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An apparatus design and testing of a flexible pipe-laying in submarine context

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ABSTRACT

A flexible pipe-laying apparatus is the actuating machine in pipe-laying ship to build flexible pipe in submarine environment. After investigating the basic principle of flexible pipe-laying mechanism, a new design is developed on its layout scheme and detail structure, including the tower support and its angle-adjusting device, the curvature adjustment wheel, the straightener, the hang-off clamp, and the tensioner selection. The main structure's strength is check and verified with the finite element method, the dynamic simulation is conducted on the hydraulic cylinder of the angle-adjusting device with ADMS software, and the kinematic simulation is also carried out on the pipe-laying system. The prototype is established and the key parameters in the system are measured and analyzed on the constant tension discharge, straightener, and pause. The results of calculation, simulation and testing show that the design alternative reaches the design requirements.

1. Introduction

The oil and gas from marine extracting are mostly transported to the users by oil pipelines (Legras, 2008). The flexible pipe (Huang et al., 2011) has many advantages as follows comparing with rigid pipe(Torselletti Enrico et al., 2006), first is better flexibility, second is fast fixing, third is good corrosion and compression capability resistance, fourth is low cost, thus, the laying the flexible pipe (Zhu, 2011) is paid high attention by the oil companies all the world. Flex-lay system is special equipment using oil pipelines under water (Qin and Zhao, 2010) and now the flexible pipe laying technology is grasped by big companies like HUISMAN. There are typical products (Marek Szczotka, 2010) as the 340 t Tilting Flex-lay System has been made by HUISMAN company for Acergy company in 2007 and the 150 t Module Flex-lay System has been made by HUISMAN company for Subsea company in 2007.

The technology of laying flexible pipe has just started in China. In this paper, a kind of design scheme of flex-lay system is carried out by referencing HUISMAN company's products. The development of this flex-lay system is mainly based on the design of lay ramp with adjoining angle device, curvature wheel, straightener, hang-off clamp and select type of tensioner, which is presented as follows.

2. Introduction to the basic laying theory on the flexible pipe

Based on the laying direction of lay ramp, there are two laying pipe methods (Jaime Garcia et al., 2009; Beltro and Bastian, 2014; Netto et al., 2005) on the flexible pipe: one is vertical laying method and the other is horizontal laying method. For example, the vertical laying method (horizontal laying method is discussed as an experimental sample later), while laying pipe, the working direction of every device in flex-lay system which is shown in Fig. 1. By adjoining hydraulic cylinder, the lay ramp angle is controlled close to 90°; then the tensioner begins to work, the tensioner crawler brings the radial tension to pipe, through friction force, the flexible pipe is laid. Once the pipe reaches to the seafloor, the pipe-laying vessel starts laying while moving ahead according to the controlled speed. When the pipe of the pipe roller is used up, the pipe head is sealed and the pipe back is joined into the corresponding structure, the pipe paying is finished.

In Fig. 1, while laying pipe, there are balance conditions from tensioner part to sag bend as follows:

$$F_{21} = G \tag{1}$$

$$F_{12} = F_{32} \tag{2}$$

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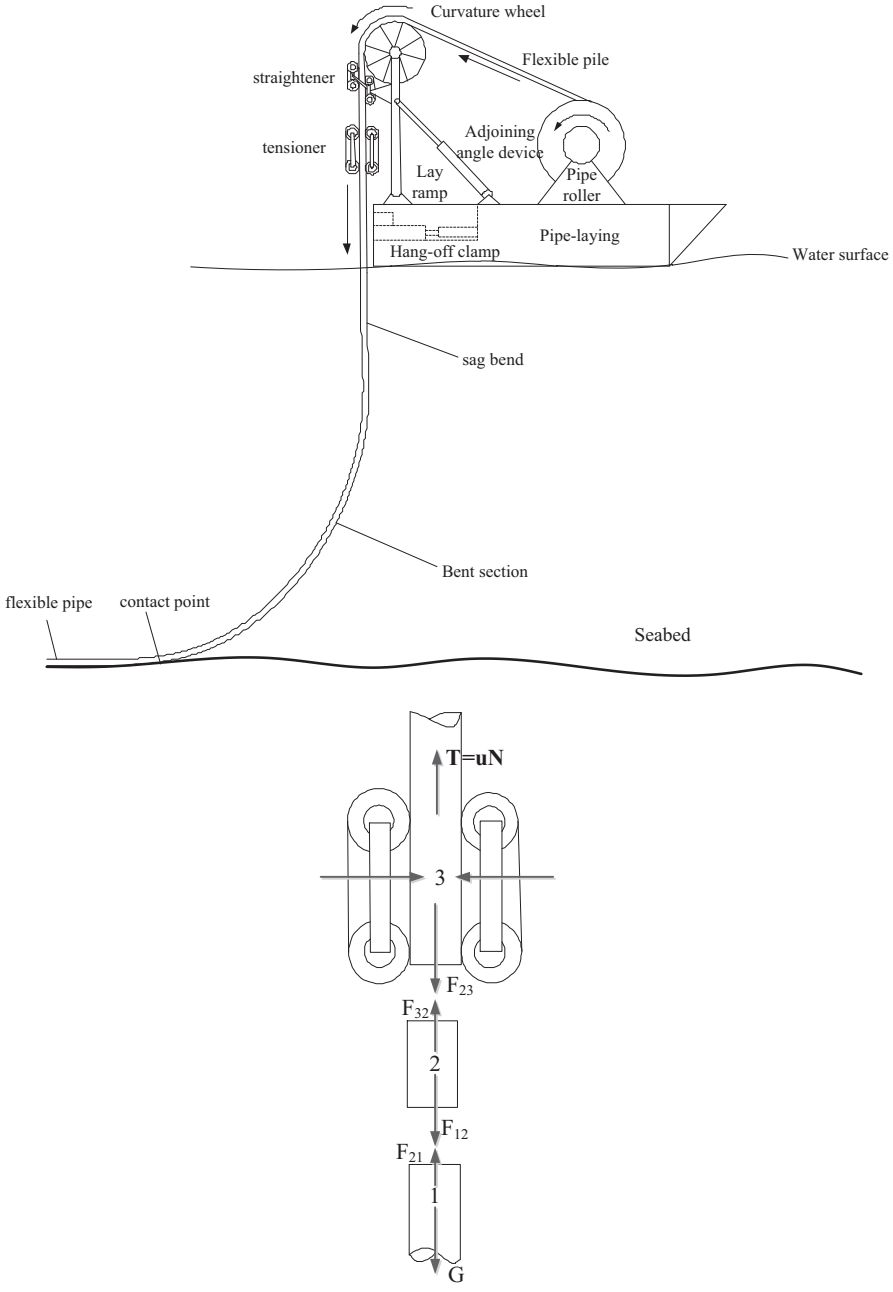

Fig. 1. Flex pipeline laying principle.

$$T = F_f = mN \tag{3}$$

$$F_{23} = T \tag{4}$$

T is pull force, N is tensioner chucking power, G is pipeline gravity, and F is middle force.

3. Design and assembly on flex-lay system

The design parameters are as follows: the flexible pipe size is from 3″ to12″, the adaptive underwater depth is from 300 m to 600 m, the capability of tensioner is 75 t, laying pipe velocity is from 0.25 m/s to 0.8 m/s.

Based on the work theory, design requirements and work conditions, the general structure of flex-lay system has been defined. The selecting type design of A&R winch and the tensioner and other key device have been decided. The flex-lay system assembly figure is shown in Fig. 2. The flex-lay system consists mainly of 1 winch support frame, 2 curvature wheel, 3 Straightener, 4 tensioner, 5 adjoining angle cylinder, 6 hang-off clamp and 7 lay ramp.

The curvature ratio and bending stress of flexible pipe can be controlled by curvature wheel from pipe roller (Zhu et al., 1997). In the normal case, the design radius of curvature wheel is bigger than 1.1 times of bending radius of pipe is shown in Eq. (5).

$$D/2 = R \geq 1.1R_{\min} \tag{5}$$

As known that three points make a line, the front point is the one contacting curvature wheel, two hind points are active crawler and fixed crawler of the straightener, through application of force to three points of flexible pipe, the pipe is straightened for eliminating residual stress of pipe. The straightener device is consisted of 1 adjusting screw, 2 fixed crawler, 3 fixed frame,4