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A TRIBOLOGICAL SOLUTION TO MANUFACTURING THE SPECIAL PIPE FOR PETROLEUM INDUSTRY

A. Tudor*), C. Mosessohn), I. Moraru**), O. Deleanu**)**
*) The Polytechnic University of Bucharest -ROMANIA
**) The HDPE and Fittings Magureni Company- ROMANIA

Abstract

This paper describes a study case of the application of tribology concept to solve a manufacturing problem of special pipes, which works in a crude petroleum fluid. To increase the durability and reliability of steel pipe for extraction of crude petroleum fluid, we develop a solution to tubing polyethylene pipe in inside of steel pipe. A tribological solution is used to correlate a pressure contact, between steel and polyethylene pipes, for some manufacturing and working conditions.

Keywords: Friction low; Compose pipe; Case study; Crud petroleum; Tribological solution

1. Introduction

Friction and rubbing of materials are among the most common phenomena in mechanics, present whenever two bodies come into contact. It is well known, however, that phenomena of contact and friction of solid bodies are among the most complex and difficult to model of all mechanical events, primarily due to the complex structure of engineering surfaces, the severe elasto-plastic deformation, damage, heat generation, the presence of contaminants, lubrication and even chemical reactions on these contact surfaces [1-2].

The corrosive effect of crud petroleum fluid, the movement of rod pomp, the wear of steel pipe and the stagnant paraffin nucleus are the principal factors to reduce of the durability and reliability of steel pipes. The fluid flow of crud petroleum into steel pipe, in some temperature condition, forms the stagnant paraffin nucleus. This nucleus reduces the debit flow of crud petroleum and it is necessary to stop the mechanical system of pump and the cleaning pipe.

The principal conditions to appears the stagnant nucleus are the by the apparent dynamic viscosity and the flow limited strength of petroleum in contact with steel pipe wall [3]. The temperature and the local friction condition between petroleum and wall can modify these rheological properties.

The aims of this paper are the application a new solution to reduce the flowing strength of crud petroleum, by used a special pipe and the manufacturing solution of this pipe. The special pipes are realized by the traction a polyethylene pipe in the inside of current steel pipe, which are used in the petroleum industry.

The different thermal properties of polyethylene and steel materials are essentially to manufacturing a special pipe.

2. The manufacturing traction forces

The technological procedure to release the special pipe is the traction of the polyethylene pipe in inside of steel pipe, in special device. A short manufacturing die is placed in affront to steel pipe. A mechanical box develops the necessary traction force with constant velocity. The model to calculus the traction force (F_a) includes the friction stress for conical gape of die and the friction stress for three cylindrical gape of steel pipe.

Thus, the traction force, for current point situated at x length to die, will be (Figure 1)

$$F_a = 2\pi \int_0^x \mu(p) R_{2x}(x) p(x) dx \qquad (1)$$

where $\mu(p)$ is the friction coefficient at the contact pressure p and R_{2x} is the current contact radius.

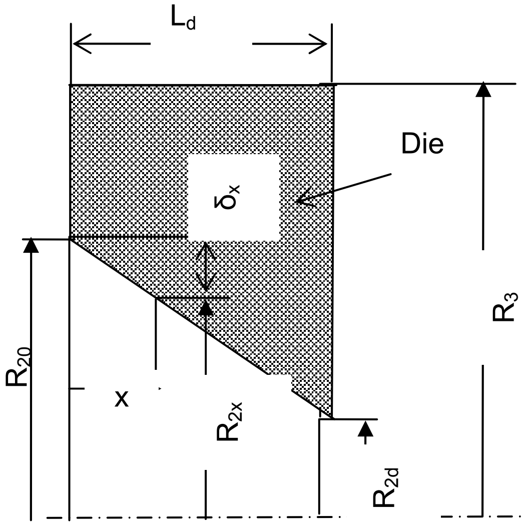

Figure 1. The geometry of manufacturing die.

The figures 2-4 show the variation of traction force in the manufacturing die, in the center steel pipes and at the end of steel pipe, respectively. These theoretically curves (continues line) and the experimental points are obtained for three lubrication conditions.

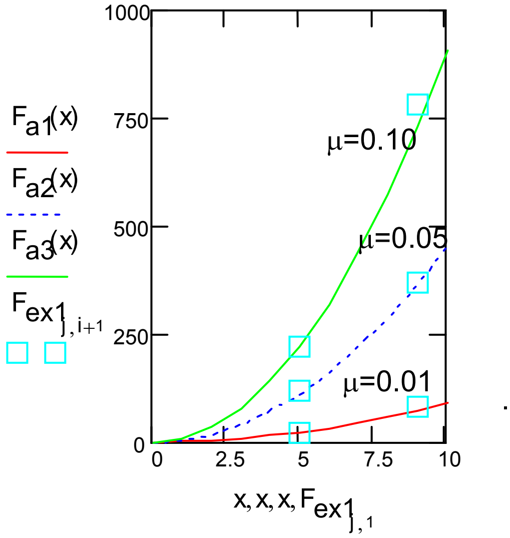

Figure 2. The traction force in die.

The residual stress of polyethylene pipe is minimum, when the traction force is minimum and the strains are elastically. The figure 5 shows the total strain of polyethylene, which is measured after finished the manufacturing traction, immediately.

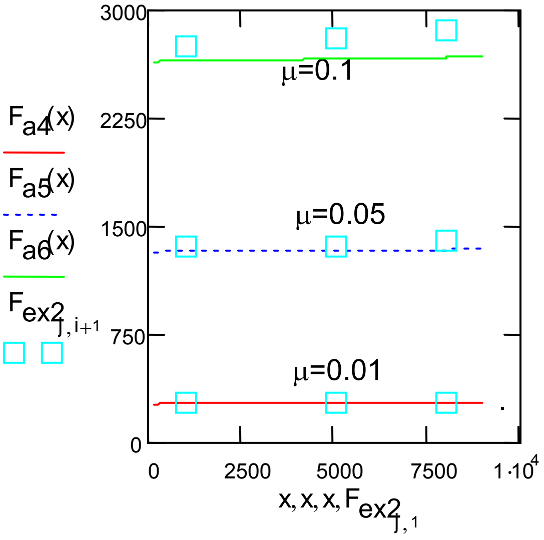

Figure 3. The traction force in center of steel pipe.

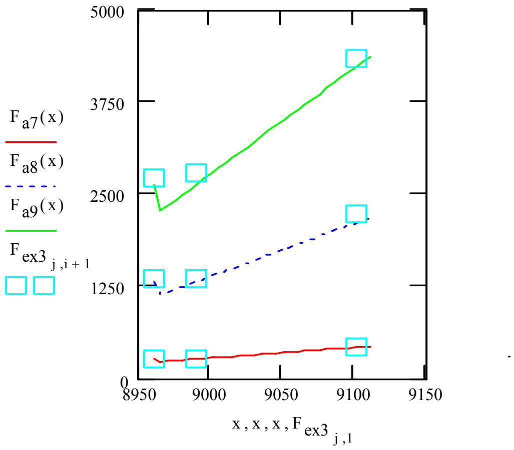

Figure 4. The traction force at the end of steel pipe.

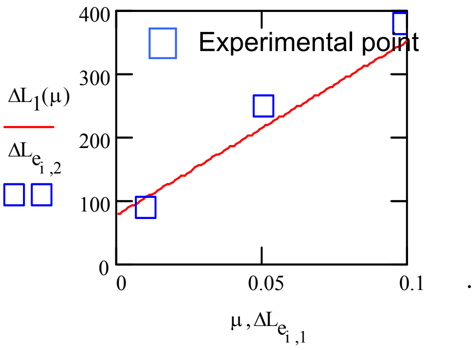

Figure 5. The total strain of polyethylene pipe.

3. Contact pressure model

The pressure contact and the friction between polyethylene pipe and steel pipe are necessary to solve aspect of relative movement for some temperature conditions. The thermal properties of polyethylene and steel materials are very different and the friction must be sufficient to stop the relative movement in time of decreasing or increasing the external and/or internal temperature.

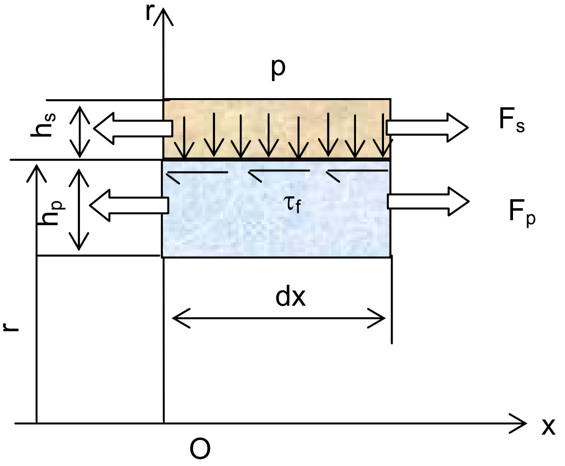

Figure 6. The load forces system.

We consider the binomial friction low between steel and polyethylene

$$\mu = \frac{\tau_0}{p} + \mu_0 \qquad (2)$$

where p is the contact pressure, τ_0 - strength of superficial layer of polyethylene and μ_0 - molecular friction coefficient.

The figure 6 shows the load forces system, which appears, in the steel and polyethylene pipes and at the interface of these pipes. The axial load for steel pipe (F_s) and polyethylene pipe (F_p) will be appear that a thermal effect ($\Delta\theta_s$, $\Delta\theta_p$), respectively. The strength by friction (τ_f), between steel pipe and polyethylene pipe, is proportional to contact pressure.

The static forces equilibrium for the very small part of the polyethylene pipe (elemental length dx) defines the minimum molecular friction coefficient between steel and polyethylene to stop relative movement when the temperature varies in time (day-night, winter- summer):

$$\mu_o = \frac{E_p \alpha_p \, \Delta\theta_p h_p - E_s \alpha_s \, \Delta\theta_s h_s}{p\,dx} - \frac{\tau_o}{p} \qquad (3)$$

where α_p and α_s are thermal expansion coefficient (1/grd) of polyethylene and steel; $\Delta\theta_p$ and $\Delta\theta_s$- temperature gradient in time for the polyethylene pipe and the steel pipe.

The contact pressure (p) is defined by the elasticity theory, when the interior and exterior radius for steel pipe and polyethylene have different values.

For the pressing δ, the elastic contact pressure will be [4]

$$p = \delta f\left(R_1, R_2, R_3, E_s, E_p, \nu_s, \nu_p \right) \qquad (4)$$

where f is a function to the internal radius of polyethylene pipe (R_1), the commonly contact radius (R_2), the external radius of steel (R_3), the elasticity modulus (E_p, E_s) and the Poisson coefficients (ν_p, ν_s).

The manufacturing process of the special pipe includes the traction of polyethylene pipe in inside of steel pipe by the conical die. To reduce the traction force, we adopt a solution to place the conical die nearly to steel pipe, the special lubricant and the optimal temperature of polyethylene pipe. The stability of the special pipe is considered when the contact pressure deforms polyethylene pipe elastically and the friction forces reduce the thermal strains.

The mechanical effect of contact pressure, about the equivalent stress in manufacturing time, can be analyzed by the elasticity parameter C_{ao}, defined as

$$C_{ao} = \frac{\sigma_{eo}(r, R_1, R_2, p, \theta_i, \theta_e, F_{ax})}{\sqrt{2}\sigma_{c1}} - 1 \qquad (5)$$

where σ_{c1} is the yielding strength of polyethylene material and σ_{eo} – equivalent total tension, as a function to current point position (r), geometry of polyethylene pipe (R_1,R_2), contact pressure, interior temperature in inside of polyethylene pipe (θ_i), exterior temperature of steel pipe (θ_e) and the manufacturing traction force (F_{ax}).

Figures 7 shows the effect of contact pressure (p), the manufacturing traction force (F_{ax}) about the elasticity parameter $C_{o.}$

4. Temperature effect

The different thermal properties of steel and polyethylene materials induce the relative tensions between two pipes. The friction is necessary to stop relative movement. The total equivalent stress between steel and polyethylene pipes is defined as a function to pressure contact after manufacturing and the thermal field for special pipe. The elastically deformation appears when the elasticity parameter *C* is negative. This parameter is defined similarly to eq. 5, but the total stress will be calculated without the traction force.

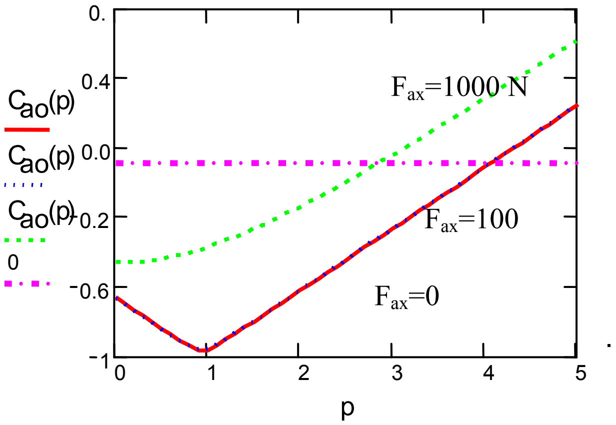

Figure 7. Elasticity parameter v.s. pressure contact and traction force.

Thus, the figure 9 shows the effect of temperature about elasticity parameter

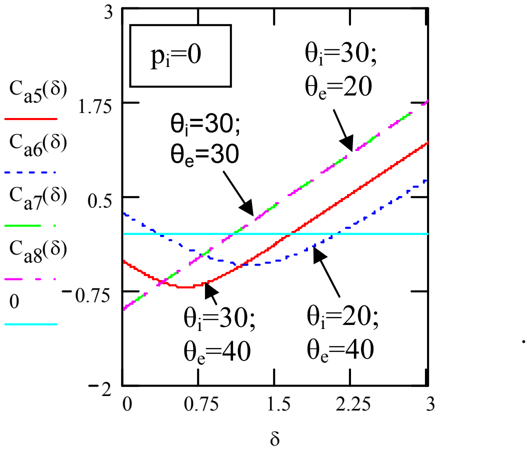

Figure 9. Elasticity parameter vs. pressing depth and interior and exterior temperature.

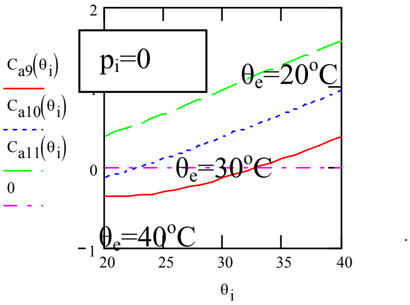

Figure 11. Elasticity parameter vs. interior temperature.

Conclusions:

1) The elastic deformation, which appears in manufacturing time, will be reduced after finishing manufacturing. These phenomena can be reduced by "relaxation" procedures.
To optimize the effect of these phenomena, it is proposed the following technical solution:

a) The "relaxation" of compose tubing at the natural temperature for 5-8 days, as a function to the axial traction force;

b) The controlled "relaxation" by the cooling of the interior of the compose tubing or by the vibrations which will be induced for external of the compose tubing.

2) To reduce of elastic strain for the polyethylene pipe, it is recommended the following technical solutions:

a) decreasing of friction coefficient in manufacturing time by full lubrication of die, and good preparation of the interior of steel pipe before manufacturing stage;

b) to control of speed in driving system as a function to thickness of polyethylene pipe and the strain deformation in the die;

c) to place of die in contact with the steel pipe, for decrease elastic strain;

d) to avoid the abrasive particles in contact between pipes in manufacturing stage.

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