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Global fatigue life modelling of steel half-pipes bolted connections

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Abstract

A steel hybrid structural solution for onshore wind turbine towers was proposed in the European project SHOWTIME. This solution is used in the lattice structure for the lower portion of the tower. Recently, a procedure for fatigue life estimation of steel half-pipes bolted connections applied in global structural models using multiaxial Smith-Watson-Topper (SWT) criteria was proposed by Öztürk et al. In this paper a procedure for design S-N curve modelling of steel half-pipes bolted connections is proposed. This procedure is based on a local approach using multiaxial fatigue criteria together with an elastoplastic analysis using the finite element method. The materials to be used in this analysis are the S355 and S690 steels. This evaluation to be performed is calibrated with experimental results of fatigue tests of the connection under consideration.

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Keywords: Half-pipes bolted connections; Finite element modelling; Fatigue crack initiation; Multiaxial damage criterion.

1. Introduction

Wind energy has been used for more than 3000 years. Today, when global warming has become one of the most serious environmental issues, the need for renewable energies is increasing. The high demand for wind energy is leading the development of more powerful wind energy converters that demand higher towers to reach zones of higher speed and less turbulent wind [1,2]. With the increase of the tower height also transportation, assembly, erection and maintenance of the tower becomes more difficult and costly. On the other hand, increase in height rises

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the generated energy. At the moment, the most commonly used type of tower for wind energy conversion (WEC) is steel tubular tower. However, for the heights above 100 m, this type of tower requires diameters at the tower base of more than 5 m which makes the usual assembling process unfeasible due to public road transportation limitations [3,4,5]. Some producers have proposed lattice solution. Comparing to tubular tower, lattice towers have many bolted connections that require frequent maintenance, do not provide protected area for workers and are aesthetically less appealing, but they are not affected by transportation limitations [6,7]. For the lattice tower, a Finnish steel manufacturer has developed a new concept using cold formed built up profiles. Cold formed pieces (Fig. 1-left) are connected together with preloaded bolts creating a hexagonal cross section. All joints of cross section are also bolted with preloaded bolts (Fig. 1-right) [1].

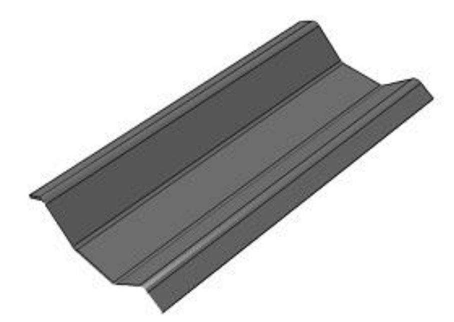

Fig. 1. Cold formed-plate for lattice towers (left), lattice steel tower (right)

Another type of tower construction that allows greater heights is the hybrid solution. This type of the tower is composed of three parts: the lower lattice part, tubular tower consisting of several parts bolted or welded together as in typical tubular tower solution, and transition piece which ensures the connection and transmission of forces between two main parts. The use of tubular tower for the upper portion beneficiates of all advantages of optimized technology for tubular steel towers with the diameters within public road transportation limitations, while the lattice portion enables the required extension of height [2,8]. Another advantage is that the lattice portion can be used to facilitate installation of the upper tubular portion and the turbine, therefore avoiding the need for very high cranes [3,8].

Lattice structures composed of hollow sections are widely used. They are used in buildings and halls, bridges, barriers, offshore structures, towers and masts. One main problem is the connections that can be used for tubular hollow sections. This has led to development of different types of welded and bolted connections between the sections. Within European project SHOWTIME [9] new type of tubular elements and connections are under development. These types of elements and connections will allow improvements in the way of construction as well as in the fatigue resistance and in the maintenance needs during service life.

The tower developed within SHOWTIME has hub height of 220m (120 m lattice part (Fig. 2), 100 m tubular part), supporting a 5 MW wind turbine. The lattice part is composed of 6 chord members placed with an angle of 120° and K braces with the angle of 45° from the horizontal. The materials to be used are S355 and S690 steels [10].