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Weight optimization and fatigue design of a welded bogie beam structure in a construction equipment

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ABSTRACT

A welded bogie beam in an articulated hauler has been designed, analyzed, produced and fatigue tested in order to demonstrate the features of the research project LOST (Lightweight Optimized welded STructures). The results from LOST, e.g. a new weld class system, effect of using high strength steel and post treatment, were applied. The general goal was achieved by 20% weight reduction compared with existing component and at the same time a decrease of the production cost. This was accomplished mainly due to less material usage and cutting cost, but also due to a more efficient design, which decreased the production time by 30 min. Reduced weight also causes less environmental impact and lower fuel costs during the operation of the hauler. The demonstrator was produced with welds in as-welded condition where TIG treatment and weld preparation were needed in a couple of welds. A major conclusion was that the inspection of the weld quality after production needs to be improved so that the demands are secured and later failures in service can be avoided. Another conclusion was made during the fatigue test due to a multi axial stress state, which will affect the design in future projects. The requirements on the static and fatigue strengths are fulfilled in the new bogie beam design. However, some fatigue improvement effects have not been incorporated in the analysis of the new design, e.g. compressive residual stresses.

1. Introduction

A common goal for manufacturers of welded structures, particularly for transportation vehicles, is to minimize weight in order to decrease fuel consumption and at the same time to prevent fatigue failure. The weight reduction is mainly accomplished by introducing thinner plates in combination with higher strength steels in welded components. However, welding without any improvement gives rise to local stress concentration, residual stresses and different types of defects which in conjunction with complex service loading give rise to failure due to fatigue. The conclusion is that since weight reduction often leads to an increased stress level, this must be accompanied with a higher or improved weld quality in order to avoid fatigue failures. This will support the use of efficient and more accurate fatigue design methods which must be connected to quality requirements which can be understood and managed during design and production.

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2. Bogie beam welded structure

An example of such a welded structure is the bogie beam in Fig. 1. The bogie beam transfer the loads of an articulated hauler from the rear axels into the frame of the vehicle in order to make it possible for the two rear axles to roll over e.g. stones in an inaccessible terrain. The existing beam structure is manufactured with steel plates of 350 MPa in yield strength forming a rectangular section with the largest height at the midsection where a bearing partly made of rubber is positioned, see Fig. 2.

The current weight of the bogie beam is 183 kg and the main goal is to decrease this weight by at least 20% (approximately 40 kg) by using thinner plates without changing the global dimensions. Current webs and flanges have thicknesses of 15 and 8 mm which are reduced to 12 and 6 mm, respectively. This implies an increased stress level of approximately 25% based on nominal dimensions. Some sections in the current design are already beyond the design limit implying that a redesign is necessary, e.g. the butt weld positioned at the midpoint between the bottom flanges. This weld was removed by introducing a bottom flange in one piece. Another step was to enlarge the radius in the bottom flange, near the bogie beam ends. See Figs. 2 and 3 for comparison of the current and the new design of the bogie beam structure.

3. Modeling

The finite element fatigue analysis was made with the effective notch stress method using sub modeling technique in order to reduce the computational time [1,2], see Fig. 4. The sub model parts can be seen in Fig. 3, which is indicated by the help lines. For each critical part of a weld a sub model is built containing a fine mesh for both weld toe and root. In some cases a weld was divided in two sub models; one for the weld toe and one for the weld root. When using sub modeling technique it is important to build a global model of the geometry which corresponds to the real geometry of the weld including

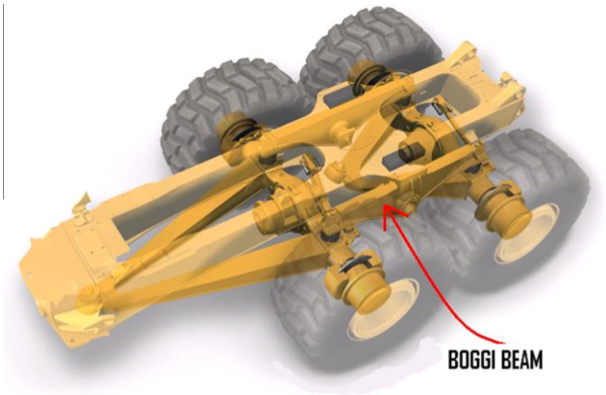

Fig. 1. The position of the boggi beam in a hauler rear frame.

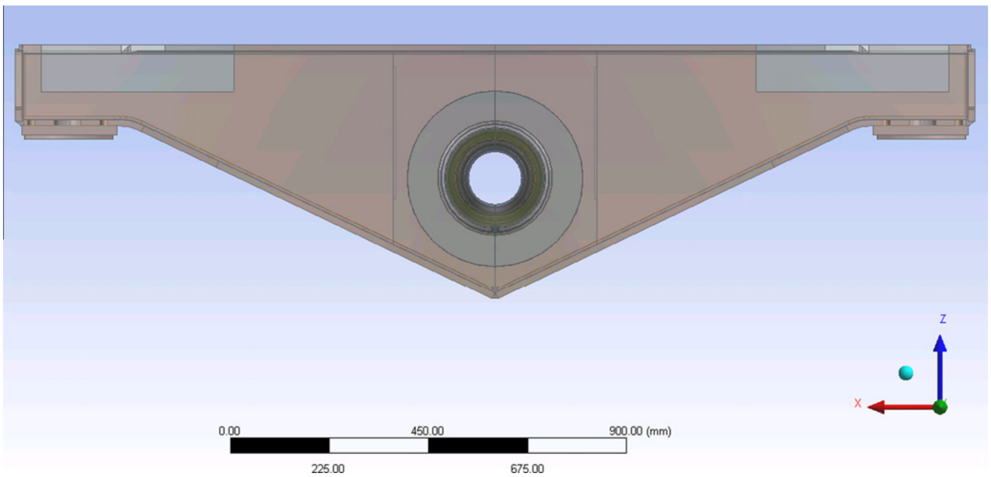

Fig. 2. Current design of the boggi beam, help lines indicate sub models.