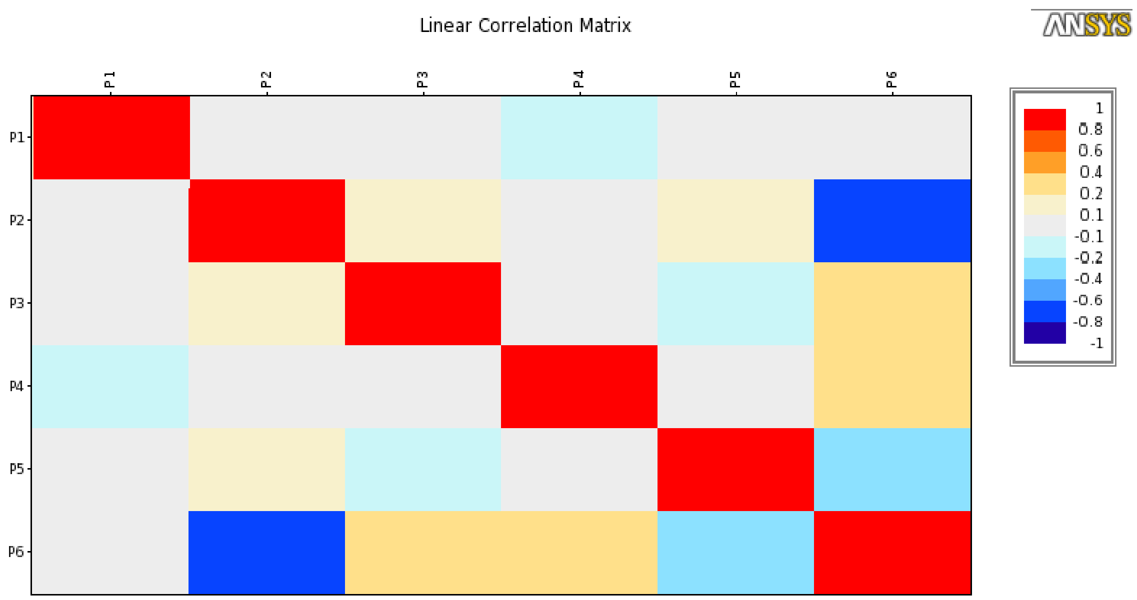

Figure 5. Correlation between input-output parameter

Table 2. Input and Output parameter optimisation

Sr. No	Width P1	Length P2	Chamber height P3	Thickness P4	Force P5	Von-Mises Stress P6
	W	L	H	t	F_Y	σ_{Max}
1	62.62	1114.95	97.87	7.68	2581.19	9.9717
2	61.69	1039.09	91.00	7.62	2793.10	12.7731
3	57.18	1062.29	90.43	7.98	2629.79	10.7803
4	57.61	1076.08	92.85	8.33	2785.50	10.8358
5	58.69	1111.09	92.31	8.19	2654.21	9.5721
6	62.92	1050.69	90.38	8.10	2678.28	10.0857
7	58.56	1069.90	95.78	7.91	2733.69	11.8230
8	57.43	1047.46	92.54	7.88	2595.69	12.4397
9	57.97	1119.11	94.38	7.82	2718.64	10.5433
10	59.37	1089.69	99.75	7.79	2586.29	11.8023
11	61.30	1092.27	93.69	8.07	2820.49	10.4405
12	60.01	1083.69	95.11	8.17	2738.77	10.6300
13	62.31	1123.99	91.96	8.39	2616.88	8.7722
14	60.95	1100.48	96.71	7.73	2767.83	11.0918
15	61.83	1040.93	93.43	7.92	2638.34	16.5849
16	59.11	1081.14	91.20	7.74	2705.00	10.7820
17	61.41	1066.91	96.31	7.80	2660.57	12.8250
18	62.62	1114.95	97.87	7.68	2581.19	9.9717
19	61.69	1039.09	91.00	7.62	2793.10	12.7731
20	57.18	1062.29	90.43	7.98	2629.79	10.7803

Table 3. Correlation matrix

Correlation Matrix	Width	Length	Chamber height	Thickness	Force	Von-Mises stress
Width	1.0000	0.0174	-0.0371	-0.1368	-0.0382	-0.0528
Length	0.0174	1.0000	0.1787	-0.0070	0.1658	-0.6043
Chamber height	-0.0371	0.1787	1.0000	-0.0576	-0.1192	0.2715
Thickness	-0.1368	-0.0070	-0.0576	1.0000	0.0197	0.3237
Force	-0.0382	0.1658	-0.1192	0.0197	1.0000	-0.2201
Von-Mises stress	-0.0528	-0.6043	0.2715	0.3237	-0.2201	1.0000

6. Conclusions

Based on the above study, the conclusions are made

- Parametric modelling and finite element analysis of leaf spring are successfully carried out in ANSYS Workbench.
- A new methodology for the design of leaf spring i.e. probabilistic design has been implemented
- Geometric parameters like Length of leaf spring, width, thickness etc. have a significant influence on Von-Mises stress
- Correlation Coefficients are obtained for the input and output parameters.

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