Measurement 65 (2015) 227–232

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Friction reduction measurement for a coiled tubing working in a marine riser

Yingchun Chen [a], Shimin Zhang [a], Donghe Yu [b], Wenming Wang [a,*], Minghao Xiong [a]

[a] College of Mechanical and Transportion Engineering, China University of Petroleum-Beijing, 18 Fuxue Road, Changping, Beijing 102249, China
[b] Production Engineering Research Institute of Huabei Oilfield, Renqiu, Huabei 062550, China

ARTICLE INFO

Article history:
Received 13 August 2014
Received in revised form 9 January 2015
Accepted 14 January 2015
Available online 28 January 2015

Keywords:
Coiled tubing
Marine riser
Friction reduction
Axial load
Transfer behavior

ABSTRACT

Due to friction loss, the injection force applied on the Coiled Tubing (CT) would be unable to completely transfer onto its end. In that case, CT might be stuck in the riser which would finally make the operation failed. This paper proceeded experimental and computational study on ways to reduce friction between CT and riser to ensure the safety and reliability of the operation. Results show that inner pipe's axial force transfer efficiency will decrease with the increasing of annular clearance, but injection velocity has almost no effect on inner pipe's axial force transfer behavior. Thus in order to make the inner pipe transfer more axial force to its bottom end, CT with bigger diameter should be used during the operation. The research done above might provide important theoretical supports for the marine application of CT.

1. Introduction

With the increasingly scarce of onshore oil and gas resources, the development of offshore oil and gas resources attract more and more attention. Due to economical and high practical efficiency, CT has been widely used in offshore oil and gas industry over the past two decades [1–11]. Schematic of CT operation in a marine riser is shown in Fig. 1(A): CT unit is fixed on the offshore platform, and the tool for special operation is fixed at the end of CT; Riser is hanged on the platform and connected to the subsea wellhead by a connector; There exists annular clearance $r_c(r_c = (D_i - d_o)/2)$ between the riser and CT, as shown in Fig. 1(B); CT would be injected into the riser to proceed operation forced by the friction provided by the injector [12].

After years of using, there would be lots of wax and other debris attached on the interior of marine riser [13]. Thus, there would be resistance forced on CT's bottom end, applied by the debris. Due to its low stiffness, CT would buckle when the resistance becomes bigger enough, as shown in Fig. 1(C). With CT buckling more and more serious, the friction between CT and riser would be so big that the CT might lockup. In that case, the injection force applied on the CT would be unable to transfer onto its end, CT would be stuck in the riser, and the operation would be failed. So finding out ways to reduce friction loss for CT working in a marine riser is the key for its application.

During the past several decades Lubinski [14], Newman [15], Mitchell [16,17], Gao and Miska [18] have published lots of papers on the mechanical behavior of CT in a fixed outer pipe. Recently, Kuroiwa et al. [19] found that riser's tension would be reduced affected by inner pipe. Simon Falser et al. [20] found that tilt angle would affect CT's axial force transfer behavior very few and radial clearance has nothing to do with riser's axial pressure. As all the achievements are based on a 'fixed' outer pipe, it would be difficult to apply these results into marine pipe-in-pipe system, in which CT is injected into a floating riser [21,22]. Thus, we proceeded experimental and computational research on

* Corresponding author.
E-mail address: wangwenmingjob@163.com (W. Wang).

http://dx.doi.org/10.1016/j.measurement.2015.01.008
0263-2241/

Nomenclature

'Force-in'	the axial load at inner pipe's top end
'Force-out'	the axial load at inner pipe's the bottom
D_o	the outer diameter of outer pipe
D_i	the inner diameter of outer pipe
d_o	the outer diameter of inner pipe
d_i	the outer diameter of inner pipe
L	the length of outer pipe
l	the length of the inner pipe
r_c	the annular clearance between the inner pipe and outer pipe, $r_c = D_i - d_o$
dl	the length of inner pipe's infinitesimal segment
F_f	the friction between inner pipe and outer pipe
F_N	the contact force between inner pipe and outer pipe
f	the friction coefficient between inner pipe and the outer pipe
T_i	the axial load at initial point of inner pipe's infinitesimal segment
$dT_i(l)$	the increase of axial load at inner pipe's infinitesimal segment
F_{fi}	the friction between inner pipe and outer pipe at any infinitesimal segment of inner pipe
F_{crh}	the critical helical buckling load
F_{crs}	the critical sinusoidal buckling load
c	the calculation coefficient, it is 0.25 when the string is helical buckled, and is 0.125 when the string is sinusoidal buckled
E	the modulus of elasticity of inner pipe
I	inner pipe's moment of inertia
W	unit gravity of inner pipe's infinitesimal segment

friction reduction for coiled tubing working in a marine riser. Results of this paper might be helpful for engineering applications.

2. Experimental method

The schematic of the platform is shown in Fig. 2. We define the axial load of inner pipe's top end as 'Force-in', the axial load of inner pipe's bottom end as 'Force-out'.

The outer pipe is held in place by 2 pillars at both ends. The inner pipe's 'top end' is fixed to a connector. The inner pipe would be forced into the outer pipe by a piston powered by hydraulic. Axial load of the inner pipe's 'top end' and 'bottom end' would be measured by force sensors. The inner pipe extends 250 mm from outer pipe's 'top end' to permit direct connection to the piston rod. During this process, data of Force-in and Force-out is our interest to study axial load transfer behavior. Two force sensors passed a 0–5.0 V signal output to an analog low pass filter with a 3 decibel cutoff at 500.0 Hz which is then sampled at >500.0 Hz. Force sensors are then scaled in Newton to represent the Force-in and Force-out of inner pipe. Force sensors signals are affected by noise generated by calibration drift, and off-axis loading; accordingly, we expect maximum error to be less than ±10.0 N. To accommodate the acquisition of these digital signals, a National

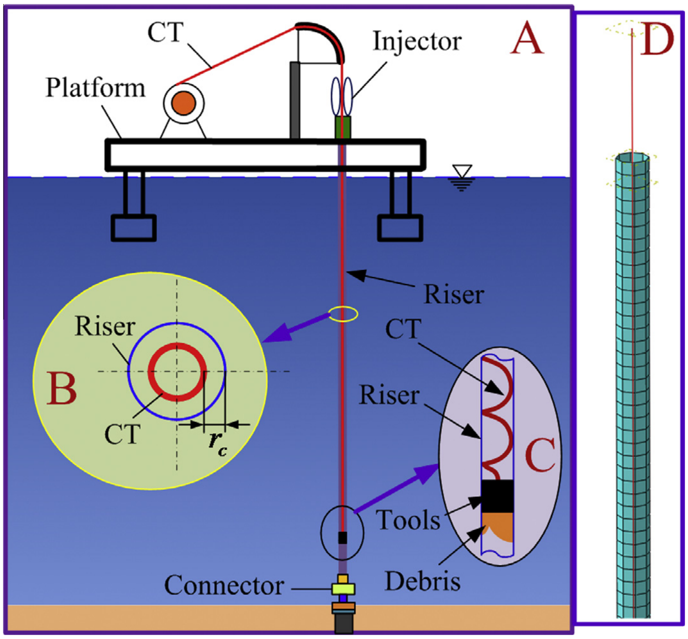

Fig. 1. Schematic of CT operation in a marine riser.