REDESIGN OF AN HELICAL SPRING APPLIED TO AUTOMOTIVE SUSPENSION

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Abstract. *Currently, the automotive market requires as a competitive edge products of good quality with an attractive value. Thus, automakers have required constant reductions in the costs of its components. This paper presents a mass reduction proposition for the helical spring used in the rear suspension system of a vehicle. The study was based on analysis of the original component design and testing a group of samples spring used in the vehicle. From this information has been designed and manufactured a new spring. This new spring was subjected to tests in order to assess their viability. From the results, it was concluded then the possibility of reducing the wire diameter of 0.20 mm and to reduce the spring body diameter of 2.00 mm, allowing material savings in manufacturing.*

Keywords: *Suspension system, helical spring, redesign*

1. INTRODUCTION

The biggest challenge for organizations today concerns the reduction of production costs and consequently, the increase in profits, which are necessary for any company that aims to stay in the market. Due to this requirement, organizations encourage reengineering actions, such as reducing waste materials [Callister, 2008; Curitiba, 2005].

The suspension system of a vehicle has the important function of isolating vibrations and aims to improve passenger comfort, maintaining the integrity of the materials transported, in addition to increased security. Helical springs, along with structural elements and frequency drives, are a major component of suspension systems in cars [Freitas, 2006]. Springs are designed to provide traction, compression or torque, or mainly to save energy.

The correct sizing of a helical spring for a vehicle suspension system allows the previous correction of problems that would be detected only in the testing of prototypes. Thus, it is possible to reduce the final cost of the product as well as the costs and deadlines for making prototypes during quotation process [Gillespie, 1992].

This study aims to demonstrate the practical application of engineering concepts in optimizing a helical spring of automotive suspension to meet the requirements to reduce cost of production of the automotive market. The objective of this study is to evaluate the possibilities for mass reduction of a spring used in automotive suspension and, consequently, reduce product cost. The required characteristics were analyzed in the original design, such as elastic constant, diameters, heights, number of turns and life (cycles). A group of 9 springs samples were evaluated by fatigue test. The spring was then resized and 10 new spring prototypes were made to validate the sizing.

2. METHODS

2.1 Original Project Analysis

The development of this study was started with choice of a helical suspension spring of an automobile recently launched on the market, so this element has not undergone improvements. The dimensional characteristics specified by the vehicle manufacturer as well as the required tests and controls were analyzed. A group of nine samples were submitted to a fatigue test on eccentric press at a frequency of 4 Hz. The results were compared to minimum life required by the vehicle manufacturer (150,000 cycles), as specified in the original project [CHEVROLET, 2014].

2.1.1 Elastic Constant Measurement

The elastic constant is an important feature of the helical spring and should be within the established range in design. It can be determined by the relationship between applied load and strain [Juvinall, 1991]. The sample group springs were subjected to measurement of elastic constant in a device known as Wolpert balance (Figure 1), obtaining the result in a Force x deformation curve.

Figure 1. Testing in the Wolpert balance.

In a metrology laboratory, the sample group springs had some of its features measures such as wire diameter, body diameter, type of finish and turns numbers. As provided in original project, the elastic constant measurement was performed on the heights of 224.30 mm and 174.30 mm, presenting the results of Table 1.

Table 1. Spring constant of the sample results.

Sample	k [N/mm]
01	31.06
02	31.12
03	31.08
04	31.09
05	31.12
06	31.09
07	31.19
08	31.23
09	31.06
Average	31.11

$^{(1)}$ measured at 25°C

It was observed that the spring constant approaching the minimum value, though it was within the tolerance 32 ± 1 N/mm), indicating a parameter that can be improved in resizing.

2.1.2 Definition of spring parameters

The comparison of the original helical spring design with the results found in the sample group allowed the identification of parameters that could be changed, such as wire diameter, body diameter and elastic constant. Table 2 shows the results of fatigue test carried out on 9 samples.

Table 2. Results of fatigue test carried out on 9 samples.

Sample	Cycles
01	997,467
02	557,763
03	897,827
04	942,771
05	784,647
06	683,748
07	726,672
08	819,525
09	586,593
Average	777,446

(1) measured at 25°C

Thus, it was proved that the current Spring is oversized because averaged lifetime 5.18 times higher than that required by the original project. These results validate the purpose of this study, confirming that the current product is robust for your application, causing unnecessary production costs.

2.2 Spring Resizing

Original design provides tolerances on diameter of the wire, the diameter of the body and consequently the spring constant. An analytical simulation, combining different wire diameter and the body diameter values was performed in order to obtain a mass reduction for the spring, maintaining the performance of the initial spring (Table 3).

Table 3. Analytical simulation of springs parameters.

	d	D_i	D_m	k	l	m
	mm	mm	mm	N/mm	mm	kg
PROJECT	12.50	104.00	112.79	32.18	2,050	1.975
SIMULATION 1	12.45	104.00	112.74	31.71	2,049	1.958
SIMULATION 2	12.40	104.00	112.69	31.24	2,048	1.941
SIMULATION 3	12.35	104.00	112.64	30.78	2,047	1.925
SIMULATION 4	12.30	104.00	112.59	30.33	2,046	1.908
SIMULATION 5	12.50	103.00	111.86	32.98	2,036	1.961
SIMULATION 6	12.45	103.00	111.81	32.50	2,035	1.945
SIMULATION 7	12.40	103.00	111.76	32.03	2,034	1.928
SIMULATION 8	12.35	103.00	111.71	31.56	2,033	1.912
SIMULATION 9	12.30	103.00	111.66	31.09	2,032	1.895
SIMULATION 10	12.50	102.00	110.94	33.82	2,022	1.948
SIMULATION 11	12.45	102.00	110.89	33.32	2,021	1.931
SIMULATION 12	12.40	102.00	110.84	32.84	2,020	1.915
SIMULATION 13	12.35	102.00	110.79	32.35	2,019	1.899
SIMULATION 14	12.30	102.00	110.74	31.88	2,018	1.882

The "Simulation 14" showed lower mass and spring constant within the design specification. Defined the dimensional characteristics of the new spring, it was analyzed the possibilities for fatigue failure, strength and buckling. Relating the free length and the average diameter of the spring it was found that failure by buckling does not occur [Chiaverini, 2008]. According to the method of Von Misses, the spring does not fail by tensile strength. Finally, using Goodman's equation, it was found that the spring does not suffer fatigue failure for a lifetime of 150,000 cycles [Shigley, 2005].

3. RESULTS

After resizing spring and validation of selected parameters (wire diameter and body diameter) were made 10 new Spring prototypes. These prototypes were subjected to the same analysis and testing of the original spring group of samples. The results are in Table 4:

Table 4. Results of the fatigue test prototypes.

Sample	Cycles
01	672,834
02	708,619
03	642,377
04	539,741
05	756,663
06	617,494
07	558,382
08	728,546
09	483,875
10	579,068
Average	628,760

(1) measured at 25°C

These results show that the new spring presents the life required in the design of 150,000 cycles. As provided for in original project, the elastic constant measurement was performed on the heights of 224.30 mm and 174.30 mm, and the results are in Table 5.

Table 5. Elastic constant results of the prototypes.

Sample	k [N/mm]
01	32.00
02	32.05
03	31.56
04	31.84
05	31.85
06	31.90
07	31.92
08	31.61
09	31.89
10	31.88
Average	31.85

(1) measured at 25°C

These results showed that prototypes have the closest value of elastic constant at the nominal value required by the design (32 N/mm).

4. CONCLUSIONS

This paper proposed the resize a component of the vehicle suspension system: the helical spring. The comparison of the original design with the results obtained in tests with spring samples showed that this component was over dimensioned, achieving a life in fatigue 5.18 times higher than that required.

With the focus on weight reduction in the helical spring and the elastic constant maintenance, have been simulated different combinations of wire diameter and the body diameter in accordance with the design tolerances. It was concluded that it is possible to reduce the wire diameter at 0.20 mm and reduce body diameter 2.00 mm, allowing a saving of approximately 60 g of material. Defined the dimensional characteristics of the new springthe possibilities of fatigue failure, strength and buckling were analyzed.

The value of the spring constant has met the design specifications, also promoting an improvement compared to the initial samples. Finally, the fatigue test determined that the prototypes showed a lifetime 4.19 times larger than required. Faced the results presented, it is concluded that the spring proposal is able to be inserted in the auto parts market, replacing the current component. Today is produced in Brazil, approximately 13,000 units of this spring to meet the domestic and Asian market, so it can estimate a considerable annual savings in consumption of raw materials.

5. ACKNOWLEDGEMENTS

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