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Buckling failure analysis of all-terrain crane telescopic boom section

Jia Yao [a], Xiaoming Qiu [a], Zhenping Zhou [b,*], Yuqin Fu [c], Fei Xing [a], Erfei Zhao [b]

[a] School of Materials Science and Engineering, Jilin University, Changchun, China
[b] School of Mechanical Science and Engineering, Jilin University, Changchun, China
[c] Xuzhou Heavy Machinery Co., Ltd., China

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ABSTRACT

In this research work, a nonlinear structure analysis by the finite element analysis (FEA) was carried out to investigate the failure reason of an all-terrain crane telescopic boom. An overall simplified model consisting of telescopic boom and luffing jib was established by beam element, and analyzed using geometric nonlinear static method. A local detailed model consisting of the 4th and 5th telescopic boom section (TBS) was established by shell and solid element, and analyzed using geometric nonlinear and contact nonlinear static method. The result of the overall simplified model FEA indicated that the boom strength met the design criteria, and the 5th TBS of local detailed model occurred stress wrinkle.

Structure experiment was designed based on the boom load characteristics in accident and analyzed using nonlinear static method and explicit dynamic method; the connection of load, boom buckling failure and stress wrinkle was studied. The result indicated that the accident was caused by elastic buckling. When the telescopic boom stress state changed from continuous state to wrinkle state, the buckling occurred. So the critical buckling state characteristic was stress wrinkle.

1. Introduction

An all-terrain crane has the features of high capacity, extraordinary mobility and convenient operability, and is usually used in projects such as high building construction and wind power equipment installation. The telescopic boom is an important load-bearing structure of an all-terrain crane, which consists of multiple independent thin-walled sections, with each section being made of unequal thickness high strength steels through bending and welding processes, and the cross-section shape being similar to an oval [1,2]. When the crane is in operation, the telescopic boom bears the coupling action of regular loads such as gravitational force, hosting load, inertia loads, and occasional loads such as wind loads or skewing loads caused by the uneven supporting legs, influenced by design, material, processing, construction environment, operational errors, the local buckling prone to occur at telescopic boom, causing accidents. Local buckling failure accident of an all terrain telescopic boom occurred in China as shown in Fig. 1.

Buckling is an important factor affecting carrying capacity and safety of the structure, therefore accurate calculation of the buckling critical load and critical stress is very important; calculation methods are analytical method, finite element method

* Corresponding author.
E-mail address: 156856503@qq.com (Z. Zhou).

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Fig. 1. Failure of all-terrain crane telescopic boom.

or according to standard design [3–5] formula. The finite element methods of buckling include linear eigenvalue, nonlinear static, nonlinear transient and explicit dynamic [6–15]. Choi B H et al. [16,17] using a nonlinear finite element method combined with the testing, analyzed the buckling strength and stiffness of longitudinally stiffened panels and the ultimate bending resistance of steel tub girders with top lateral bracing. Rikards R et al. [18] using explicit dynamic method, analyzed the buckling strength and the critical load of the stiffened composite shells, and optimized the geometrical parametrical dimensions. Rust W et al. [19] using implicit FE method and explicit method, analyzed the limit load of thin-walled structures. In above design standards and references, structures of buckling analysis include flat structure, I-shaped beam structure, box section, circular and oval cross-section thin-walled structure, while the buckling analysis of oval-like cross-section telescopic boom is not much. Derlukiewicz D et al. [20] checked the boom of box section telescopic boom mounted on mobile platform. Savković M et al. [21] analyzed the local strength of the truck cranes box section telescopic booms contact zone, and deduced the contact local stress formula.

In this paper, varieties of finite element methods were used to analyze the failure reason of the all-terrain crane telescopic boom; furthermore the connection of stress wrinkle and buckling was discussed. Firstly, an overall simplified structure was modeled by beam element according to the accident conditions, and calculated using the static geometric nonlinear method. It was found out that the telescopic boom met the strength design requirements, and no buckling occurred. Then a local detailed structure was modeled by shell and solid element, and calculated using the static method considering geometric nonlinear and contact nonlinear. It was found out that the stress wrinkle occurred on the telescopic boom and the calculation could not converge. Finally, the structure

Table 1
Material properties of Weldox 960.

Material	Density ρ (t/mm^3)	Elastic modulus E (Mpa)	Poisson's ratio μ	Yield strength σ_s (Mpa)	Tensile strength σ_b (Mpa)
Weldox 960	7.85e−9	2.1e5	0.3	960	1100