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Buckling failure analysis of truck mounted concrete pump's retractable outrigger

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A B S T R A C T

In this research work, the failure reasons of retractable outrigger were analyzed by nonlinear finite element method firstly. Then the actual failure modes and loads were obtained by working condition simulation and destruction test on the two original designs. Both results from analysis and test show that the failure is due to instability of first class retractable outrigger side plate attached with fixed leg. Finally, the front outrigger was strengthened and this optimization was certified to meet bearing requirements through nonlinear finite element analysis and loading test. The method could be used to analyze buckling failure problem of similar structure.

1. Introduction

With the acceleration of urban construction and the increasing investment in the infrastructure construction, the truck mounted concrete pump has become an indispensable construction equipment and is widely used in the construction industry due to mobility, flexibility and high casting speed [1]. As one of the most important support components, the outrigger's security is the prerequisite of construction safety. Outrigger structure is rectangular box welded by sheet and can be classified into two styles: retractable and swing. Generally, retractable is for front outrigger and swing for rear. Retractable outrigger occupies small space and can be arranged more easily, while its section can't be too large as complicated structure, and its bearing capacity is lower. Currently, steel with yield strength over 700 MPa is widely used, and the truck becomes lighter, non-renewable resource consumption and carbon emission decrease at the same time. However, the area instability occurs as sheet becomes thinner. As shown in Fig. 1, a truck mounted concrete pump collapsed due to the retractable outrigger failure during testing.

According to QC/T 718-2004 [2], counterweight hanged on each section as the replacement of concrete in the conveying pipe. The accident occurred when whole boom was horizontal and full-extended, and slewing from rear to front. The failure occurred on the first section side plates overlapped with the fixed section of large bending deformation. From the phenomenon, we can preliminarily speculate that failure was likely caused by insufficient stability of local structure.

Calculation and test are two dependent methods to solve structure buckling stability issue. And for plate or shell, two calculation methods can be used, one is analytical method [3–6] or basing on regulation [7–10], the other is simulation [11–13]. But the former is usually difficult to be used as most structure is very complicated while simulation is more feasible, and one of the most widely used is Finite Element Method [14–15]. In recent years, many scholars had studied structure buckling stability issue through finite element method [16–19]. Rust et al. [16] analyzed extreme load of thin-walled structure through ANSYS (implicit) and LS-DYNA (explicit). Diaz et al. [18] analyzed nonlinear buckling failure of a self-weighted roof with and without skylights with finite element method and determined the importance of each design parameter with design of experiment (DOEs). Zhao et al. [19] analyzed area stability of outrigger using implicit FEA and explicit FEA and improved the outrigger structure according to calculation results.

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Fig. 1. Instability example of retractable outrigger.

Besides, test is also very necessary to study the bucking stability issue. Due to the effect of initial geometric imperfection, residual stress and eccentricity loading [20], there is always some gap between theoretical results and actual results. Therefore, it is necessary to conduct some tests to verify calculation results and improve the calculation models. Finite element method combined with test was used by many scholars to study buckling stability issue, and acquired very good results [21–23]. Yuan et al. [21] studied area and overall interactive buckling of welded stainless steel box section compression members, improved the current EN 1993-1-4. Besides, Yao et al. [23] investigated the failure reason of an all-terrain crane telescopic boom by the finite element analysis (FEA) and preformed structure experiment based on the boom load characteristics in accident, and the results showed that the failure was caused by area instability.

These previous efforts provided important guidelines for this study, in this paper, nonlinear finite element method and loading test were used to investigate the failure reason of retractable outrigger. Firstly, the theoretical failure loads and modes were obtained through nonlinear finite element method, considering geometric nonlinearity and material nonlinearity. Then loading tests were conducted to obtain actual failure loads and failure modes. Afterwards, the failure reason of outrigger in test field was confirmed by comparing nonlinear FEM results with test results. Meanwhile, nonlinear FEM was verified to be effective and reliable to solve the buckling stability issue of retractable outrigger. Finally, outrigger structure was optimized, which was verified to meet bearing requirements in heavy working condition through nonlinear finite element analysis and loading test.

2. Finite element analysis

2.1. FE model

As shown in Fig. 2, retractable outrigger is composed of fixed section, first section and second section. The outrigger is in full contraction when traveling and is full-extending when conveying the concrete. When the retractable outrigger is full-extending, there are two overlapping regions, in which fixed section and first section overlap at overlapping region 1, and first section and second section overlap at overlapping region 2. The force transferring from one section to another in overlapping region is very large due to

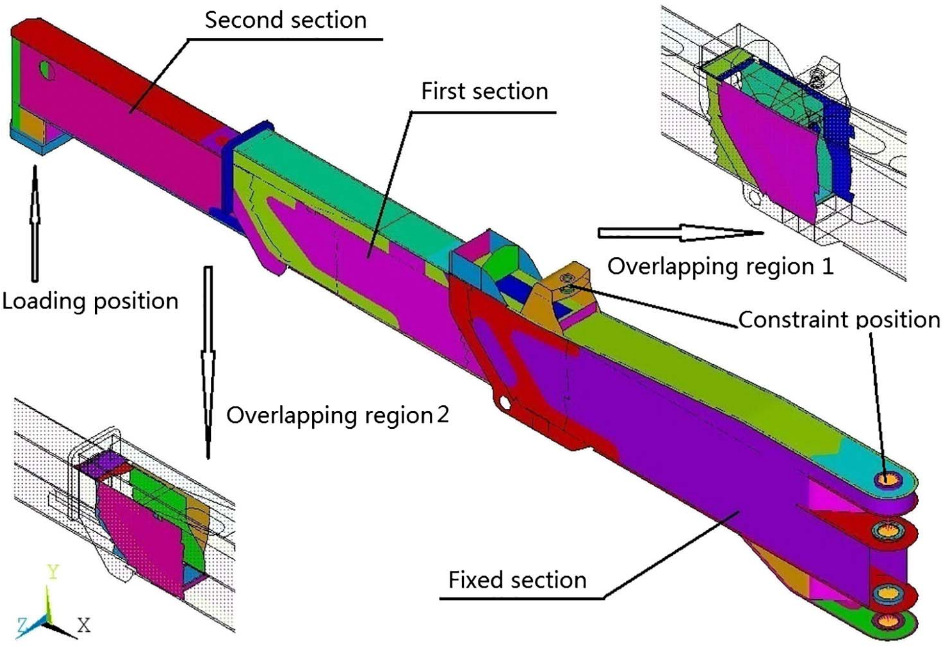

Fig. 2. The FE model of retractable outrigger.