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ANALYSIS OF INFLUENCE OF TEMPERATURE ON WELLBORE TUBING DIMENSIONS

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Abstract

The construction of exploitation wellbore is complex, it consists of several columns of pipelines which perform different tasks. It is very important to preclude flow of reservoir fluid between wellbore and ground. Tubing is a kind of a pipeline which is very important element of oil and gas wellbore construction. It allows to transport fracturing medium between wellbore station and underground deposit. Manufacture quality and correct mounting of tubing in the wellbore are the key for effective exploitation. However, during work those pipes are subjected to changeable loads which results in temperature value changes for example. That temperature variations can be caused by cold medium transport inside the pipe. In the paper, analyses of influence of temperature value changes on the tubing shrinkage were presented. Numerical analyses of section of pipe vertically located in the wellbore and loaded with changeable temperature were carried out. The calculations were made with the use of coupled structural and thermal analyses. Received results of tubing shrinkage for fragment of pipe were adapted to the column of pipes of 3000 m length. Results of numerical analyses were verified with the analytical calculations. Material of tubing was assumed as steel P110 which is often applied in the wellbore construction.

Keywords: *wellbore, tubing, heat, thermal extension, pipe, steel P110, thermal analyses, Finite Element Method*

1. Introduction

Application of different kind of pipes in the wellbore is performed to ensure isolation from ground water and proper sealing between soil layers. It is very important to preclude flow of reservoir fluid between wellbore and ground. Strength of several kind of casing must be appropriate to install equipment which secure wellbore from reservoir eruption. The structure of wellbore includes different types of casing columns where each of them plays different role in the borehole. The first of applied structures is conductor casing column which supports the end of well and enhances the initial segment where loose and poorly concise rocks are present. This column should be located as deep as possible because the upper geological layer often has complex structure. The next type of applied column is surface casing which supports borehole on the layers under top loose material. This column of pipes must isolate ground water, support the proper direction of well and also secure from high pressure which may occur when drilling the last distance before next section. The next column is intermediate casing, often named technical one, which is used to protect the wellbore from complications that can occur during drilling the lowest section. It is acceptable to apply several intermediate casing depending on the situation in the well. When the geological conditions are good, this column is not required. The last column is production tubing which reaches the deepest layer of wellbore. This tubing pipe first of all serves to transport reservoir fluid to the ground, but also allows to do specialised work in the borehole [1].

In Fig. 1 scheme of pipes columns in the wellbore was shown. The major kind of pipe used in the well is casing and tubing. All pipes which are applied in well should meet strength criterion described in the guidelines developed by American Petroleum Institute (API) ISO 11960:2011 Petroleum and natural gas industries − 5CT Steel pipes for use as casing or tubing for wells. 9th Edition, June 2011 [2].

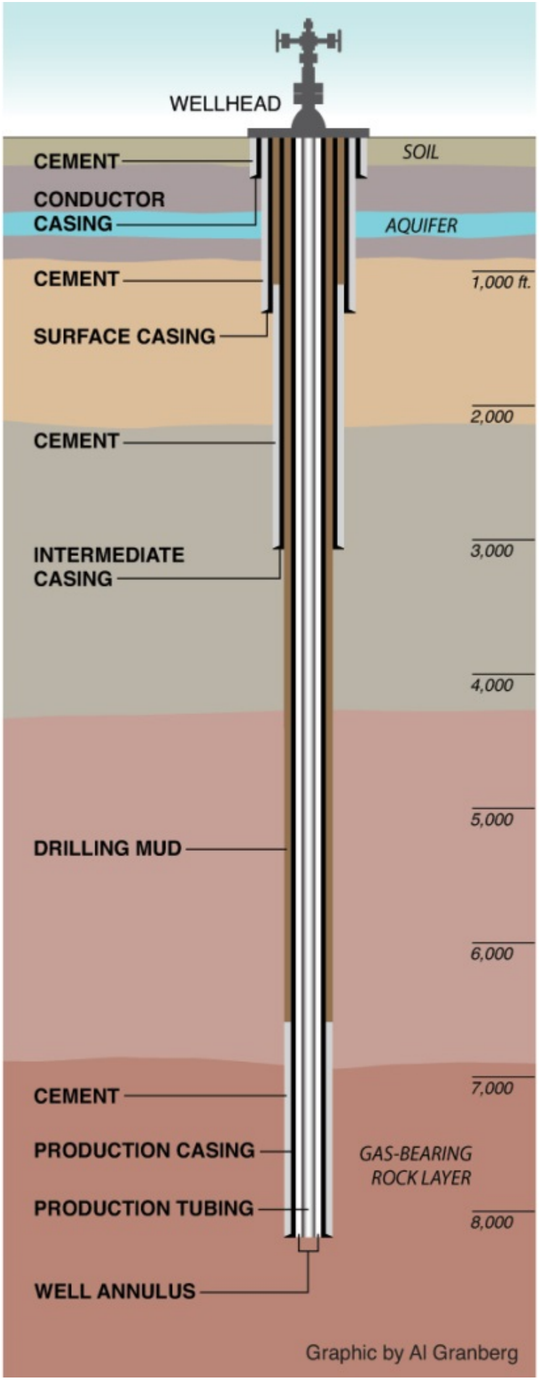

Fig. 1. Scheme of pipes columns in the wellbore [3]

In this paper, temperature influence on tubing dimensions was analysed. For calculation Finite Element Method was used what enabled to solve a wide range of engineering problems in short time. The results were compared with analytical calculations. The terms of this analysis include the use a fragment of tubing pipe and rapid decrease of temperature below zero degrees of Celsius. Longitudinal shrinkage was a result of calculations.

2. FEA tubing model

The analysis was performed in LS-DYNA solver. The model was prepared as a tubular segment which had 3 m length. External diameter of pipe was 72 mm and internal diameter was 62 mm. For material of tubing pipe steel P110 was adopted, which is widely used in oil/gas industry. For a discretization 220800 elements with 8-node hexahedron type of model were used. geometrical model with mesh of finite elements was shown in Fig. 2 [4, 5].

Fig. 2. Discrete model with constraint conditions

Constraint condition was given at one end of the pipe. The last layer of nodes were selected in order to fix all degrees of freedom. Constraint conditions were shown on Fig. 2. Second end of pipe was set free. The purpose of this analysis was to study thermal influence on pipe dimensions. Initial temperature of model was 20°C and after first second of analysis, temperature of model decreased to –20°C and stay steady to the end of analysis. Graph of applied temperature value was shown in Fig. 3. Temperature was applied in all nodes of the model.

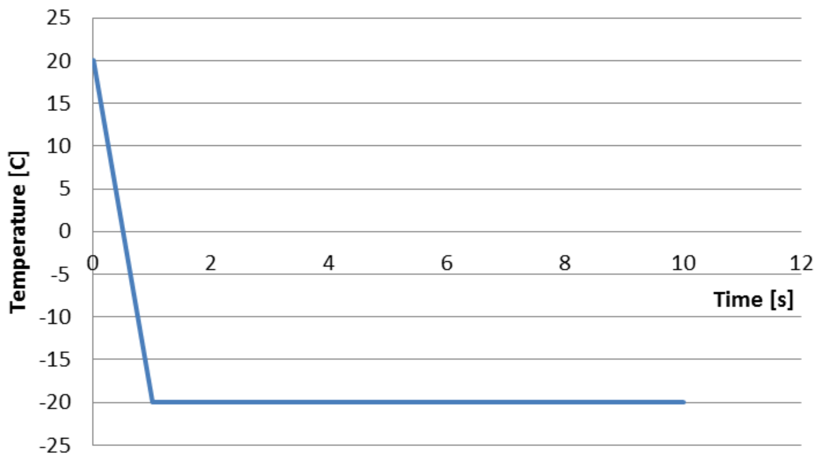

Fig. 3. Temperature applied in the model

To simulate behaviour of steel P110, material model MAT_ELASTIC_PLASTIC_THERMAL was used. In addition, material card THERMAL_ISOTROPIC was used where value of thermal coefficients were defined. Values of thermal parameters are the most important to simulate proper behaviour of material under thermal load. Material model which was chosen for numerical analysis has linear character for temperature range used in this simulation. Parameters of steel P110 was shown in the Tab. 1.

3. Result of analysis

As the result displacement of unconstrained end of tubing pipe was received. Change of temperature to sub-zero value caused 1.5 mm shrinkage of 3 m fragment of tubing. Value and progress of this displacement was shown in Fig. 4. Displacement changes are compatible with declared temperature change in the analysis.

Tab. 1. Parameters of steel P110 [6]

	Unit	Value
Density	g/mm^3	0.00775
Young's modulus	GPa	212
Poisson's ratio	–	0.3
Tensile strength	MPa	758
Heat capacity	10^6 $J/m^3°C$	3.5
Thermal conductivity	W/m°C	41.5

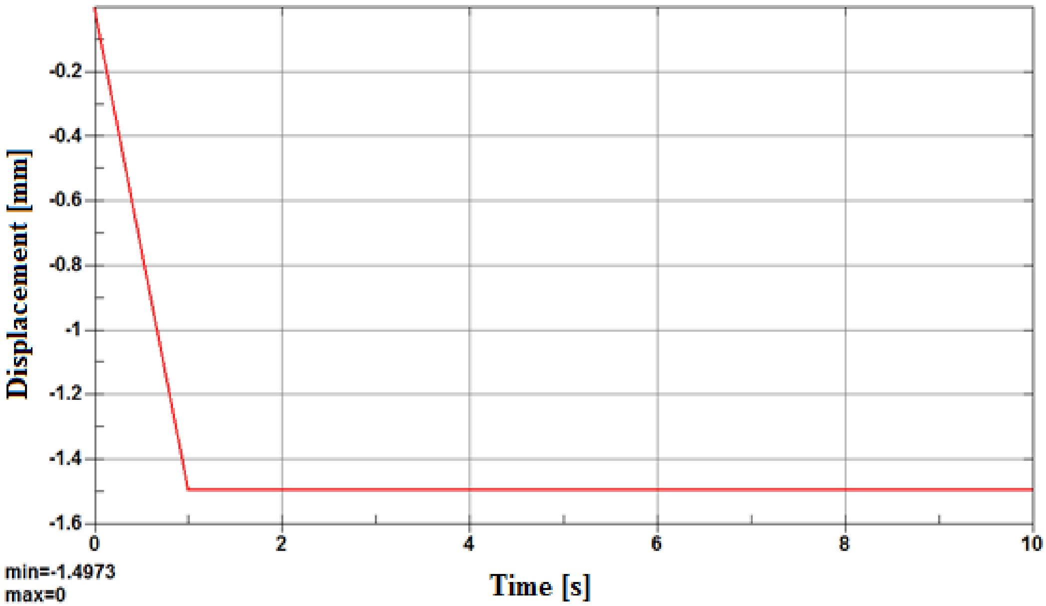

Fig. 4. Displacement of unconstrained end of tubing pipe

4. Analytical calculations

Accuracy of numerical calculations was easy to verify by analytical calculations. Change of length is proportional to temperature changing which is given by the linear expansion equation:

$$z = z_0(1-\alpha\,\Delta T)\,, \tag{1}$$

where:
z – length of pipe after temperature changing [mm],
z_0 – initial pipe length, $z_0 = 3000$ mm,
α – linear expansion coefficient, $\alpha = 12.5 \cdot 10^6$ 1/°C,
ΔT – temperature changing, $\Delta T = 40$°C.

$$z = 3000 \cdot (1 - 12.5 \cdot 10^6 \cdot 40)\,. \tag{2}$$

Finally:

$$z = 2998.5 \text{ [mm]}. \tag{3}$$

Result of analytical calculations showed that length of pipe after temperature changing is 1.5 mm lower then length of pipe in starting point.

5. Conclusions

The analysis simulate the sub-zero medium implementation to the interior of the pipe. Influence of temperature decrease was observed on fragment of tubing pipe which was analysed. The temperature range in the analysis as assumed earlier was 40°C, which was reached after 1 s of analysis. From numerical calculation 1.4973 mm of shrinkage was received. This result is very close to analytical calculation, therefore it can be concluded that the model is correct. Change of tubing dimensions depends on linear equations for small changes of temperature. Chosen model is a part of the real pipe and obtained results can be applied to the wells with various depths.

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References

[1] Wójcikowski, A., *Przygotowywanie otworów do wiercenia 311[40].Z1.04*, Institute For Sustainable Technologies – International Research Institute, Radom 2007.
[2] *ISO 11960:2011 Petroleum and natural gas industries — 5CT Steel pipes for use as casing or tubing for wells*, American Petroleum Institute (API), 9th Edition, June 2011.
[3] Liu, Z. Y., Li, H., Jia, Z. J., Du, C. W., Li, X. G., *Failure analysis of P110 steel tubing in low-temperature annular environment of CO_2 flooding wells*, Engineering Failure Analysis, Vol. 60, pp. 296-306, www.propublica.org/article/anatomy-of-a-gas-well-426, access, 03.2016.
[4] Massalski, J., Massalska, M., *Fizyka dla inżynierów, cz. I*, WNT, Warszawa 2013.
[5] Szczeniowski, S., *Fizyka doświadczalna*, *cz. I*, PWN, Warszawa 1953.
[6] *Pipe Body Performance Properties Catalogue*, Tenaris, 2011.