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# Optimization Design for Steel Catenary Riser with Fatigue Constraints

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**This paper presents an efficient optimization strategy for deepwater risers' design under fatigue life constraints. The Steel Catenary Risers (SCR) concept has been considered to be a vital option for most new deepwater field developments around the world. The deepwater riser design is characterized by the consideration of numerous load cases, geometric nonlinearity and highly responsive dynamic nature of the system. It is very computationally expensive for the optimization process. Moreover, very little research has been conducted to incorporate the fatigue constraints into SCR optimization design. As water depths increase further, the large vertical motion at the semi or FPSO induces severe riser response, which results in difficulty meeting strength and fatigue criteria at the hangoff and touchdown point locations. This work analyzes the use of an Island-based Genetic Algorithm (IGA) to minimize the riser cost while keeping all constraints satisfied. A Kriging method in conjunction with design of experiments is used to construct an approximation model for dynamic and fatigue analysis. The geometric size and density of the coating types for SCR are varied so as to determine an optimum configuration. It demonstrates the effectiveness of this optimization strategy by integrating the approximation model into the design process considering fatigue life constraints.**

## INTRODUCTION

Steel catenary risers (SCR) are being considered and used in conjunction with a semisubmersible or Tension Leg Platform (TLP) in deepwater harsh environments. However, for ultra-deepwater risers can frequently exceed the technical feasibility limits (Karunakaran et al., 2005). Fatigue damage is a critical issue for the deepwater risers design (Yang and Li, 2010); it can occur due to the limitation of the viable riser diameter, particularly when associated with high external pressures and temperatures, and to significant static offsets and heave motions, associated with reduced capability of sustaining harsh service conditions (Xia et al., 2008). The experience of deepwater SCR applications has shown that fatigue is usually one of the most challenging design considerations (Thompson et al., 2002). The SCR fatigue damage is related to the combined effect of various parameters, such as environmental conditions, fluid density, riser diameter, water depth and host vessel motions (Bhat et al., 2004).

It is necessary to apply optimization techniques to speed up the design process while incorporating the fatigue into SCR optimization design. For a real SCR design problem, simulation-based fatigue life design demands not only the evaluation of strength requirements but also fatigue life. Optimization schemes have been implemented in both rigid risers and other offshore structures using traditional methods (De Lima et al., 2005; Larsen and Hanson, 1999; Sørensen and Tarp-Johansen, 2005). Various publications exist on SCR designs with hybrid designs (titanium and steel), or by changing its shape near the seabed through provision of significant buoyancy (lazy wave), which improves both fatigue and strength characteristics of the riser at the touchdown zone. As the riser system is highly nonlinear, this analysis is computationally expensive and time-consuming (Fu and Yang, 2010; Grealish et al., 2007). The optimization strategy must then be very efficient in order to handle fatigue life prediction within a reasonable time.

This work presents a methodology considering fatigue requirements in the optimal design of SCR. The fatigue life is considered as boundary constraints, and the structure weight as the objective function. A case study for SCR is performed, varying the material of the riser coating, and riser thickness of different segments. First, the Latin Hypercube simulation (LHS) (Koehler and Owen, 1996) for the experimental design is used for constructing the Kriging model. Second, the dynamic and fatigue response was calculated by simulation programs according to the sampled designs; the Kriging response surface fits with the simulation out and input parameters. In addition, the accuracy of the approximation model was evaluated; accurate response surfaces will be developed that may be used instead of numerical analysis procedures. Third, the Island-based genetic algorithm (IGA) was applied for the optimization design of deepwater SCR. This study intends to find the minimum riser weight by employing the approximation model while considering both strength and fatigue constraints.

## MATHEMATICAL MODEL

### Island-Based Genetic Algorithm—IGA

Many numerical deterministic techniques are available for solving the nonlinear constrained optimization problems to optimize

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