FAILURE ANALYSIS OF THE SUSPENSION SPRING OF A LIGHT DUTY TRUCK

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ABSTRACT

In this paper the failure of the rear suspension spring of a light duty truck is analysed in detail. The rear axle suspension system of the truck and its flat spring which is failed by brittle fracture is investigated. Fracture surface, mechanical and chemical properties and microstructure of the spring materials are analysed. Forces acting on the spring are determined and the strength calculations are carried out. The cause of fracture is revealed by analysing the microstructure of the materials and using the results of the strength calculations. Recommendations are given to prevent the similar failures.

1. INTRODUCTION

The vehicle is a 2003 model N2-class light duty truck. Fracture occured at the flat spring second from the bottom of the right rear suspension system, while the truck is 17251 km.

The function of the multy-lead spring (MLS) is to transmit and partly absorb the forces coming from the axes to the chassis. The MLS consists of lead springs which are joined together with a shackle bush and stabilisied by a shackle pin (Fig. 1). Parabolic flat springs are used in this suspension system.

2. ANALYSIS OF SUSPENSION SYSTEM OF THE TRUCK

The truck has a closed rear cabin to prevent an overloading during the transportation of fabrics.

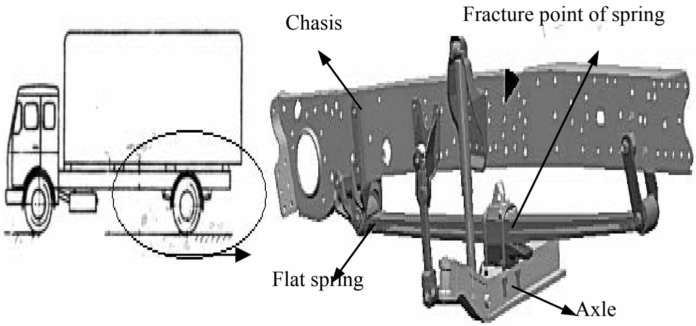


Figure 1: Rear suspension and multy-lead spring system

The truck was lifted, rear suspension and MLS were investigated in the University laboratuary. No over loading and impact effects on the MLS and load transmitting points were detected. Brittle fracture has occured around the shackle pin hole. By the analysis of the fracture surface it is concluded that failure occured by brittle fracture.

Altough no fatigue beach marks is detected on the fracture surface, brittle fracture probably started immediately after the fatigue-crack-initiation stage. Because fatigue limit of the flat spring is calculated as 395 MPa which is smaller than the alternating applied stress, namely 712.5 MPa.

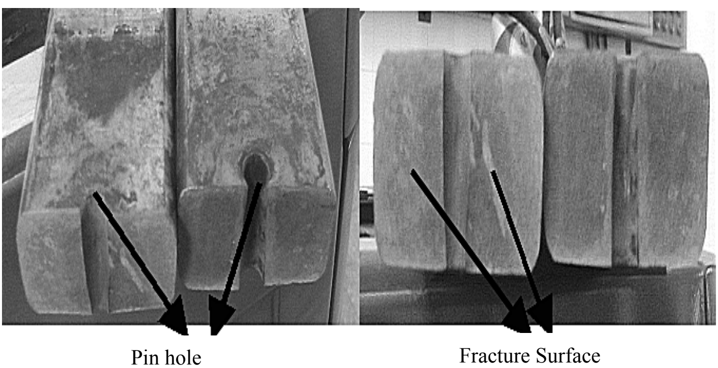


Figure 2: Macroscopy of fracture surface

3. PROPERTIES OF THE MATERIAL

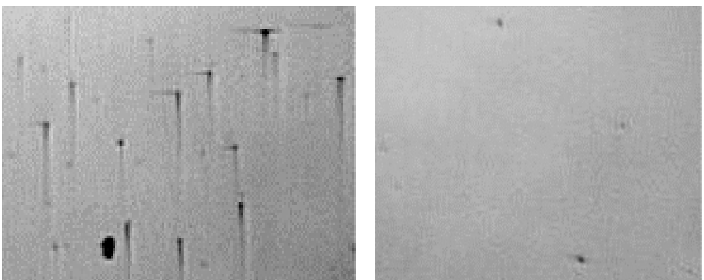
Two flat springs, one damaged and the other undamaged, were compared by analyzing their chemical and mechanical properties given in Table 1 and Table 2 respectively.

Table 1: Carbon and sulfur content of the springs

	C %	S %
Fractured spring	0,675	0,212
Undamaged spring	0,725	0,028

Table 2: Mechanical properties of flat springs

Spring	Yield Str. (MPa)	Tensile Str. (MPa)	Rapt. elong. (%)	Hardness (HRC)
Fractured	1465	1620	6	36
Undamaged	-	-	-	32



Fractured Undamaged

Figure 3: Microstructure of flat springs (X 200)

The dark pjases in the fractrued spring are MnS inclusions.

4. STRENGTH ANALYSIS OF THE FRACTURED SPRING

The springs are under the effect of different forces.

Table 3: Forces acting on the spring

Force Typ	Formation Typ	Direction	Value (kg)
$F_{Z,\ Stat.}$	Nominal axle load	Z	4500
$F_{Z,\ Dyn.}$	Road roughness	Z	4950
F_X	Braking, acceleration	X	1980

The static stress (σ_{Stat}) caused by maximum nominal axle load, can be calculated as;

$$\sigma_{Stat.} = \frac{6F_{Z,Stat.} \cdot l_a l_b}{nbh_0^2 (l_a + l_b)} \quad (1)$$

The total stresses (σ_T) acting in the spring can be given as:

$$\sigma_T = \sigma_{Stat}(1 + \frac{F_{Z,Dyn} + F_X}{F_{Z,Stat}}) \quad (2)$$

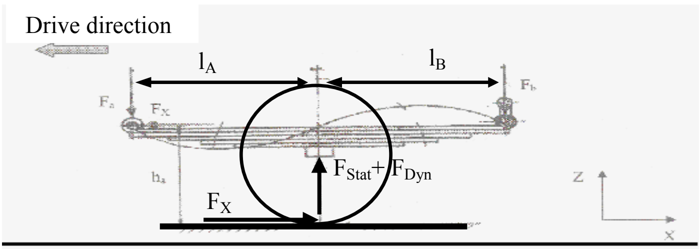


Figure 4: Forces acting on the flat springs

Table 4: Stresses occuring in the spring

σ_{Yield} (MPa)	σ_{Stat}(MPa)	σ_T(MPa)	φ	K_T	σ_{Max}(Mpa)
1465	224	570	1,1	2,5	1425

φ is impact factor and K_T notch effect. Eventually safety factor (S) is calculated as;

$$S = \frac{\sigma_{Yield}}{\sigma_{Max}} = \frac{1465}{1425} = 1.03 \quad (3)$$

5. FAILURE ANALYSIS

Failure analysis was carried out based on the material properties and the results of strength analysis.

After chemical and microstructural analysis high amount of sulphur, namely 0.212 percent, is detected in the form of MnS inclusions. This high level of inclusions seriously decreases the static and dynamic fracture toughness of the material.

Strength analysis shows that safety factor is too low (1.03) for this kind of applications.

6. PRECAUTIONS TO BE TAKEN TO PREVENT SIMILAR FAILURES

Two precautions namely using using clean steel and to changing spring design parameters can be recommended to prevent similar failures.

Equation (1) shows that static stress is strongly effected by the thickness (b) of the spring. By assuming no change in static and dynamic loads, the effect of increasing the thickness of spring on the stress distribution was investigated using finite element method (FEM) (Figure 6). FEM and analysis were performed by using commercial software I-DEAS.

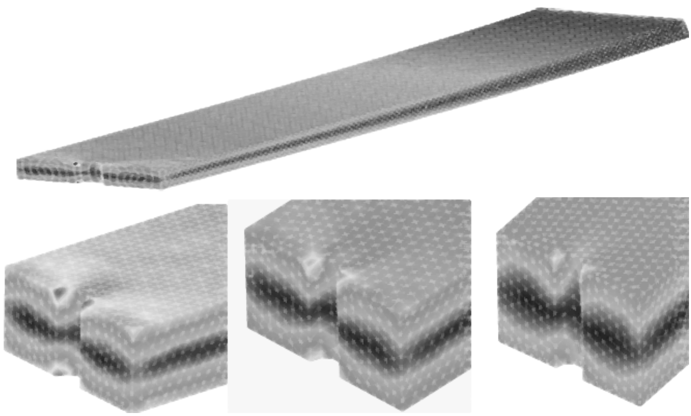


Figure 6: Analysis of stress distribution change of flat spring by increasing the thickness using FEM.

It can be seen from figure 7 that an increase of 3 mm in thickness could increase the safety factor from 1.03 to 1.2.

Figure 7: The effect of spring thickness on stress distribution

7. CONCLUSIONS

The failure of a light duty truck rear suspension flat spring is analyzed. The calculations showed that the safety factor of the spring is low because of low spring thickness and notch effect. Stresses would increase under extreme impact conditions during the navigation such as ride on pot-holes or road furrows, which could cause a sudden brittle fracture. Because of low fatigue limit of the spring, brittle fracture probably started immediately after the fatigue-crack-initiation so that no fatigue beach marks is detected on the fracture surface.

By the analysis of fracture surface and microstructure, high amount of MnS inclusions were detected causing a decrease in fracture toughness, which may be a dominant reason for the fracture. Using finite element method analysis, the effect of changing the thickness of flat spring on the stress distribution around the pin hole, where the fracture initiated is analysed. It is concluded that an increase in spring thickness could decrease the sress distirbution and increase the safety factor which could prevent a similar failure.

8. REFERENCES

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