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Application of hybrid laser arc welding for the joining of large offshore steel foundations

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Abstract

To reduce the costs of the fabrication of offshore wind turbine foundations it is necessary to investigate new fabrication technologies. Hybrid laser arc welding is a potentially well-suited process for this because it requires less groove preparation to achieve deep weld penetration and lower heat input, compared to traditional arc welding. A skirt section of a suction bucket in 16 mm steel was used as a case to investigate the hybrid laser-arc welding in order to demonstrate which types of weld and which weld positions are possible. Three types of weld joints were chosen and welded with different welding positions; a butt joint of a bended section, a butt joint of a flat section and a lap joint. Stable welds with sufficient penetration were achieved for the flat welding position of the butt joint of bended section and butt joint of flat section.

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Keywords: Hybrid laser welding; Weld penetration; Weld position; Offshore wind turbine foundation

1. Introduction

In many cases, the production of wind energy has moved to offshore locations because larger wind turbines are produced, and suitable space on land is limited in some regions. At sea the locations with low water levels are utilized first, and new offshore wind turbine parks have to be located at deeper water levels. At the same time, the Levelized Cost of Energy (LCoE) produced from offshore wind turbines must be lowered to make production cost-effective. The cost of the offshore wind foundation, including production and installations, amounts to 20-30% of the entire cost of

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setting up an offshore wind park, Offshoreenergy (2016-2017). For this reason new foundation designs are required, see Fig. 1, which can lower the costs by reducing the material consumption and reduce costs of production, transportation and installation. The idea behind this design is the bucket which is sucked into the seabed for the purpose of serving as a foundation for the entire structure, including the tower and wind turbine. The skirt consists of modular segments of steel plates which must be joined by lap joints to form the circular skirt.

One of the promising methods for reducing the production costs of such large steel structures is the use of hybrid laser arc welding (HLAW). Owing to the high intensity laser energy in HLAW, this makes it possible to reduce the number of passes and minimize the heat distortion compared with that seen in conventional arc welding techniques. This drives the trends found in heavy industries, where they are looking for new opportunities for substituting their conventional welding methods with hybrid laser welding, Nielsen (2015). The shipbuilding industry was a pioneer in using hybrid laser welding for thick-section steels. Almost two decades ago hybrid laser welding was taken into use for the manufacturing of several-meter-long ship panels. The plate thicknesses are usually between 3 to 12 mm, and in some cases up to 30 mm, Kristensen (2009). Other potential applications of hybrid laser welding which are of high economic interest are the longitudinal and orbital weldings of pipelines, Bachmann et al. (2016). Thanks to the wavelength of solid-state lasers, which allows beam delivery via fiber optics, positional welding and the welding of complex geometries are possible, using robotized processes. This becomes especially advantageous in the case of pipeline assembling or the thick-section welding of large and heavy structures, in which the manipulation of the workpiece is almost impossible. Studies of orbital welding of thick-section steel pipes in Rethmeier et al. (2009), Gebhardt et al. (2009), and Gook et al. (2010) show that single-pass welding of pipes of up to 16 mm in thickness is possible when using appropriate process parameters. The authors also suggested using either a beveled groove (Y-groove) or preheating in order to obtain sound joints.

As mentioned above, large and heavy structures such as offshore steel foundations demand positional welding processes, as the manipulation of such parts is unpractical. Owing to the flexibility in the beam delivery of high power solid-state lasers, robotized hybrid laser welding processes can potentially be a promising cost-efficient solution to this challenge. However, positional welding seems to be challenging, especially with thicknesses of 16 mm and above, and therefore, further practice is required on this subject.

Fig. 1. Offshore wind foundations. (a) Suction bucket jacket. Photo: Courtesy of DONG Energy. (b) Two mono buckets on a jack up wessel for installation. Photo: Courtesy of Universal Foundation Norway.