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# Advanced Nonlinear Analysis Methodologies for SCRs

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## Abstract

As the offshore industry continues to progress developments in deep and ultra-deep water locations, in many cases the considered or preferred riser solutions are steel catenary risers (SCRs) or lazy wave SCRs. The design of SCRs requires the use of advanced finite element techniques, to be able to accurately represent the complex interaction of the SCR with the environment and support structures, and hence demonstrate their suitability for use. This paper presents new advanced models for the nonlinear analysis of the SCR behavior.

For SCRs, the two critical design challenges are the characterisation of the SCR behavior at the vessel hang-off and the modeling of the SCR interaction with the seabed. At hang-off the predominant solution used in the industry is to have a FlexJoint® interface at the vessel. The response characteristics of the SCR at the flex joint and at the seabed are highly nonlinear phenomena. For ultra deepwater in particular it is essential not to restrict the modeling of such effects to linear approximation. To date most analysis models attempt to apply linear solutions to these nonlinear problems.

A significant amount of work has been undertaken recently to develop advanced models of the critical interfaces. This paper describes the modeling approaches used and assesses the potential conservatism or unconservatism in the more traditional linear approaches. The use of a fully nonlinear structural model of the flex joint to evaluate and assess equivalent linear modeling approaches is presented and discussed. This highlights a level of conservatism in the current approaches. In addition, advanced seabed modeling features, such as accurate modeling of suction and trenching effects are presented and the effect of these on SCR fatigue performance characteristics are highlighted.

The requirement for more accurate modeling techniques is driven by the criticality of SCR design in many applications, particularly with respect to fatigue response characteristics. Issues such as corrosive fluids, forcing the requirement for clad pipe and larger FPSO motions, driving the requirement for very long nipples in the flex joint, are pushing the requirement for more accurate modeling techniques, such as those presented in this paper.

## Introduction

This paper presents advanced analysis methodologies for the global modeling of the non-linear behaviour of SCRs at two critical locations for fatigue, specifically the vessel hang-off and the touchdown region, as part of a three-dimensional time-domain nonlinear beam finite element solution scheme.

At vessel hang-off, the dynamic motions of the vessel are transferred to the top of the SCR. SCRs require either a flex joint or tapered stress joint at the vessel/platform connection in order to accommodate the bending moments in this area. The first part of the paper outlines a non-linear methodology for the selection of an accurate stiffness to model the non-linear behaviour of a flex joint, and assesses the conservatism of the approach vis a vis a traditional approach.

The touchdown region and the interaction of the SCR and soil are critical for fatigue. The pipe-soil interaction for trenched SCRs is non-linear and follows a hysteretic type load path. The non linear pipe soil interaction behavior was studied and documented in earlier studies [1]. The pipe-soil interaction non-linear behavior described in Ref. [1] is used as a basis of the modeling techniques presented in this paper. Two advanced methodologies for modeling the non-linear behaviour of pipe soil interaction using springs with and without hysterestic behavior for an entrenched SCR are presented in this paper and the relative conservatism of the two methodologies is assessed against the traditional approach (modeling the touchdown region as a flat seabed with only linear pipe soil interaction) for assessment of 1$^{st}$ order wave fatigue.

In general, the approach for assessing the advanced modeling methodologies for nonlinear behaviour at vessel hangoff and entrenched touchdown region has been as follows;

a) Simple verification model to verify methodology is correctly modeling nonlinear behavior;

b) global SCR modeling using traditional methodology (Traditional model);

c) global SCR modeling using advanced methodology (Advanced model);

d) Comparision of “Traditional model” versus “Advanced model”