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PODBANSKÉ 2016
SLOVAKIA

NOVÉ POZNATKY V OBLASTI VŔTANIA, ŤAŽBY, DOPRAVY A USKLADŇOVANIA UHĽOVODÍKOV
PODBANSKÉ 2016

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NOVÉ POZNATKY V OBLASTI VŔTANIA, ŤAŽBY, DOPRAVY A USKLADŇOVANIA UHĽOVODÍKOV NEW KNOWLEDGE IN THE AREA OF DRILLING, PRODUCTION, TRANSPORT AND STORAGE OF HYDROCARBONS

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CONTENST

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ANALÝZA TEPLOTNÉHO POĽA PRE LINIOVÚ ČASŤ TRANZITNÝCH PLYNOVODOV ZEMNÉHO PLYNU

ANALYSIS OF TEMPERATURE FIELD FOR LINE PART OF TRANSIT GAS PIPELINES

Dávid Széplaky[1], Erika Škvareková[2], Augustín Varga[3]

Abstract: *The article describes how to specify course of temperatures and pressures during transportation of natural gas by transit gas pipeline. For final pressure and temperature calculations mathematical formulas were entered to mathematical modelling software Matlab. Natural gas temperature on the output of the compressor station 40°C, initial pressure was set to 7 MPa and temperature of the surrounding environment decreased with time from 20°C about 2°C/hour. Results of mathematical model are specified values of temperatures and pressures each kilometre according to input parameters in ten time steps which are shown in graphical dependence of the temperature (pressure) on the distance from the compressor station.*

Key words: *Line part of transit gas pipelines*

INTRODUCTION

The purpose of the task to determine the temperature field from pipeline to the environment is to define the heat flux passing through the pipeline and soil. Temperature field helps to set up the depth and intensity in which transported natural gas can influence on surrounding soil in terms of temperature. It is necessary to solve out factors which influence on the temperature distribution such as temperature of the transported natural gas, material composition of the pipeline, depth of deposit and setting up the thermal properties of the pipe and soil. [1]

MATERIAL CHARACTERISTIC OF THE TRANSIT GAS PIPELINE

For calculation of heat transfer is necessary to know all the information about the materials used in transit gas pipeline. Pipeline is composed of several layers, which are characterized by different physical properties. For Slovak transit system is currently used three-layer polyolefin insulation. Listed isolation is a combination of a thermosetting epoxy powder (FBE) copolymer adhesives and thermoplastic outer packaging (polyethylene).

Copolymer adhesive provides the connection with epoxy outer shell, which provides mechanical protection epoxy coating and steel pipes. Polyolefin insulation is applied to the outer surface of steel pipe (Fig. 1). The most commonly used steel is API X 7% steel. Table. 2 show the physical properties and thickness of each material of gas pipeline. [2]

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Tab. 1. *Physical properties of materials of transit pipeline [2].*

Material	λ [$W.m^{-1}.K^{-1}$]	c_p [$J.kg^{-1}.K^{-1}$]	ρ [$kg.m^{-3}$]	β [K^{-1}]	a [$m^2.s^{-1}$]	Thikness [mm]
X 70 Steel	21	46	7850	13	$5,8.10^{-6}$	15
Epoxid	0,02	1000	1400	55	$3,2.10^{-7}$	0,15
Polyetylén	0,02	2250	950	200	$9,3.10^{-8}$	5

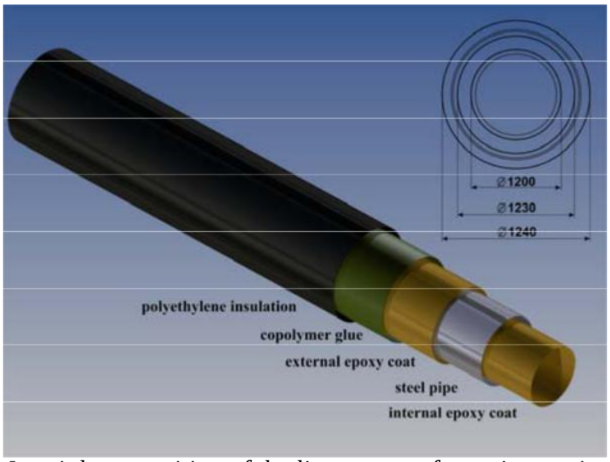

Fig. 1. *Material composition of the linear part of transit gas pipeline [2].*

THE CALCULATION OF NATURAL GAS TEMPERATURE

Temperatures of the moving gas in the pipe depend on the physical conditions of the movement of the gas and heat exchange with the surroundings.

Equation (1) characterizes the temperature distribution along the length of the pipeline. Even in this formula characterizes the last member of Joule- Thomson´s effect. Decreases in temperature in the pipeline due to Joule-Thomson´s effect are between 3 to 5°C. [3]

$$T = T_{ok} + \left(T_p - T_{ok}\right).e^{-a.x} - D_{J-T}.\frac{p_p - p_k}{L}.\frac{1-e^{-a.x}}{a} \quad [K] \qquad (1)$$

where: T_{ok} – temperature of the environment [K]
T_p – temperature of natural gas [K]
D_{J-T} – Joule-Thomson's coefficient [K.MPa]
x – elementary pipeline section [m]
L – total length of the pipeline [m]
k – heat transfer coefficient [W/(m.K)]
p_p – initial pressure [Pa]
p_k – final pressure [Pa]

Coefficient of heat transfer α depends on the fluid properties, the state of motion, used insulation and other factors. Heat transfer coefficient is a difficult function of more variables determining the process of heat transfer. [4]

Formula for the calculation of α_1 forced to wrap the gas velocity greater than 1 m/s and the inner diameter greater than 0,3 m:

$$\alpha_1 = \frac{\dfrac{\frac{\xi}{8}.\Pr.\mathrm{Re}}{1+12,7\sqrt{\frac{\xi}{8}}.\left(\Pr^{\frac{2}{3}}-1\right)}.\left[1+\left(\frac{d}{l}\right)^{\frac{2}{3}}\right].\lambda}{d} \quad [W/(m^2.K)] \qquad (2)$$

Formula for the calculation of α_2 is obtained from Stefan-Boltzmann's law [11] :

$$\alpha_2 = c.\frac{\left(\frac{T_p}{100}\right)^4 - \left(\frac{T_{ok}}{100}\right)^4}{T_p + T_{ok}} \ [W/(m^2.K)] \qquad (3)$$

where: c [W.m^{-2}.K^{-4}] – constant 5,68

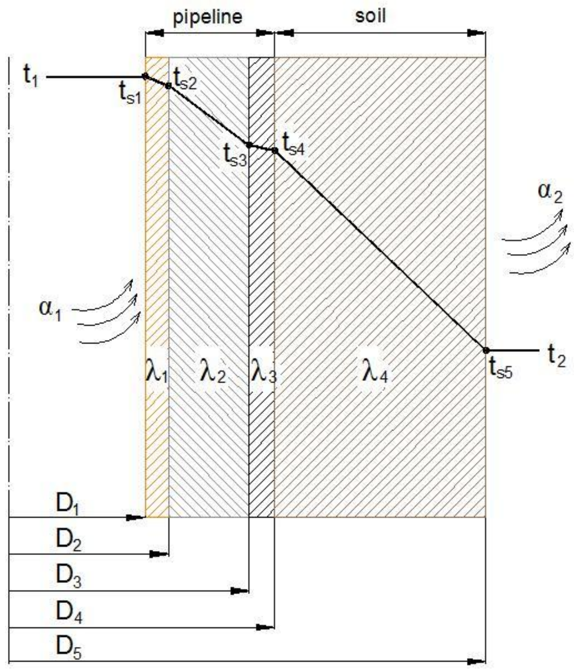

Fig. 2. *Temperature course in transit gas pipeline.*

THE CALCULATION OF PRESSURE LOSS

The decrease in temperature affects the pressure drop significantly. For the calculation pressure losses in individual elementary section the formula for the horizontal pipelines without cant has been used.

When determining the pressure loss for the entire transit system it is necessary to take into account the profile of gas-pipeline route. In section between KS01 and KS02 difference in height reaches 200 m. For this reason, it is necessary to calculate this section with formula of pressure drop in taking into account the relief routes (pipeline with cant). [5]

$$p_p^2 - p_k^2.e^b = \lambda.m^2.\frac{Z.r.T_S.x}{F^2.d}.\frac{e^b - 1}{b} \ [MPa] \qquad (4)$$

$$a = \frac{2.g}{Z.r.T_S}, \ b = a.\Delta z \qquad (5)$$

where: m – mass flow of the gas in pipeline [kg/s]
Z – compressibility factor [-]
r – specific gas constant [J/(K.kg)]
T_s – middle gas temperature [K]
F – area of pipeline [m^2]
λ – resistance coefficient [-]

The basic premise of calculating the pressure loss in the pipeline is determination of the appropriate value of resistance coefficient, which in itself involves difficult character the effects of flow arising from pipeline properties (diameter, roughness of pipeline).

Relation for the area of rough pipes, Re > Re_{k2}:

$$\lambda = 0,111.\left(\frac{\delta}{d}\right)^{0,25} \qquad (6)$$

Coefficient of roughness δ is quite diff icult for dete rmine, and t herefore is b eing determined on the basis of c omparative r oughness coef ficient δ_S, whose values ar e given in Tab le 2. [5, 6]

Ta b. 2. *Pipelin e roughness coefficient for different states of pipeline [5].*

Pipeline state	δ_s [mm]
New pipelines transporting c lean gas, onl y traces of rust	0,04 – 0,1
Older pipelines, balanced con taminated, co rroded coatin g	0,15 – 0,6
Very corro ded pipelines, uneven spot pollution	1,00 – 1,60
Strong contaminated pipelines, sed iments	2,00 – 4,00

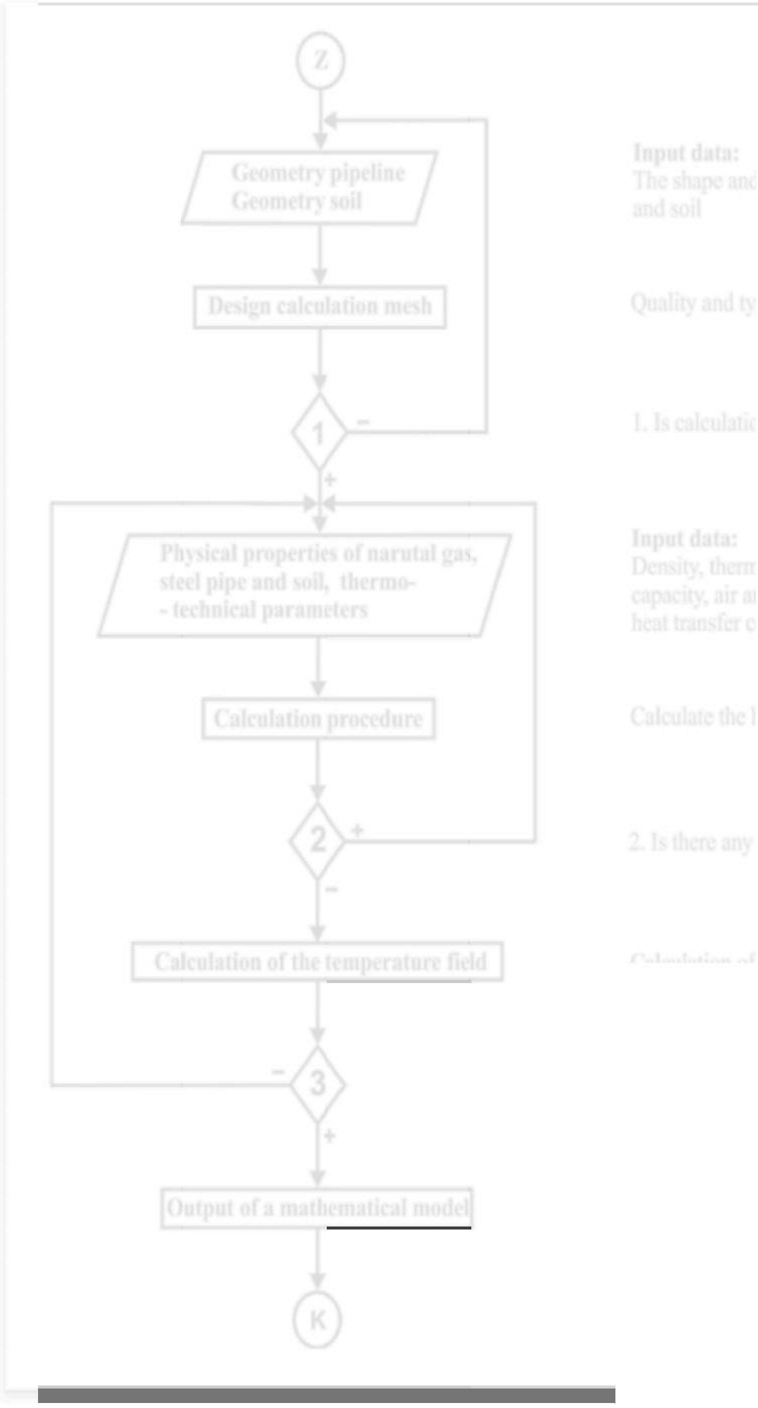

Fig. 3. *Matlab alg orithm.*

RESULTS OF THE MATHEMATICAL MODEL

Calculations were made for transit pipeline diameters DN 1200 on the length approximately 220 km (distance between KS 01 Veľké Kapušany and KS03 Veľké Zlievce). Output temperature of the natural gas was set to 40 °C, output pressure to 7 MPa, flows 281, 233 and 229 mil.m^3/day and temperature of the environment to 20°C with temperature drop 2°C/ hour.

Tab. 3 *Values thermos-physical parameters for the transfer of heat through the cylindrical wall.*

Distance [km]	Pressure [MPa]	Temperature [°C]	DN 1200			
			k [W/(m.K)]	q [W/m]	t_1 [°C]	t_2 [°C]
0	7	40	10,98	491,64	29,9	30
10	6,87	38,72	10,8	431,38	28,63	28,72
20	6,75	37,42	10,61	405,51	27,34	27,42
30	6,63	36,16	10,43	340,94	26,09	26,16
40	6,5	34,91	10,25	286,82	24,85	24,91
50	6,37	33,69	10,07	267,11	23,63	23,69
60	6,24	32,48	9,9	193,84	22,44	22,48
70	6,1	31,28	9,74	176,8	21,24	21,28
80	5,96	30,1	9,57	123,31	20,07	20,1
90	5,82	28,93	9,41	42,28	18,92	18,93
100	5,68	27,78	9,26	44,49	17,77	17,78

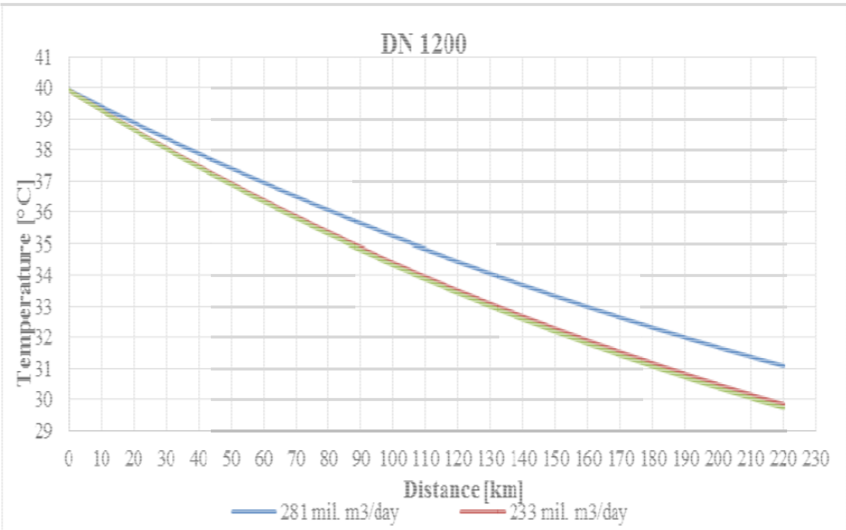

Fig. 4. *Graphical dependency of temperature drop between KS01 and KS03 for different flow rates.*

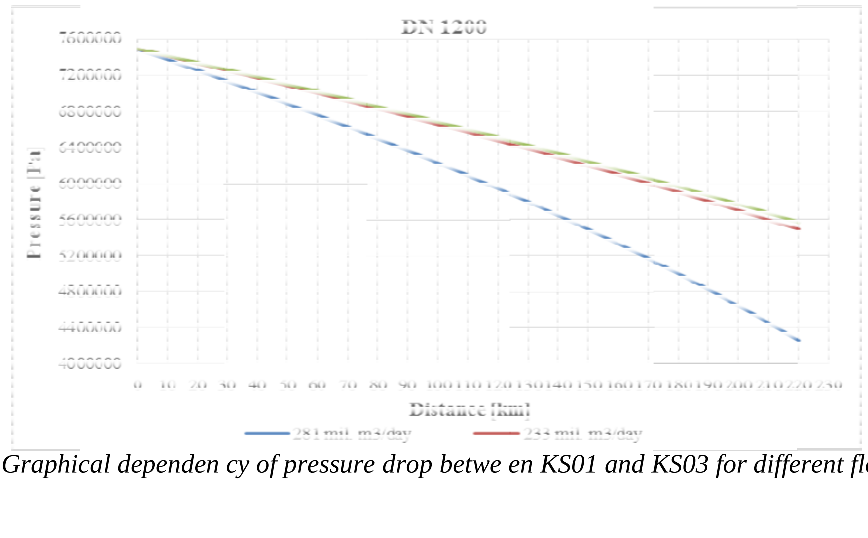

Fig. 5. *Graphical dependency of pressure drop between KS01 and KS03 for different flow rates.*

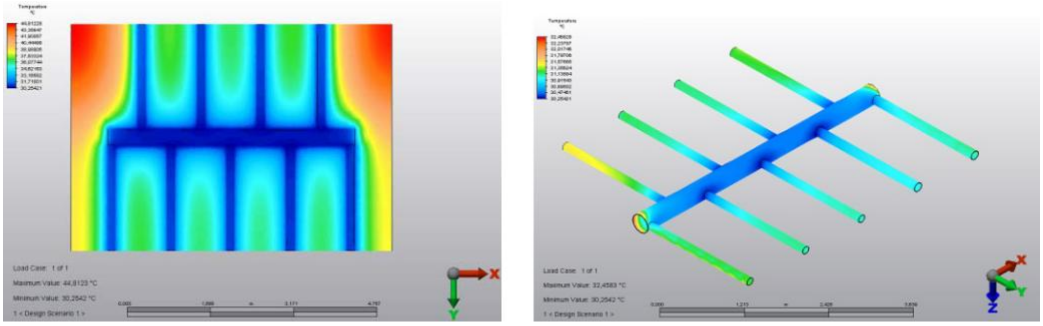

Fig. 6. *Temperature field around the pipeline (left) and temperature distribution on the surface of the pipe (right).*

CONCLUSION

Into a mathematical model temperature profile of natural gas was necessary to include many factors that affect the actual course of temperatures. Inputs parameters were physical properties of each material of gas pipeline, boundary conditions and temperature of the environment. These parameters were given as input information for mathematical modelling software called Matlab. The outputs of the program are data files that have been processed into graphical temperature dependence (Fig. 5) and pressure (Fig. 6) of the natural gas. To change the temperature during transport significantly impacts the pressure, which is dependent on the current flow. Calculations of the temperature were performed for flows 281, 233 a 229 mil.m^3/day, while the differences in temperatures in the case of flow 233 a 299 mil.m^3/day were almost negligible. The lowest temperature drop in both averages was registered at a rate of 281 mil.m^3/day, which was caused by a decrease in pressure.

Elaboration of a mathematical model can monitor the behaviour of temperature and pressure during transport in high pressure pipe. In practice, this means the safe and efficient transportation of natural gas. On the basis of the drop in temperature and pressure can be adjusted the optimal outlet temperature of natural gas to prevent mechanical damage to the insulation and gas pipeline. For more accurate calculations it would be appropriate to include a relief route, respectively height profile of the pipeline, which would clarify the course of pressure during transportation of natural gas.

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