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Correlation of Simulation, Test Bench and Rough Road Testing in terms of Strength and Fatigue Life of a Leaf Spring

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Abstract

There are three major methods to verify the durability characteristics of a new designed leaf spring. These are simulation, test bench and rough road testing.

Simulation is a rapid approach to find out the very first results for the assessment of the design. Test bench uses a pre-defined load program to estimate the lifetime of the leaf spring. It takes more time than simulation and is more costly. Rough road testing covers a complete endurance run for the whole heavy duty truck structure which is very costly and takes a very long time to accomplish.

The aim of this paper is to reduce the time and the cost of the development procedure of a new designed leaf spring. The most efficient way to reach this goal is to correlate the results of the testing and simulation, so that, it would be possible to release new designs mostly depending on the simulation which is the fastest and the reasonable way to reach a final evaluation.

A new designed leaf spring, with two leaves, is simulated in finite element analysis with the loads from multi body simulations in order to reach a fatigue life assessment; is tested in the test bench with the pre-defined loads from the rough road; is mounted to a complete truck structure to run a full rough road truck program to reach the final evaluation.

In this paper, these three durability assessment techniques are compared and correlated with each other as a main scope. Additionally, the simulation methodology, the structure of the test bench and the procedure of the rough road testing are given in details.

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Keywords: Leaf Spring, Test Bench, Virtual Test Rig, Load Spectrum Determination, Test Spectrum, Fatigue, Finite Element Method, Multi Body Simulation

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1. Introduction

Correlation of simulation is a profitable method to help the designers to achieve their goals in a more reasonable way. Because of high competition aspect in the market, cost and weight optimized designs are noteworthy nowadays within the vehicle engineering development activities. Therefore, strength and fatigue life simulation of leaf springs is going to be explained and correlated within this paper including examples.

Nomenclature

FE	finite element	P_o	probability of occurrence
FEM	finite element modelling	σ	stress for constant amplitude loading
MBS	multi body simulation	$\overline{\sigma}$	stress for variable amplitude loading
D	damage sum	σ_k	knee point of the S-N curve
L_s	sequence length	a	amplitude
L_{Test}	test spectrum length	f	frequency
L_{Design}	designed service length	k	slope of the S-N curve
N	number of cycles for constant amplitude loading	k'	slope of the prolongation
$\overline{N}$	number of cycles for variable amplitude loading	n	number of tests, number of cycles
N_k	fatigue life at knee point	t	time
P_s	probability of survival		

Multiaxial loads are acting on the leaf spring assembly in a truck structure and therefore they have great influence on the drivability of the truck. Vertical, lateral and longitudinal forces, with high moments during start, braking and torsion are acting on the leaf spring and should be investigated in detail for an accurate correlation of the simulation.

Sonsino [1] stated that variable amplitude loading tests are performed because none of the cumulative damage hypotheses can predict the fatigue life for these loadings. Hence such tests are required to have real damage sums with Wohler- and Gassner-lines, see Fig. 1.

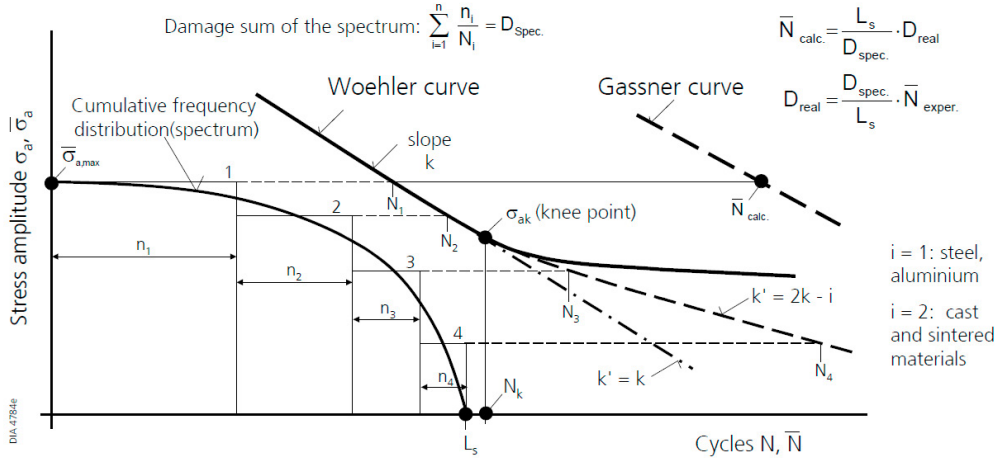

Fig. 1. Modification of S-N curve and calculation of fatigue life [2]

Based on the Palmgren-Miner-Rule modified by Haibach [3], the damage of a spectrum with size L_s can be calculated: