Probability study of Steel catenary riser fatigue at touch down zone

Ying Li, Penglong Ding, Liange Shan
School of Civil Engineering, State Key Laboratory of Hydraulic Engineering Simulation and Safety, Tianjin University, Tianjin, China

ABSTRACT

Steel catenary risers (SCRs) are preferred solution for deepwater application, however their fatigue design at touch down zone (TDZ) is challenging. With uncertainties of SCRs fatigue usually a larger safety factor is used in practice. In this work, the significance of relevant parameters on the SCR fatigue in TDZ is investigated with Morris method. By ranking the parameters in order of significance, the results show that the undrained shear strength of mudline has more influence on SCR fatigue in TDZ. Moreover, the probability of fatigue life of SCR in TDZ is presented as an alternative to deterministic fatigue life.

KEY WORDS: steel catenary risers; touch down zone; Morris; Monte Carlo; Latin hypercube sampling.

INTRODUCTION

Steel catenary risers (SCRs) are recognized as a preferred solution in exploring the deep-water oil and gas, since it is cheap and easy to produce and install. However, fatigue performance in touchdown zone (TDZ) is still a challenge in the design due to the uncertainty with respect of design parameters, which are generally related to riser itself, the connected floater and the seabed soil characteristic. The uncertainty related to the seabed soil mainly comes from the complex nature of riser-seabed interaction in the TDZ.

During the past two decades, many researchers have focused on elaborating the riser-seabed interaction (Elosta et al. 2013, Katifoglu an Chatjigeorgiou, 2012, Wang et al. 2013, Shiri, 2014) given that the uncertainty of riser-sea interaction affects the fatigue design of SCRs in the TDZ. They investigated the riser-soil interactions in terms of vertical embedment and large lateral movements of SCR in the TDZ by developing numerical model or using commercial finite element software. The advanced model can reflect the riser-seabed interaction more realistically; however the soil property at a specific site for SCR TDZ generally cannot be measured accurately, especially in deep water. In addition to the uncertainty of the soil property, there is uncertainty associated with the motion of floater connected with SCRs. For one thing, the floater neutral position may be relocated a few times during design life. Moreover, the SCRs property may also have uncertainty.

Without taking accounting for the variation of TDP, the fatigue damage at the TDZ of the SCRs can be overestimated (DNVGL, 2017).

Given the uncertainty above, apart from the deterministic estimation of fatigue damage in TDZ for SCRs, it is necessary to define the probability of SCRs fatigue. With respect of the uncertainty of riser fatigue prediction, some researchers have presented their work, including Sen (2006), Li and Low (2012), Li (2012). These stochastic parameters governing the uncertainty in the fatigue damage estimate needs to be identified. Fortunately, there is an advanced statistic methodology available for this purpose. Morris method is particularly well-suited when the number of uncertain factors is high and/or the model is expensive to compute. The method is based on calculating each input a number of incremental ratios, called Elementary Effects (EE), from which basic statistics are computed to derive sensitivity information. The EE method was proven to be a reasonable compromise between accuracy and efficiency, especially for sensitivity analysis of large models. The philosophy of the original EE method (Morris, 1991) is to determine which input parameters may be considered to have effects that are negligible, linear and additive, or non-linear or involved in interactions with other parameters. Morris method is individually randomized ‘one-factor-at-a-time’ experiment. Accordingly, the impact of changing one parameter at a time is evaluated.

Given the stochastic characteristic of parameters related to SCR fatigue, the aim of this work is to investigate the effect of different parameters on SCR fatigue in TDZ and rank the parameters in order based on effect significance and capture the confidence interval of the fatigue damage induced by the parameter uncertainty. One concern of this work was to carry out sensitivity analyses of SCR fatigue damage in TDZ considering parameters related to soil, SCR and floater with Morris method. In addition, given the uncertainty of those parameters, Monte Carlo simulation was carried out to quantify the fatigue life uncertainty in TDZ.

METHODOLOGY

Fatigue analysis

SCRs fatigue typically includes first order floater motion induced fatigue due to waves and lower frequency second order floater motion induced fatigue, vortex induced vibration (VIV), deep draft floater vortex induced motion (VIM), and installation. Here only the first order floater motion induced fatigue due to waves is mainly concerned, and