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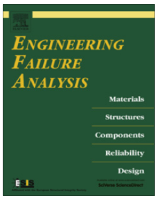

Failure analysis of frame crack on a wide-body mining dump truck

Sen Zheng [a], Kai Cheng [a], Jixin Wang [a,*], Qingde Liao [b], Xiaoguang Liu [c], Weiwei Liu [a]

[a] *School of Mechanical Science and Engineering, Jilin University, Changchun, China*
[b] *Xiamen XGMA Heavy Industry Co., Ltd., Xiamen, China*
[c] *Aviation University of Air Force, Changchun, China*

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ABSTRACT

The wide-body mining dump truck is a type of heavy-duty, off-highway truck that is mainly used for transporting rock and ore in open-pit mines. Because of various potholes, obstacles, slopes and curves on the bumpy road, the frame of the truck is impacted by the multiform large loads from ground. After five to six months in service, cracks tend to appear in the frame of the truck, near the rear seating of the front leaf springs. To identify the cause of these failures and propose an approach for improving the design, a practical method combined with finite element analysis (FEA), as well as static and dynamic testing, was applied. FEA was used to analyze the cause of the cracking, after which the design of the frame was improved. Static and dynamic tests were conducted to verify the FEA results of the improved frame. Analysis results indicated that the stresses are concentrated in the frame near the rear seating of the front leaf springs, which results in the premature appearance of fatigue cracks. A solution for preventing the appearance of these cracks was proposed. The improved frame has been in service for more than twelve months in the mine and no cracks have appeared to date.

1. Introduction

The wide-body mining dump truck (WMDT) is used in many small-scale mines in China. Considering the bad mine roads having potholes, obstacles, slopes and curves, and the influence of manufacturing cost and service cycle, with a short design-life of 2 years, the WMDT uses leaf spring for its suspension instead of hydro-pneumatic suspension. Hence it is a transition vehicle between traditional mining dump truck and the highway heavy dump truck. One type of WMDT is shown in Fig. 1. The model that was the subject of this study has an unladen weight of 24 t, a maximum load capacity of 72 t, and a normal speed of 10 km/h when carrying a full load or 50 km/h when empty. However, after five to six months in service, cracks tend to appear in the frame near the rear seating of front leaf spring (RSFLS), which results in significant downtime.

Either finite element analysis (FEA) or testing alone could not fully analyze the causes of these frame failures. Rather, any analysis of the cracking would require a method that combined both FEA and testing [1–4]. Mi et al. presented a method for predicting the fatigue life of the frame of a 220-t mining dump truck through multibody dynamic analysis and the application of the finite element method [5,6]. Feng et al. analyzed the static, modal, and response spectra of the FEA model and confirmed its feasibility as a means of verifying the failure of a dump truck's push rod [7]. Shao et al. presented an analysis

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[*] Corresponding author. Tel.: +86 130 6920 1036.
E-mail address: 66227616@qq.com (J. Wang).

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method based on dynamic strain measurements of actual road surface conditions combined with FEA, which was applied to the analysis of the failure of the drive axle housing of a mining dump truck, using ANSYS software [8].

These previous efforts provided important guidelines for this study, given that the application of the finite element model, the loads to be applied, and the boundary conditions can be referenced in these papers [9–14]. The interaction between the frame and the leaf springs also plays an important role in the appearance of cracks in the frame. The design of the frame must not only provide sufficient mechanical strength, but also satisfy the technical process requirements. With a goal of solving these practical problems, we set out to devise an effective method of improving the design of the frame. To identify the reasons for the frame cracking and improve the mechanical strength, FEA and static/dynamic tests are carried out. The frame was analyzed using FEA, after which measures were implemented to improve the stress distribution. A static test was conducted to verify the improvement in the frame design by comparing the measured results with those obtained with FEA. A dynamic test was performed to further confirm the improvement, after which the results were compared with those of the static test to determine a matching coefficient. Based on the FEA and static test results, the dynamic test data for the original frame could be acquired by multiplying the FEA results by the matching coefficient. The research conducted during this study is shown in Fig. 2.

2. FEA models

2.1. Frame and leaf spring seating

The frame, which connects the engine, cab, dump body, and other major parts, is a supportive and connective component of a mining dump truck. The frame supports its own weight and other complex loads, such as impact loads from the suspension and gravitational loads imposed by other components. Therefore, the reliability of the frame directly affects the service life of the WMDT and the technology that it employs. As shown in Fig. 3, the frame consists of two side rails and seven welded crossbeams of different thicknesses. The side rails are designed as D-type box beams, and the second and third crossbeams are connected to the side rails through the leaf spring seatings. The other crossbeams, however, are welded to the inner plates. The frame is fabricated from high-strength, low-alloy quenched and tempered Q460CFD steel, the specifications of which are listed in Table 1.

The leaf springs transfer forces and torques from the ground over which the WMDT is traveling. The leaf springs are rigidly fixed to the front axle by two U-bolts, and their ends are connected to the frame through the leaf spring seatings, which are bolted to the bottom surface and outside plates of the frame. Fig. 3 shows the openings in the frame near the RSFLS that are required in order to access and tighten the fixing bolts. When the truck travels over rough ground, the frame is subject to alternating dynamic loads that cause bending and twisting. The leaf springs are connected to each RSFLS with pin rolls, which bear more force than the slide of the front seating of the leaf spring, as shown in Fig. 3. Based on the results obtained for the combined effects of TX, TY, TZ and RX, RY, RZ, it is clear that each RSFLS plays a pivotal role in transferring loads. When the WMDT is turning or traversing a tilting surface, there is an *X*-direction force in the spring seating, which acts toward the outer plate of the frame, while the main loads in the *Y* direction are the weight of the WMDT's dump body, its payload, and its powertrain. When the WMDT starts to move or brakes, an inertia force is generated in the forward direction, that is, the *Z* direction. Given the tight interfaces between the bolts, seating and frame, a torque is applied that is a function of the distances, in the *X*, *Y*, and *Z* directions, between the bolts in this area. As a result, forces are generated between the leaf spring and the side rail in all three directions [15,16].

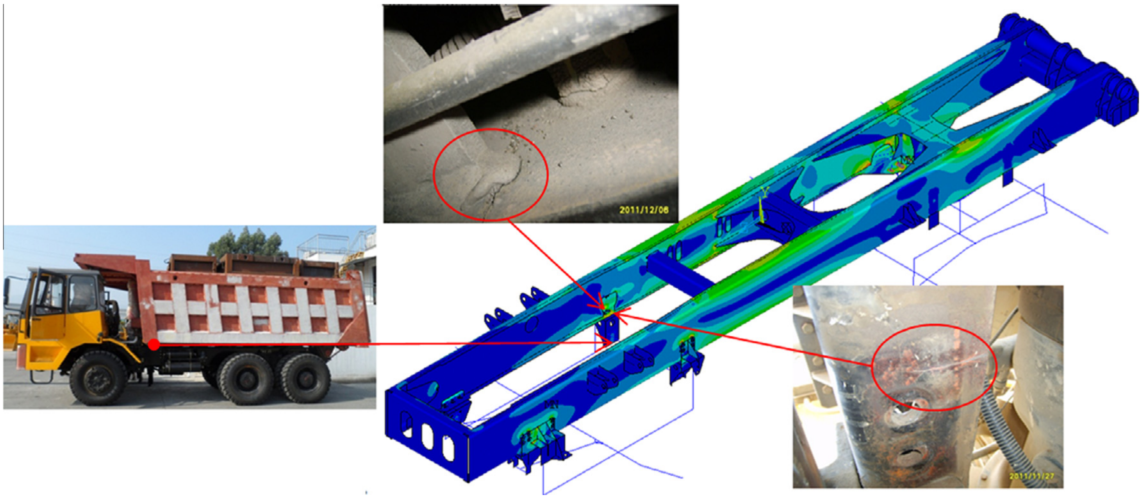

Fig. 1. Crack failure of frame.