Anchoring FRP Composite Armor in Flexible Offshore Riser Systems

Unbonded flexible pipes find extensive use in the offshore oil industry. Although more expensive than rigid pipe, the total cost of flexible pipe installations are often less. This is because flexible pipes are easier to store and deploy, coupled with superior fatigue performance. Among other things, they serve for the transportation of hydrocarbons from the subsea facilities to the production and drilling equipment at the sea surface. Flexible risers are the prime choice for connecting floating production, storage and offloading facilities, because they are specially designed for dynamic capabilities. The structure of flexible pipes consists of several concentric layers, each with a specific purpose. The most common used flexible pipe is the type III, which contains a central component, made from an interlocking stainless steel structure that provides collapse strength. The central component is called the carcass. A permeation polymer barrier is extruded over the carcass, followed by the pressure armor. On top, two counter-wound helical layers form the tensile armor. These carry forces in axial direction, and constitute the main focus of this thesis. In conventional flexible pipes, the tensile armor layer is made from steel. However, as oil exploitation goes to deeper and deeper waters, the strength/weight ratio of steel armor become unfavorable. In order to achieve higher tensile strength and to reduce the overall weight of the pipe, in the future, the tensile armor must be made of composite materials. One of the problems related to the substitution of tensile steel members is that anchoring in the metallic end fittings of the pipe is very challenging. The purpose of this thesis is to ensure the transfer of tensile loads between a unidirectional fiber reinforced polymer and a metallic counterpart. A new double grip design with flat faces is proposed, in which the loads are transferred through friction. The behavior of such grip is studied by means of experimental testing and finite element modeling. Several iterations of the grip system were evaluated over the course of the project. Initial effort did concentrate on creating an experimental setup which allows to control and record force and displacement values with great accuracy. Pullout tests using several sets of materials and grips, with different geometries and surface roughness were executed. Besides the experimental work, a finite element model was constructed for each of the experimental configurations. Initial effort is used to understand the behavior of the grip and obtain good accuracy with the finite element model. Experimental data is used as input. The model makes it possible to visualize the piece-wise onset of movement in the grip, and to measure the contact stresses distribution and evolution during pullout. The results of the experimental and numerical analysis show that it is possible to reliably anchor composite materials using a metallic grip. The models developed during the project show how to improve the efficiency of the grip system. Analysis of the boundary conditions show that several technical solutions can be chosen, without sacrificing performance. It is possible to create grips to fit a wide variety of constructive solutions.