Finite element simulations of the laser surface treatment process and cavitation loads of a two-material propeller

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ABSTRACT

Cavitation erosion is a problem that concerns scientists and engineers in various disciplines. In the shipping industry, in parallel with the growth of ship size, speed and engine power, the propeller loading is increased as well, which leads to an increased danger of cavitation nuisance. Erosion damages are often found on propellers and the appendages. Severe material loss due to cavitation erosion may lead to rupture of propeller blades, leading to efficiency loss, deterioration of cavitation and noise, and even malfunction of the propulsion system. The repair of damaged propellers is also costly. Design measures to eliminate cavitation on propellers, i.e., the design of cavitation-free propellers, are however not preferable because they are always at the cost of propeller efficiency. Other measures to reduce the risk for severe erosion damage is therefore needed.

Scientists and engineers have not found alternative materials that meet the various operational and economic requirements of marine propellers. However, as only the properties of the surface layer of the propeller contributes to the erosion resistance, coating and surface treatment technologies offer a rational and economical solution to combat cavitation erosion. Laser surface treatment techniques are commercially available in several industrial applications such as the nuclear and tooling industries. The laser cladding technique adds a surface layer of metallic or ceramic powders on the location of a material/component where specific mechanical properties are needed, and the process have shown to give excellent metallurgical bonding between the cladded layer and the substrate material.

The present paper presents a study where the finite element (FE) method was used to simulate the laser cladding process of a propeller blade and material. Many paramateres can be varied in the laser cladding of propeller blades and the paper presents a systematic parametric study of how the cladding to substrate thickness affects the residual stress state in a two-material propeller. In addition to the FE simulation of the laser cladding process, FE simulations are presented which compare cavitation buble implosion loads on a non-cladded propeller blade with different surface-cladded propeller blades, in order to analyse and demonstrate the benefits of using two-material propeller blades with respect to reduction of erosion damages and risk for fatigue damages.

Keywords: Cavitation erosion; Fatigue damage; FE analysis; Laser cladding; Marine propeller;