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The fatigue analysis of a vehicle suspension system-A review article

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Abstract

In this review paper an effort is made to review the investigations that have been made on the different fatigue analysis techniques of a vehicle suspension system. A number of analytical and experimental techniques are available for the fatigue analysis of the vehicle suspension system. Determination of the different analysis around different condition in vehicle suspension system has been reported in literature.

Keywords

Cyclic stresses, Propagation rate, Suspension spring failure, Fracture mechanism.

1. Introduction

Fatigue is a phenomenon associated with variable loading or more precisely to cyclic stressing or straining of a material. Just as we human beings get fatigue when a specific task is repeatedly performed, in a similar manner metallic components subjected to variable loading get fatigue, which leads to their premature failure under specific conditions.

According to ASTM fatigue life define as the number of stress cycles of a specified character that a specimen sustains before failure of a specified nature occurs [1].

Due to the cyclic load on a suspension system of vehicle it can be failed .Thus, fatigue study and life prediction on the suspension system is necessary in order to verify the safety of this suspension system during its operation.

Many researchers in the automobile industry have taken the opportunity to improve the design of suspension system.

One of the most important parameters which determine the reliability and running safety of vehicles is functionality of the suspension system. In addition, the functionality of the suspension system affects the quality of ride comfort of passengers [2].

Even recently, in 2005 Chalk's Ocean Airways Flight 101 lost its right wing due to fatigue failure brought about by inadequate maintenance practices. Fatigue becomes an obvious design consideration for many structures, such as aircraft, bridges, railroad cars, automotive suspensions and vehicle frames. For these structures, cyclic loads are identified that could cause fatigue failure if the design is not adequate.

2. Factors affecting the fatigue life of a suspension system

There are number of parameters which affect the fatigue life of the structure as listed: Cyclic stress state, Geometry, Surface quality, Material Type, Residual stresses, Size and distribution of internal defects, Direction of loading, Grain size, temperature, and environment.

3. Early fatigue research history related to suspension system

Many researchers carried out study on component of suspension system. Dragan Z. Petrovic, Milan B. Bizˇic investigate the Improvement of suspension system of Fbd wagons for coal transportation [2]. E.A. Ossa, C.C. Palacio, M.A. Paniagua investigated Failure analysis of a car suspension system ball joint. [3] I.B. Eryu rek, M. Ereke, A. Go ksenli investigated Failure analysis of the suspension spring of a light duty truck [4]. Wöhler summarises his work on railroad axles. He concludes that cyclic stress range is more important than peak stress and introduces the concept of endurance limit [5]. William John Macquorn Rankine recognises the importance of stress concentrations in his investigation of railroad axle failures. The Versailles train crash was caused by axle fatigue. [6]

Rankine's investigation of broken axles in Britain highlighted the importance of stress concentration, and the mechanism of crack growth with repeated loading. His and other papers suggesting a crack growth mechanism through repeated stressing, however, were ignored, and fatigue failures occurred at an ever increasing rate on the expanding railway system. Other spurious theories seemed to be more acceptable, such as the idea that the metal had somehow "crystallized". The notion was based on the crystalline appearance of the fast fracture region of the crack surface.

4. Cyclic stress

There are three common ways in which stresses may be applied on a material.

1. **AXIAL STRESS:-**

Fig:-1

2. **TORSIONAL STRESS:-**

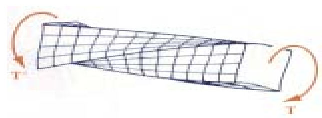

Fig:-2

3. **FLEXURIAL STRESS**

Fig:-3

There are also three stress cycles with which loads may be applied to the sample. The simplest being the reversed stress cycle.

This is merely a sine wave where the maximum stress and minimum stress differ by a negative sign.
An example of this type of stress cycle would be in an axle, where every half turns or half period as in the case of the sine wave, the stress on a point would be reversed.

The most common type of cycle found in engineering applications is where the maximum stress (σ_{max}) and minimum stress (σ_{min}) are asymmetric (the curve is a sine wave) not equal and opposite. This type of stress cycle is called repeated stress cycle.

A final type of cycle mode is where stress and frequency vary randomly. An example of this would be automobile shocks, where the frequency magnitude of imperfections in the road will produce varying minimum and maximum stresses.

5. Fatigue life method

The three major fatigue life method used in design and analysis are.

1. Stress-life method.
2. Strain life method.
3. Linear-elastic fracture mechanics method

STRESS- LIFE METHOD:
This method is based on stress levels only, so, it's a least accurate method, especially for law-cycle application.
However it is the most traditional method, since it is the easiest to implement for a wide range of design application, has ample supporting data, and represent high-cycle application adequately.

STRAIN-LIFE METHOD:
This method involves more detailed analysis of plastic deformation at localized regions where the stresses and strain are considered for life estimates. This method is especially good for law cycle fatigue application.

FRACTURE MECHANISM METHOD:
In this method assume a crack is already present and detected. It is then employed to predict crack growth with respect to stress intensity.

It is most practical when applied to large structure in conjunction with computer codes and a periodic inspection program.

6. The linier-elastic fracture mechanics method

Generally fatigue cracking has three phases.

1. STAGE I FATIGUE
2. STAGE II FATIGUE
3. STAGE III FATIGUE

In the first phase of fatigue cracking, Crystal chips that extend through several contiguous grains, inclusion, and surface imperfection are presumed to play a role.
So most of this is invisible to the observer we just say that stage I involves several gains.
The second phase is called stage II fatigue, that of crack extension.
The advance of the crack (that is, new crack area is created) does produced evidence that can be observed

on micrographs from an electron microscope. The growth of the crack is orderly.

The final fracture occurs during the stage III fatigue, although fatigue is not involved.

Demonstration of Crack Propagation Due to Fatigue

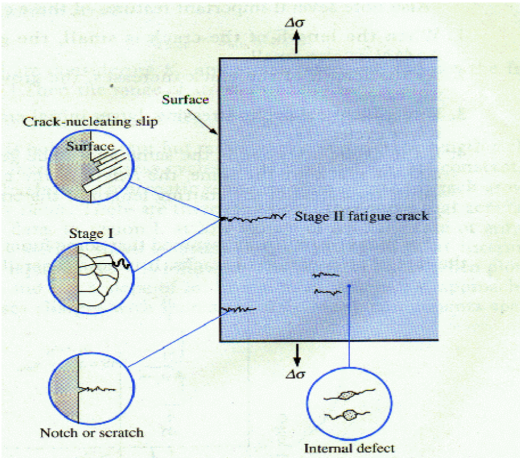

Fig:-4

The figure above illustrates the various ways in which cracks are initiated and the stages that occur after they start.

This is extremely important since these cracks will ultimately lead to failure of the material if not detected and recognized. The material shown is pulled in tension with a cyclic stress in the y, or horizontal, direction.

Cracks can be initiated by several different causes; the three that will be discussed here are nucleating slip planes, notches, and internal flaws.

7. Design against fatigue

Dependable design against fatigue-failure requires thorough education and supervised experience in structural engineering, mechanical engineering, or materials science. There are three principal approaches to life assurance for mechanical parts that display increasing degrees of sophistication:

- Design to keep stress below threshold of fatigue limit (infinite lifetime concept).
- Design (conservatively) for a fixed life after which the user is instructed to replace the part with a new one (a so-called lifted part, finite lifetime concept, or "safe-life" design practice).
- Instruct the user to inspect the part periodically for cracks and to replace the part once a crack exceeds a critical length. This approach usually uses the technologies of nondestructive testing and requires an accurate prediction of the rate of crack-growth between inspections. This is often referred to as damage tolerant design or "retirement-for-cause".

8. Different type of methods and applications of fatigue analysis

Sr no	Author	Year	Method used	Area of used
1	Cicek Karaoglu & N. Sefa Kuralay[14]	2001	FEM(finite element method)	Stress analysis of a truck chassis with riveted joints.
2	U.Kocabicak,M Firat[11]	2001	Numerical analysis	Numerical analysis of wheel concerning fatigue test
3.	Marcin Kaminski[13]	2002	probabilistic approaches	Fatigue models for composite materials
4	C.R. Williams [12]	2003	Practical method	Statistical analysis of strain– life fatigue data
5	O.Gundogdu[8]	2007	Genetic algorithm	Optimal seat and suspension design for a quarter car with driver
6.	I.B.Eryurek [9]	2007	FEA(I-DEAS)	Failure analysis of the suspension spring of a light duty truck
7	E.A. Ossa [10]	2011	FEM METHOD	Failure analysis of the car suspension system of ball joint

I.B.Eryurek did the failure analysis of the suspension spring of a light duty truck. The failure of the rear suspension spring is analyzed in detail. The rear axle suspension system of the truck and fractured flat spring is investigated. Fracture surface, mechanical and chemical properties and microstructure of the spring material is analyzed. Forces acting on the spring are determined and strength calculations are carried out. Later, failure Behavior and cause of fracture is revealed after carefully analysis of microstructure and results of calculations. At the end precautions to be taken to prevent a similar failure is recommended.

The analysis showed that increasing the thickness can reduce stresses or using the clean steel to avoid the fatigue failure.

FEM and analysis are performed by using commercial software I-DEAS. During the analysis, load effect of maximum permit table load (10.300 kg) is taken into account.

Fig. 8 demonstrates the effect of change in thickness of spring element on maximum stress. By spring thickness of 53 mm, the maximum stress value is equal to the endurance limit [9].

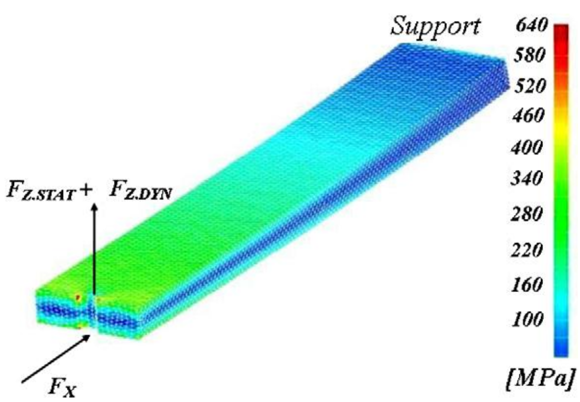

Fig:-5 : Analysis of stress distribution using FEM (I-DEAS)

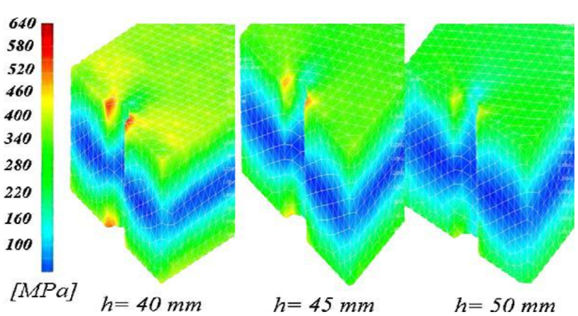

Fig:-6: Analysis of stress distribution change of flat spring by increasing the thickness (h)

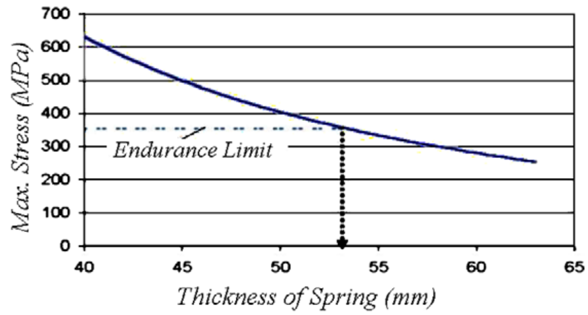

Fig:-7: Graphical view of the effect of change in flat spring thickness on stress distribution

9. Conclusions

An attempt has been made in the article to present an overview of various techniques developed for the fatigue analysis of component of suspension system. An information of assessment of a suspension arm, vehicle suspension components, fatigue analysis of truck chassis, fatigue analysis of a car suspension system of ball joint, Failure analysis of the suspension spring of a light duty truck.

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