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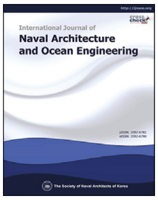

Preliminary optimal configuration on free standing hybrid riser

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ABSTRACT

Free Standing Hybrid Riser (FSHR) is comprised of vertical steel risers and Flexible Jumpers (FJ). They are jointly connected to a submerged Buoyancy Can (BC). There are several factors that have influence on the behavior of FSHR such as the span distance between an offshore platform and a foundation, BC up-lift force, BC submerged location and FJ length.

An optimization method through a parametric study is presented. Firstly, descriptions for the overall arrangement and characteristics of FSHR are introduced. Secondly, a flowchart for optimization of FSHR is suggested. Following that, it is described how to select reasonable ranges for a parametric study and determine each of optimal configuration options. Lastly, numerical analysis based on this procedure is performed through a case study. In conclusion, the relation among those parameters is analyzed and non-dimensional parametric ranges on optimal arrangements are suggested. Additionally, strength analysis is performed with variation in the configuration.

1. Introduction

In recent years, oil & gas field developments have increased in deep water. A hybrid riser is one of the field-proven concept for the deepwater development. This concept consists of Flexible Jumpers (FJ), vertical bundle of rigid riser and sub-surface Buoyancy Can (BC). The BC at the top of the steel riser is located deep enough to avoid critical hydrodynamic loading on the riser.

In addition, with steel riser decoupled from platform motion, the hybrid riser system has benefits in fatigue damage and payloads. However, this concept has limitations in engineering, manufacturing cost for complex components and bottom assembly connection on the seabed.

Several pieces of research into on its configuration have been performed. Dingwall (1997) observed that the FPU should be kept certain distance away from a riser base due to interference issues. Dingwall (1997) also explained the main factors for the BC's location, such as wave induced motions as well as interference between the BC and any of mooring lines. Fernandes et al. (1999) suggested a method to calculate the critical flexible jumper length using the consistent catenary concept, which has minimum tension at the end of the FJ. This length led to an economical approach in flexible jumper design. McGrail and Lim (2004) discussed several factors for global arrangements. In addition, structural characteristics on FSHR were analyzed with strength and fatigue analysis. Song et al. (2010) suggested the design flowchart for FSHR considering the complexity of the system and interface with manufacture and installation. Qin et al. (2011) suggested an optimum configuration design of the FSHR through parametric sensitivity analysis with single-variable control. Kang et al. (2012) suggested the method to determine the size of the BC considering key elements: the ratio of the length to the outer diameter of BC (L/D of BC), Top Tension Factor (TTF), the number of compartments, inner stem pipe and BC strength.

The main objectives of this paper are to propose the procedure for optimal configuration of FSHR and select optimal FSHR models through a case study. Then, useful non-dimensional parameters, which are span distance, submerged buoyancy can water depth and size, for preliminary design are suggested to provide guidance on the structural analysis of steel riser including optimization. Also, structural effects on the steel riser are investigated with variations of global arrangements (see Fig. 1).

2. Methodology

2.1. Flow chart with global arrangement of FSHR

There are a few key parameters which influence the global

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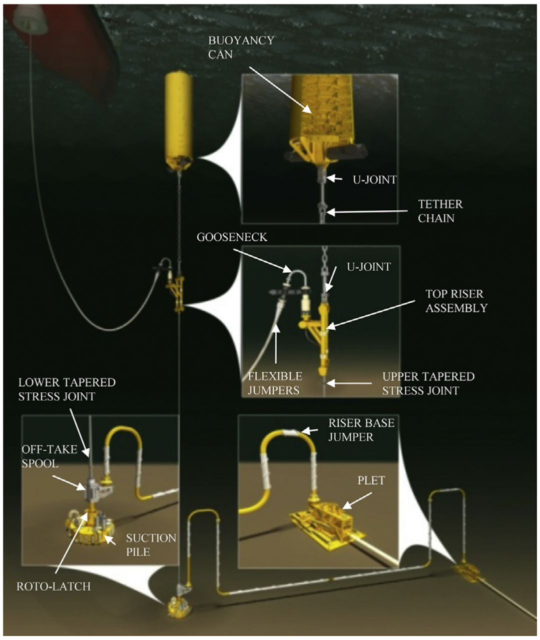

Fig. 1. Main components for FSHR concept (Song and Streit, 2011).

FSHR's arrangement, as can be seen below as Fig. 2.

- Submerged buoyancy can water depth
- Buoyancy can size
- Span distance
- Flexible jumper length (L_{FJ})
- Field interference

With these parameters, an overall flowchart for the design procedure on the optimal configuration is introduced as shown in Fig. 3. According to Fig. 3, the flow chart, it is seen that the depth of buoyancy can be determined by initial value, and then the span size and length and diameter of buoyancy can estimated by Metocean data and buoyancy can data. In the first criterion of them, convergence test would be run until all parameter met the criteria. And it proceed to second stage which is fatigue analysis. If it is failed to satisfy the fatigue criterion, whole procedure start over. The final stage on this procedure is cost estimation.

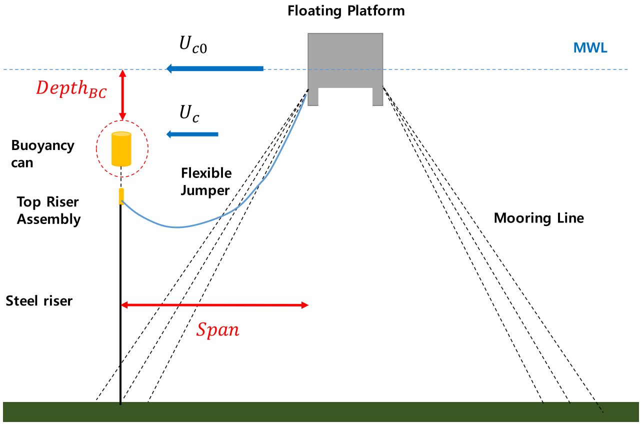

Fig. 2. Global arrangement of FSHR components.

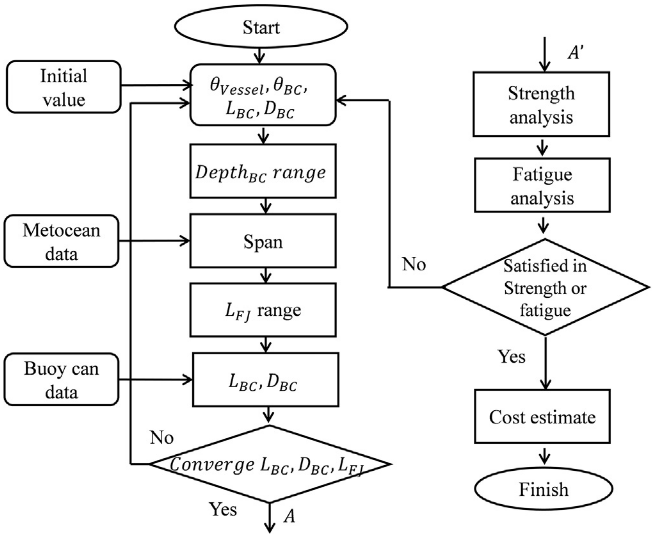

Fig. 3. Overall flowchart for optimal configuration.

2.2. Buoyancy can depth

First of all, basic design data such as the hang-off angle of the flexible jumper and the buoyancy design data are assumed to be reasonable value or brought from previous engineering experience. A BC is normally located deep enough to avoid critical wave and current loading. In a view of engineering experience, it is normally located between 50 and 150 m below free surface. In detail, it depends on wave and current loading in the environmental conditions for the certain field (Kang et al., 2012; Roveri et al., 2008).

According to Dingwall (1997), the BC should be located at which there is 5% wave energy relative to that on the free surface for fatigue issue. Thus, BC water depth where it has 5% of the acceleration of wave particle compared to that on the free surface is considered standard water depth (100%) as in Eq. (1) using deep water approximation, and then ranges of the BC water depth are divided into 100–250% at an interval of 5%.

$$a_x = kgA \times e^{ky} \times \sin(kx - \omega t)$$

$$\omega = \frac{2\pi}{T_p} (\text{wave angular frequency})$$

$$k = \frac{2\pi}{\lambda} (\text{wave number}) \tag{1}$$

where A and y are wave amplitude and water depth. T_p is wave period and λ is wavelength. g is a gravitational acceleration. x is x -coordinate of a wave particle.

2.3. Span distance

Span is the distance measured from the riser base on the seabed to a fairlead of FPU. For the interference aspect, the BC should not come into contact with other structures such as FPU and mooring lines. Thus, span distance can be expressed as Eq. (2) and Fig. 4.

$$\text{Span} = WC_{FPU} + WC_{BC} + Margin \tag{2}$$

where WC_{FPU} and WC_{BC} mean the watch circle (maximum lateral offset) of the FPU and the BC, respectively. The margin is an additional offset distance for the purpose of marginal safety factor for

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