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Fatigue Strength Analysis of Bogie Structure in Mining Equipment Subjected to Multi-axial Loading

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ABSTRACT

During operation of bulk material handling machine, there are variety of static and dynamic loads acting on machine components and structure. Different components and structures having different nature of relative motion and different dynamic load. Design of component and structures of such machine are adaptive in nature, hence designs need to be verified by finite element analysis to cross-check strength. Presently static analysis is performed with design codes and standard. Static analysis results in heavy design, hence there is need to optimize design. Bogie structure made up of steel plates welded together is selected for analysis. Fatigue design and analysis of structure is based on the nominal stress using the classified S-N curves with corresponding fatigue classes for typical details. The hot spot stress method has been developed to enable an accurate estimation of the load effects for the fatigue strength of welded steel structures, in cases where the nominal stress is hard to estimate because of geometric and loading complexities or in cases where there is no classified detail that is suitable to be compared with. Effective notch stress method is most accurate method of estimating fatigue life of welded steel structure geometry with numerous details. This paper intends to optimize design of bogie structure subjected to multi-axial loading, by performing fatigue analysis. Ansys is used to perform finite element analysis.

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I. INTRODUCTION

Fatigue is a localized and progressive process in which structural damage accumulates continuously due to the repetitive application of external loadings, while these applied loadings may be well below the structural resistance capacity. The loading sequence can be determinate, periodic or aperiodic, and also stochastic (random).This kind of process is extraordinarily dangerous because a single application of the load would not create any abnormal effects, whereas a conventional structural stress analysis might lead to a conclusion of safety that does not exist. Over a long period of time, the strength and serviceability modes of failure have been well investigated in the professional engineering communities. However, as one of the most critical forms of damage and principal failure modes for steel structures, fatigue is still less understood in terms of the cause of formation and failure mechanism. Fatigue is one of the main causes involved in fatal mechanical failures of a wide range of structures and infrastructures. Such devastating events occur suddenly and result in heavy losses of life and property. Even though no exact percentage is available on the mechanical failures due to fatigue, many studies have suggested that 50 to 90 percent of all mechanical failures are fatigue failures.

Goal for every designer and manufacturers of welded structures is to minimize weight and at the same time to prevent fatigue failure. The weight reductions 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. 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.

II. WELDED BOGIE STRUCTURE

Bogie structure is the main load bearing components and power transmission components of the mining equipment and vehicles, when these are in motion, bogie structure need not only withstand loads, but also need to pass a variety of forces, and they may be static and dynamic. Bogie structures acts as equalizer as it distributes forces at two points of structure equally. Such structure exits in travelling mechanisms of mining equipment such as long travel drive (LTD) and crawler. Based on types of bulk material machines and load class there are different types of design and configuration of bogie structure. Bogie structures are classified according to number of wheels they support. These wheels move on rail track. One wheel bogie structure holds one wheel, two wheel bogie structure holds two wheels, four wheel bogie structure mounted on two number of two wheel bogie structure, six wheel bogie structure mounted on a two wheel bogie structure and a four wheel bogie structure, eight wheel bogie structure mounted on two number of four wheel bogie structure, twelve wheel bogie structure mounted on two number of six wheel bogie structure, sixteen wheel bogie structure mounted on two number of eight wheel bogie, etc. These bogie structures are connected with help of structure called pillow which consist of pin connection. Bogie structures are free to rotate about axis of the pin to have relative motion between two structures. Fig 1 shows bogie structure in LTD of one of bulk material handling equipment.

Fig. 1 The Position of the bogie structure in LTD

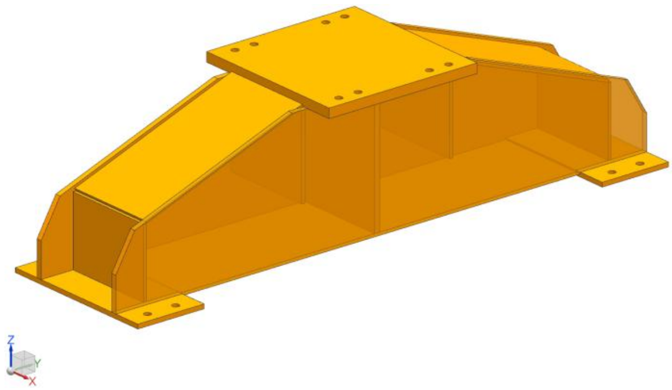

Fig. 2 Existing design of the bogie structure.

The existing bogie structure made up of ten numbers of plates with thicknesses of 10, 12, 16, 20 and 35 mm. The existing weight of the bogie beam is 537 kg. Some plates in the existing design are already beyond the design limit implying that a redesign in weight is necessary. Hence the main goal is to decrease this weight by using thinner plates and removing unwanted stiffeners without changing the global dimensions. Existing bogie structure has two plates of 12 mm thickness reduced to thickness of 10. Threes plates which acts as stiffener are removed. With this changes weight of bogie structure becomes 479 kg. This implies an increased stress level based on nominal dimensions. Fig. 2 shows existing bogie structure.

III. MODELLING

a The finite element fatigue analysis was made with the effective notch stress method. Geometry for weld beads created in CAD itself. Whole model of bogie structure is fine meshed. The load is applied at the top surface of the top plate and fixed support at the lower surface of the extreme plates at bottom. The main load consists of forces from bogie structure mounted on it which are 543 N in positive X-direction, 12127 N negative Y-direction and 181312 N in negative Z-direction determines both the fatigue and max static load cases.

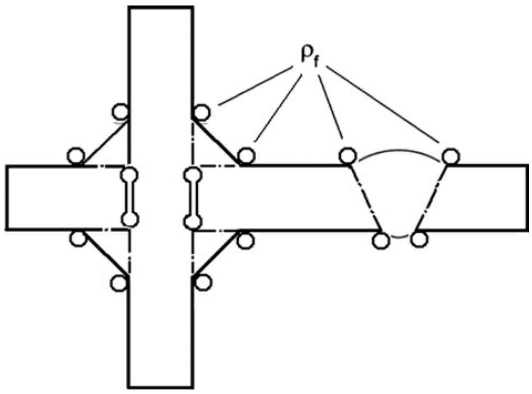

Fig. 3. Notches positioned in welds.

IV. FATIGUE ANALYSIS

Static loads are not an issue for the existing design, however, since the thicknesses have been reduced in the new design these loads needs to be considered. The vertical maximum load is 181312 N and if this is applied to the bogie structure, some highly stressed areas (von Mises stresses) can be identified. Fatigue analysis performed on the bogie structure which gives maximum stress of 132.49

MPa, and deformation of 0.1505 mm which can be seen from the figure 4 and figure 5. A life of 115920 cycles is obtained through fatigue analysis.

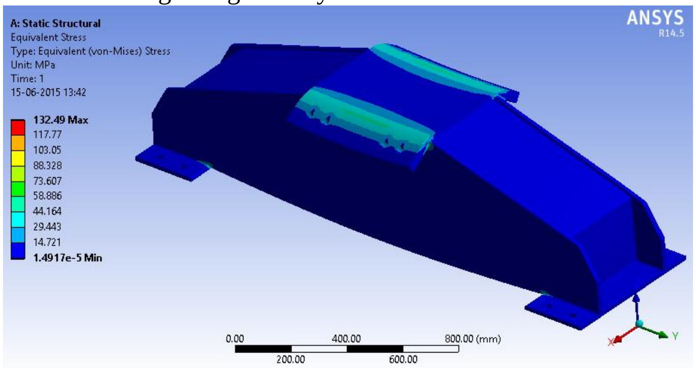

Fig.3 von Mises effective stress levels at max vertical load.

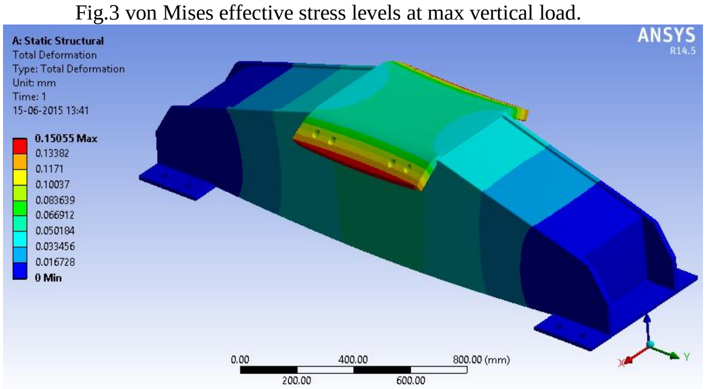

Fig. 4 Deformation with vertical max load applied

V. CONCLUSION

Optimization and weight reduction have been carried out on a welded bogie structure in a mining machine. The goal was to decrease the weight compared to existing design and still maintain the same global dimensions.

– The weight reduction achieved was 11%

– Production cost was estimated to decrease approximately 9%.

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REFRENCES

1. Włodzimierz Będkowski, Assessment of the fatigue life of machine components under service loading – a review of selected problems, Journal of Theoretical and Applied Mechanics, 2014, 52, 2, pp. 443-458.

2. Gary B. Marquisa, Zuheir Barsoumb, A guideline for fatigue strength improvement of high strength steel welded structures using high frequency mechanical impact treatment, Procedia Engineering, 2013, 66, pp. 98 – 107.

3. T. Bruder, K. Störzel, J. Baumgartner, H. Hanselka, Evaluation of nominal and local stress based approaches for the fatigue assessment of seam welds, International Journal of Fatigue, 2012, 34, pp. 86–102.

4. E. Pagnacco , S. Lambert L. Khalij, D.A. Rade, Design optimisation of linear structures subjected to dynamic random loads with respect to fatigue life, International Journal of Fatigue, 2012, 43, pp. 168–177.

5. B. Jonsson, Z. Barsoum, J.-O. Sperle, Weight optimization and fatigue design of a welded bogie beam structure in a construction equipment, Engineering Failure Analysis, 2012, 19, pp. 63–76.

6. Zhigang Wei, Pingsha Dong, Multiaxial fatigue life assessment of welded structures, Engineering Fracture Mechanics, 2010, 77, pp. 3011–3021

7. X. W. Ye, Y. h. Su and J. P. Han, A State-of-the-Art Review on Fatigue Life Assessment of Steel Bridges, Mathematical Problems in Engineering, 2014, Article ID 956473.
8. Gary B. Marquis, Zuheir Barsoum, A guideline for fatigue strength improvement of high strength steel welded structure using high frequency mechanical impact treatment, Procedia Engineering, 2013, 66, pp. 98-107.
9. B. Jonsson, Z Barsoum, J.-O. Sperle, Weight optimization and fatigue design of a welded bogie beam structure in a construction equipment, Engineering Failure Analysis, 2012, 19, pp. 63–76.
10. C.M. Sonsino, W. Fricke, F. de Bruyne, A. Hoppe, A. Ahmadi, G. Zhang, Notch stress concepts for the fatigue assessment of welded joints – Background and applications, International Journal of Fatigue, 2012, 34, pp. 2–16
11. Dieter Radaj, Dr-Inghabil, Design and analysis of fatigue resistant welded structures, Abington Publishing, 1990
12. Nitin S. Godbole, Practical finite element analysis, First edition, Finite to Infinite, 2008.

