BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LX No. 1/2008	25 - 30	Seria Tehnică

Influence of Wall Thickness on the Behavior of Coiled Tubing to Cyclic Bending with Internal Pressure

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Abstract

Under variable loads, the coiled tubing undergoes irreversible damage, which consists in crack initiation and propagation, eventually leading to fatigue failure. This paper presents the results of the experimental research concerning the influence of the wall thickness on the fatigue behavior of coiled tubing manufactured from A and X 70 materials subjected to cyclic bending with internal pressure.

Key words: *coiled tubing, bending, internal pressure, fatigue, cracking.*

Introduction

The present tendency of the oil industry, regarding the drilling and the service of the wells, led to increased demands on the safety measures for the coiled tubing [1, 2]. In this context, the article tackles the fatigue behavior of coiled tubing subjected to cyclic bending and internal pressure. Figure 1 presents a coiled tubing unit.

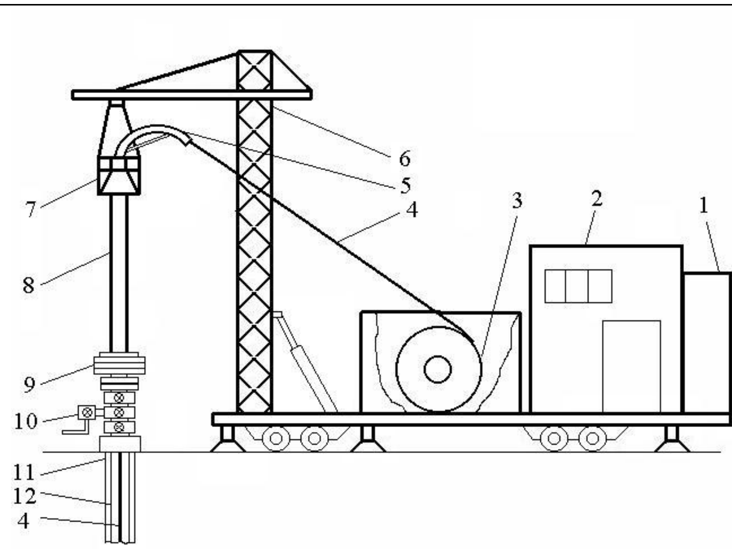


Fig. 1. The coiled tubing unit. 1 – pump room; 2 – control room; 3 – coiled tubing reel; 4 – coiled tubing; 5 – guiding arch („goose neck”); 6 – mast; 7 – injector head; 8 – lubricator; 9 – BOP stack; 10 – well head; 11 – casing; 12 – production tubing.

The coiled tubing is a continuous pipe manufactured from metallic material with high mechanical characteristics and controlled chemical composition, which confers it increased plasticity properties.

The research made in field conditions led us to the conclusion that the main reason of coiled tubing crack is fatigue (figure 2), due to its bending over the reel and / or the guiding arch of the coiled tubing unit (figure 1) [3, 4].

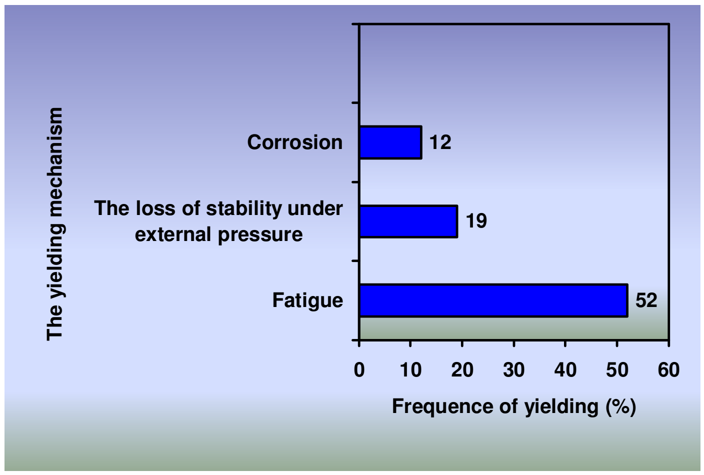


Fig. 2. The frequency of the coiled tubing yielding mechanisms [5].

In exploitation, over the bending continuous load, the internal pressure load is overlapped. The main objective of the research of this article consists in the experimental investigation of the fatigue life of the coiled tubing manufactured from A and X 70 materials, under the cumulative action of bending and internal pressure.

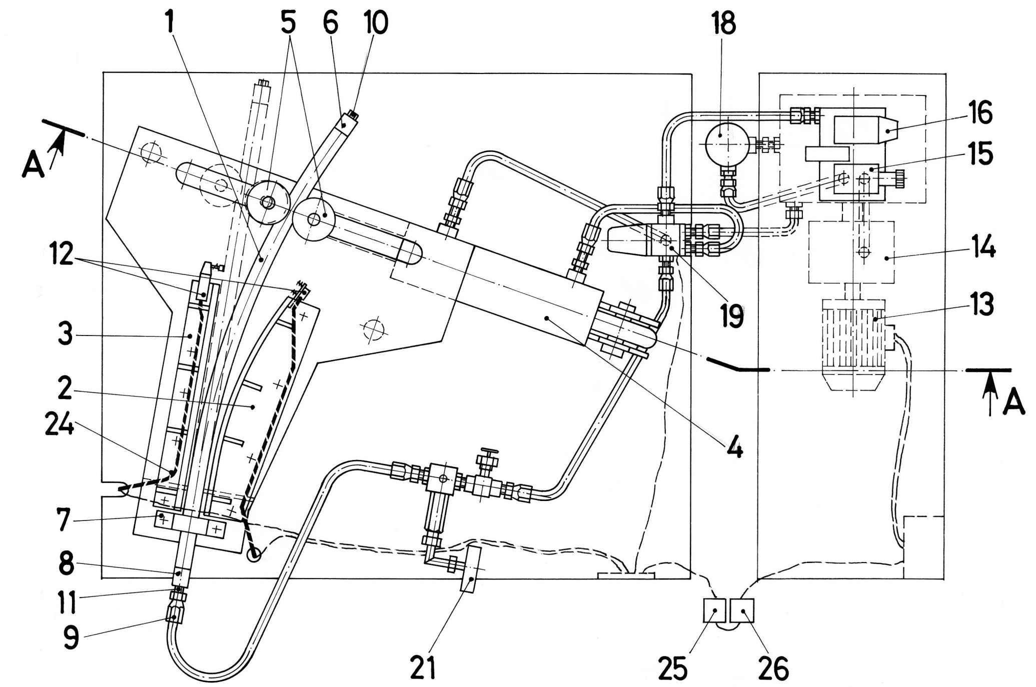
For the experimental fatigue life determination of the coiled tubing tests were performed in lab conditions on a stand [5] designed for bending with internal pressure, illustrated in figure 3 [5]. The fatigue life determination is based on the number of cycles for cracking of the coiled tubing.

Experimental Research Concerning the Influence of the Wall Thickness on Coiled Tubing Fatigue Life Subjected to Cyclic Loadings of Bending with Internal Pressure

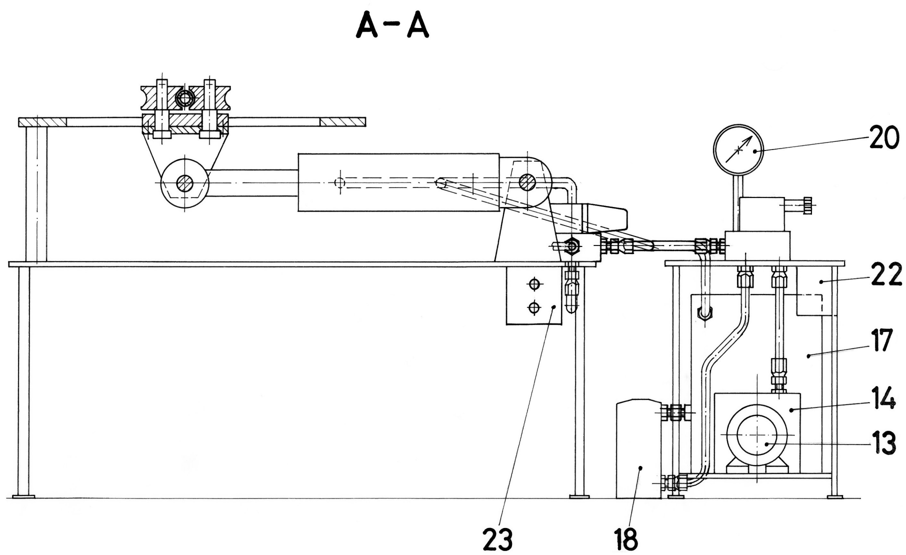
The stand used for experimental research (figure 3) was designed to accomplish the representative loads in exploitation: bending with internal pressure [5].

In order to control the bending form, the coiled tubing was modified over a bending form with the radius corresponding with the usual construction of the coiled tubing units – 1219 mm (see figure 1).

The internal pressure is maintained to a constant value. The admitted criterion for the failure of the coiled tubing was its cracking, emphasized through the loss of the internal work pressure.



a.



b.

Fig. 3. The stand used for tests to bending with internal pressure:
a – the scheme of the stand; b – A-A section of the stand.

1 – coiled tubing; 2 – bending form; 3 – straight form; 4 – hydraulic linear engine; 5 – profiled rollers; 6 – upper adapter; 7 – clamp device; 8 – lower adapter; 9 – hydraulic connection; 10 – inferior valve; 11 – superior valve; 12 – check piece; 13 – electric motor; 14 – hydraulic pump; 15 – pressure valve; 16 – hydraulic oil manifold; 17 – oil container (oil tank); 18 – oil filter; 19 – hydraulic oil manifold with slides; 20, 21 – manometers; 22 – switch panel of the stand; 23 – control panel of the electrical engine; 24 – electric power cables; 25 – contactor; 26 – switch plug.

The coiled tubing (1) is reeled over the bending form (2) and then it is straightened in contact with the straight form (3). The hydraulic linear engine (4) generates the force which is necessary for coiled tubing bending in both directions (towards 2, respectively to 3), through the profiled rollers (5). The test specimen has a 1200 mm length, which is introduced on the superior part of the stand, through the rollers (5) and it is rigidly fixed in the clamp device (7). The superior end of the specimen is closed by the upper adapter (6). The inferior end of the specimen has a lower adapter (8), where the hydraulic connection (9) is connected, in order to charge it with under pressure work liquid.

The specimen is filled with oil through the hydraulic connection (9) and the existent air is eliminated through the inferior valve (10). The specimen is loaded with the adequate hydraulic medium and the hydraulic linear engine is actuated, which will deform the coiled tubing to the right, through the rollers (5). The check piece (12) detects the position of the coiled tubing on the bending form (2) and reverses the motion sense (to the left). The sample is straightened on the straight form (3) until it hits the other check piece (12) and the motion sense of the hydraulic engine (4) is inverted.

The test is stopped when the meaningful reduction of the coiled tubing internal pressure is observed (with approximately 10 % of the work pressure value).

The hydraulic medium is eliminated from the inside of coiled tubing, the system is stopped and the sample is removed from the stand. The specimen is submitted to consequent tests and lab specific analyses [4, 5].

The research were made on 16 specimens of coiled tubing (8 manufactured from X 70 and 8 made from A), with the external diameter of 32 mm and different wall thickness (2,76 mm and 3,18 mm) [3, 5].

The mechanical characteristics and the chemical composition are presented in Table 1, respectively Table 2 [3, 5].

Table 1. The mechanical characteristics of the coiled tubing specimens.

*Type of steel**	*Yield Strength*	*Ultimate Tensile Strength*	*Hardness*	*Elongation*
	MPa	*MPa*	*HRC*	*%*
A	329	451	-	39
X 70**	483	552	22	30

* According to the API classification

** Pipe for coiled tubing QT 700: QT = Quality Tubing; 700 = 70000 psi = 483 MPa – minimal yield strength

Table 2. The chemical composition of the coiled tubing specimens.

Type of steel	*C*	*Mn*	*P*	*S*	*Si*	*Cr*	*Cu*	*Ni*
	%	*%*	*%*	*%*	*%*	*%*	*%*	*%*
A	0,09-0,16	0,40-0,80	max. 0,040	max. 0,045	0,17-0,37	-	-	-
X 70	0,10-0,15	0,60-0,90	max. 0,030	max. 0,005	0,30-0,50	0,55-0,70	0,20-0,40	max. 0,25

Figure 4, presents the influence of the wall thickness and the type of the coiled tubing manufactured material on the total number of cycles until cracking [4, 5].

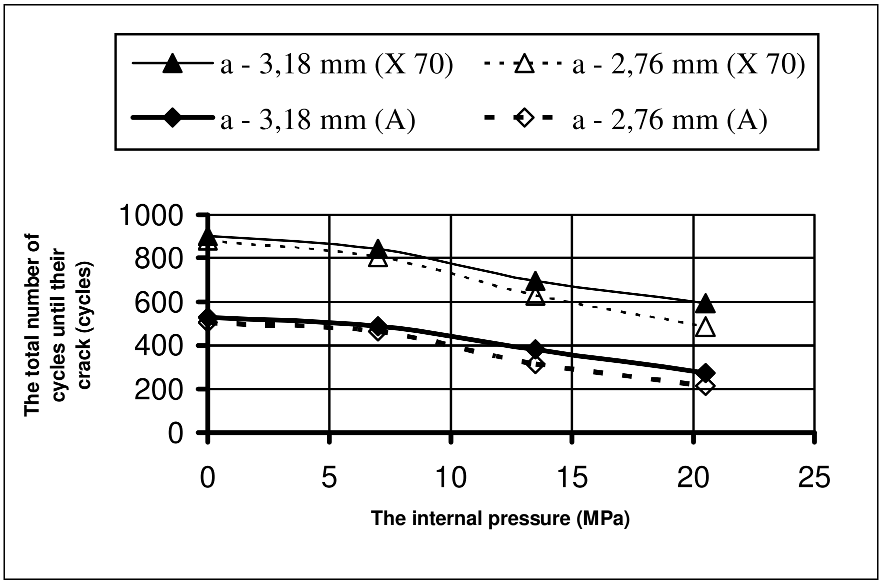


Fig. 4. The influence of the wall thickness and the material of the coiled tubing on the total number of cycles until cracking.

Conclusions

The results of the experimental research conducted us to the following conclusions:

- an inverse proportional relation results when the coiled tubing is continuously loaded to bending with internal pressure between the internal work pressure and the total number of cycles until cracking;
- the decaying of the coiled tubing wall thickness with 13 % (from 3,18 mm to 2,76 mm), determined the decreasing of the total number of cycles until cracking up to 45 %, when using samples manufactured from X 70 material, respectively up to 60 %, in case of the samples manufactured from A material;
- a major influence of the coiled tubing wall thickness on the total number of cycles until cracking is noticed when internal work pressures over 13,5 MPa are used. For internal work pressures under 13,5 MPa, the reduction with 13 % of the coiled tubing wall thickness determined insignificant decreasing (with 2…7 %) of the total number of cycles until cracking, whereas for internal work pressures over 13,5 MPa, a reduction with 18…27 % of the total number of cycles until cracking was observed;
- some fractures appear on the specimen surfaces when internal work pressures fewer than 13,5 MPa are used. But they are more dangerous as compared to those occurring when using the internal pressures over 13,5 MPa, when a meaningful growth with 10…15 % of the specimens external diameter was recorded;
- the lab analyses performed on fractured specimens of coiled tubing denoted that the cracks were initiated in transverse direction, from the inside to outside of the tube, through micro-cracks initiation and propagation because of the “hydraulic breakdown” effect caused by the fluid. When the section which contains the crack covers the distance between the bending form towards the straight form and the coiled tubing becomes rectilinear, the crack tends to close, but the fluid from inside (being incompressible) performs a hydraulic chock, which will determine the crack propagation.

The experimental research presented in this article represents a first stage in the elaboration of an endurance estimation methodology for the pipes used in manufacturing the coiled tubing. They are going to be extended through the influence of the external diameter, as well as of a large variation of the coiled tubing wall thickness on their lifetime.

References

1. Newman, K. R., Newburn, D.A. *Coiled Tubing Life Modelling*, Texas, Dallas, 1991.
2. Rusu, O. *Oboseala metalelor, Baze de calcul*, Vol I, II. Editura Tehnică, Bucureşti, 1992.
3. Ulmanu, V. *Material tubular petrolier*, Editura Tehnică, Bucureşti, 1992.
4. Ulmanu, V., Zisopol, D. G., Trifan, C. N. *Cercetări teoretico-experimentale privind influenţa caracteristicilor de exploatare asupra duratei de viaţă a tubingului flexibil utilizat în industria petrolieră*, Grant CNCSIS nr. 33350/29.06.2004 tip TD, 2004-2006.
5. Zisopol, D. G. *Cercetări privind construcţia tubingului flexibil utilizat în industria petrolului*, Teza de doctorat, Universitatea Petrol-Gaze din Ploieşti, Septembrie, 2000.

Influenţa grosimii de perete asupra comportării materialului tubular flexibil la încovoiere cu presiune interioară

Rezumat

Sub acţiunea solicitărilor variabile, materialul tubular (tubingul flexibil) suferă degradări ireversibile, constând în iniţierea şi propagarea fisurilor, al căror stadiu final este ruperea la oboseală. În cadrul acestei lucrări sunt prezentate rezultatele cercetărilor experimentale privind influenţa grosimii de perete asupra comportării tubingului flexibil confecţionat din materialele A şi X 70, la încovoiere cu presiune interioară.