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Fatigue behavior analysis of a rear tow hook pin of a passenger vehicle

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ABSTRACT

The main goal of this work is to analyze the fatigue behavior of an automobile body part, according to the standards of performance. The methodology is based on experiments performed on a rear trailer tow hook pin of a passenger automobile vehicle. Experiments were performed simulating the actual conditions in the customer environment. Stress and strain were experimentally measured by using strain gages, bonded on assembly critical points. Besides, stress analysis was also performed using a finite element program. Fatigue analysis is used to access and to compare the fatigue damage imposed during laboratory experiments.

1. Introduction

The goal of durability analysis during the vehicle and/or component development cycle is the reduction of product development time and costs, prevention of field failures and optimization of vehicles and components. One of the most important tasks during development cycle is vehicle and component life assessment. Vehicle operating data are measured during road experiments using an instrumented vehicle under different public roads and proving grounds. It is now quite common to measure the strains generated by these track test conditions on the vehicle and to use the measured strains for laboratory-based simulations. In this way, much of the track tests can be brought into the laboratory, where customer's service operations may be simulated under controlled conditions, producing an economical basis for life assessment [1–3].

Fatigue is one of the most commons automotive components failures [4]. Numerous researches have investigated fatigue failures of automotive components such as chassis, engine components, final drive transmission, leaf spring, and bolts. Most of these papers present a case study in failure analysis of a specific mechanical component [5–12]. Gagg and Lewis presented a review of important points relating to fatigue as a failure mechanism [5]. Other authors have used finite element modeling to perform stress analysis and to indicate the critical fatigue cracking regions [7–9]. Generally, these authors have also used strain-gages to measure strain and stress, and comparisons between experimental and numerical life predictions were showed in these papers [9–12]. A compendium of fatigue failures in engine piston was presented by Silva [13]. A linear static stress analysis, using finite elements software, is used to determine the stress distribution during the combustion.

Trailer rear tow hook assemblies used in some passenger vehicles were found to fail after a short service time. These assemblies are subjected to cyclic stresses during lifetime, which can lead to crack nucleation and propagation due to local fatigue damage. The rear tow hook pins are welded in the body base plate (chassis) of the vehicle. These tow hook pins provided support for the elements attached to it and transmit forces to the chassis. In case of complex structural components, as pin welded joints, to which neither a nominal stress nor a code design can be assigned, only local stress concepts are applicable for assessing fatigue strength [14,15]. These local stresses or strains can be analytically calculated, experimentally

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measured or numerically determined for the sharp or mild notches at the weld toe. It has been shown that fatigue life and strength are influenced by local state of stress and strain, and the local strain analysis is a practical engineering approach as long as crack nucleation plays a dominant role in fatigue life assessment [16,17]. In this way, fatigue failure simulations can be performed using local stress strain response of material measured during experimental tests together with accumulation rule. In this paper, the fatigue damage of rear trailer hook town assembly is determined using the local material response, measured during experimental tests.

2. Methodology

2.1. Presentation of the problem

Vehicles sold abroad are transported by ship and are tied by the front and rear trailer hook assemblies. Besides, these hooks are also used to tow or to be towed by another vehicle. Before going into production, structural and durability tests are performed to validate the design of this assembly. The rear trailer hook assembly was designed to last at least 1000 load cycles in durability tests, but did not meet the expected life, since cracks were observed in some places. Fig. 1 shows the exploded view of the rear town hook pin assembly system. The superior and inferior crash box (labels B1 and B2 in Fig. 1), and the hook fasten pin (C) are welded in the body base plate (A). The assembly is hold tied by the rear profile cross-beam (D). The mounted system is shown in Fig. 2, without the rear profile crossbeam. The rear tow hook pin, not shown in both figures, is assembled by screwing in the hook fasten pin. Three locking bolts are used for assembly the body plate in the chassis. Initially, there was observed cracks occurrences in weld toes of both, the hook fasten pin and crash boxes on body base plate during laboratory tests. These cracks were initiated at the weld toes, and propagated through the body plate. After some design changes, cracks during fatigue tests were observed only at welds of crash box on body base plate (see the arrow in Fig. 2).

The rear tow hook pin is shown in Fig. 3. Fatigue and static loads during tests are transmitted by the hook pin to the rear trailer tow hook assembly. Thus, there is a cyclic deformation of these components.

2.2. Material characterizations

The body base plates were made by forging, using the extra low carbon FEE340 steel (Fiat Code), which corresponds to a 1005-1009 SAE steel. The chemical composition and mechanical properties of this steel are presented in Tables 1 and 2, respectively. The plates were forged with thickness of 2.50 mm. All these results are in very good agreement with recommended values.

The rear tow hook pins were forged using 1020 SAE steel with yield strength of 185.0 MPa. The other components (hook fasten pins and crash boxes) were made using SAE 1009 steel with yield strength varying between 340.0 and 420.0 MPa. The hook fasten pins, were the rear hook town pins are screwed, have length of 136.0 mm and an external diameter of 26.0 mm. After assembly of the rear trailer system, the total length between the hook extremity (where the loads are applied) and the body base plate is 249.0 mm. This is the arm lever, which creates the bending moment caused by forces applied to the hook.

2.3. Experimental test procedures

2.3.1. Body base plate instrumentation

A strain measurement system was used for measuring the local strains at the fillet welds of body plate during static and fatigue tests. The regions for fixing the sensors were those where cracks have been observed, and later were also defined

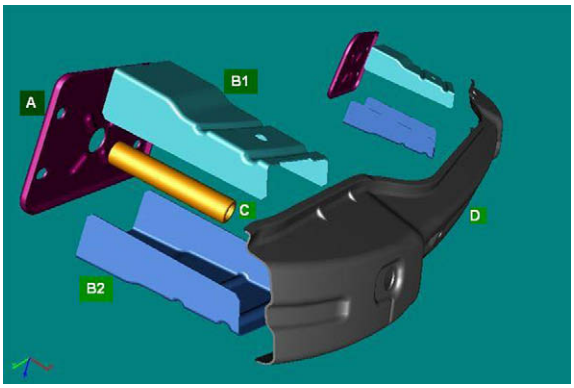

Fig. 1. Exploded view of the rear town hook pin assembly system.