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Fatigue life prediction of existing crane runway girders

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ABSTRACT

In this study, fatigue life of crane runway girders of a steel mill structure was investigated. Load spectra were generated based on former crane operation records. Detailed finite element models of the crane runway girders were prepared using shell and beam elements. Quasi-static load tests were conducted with the help of overhead cranes that travelled with crawling speed. Strain data was collected by using transducers mounted on preselected locations of the crane runway girders. These data were then used to refine the finite element models. Numerical analyses by means of the calibrated finite element models were performed to evaluate the remaining fatigue life. It was found that due to lack of continuity of vertical stiffeners to upper flange, fatigue life of the crane girders is exceeded. To overcome this problem, fillet welding of the stiffeners to flanges is suggested and this modification is verified by carrying out necessary calculations for the updated detail.

1. Introduction

Fatigue life of a structure can be described as the number of cycles of loading required to initiate and propagate a fatigue crack to fracture. Therefore, structures subject to dynamic actions may be prone to serious fatigue problems and results may be catastrophic. Crane runway girders are one of these types of structures at risk. Principal factors affecting the fatigue performance of a crane runway girder are the range of stress to which it is subjected, and the number of cycles of load that is transported. The vast majority of crane runway girder problems are caused by fatigue cracking of welds, bolts or base materials. Experimental and analytical fatigue studies by Demo and Fisher [1] were conducted for welded crane runway girders and web cracks were observed at the ends of stiffeners. For the inspection and repair of fatigue cracks that occur in the bottom tension flanges of girders, a method is presented by Kuwamura and Hanzawa [2]. To address conditions related with crane runway girder problems which are associated with fatigue cracks, Fisher and Van de Pas [3] have reviewed fatigue provisions in the AISC specification as well as crane loads and typical connection details.

Tong et al. [4] presented procedures for assessing the fatigue life of end-coped crane runway girders, and finite element analyses of two typical crane runway girders with different spans were conducted to investigate the stress concentration at the coped ends. For girders with undulating webs, a review of their static and fatigue resistance based on tests and theoretical analyses is presented and described by Machacek and Tuma [5]. In another article by Alampalli and Lund [6], AASHTO specification procedures and strain measurements from critical structural members of an actual multi-span bridge were used to estimate the remaining fatigue life of its components. As parts of the damage accumulation calculations, rainflow algorithm and Miner's rule were used.

In this study, model identification of the crane runway girders is conducted by using acquired strain data from quasi-static load tests. Following these tests, refined models of various types of crane runway girders were generated based on test results and these models were used for fatigue life assessment of the crane girders.

2. Description of the crane runway girders

This study was performed for the crane runway girders in the scrap melting and casting halls (see Fig. 1) at a steel mill at Bursa, one of the biggest industrial towns in Turkey. As is shown in the schematic layout of the girders in Fig. 1, different cross sections from 1 to 6 are used throughout the steel mill structure. The material used is S235 quality structural steel. Beam heights vary between 1500 and 3000 mm with flange widths between 400 and 550 mm. Flange and web thickness values differ from 15 to 30 mm. Types of crane runway girders are given in Fig. 2. Crane rails are of A100 section as defined in relevant DIN standard [7] and are attached to girder flanges with rail clips at 50 cm spacings. The total load exerted by crane bridge to crane runway girders at each side sums up to 3400 kN including self-weight. A view of K2 and K3 type crane runway girders are given in Fig. 3.

Girder webs are stiffened using channels at each side of the webs. Although these vertical stiffeners reach up to upper flanges, tops of stiffeners are not welded to the underside of flanges, as seen in Fig. 4.

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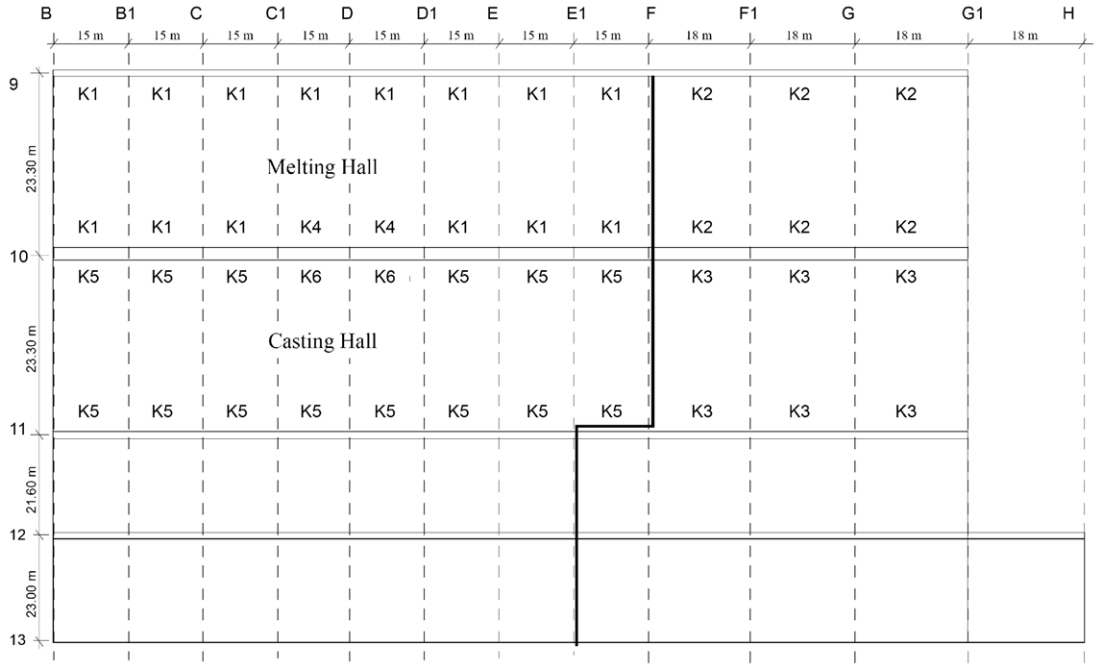

Fig. 1. Plan view of the crane girders.

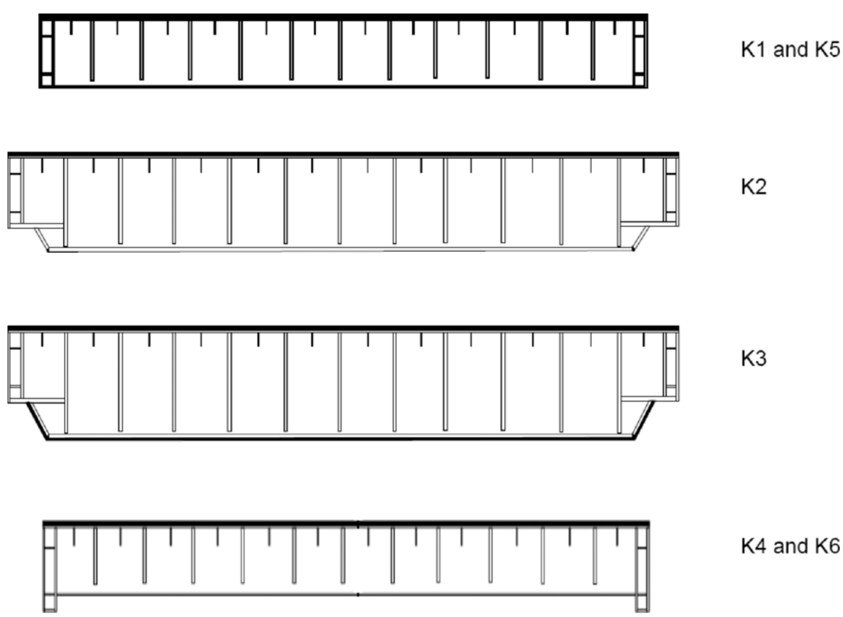

Fig. 2. Types of crane runway girders.

3. Quasi-static load tests

Static load carrying system of the crane runway girders in melting and casting halls fall between an 11-span continuous girder and a series of simply supported girders. In order to obtain realistic data under proposed operational load spectra, load carrying mechanism of these girders needed identification. In this manner, it would be possible to obtain reliable stress data during analyses. Reusable Hottinger Baldwin DS-5 type strain transducers were mounted next to crane rails at upper flanges at mid-spans, and also near the bolts interconnecting the crane runway girders (referred to as "mid-span" and "end-points", respectively, see Figs. 5 and 6) to collect strain values while crane bridge passed over the crane runway girder with crawling speed of approximately 50 cm/s, as shown in Fig. 7. Total axle load was approximately 1900 kN as the crane bridge did not carry the scrap metal basket and therefore four wheels on each side exerted only the self-weight of the crane to the crane runway girders.

Two portable NEC computer based dynamic data acquisition systems having 16 channels each at a 800 sps sampling rate capacity for each channel were used for data collection. Schematic description of the data acquisition systems are given in Fig. 8. A sample of recorded stress trace for a crane bridge crossing is given below in Fig. 9.

4. Model calibration procedure

A systematic optimization scheme was utilized to calibrate the finite element model with respect to measured strain values. In this procedure, an objective function was considered. This objective