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Case Study

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APPLICATION OF HIGH-STRENGTH COMPOSITE MATERIALS FOR THE NUCLEAR WASTE CONTAINERS AND FLASKS

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1 Introduction

For the permanent nuclear waste disposal at the Nuclear Waste Management Organization (NWMO) site requires the waste containers and flasks to be corrosion-proof. Consideration of the transportation or acceleration load and the fatigue load is critical component for the proper design of the nuclear waste containers. If a nuclear waste container is made of steel, it can be corroded in presence of oxygen and water at the temporary or permanent storage facility; and it if it made of aluminum, it can be corroded in presence of another metal (galvanic corrosion). Therefore, a new and innovative corrosion-free and non-magnetic composite material should also be considered for the manufacturing of these containers. Application of this high-strength and corrosion-free composite materials will also ensure a higher fatigue and transportation acceleration strength.

2 Project Overview

Nuclear Waste Management Organization (NWMO), Ontario Power Generation (OPG), Bruce Power and Canadian Nuclear Laboratories (CNL) in Canada are currently pursuing several nuclear waste management projects. For all these projects, a proper structural design of the nuclear waste containers and flasks is a crucial component. For the permanent nuclear waste disposal at the NWMO site requires the waste containers and flasks to be corrosion-proof.

3 Innovation

The innovation of the new system is a corrosion-resistant and high-strength nuclear waste container that is capable to sustain the transportation and the acceleration load.

4 Lessons Learned

The key lessons related to the consideration of the transportation load are as follows:

The transportation load can vary depending on the mode of transport – truck, rail, ship or airplane (Germonos 1992 and Maheras et al. 2013). The following acceleration-induced (impact) and wind loads is suggested as the transportation load:

(i) Roll + heave: 0.67 g transverse and 1.28 g vertical
(ii) Roll – heave: 0.54 g transverse and 0.60 g vertical
(iii) Pitch + heave: 0.34 g longitudinal and 1.67 g vertical

(iv) Pitch – heave: 0.27 g longitudinal and 0.30 g vertical

The key lessons related to the consideration of the composite materials for the manufacturing of nuclear waste containers based on Egusa (1991), Homan (2005) and Saboui (2012) are as follows:

The high efficient structural materials include Carbon Fiber Reinforced Polymer (CFRP), Glass Fiber Reinforced Polymer (GFRP), Aramid Fiber Reinforced Polymer (AFRP) and Basalt Fiber Reinforced Polymer (BFRP). FRP has high tensile strength, non-corrosive behavior, good chemical stability in hostile environment, good resistance to creep and degradation, low weight, potential for high modulus of elasticity, good fatigue capacity, non-susceptibility for electric conductivity and magnetic conductivity. Because of FRP's non-corrosive properties in the presence of de-icing chemicals, salt and brackish water, FRP is used as an effective reinforcement option for the manufacturing of the nuclear waste containers.

Although the material cost of Carbon Fiber Reinforced Polymer (CFRP) plates is much higher than steel plates, only 6.2 kg of CFRP plate is required to carry the same load as 175 kg of steel plates. In addition, considering the life-cycle cost, fabrication, application, protection and maintenance costs, the total cost is usually less for CFRP plates over steel plates.

Out of all the FRP materials, CFRP has the highest ultimate tensile strength and the highest modulus of elasticity. CFRP has higher stiffness, longer fatigue life, better creep properties, lower relaxation, lower density, and less susceptibility to aggressive environment than the other fiber materials. The cost of CFRP is also the highest. The elastic modulus of GFRP and AFRP tendons is about 25-30% of steel tendons. CFRP tendons have an elastic modulus of 75-105% of steel tendons.

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