XXII International Conference MHCL 2017 – Extended Review Abstract

Fatigue life assessment of steel structures of a gantry crane

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Abstract:

Gantry crane was a typical material handling equipement, used in ports, docks and other logistics fields. Rubber tire container gantry crane was a primary type of gantry crane. It subjected alternating loads under different cases, and these external loads were huge. In general they worked in bad environment such as wind, snow, rain and corrosion of seawater. These characteristics would easily arise degradation of structural properties. When the degradation accumulated to a critical level, fatigue failure became a common phenomenon which resulted in many accidents. This lead to large economic damage and injury of peoples lives. Therefore, fatigue life assessment played a significant role in application of gantry cranes which attracted more and more interest in current researches.

Fatigue life theory could be devided into direction, one is cumulative fatigue damage theory, the other is fatigue crack propagation theory[1]. Moreover, cumulative fatigue damage theory could be devided into stress-based approach[2-3], strain-based approach[4-5], energy-based approach[6-7] and Continuum damage mechanics approaches[8-9] according to different formulas of macroscopic quantities. Fatigue crack propagation theory was developed into three method: long crack growth was based on linear elastic fracture mechanics[10], physically small crack growth was based on elastic plastic fracture mechanics[11], and microstructurally small crack growth was based on microstructural fracture mechanics[12]. In the literature, many researches referred to gantry cranes. Bing[13] introduced finite element model of steel structures of railroad container gantry crane, and lifetime fatigue analysis of steel structures and welds was adopted to using MSC Fatigue software, so that life distribution of the entire structure and fatigue life of dangerous position were approached. Zhang[14]introduced finite element model of gantry crane, and fatigue life based on crack propagation theory was approached by Paris formulus. Li[15] analyzed the causes, common types and hazards to structural corrosion and wear of gantry crane, and safety assessment system was developed based on fuzzy analytical hierarchy process.Zrnic[16] discussed a combined finite element and analytical method for obtaining transverse and longitudinal vibrations of a gantry crane system subjected to an elastically suspended moving body, and the two-dimensional inertial effects of the moving body are included in derivation of differential equation of motion for the system. A great progress had been carried out in many researches, however, there are still some deficiency in practical load spectrum and numerical analysis.

In this paper, non-destructive testing, finite element analysis, experimental stress analysis and cumulative damage theory were integrated into fatigue life assessment of steel structures of rubber tire container gantry crane. Ultrasonic testing (UT) was adopted to test thickness of steel structures in order to evaluate the corrosion situation; based on actual dimensions three dimensional finite element model was built to execute strength and stiffness analysis, and load spectrum of dangerous positions were extracted in a whole working cycle; wireless dynamic resistance strain gauges were applied in stress test in order to verify the precision of finite element analysis. Finally, based on S-N fatigue analysis theory, Miner rules was adopted to calculate total damage, and fatigue life of steel structures was predicted.

Keywords: Gantry cranes, fatigue life assessment, Ultrasonic test, finite element analysis, experimental stress analysis

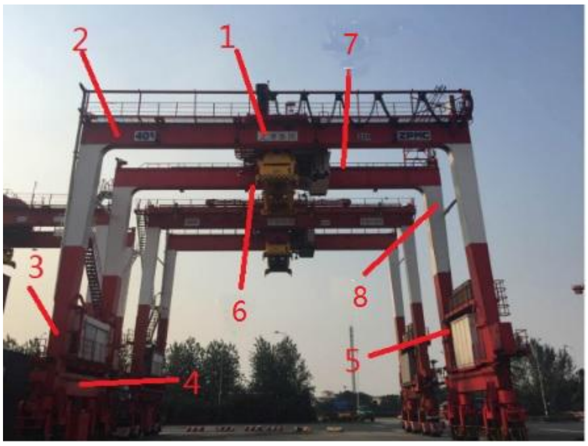

Fig. 1. Gantry crane and tested points.

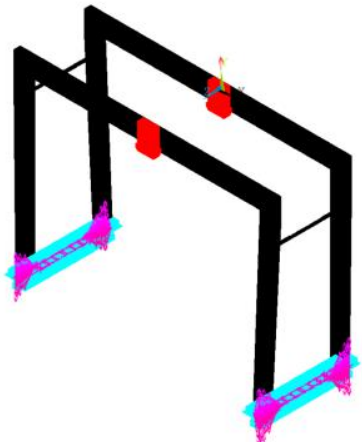

Fig. 2. Three-dimensional FEA model.

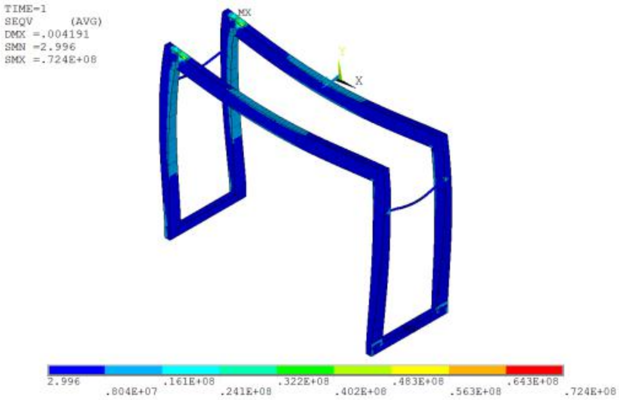

Fig. 3. Stress contour of case 1

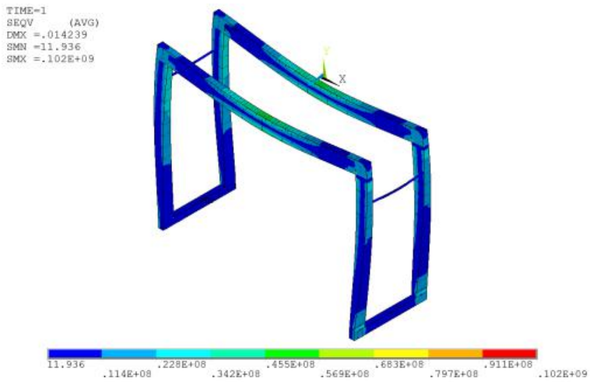

Fig. 4. Stress contour of case 2

Fig. 5. Stress tested point 1 and sensor

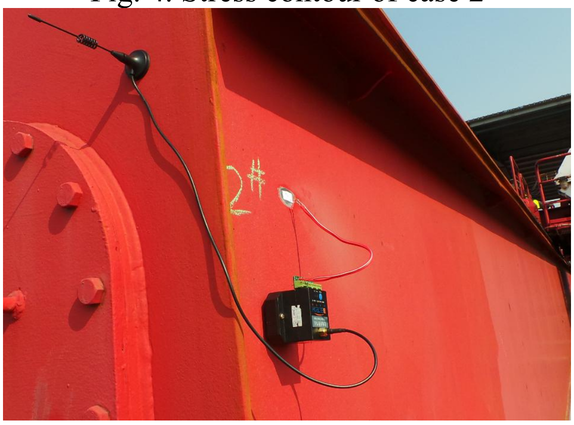

Fig. 6. Stress tested point 2 and sensor

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