Stability Analysis of Offshore Wind Turbine Installation Jack-Up Vessel Based on Multi-attribute Decision Making Theory

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ABSTRACT

Stability mechanism of the offshore wind turbine installation jack-up vessel was studied considering the impact of environmental loads and lifting operation. The stability performances of jack-up vessel under lifting operation were analyzed, which include buckling stability of leg, overturning stability and foundation stability. A stability assessment method of lifting operation in the installation vessel is established based on information entropy. Based on the stability assessment method and research of wind turbine lifting operations processes, lifting strategy is optimized. Through the case study, the paper illustrates how these lifting operation challenges were overcome.

KEY WORDS: Wind turbine installation jack-up vessel; operation stability; multi-attribute decision making; information entropy; lifting strategy.

INTRODUCTION

Wind turbine installation vessel (WTIV) has become the main installation equipment of offshore wind farm construction because of its advantages of self-propelled, high work efficiency, large deck load capability and accurate lifting operation. Before lifting operation of WTIV, the spudcan penetration is needed to lift the vessel up the sea level, so as to provide steady work condition for wind turbines lifting. Installation vessel is subjected to dynamic environmental loads and time-varying moment caused by lifting operations, and eventually these loads are transmitted to the seabed through the legs. As a result, the carrying capacity of leg and foundation is one of the key factors that affect the safety performance of the installation vessel under lifting operations.

Before spudcan penetration of WTIV, bearing capacity assessment of foundation needs to be carried out to ensure the safety of WTIV during the lifting operation. An integrity assessment process about jack-up rig has been clearly defined in SNAM (2002). In recent years, more complex and precise pile-soil interaction models were established which has been validated through a detailed theoretical and experimental study (Zhang and Ding, 2011; Gaudin et al., 2011). Considering the overturning stability of mobile crane under lifting operations, the interaction mechanism between outrigger and foundation was studied under overturn condition caused by larger time-varying lifting moment (Tamate et al., 2005; Zhang et al., 2005).

Lifting operations is completed under the guidance of qualitative reference specification, which resulted in the subjective experience being one of the dominant factors that affect operating decision-making (Thomsen, 2014). This way of decisions-making depends on experience excessively and is very detrimental to the safety performance of the vessel. To ensure the vessel operate under safe condition, the layout and procedure should be improved using optimization strategies which mainly includes Multiple attribute decision making (MADM), expert experience method, simulation method, neural network method, etc. MADM is a method to determine the optimal solution. In this method, multiple evaluation is applied to make evaluation of the research object using existing decision-making data. Much valuable work had been done for related algorithms and theories of MADM (Kahraman, 2008; Gu and Zhu, 2006), and it has been widely used in engineering, technology, economics, management, military and other fields currently (Khan FI, 2004).

The authors studied the stability assessment methods of the WTIV under lifting operations. Accurate finite element model was established using reasonable boundary conditions, and buckling stability of leg, overturning stability and foundation stability were analyzed in accordance with industrial standards. Considering three types of stability which were analyzed in detail, a stability assessment methods was establish based on MADM and information entropy theory. An optimization of lifting strategy was performed between different installation locations. The results show that this paper’s stability assessment method is efficient and the lifting strategy can be established exactly.

STABILITY MECHANISM

Buckling Stability of Leg

As one kind of slender tubular structure, the leg of WTIV endure both axial force caused by the weight of hull equipment and lateral forces caused by environmental load, which lead to leg buckling likely. In this case, average stress of pipe section is much lower than the yield limit