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Failure mode analysis of torsion beam rear suspension under service conditions

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ABSTRACT

The failure mode of torsion beam rear suspension under service conditions was investigated, which refers to the identification of the failure position and failure critical loads because the failure of automobile structures was mainly caused by fatigue. Service loading histories, in the form of wheel loads (forces and moments) and strains of critical regions were measured on a test track of a proving ground. Failure position was determined by comparing the damage values of the critical regions calculated with linear damage rule, while critical loads were determined by the correlation analysis between wheel loads and strain of failure position. The results of damage comparison and correlation analysis indicate that fatigue failure occurs on the torsion beam near the welding seam between it and reinforcing part and could be attributable to vertical forces on the wheel, especially the difference between left and right wheel which introduced an additional torque on the beam. The correctness of the deduced failure mode was demonstrated by conducting fatigue tests on MTS 6DOF road load simulator under all wheel loads and only vertical forces. The conclusion could be helpful for the design and developing load spectrum for accelerated durability test of this kind rear suspension.

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0. Introduction

Minimizing weight to save costs while assuring reliability and durability is the primary objective of structural design for modern products, especially for the automotive industry which also faces reducing fuel consumption and improving safety at the same time [1]. Due to the failure of structural components of automobiles mainly result from fatigue [2,3], it is necessary to recognize the fatigue failure mode and identify the most likely causes for the achievement of light weight design on the basis of satisfying reliability indices, particularly for the safety components, such as wheel, hub, spindle and suspension [4].

Torsion beam rear suspension is widely adopted in non-driven rear axles for its simple, economical and space saving, etc. As a key safety component which supports the car, it is important to assure the reliability and durability in the design stage, especially in light weight design. Therefore, many studies have been made to investigate the parameters that affect the performance and durability of it [5–9]. However, with respect to the failure mode and failure critical loads, they are still not clear because of the complexity of loads exerted on it (the change of gross weight, the variation of dynamic load coefficient due to fluctuation of road surface, and additional forces induced by driving conditions, e.g. accelerating, braking and cornering) and fatigue failure is relevant to both the magnitude and number of cycles of load.

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In this investigation, the failure mode and failure critical loads of torsion beam rear suspension under service conditions were studied. First, load histories in the form of wheel forces and strains of critical regions are measured on a test track of proving ground. Then the region where fatigue failure occurs was located by comparing the damage value calculated with linear cumulative damage theory. Third, failure mode and failure critical loads were identified by correlation analysis. Finally, fatigue tests were conducted on MTS road load simulator for verification.

1. Target rear suspension, data acquisition and road type

The rear suspension under consideration is used in a compact car with a curb weight of 1325 kg, and is constructed of seven parts jointed together by seam welding, Fig. 1. The materials of rear suspension is TL1114 with an ultimate tensile strength 500 MPa, yield strength 390 MPa. The loads (forces and moments) exerted on wheel are transmitted via rear suspension to the unitized body of the car. The springs and shock absorbers transmits forces in vertical direction, while trailing arm transmits longitudinal and lateral forces, and torsion beam accounts for roll stiffness.

Load-time histories are measured on a test track of proving ground, which composed of various rough road conditions and driving maneuvers. The track drive program in present investigation consists of:

- Left and right cornering at constant speeds.
- Accelerating and braking during straight driving and cornering.
- Driving on Belgium road, uneven road, washboard road, pothole road, well cover road, railway crossing, transverse cross-tie, and up-and-down hills, etc.

The wheel forces and moments of left and right wheels are measured with two multi-axial wheel force transducers (MTS WFT 205/55R16). The installation of transducer and the assignment of wheel loads direction are shown in Fig. 2. For fatigue failure is more of a localized problem, strain-time histories at various critical regions are measured to determine the position of fatigue failure using strain gauges (KYOWA, 120 Ω, length 1 mm, width 1.1 mm). Due to welding can significantly affect the fatigue strength and causing crack initiated near the welding [10], strain gauges are placed near the welding seam of two parts and perpendicular to it, Fig. 3. Moreover, for a rib was build up by means of overlay welding at the end of welding seam between torsion beam and reinforcing part in order to improve local strength, which makes the strain more complex, a strain rosette was used at this region. The internal angel of strain rosette is 45° and the gauge of 0° was placed parallel to the overlay welding rib (on the left side E_HAR1, right side E_HAL3 as shown in Fig. 2). The position and definition of channel for each strain gauge are summarized in Table 1. Load histories are recorded using a MTS 64-channel mobile data acquisition instrument. All data are filtered with a 50 Hz low-pass filter, and sample rate is set to 512 Hz.

2. Fatigue analysis

The purpose of fatigue analysis is to determine the most dangerous position, where fatigue crack first occurs. Local stress histories are calculated from the strain histories of aforementioned critical points and range-mean matrix was obtained by Rain flow counting method. The mean stress effect was corrected by Gerber's mean stress correction. Fatigue damage was assessed with modified Miner's rule [11,12], using a *S*–*N* curve with $k = 3.5$ before the knee point (1×10^7) and $k' = 22$ after the knee point according to IIW recommendation [13], and FAT-value at 2×10^6 was taken as $\sigma_a = 82.5$ MPa. The fatigue damage of each channel during driving on the test track is shown in Fig. 4. The damage value of channel E_HAR1 and E_HAL3 are larger than others, the position of which symmetrically located on the torsion beam and near the welding seam

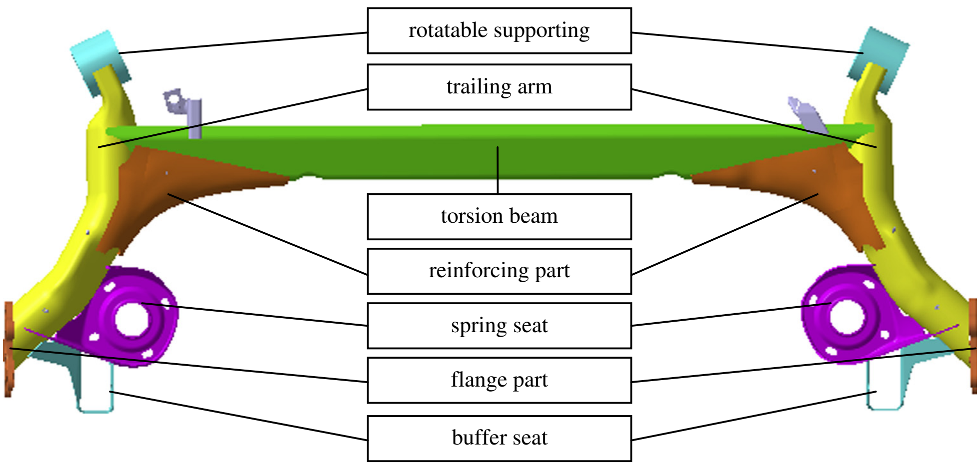

Fig. 1. Target torsion beam rear suspension.

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