Saimaa University of Applied Sciences
Faculty of Technology, Lappeenranta
Degree Programme in Mechanical Engineering and Production Technology

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Strength Analysis of Copper Gas Pipeline span

Thesis 2016

Abstract

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The purpose of the study was to analyze the stresses in a gas pipeline. While analyzing piping systems located inside building were used. Calculation of the strength of a gas pipeline is done by using information of the thickness of pipe walls, by choosing the suitable material, inner and outer diameter for the pipeline.

Data for this thesis was collected through various internet sources and different books. From the study and research, the final results were reached and calculations were made by paper calculations and in SolidWorks and ANSYS programmes. The pipeline was designed using a SolidWorks and ANSYS programme.

The results of the study show the displacement and stresses during the length of the gas pipeline, the methods of choosing the wall thicknesses and diameters for pipelines. Further, the comparison of different fields of application of the gas pipeline were explained as the results.

Keywords: Pipeline, Natural gas, internal pressure, circumferential or hoop stress, longitudinal or axial stress, application of Natural gas, SolidWorks, ANSYS.

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List of abbreviations and symbols

D_i	Internal diameter [mm]
D_o	Outer diameter [mm]
R_i	Internal radius [mm]
R_o	Outer radius [mm]
m	Mass of gas [g]
n	Number of moles
M_g	Average molecular weight of gas mixture [kg]
z	Compressibility factor (gas-deviation factor)
T	Absolute temperature [C]
ρ_g	Density of gas [kg/m3]
P_i	Internal pressure [MPa]
P_o	Outside pressure [MPa]
S	Maximum allowable stress in tension [MPa]
σ_H	Circumferential (hoop) stress [MPa]
σ_L	Longitudinal stress [MPa]
σ_r	Radial stress [MPa]
t	wall thickness [mm]
t_{min}	Minimal Wall thickness [mm]
A	a constant
B	a constant
C	a constant
D_{max}	Maximum outside diameter [mm]
P	Allowable pressure [MPa]
τ_{max}	Maximal shear stress [MPa]
τ	Shear stress [MPa]
M_g	Average molecular weight of gas mixture
LNG tankers	Liquefied natural gas tankers
V	gas volume [L]
N	amount of substance of gas [mole]
R	universal gas constant
T	temperature of the gas [K]
FEM	Finite Element Method

1 Introduction

The goal of the thesis is to analyze the stresses in a gas pipe, which transmits the natural gas. As design, parameters are taken: the wall thickness of gas tube, the inner and outer diameter, and the material for the pipe. Different loads on pipeline have to be chosen according to the field of gas application, for understanding the behavior of gas inside the pipe. For analyzing of stresses inside the pipe such factors were taken: the internal gas pressure, the weight of the transported gas, the weight of the gas pipeline, seismic effects. Copper has been chosen as the material for the pipe. The goal of the theory part consists of explanation about the design, maintenance, installation and modification of the gas piping system.

2 Production, transmission and distribution of natural gas.

Natural gas is a combustible mixture of hydrocarbon gases, where the main component is methane. Other components, which are included in a natural gas mixture, are ethane, propane, butane, and many other combustible hydrocarbons and in this mixture of gases among the particles, there is no significant interaction. The movement of particles is characterized as chaotic movement, where particles are trying to fill the existing space. Natural gas is formed by the chemical processes, which occur in the bowels of the earth. The natural gases which are existing are quite difficult to classify due to the differences in the structure of the molecular lattice. (NaturalGas 2016) (Madehow 2016)

2.1 Preparation for transportation of natural gas

Natural gas, which is coming from the gas wells and transported across the countries is firstly required to prepare before shipping directly to consumers, such as chemical plants and urban gas networks. This is due to the various impurities in its composition, and that could hamper for the transportation of the gas. The three main types of transportation pipelines are the gathering pipelines, transmission pipelines, and distribution pipelines. Before distribution the natural gas is firstly being extracted, gathered, processed, and transported. Besides of the gas preparation, also preparation for pipelines is mandatory, in most cases provided through special nitrogen units that are used to create the inert medium in the the pipeline. (NaturalGas 2013)(Energy 2013)

2.2 Transportation of natural gas

2.2.1 By gas pipeline

Nowadays, the main method of transporting the natural gas to the consumers is the pipeline, which is providing transportation of gas through the pipes with a diameter of up to a 1.4 m. The gas loses potential energy during the movement in the pipe, due to the friction between gas and pipe wall. That is why pipes are equipped with special compressor stations through the certain distance to ensure that the natural gas flowing through the pipeline remains pressurized, these stations keep up the pressure in pipelines by compression the gas up to a pressure of 5.5 to MPa, followed by cooling. (NaturalGas 2013)(NaturalGas 2016)

2.2.2 By liquefied natural gas tankers

Nowadays, the method of transporting gas to its final destination by special LNG tanks, is also widely used. Tanks transport gas in special insulated tanks at low-level temperatures, due to the converting natural gas into LNG makes it easier to transport where there are no possibilities to use pipelines. To transport the gas by LNG tanks, also needs the usage of pipelines, which go directly from the gas production point to the nearest seacoast. To condense the natural gas into LNG, a refrigeration process is used, the condensation is done by cooling gas to a temperature of minus 126 °C. The process of refrigeration is accompanied by removing the water, hydrogen sulfide, carbon dioxide, and other impurities. When LNG's shipment reaches its destination, it must be regasified. Regasification is done by heating the LNG and that allowing it to evaporate back into natural gas. Transportation of gas by LNG tanks is more economical, in comparison with the pipeline transportation, in case if the distance to the destination point is very high, in this case the basic financial costs are going to loading and unloading works and not for transportation of gas. As an advantage of LNG transportation of gas can also be considered the higher level of safety during transportation and storage of liquefied gas, which is much safer than in a compressed form. (Geology 2012)

2.2.3 Other methods of gas transportation

There are several other methods of natural gas transportation, such as railway tanks, where gas is transported in a condensed form. The methods of natural gas storage and transportation to the customers are shown in Figure 1.

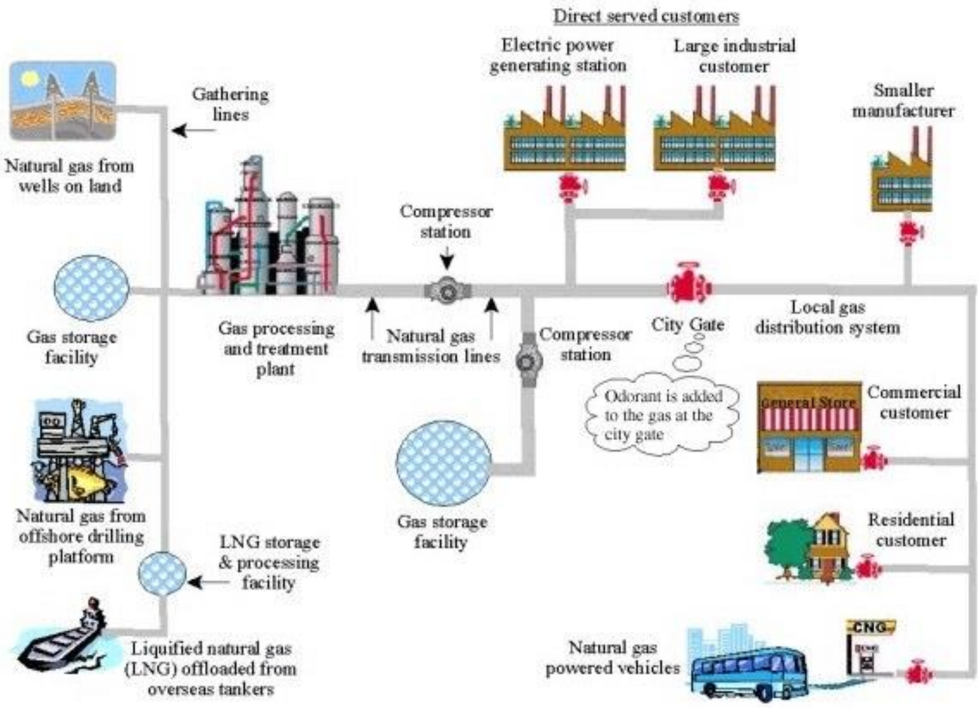

Figure 1 Natural Gas Pipeline Systems (PSSC 2014).

2.3 Methods for processing of natural gas

“Natural gas processing consists of separating all of the various hydrocarbons and fluids from the pure natural gas, to produce what is known as ‘pipeline quality’ dry natural gas. That means that before the natural gas can be transported it must be purified.”(NaturalGas 2013) Methods of processing the natural gas are based on the processes of catalytic synthesis with obtaining a main component of natural gas, which is methane hydrogen. (NETL 2013)

3 Types of natural gas pipelines

The pipelines are divided into underground and aboveground, and building underground pipes is much more expensive, than aboveground pipeline, but an underground gas pipeline transportation is more popular, due to the fact that the tube under the ground is much more secure than the tube, which is passing through the air, and hence it will last much longer. By carrying gas at different rates of pressure, pipelines are divided in flowlines, gathering lines, transmission lines, distribution lines, and service lines. Flowlines are carrying a natural gas from the wellhead to nearby storage tanks or transmission compressor stations, at a low pressure. Gathering lines are carrying the gas from multiple flowlines to processing facilities or tanks. Transmission pipelines move natural gas across long distances, such as distances between cities, and gas carried to a distribution center or storage facility. Distribution pipelines carry natural gas to a commercial or residential customer. ”Service pipelines connect to a meter that delivers natural gas to individual customers.”(Energy.about 2014) (AsmInternational 2006)

3.1 Materials approved for gas pipes

There are several types of materials approved for gas work.

Steel pipes	Steel pipes can be used above ground as long as corrosion due to the environment and the conveying gas is of no problem. Steel pipes and copper pipes are the most common materials used inside buildings.
Copper pipes	Copper pipes used in gas systems should be of type L or K and approved for gas.
Yellow brass pipe	Yellow brass pipes may be approved for inside installations.
Aluminum pipe	Aluminum pipes should not be used in the ground. Aluminum is not approved in all jurisdictions

PVC pipes	PVC - Polyvinyl Chloride - pipes may be used in pipelines buried outside a building.
PE pipes	PE - Polyethylene - pipes may be used in pipelines buried outside a building.
Ductile iron	Ductile iron pipes may be approved in some jurisdiction for underground work.
Flexible connectors	Flexible connectors are used to connect appliances to gas sources. Flexible connectors must be approved.

Table 1 Types of materials for gas work (Engineeringtoolbox 2014)

4 Calculation properties of natural gas

Natural gas is composed primarily of methane, but may also contain ethane, propane and heavier hydrocarbons. Small quantities of nitrogen, oxygen, carbon dioxide, sulfur compounds, and water may also be found in natural gas. The composition of natural gas is methane (93,32%), ethane (4,65%), propane (0,84%), butane (0,18%), nitrogen (1,01%). (Utexas 1998)

1 mole of C atoms $6.02214\ x\ 10\ ^{23} atoms =\ 12.01\ g/mol$ and a Hydrogen has a molar mass of $1.01\mathrm{g/mol}$

Molecular weight of Methane $CH_4 = 12{,}01 + 4 * 1{,}01 = 16{,}05\ \mathrm{g/mol}$

Molecular weight of Ethane $C_2H_6 = 30.07\ \mathrm{g/mol}$

Molecular weight of Propane $C_3H_6 = 44.1\ \mathrm{g/mol}$

Molecular weight of Butane $C_4H_{10} = 58.12\ \mathrm{g/mol}$

Molecular weight of Nitrogen $N\ =\ 14.0067\ g/mol$

Molar mass of Natural gas $M_g = 16{,}05 * 0{,}933 + 30{,}07 * 0{,}0465 + 44{,}1 * 0{,}0084 + 58{,}12 * 0{,}0018 + 14 * 0{,}0101 = 17\mathrm{g/mole})$ (Petrowiki July 2015)

In order to calculate the approximate mass of natural gas (in grams) inside the pipe, the ideal gas law can be used: (General Chemistry p.176 2013)

$$PV = NRT,$$

Taking into account that $\mathrm{P} = 34000\ [\mathrm{Pa}] \approx 0.33555391\ [\mathrm{atm}]$, one may get:

$$N = \frac{PV}{RT} \approx \frac{(0.33555391\ [atm] * 3.1415 * 4^2 * 500 * 10^{-6}\ [L]\ )}{0.0821\ \frac{[L][atm]}{[mol][K]} * (20\ + 273)[K]} \qquad (1)$$

$$\approx\ 0.35057 * 10^{-3}\ [mol].$$

Since $0.35057\ [\mathrm{mol}] \approx 0.35057 * 10^{-3}[\mathrm{mol}] * 17\frac{[\mathrm{g}]}{[\mathrm{mol}]} \approx 5.96\ * 10^{-3}[\mathrm{g}]$,

$$m \approx 5.96 * 10^{-3}[g],$$

which could be neglected during subsequent calculations.

5 Calculation of stresses in gas pipeline

For the gas pipeline, the Annealed Copper alloy gas pipe was chosen, which respects to Type L, which is manufactured to ASTM (American Society for Testing and Materials) standard B280. (Copper Tube Handbook 2014). Type L is a type for general plumbing and underground service -available in soft or hard temper, which is also common to use for natural gas.

Product	Temper	Lengths	Code	Uses	Specifications
Copper Water Tube, Type L (medium wall)	Hard	10 ft. straight 20 ft. straight	Blue	Domestic water service and distribution, fire protection, solar, fuel/fuel oil, HVAC, snow melting, compressed air, natural gas, liquefied petroleum (LP) gas, vacuum	ASTM B88
	Soft	20 ft. straight 30 ft. coils 40 ft. coils 60 ft. coils 100 ft. coils			

Table 2 Copper tube for construction applications (Cerrotube 2015).

TABLE 14.2b. Dimensions and Physical Characteristics of Copper Tube: Type L

Nominal or standard size, inches	Nominal dimensions, inches			Calculated values (based on nominal dimensions)				
	Outside diameter	Inside diameter	Wall thickness	Cross sectional area of bore, sq. inches	Weight of tube only, pounds per linear ft.	Weight of tube & water, pounds per linear ft.	Volume of tube, per linear ft. Cu ft.	Volume of tube, per linear ft. Gal.
¼	.375	.315	.030	.078	.126	.160	.00054	.00405
⅜	.500	.430	.035	.145	.198	.261	.00101	.00753
½	.625	.545	.040	.233	.285	.386	.00162	.0121
⅝	.750	.666	.042	.348	.362	.506	.00232	.0174
¾	.875	.785	.045	.484	.455	.664	.00336	.0251
1	1.125	1.025	.050	.825	.655	1.01	.00573	.0429
1¼	1.375	1.265	.055	1.26	.884	1.43	.00875	.0655
1½	1.625	1.505	.060	1.78	1.14	1.91	.0124	.0925
2	2.125	1.985	.070	3.09	1.75	3.09	.0215	.161
2½	2.625	2.465	.080	4.77	2.48	4.54	.0331	.248
3	3.125	2.945	.090	6.81	3.33	6.27	.0473	.354

Table 3 Dimensions and physical characteristics of copper tube (Cerrotube 2015).

5.1 Data for calculations

The nominal wall thickness is 0.765 mm.

The outside diameter is 9.53 mm.

The inner diameter is 8 mm.

The maximum working pressure is 5.02 MPa.

The internal pressure of gas pipeline P_i =0.034 MPa.

The external pressure of gas pipeline P_o=0.

“The maximum design operating pressure for piping systems located inside buildings shall not exceed 5 pounds per square inch gauge (psig) =34 KPa=0,034MPa” (Publicecodes 2015)

5.2 Calculating of circumferential (hoop) stress, longitudinal stress, shear stress and axial stress

For the thin-walled assumption the pipe ratio of inner radius R_i, to wall thickness t, should be R_i/t≥10 .The ratio of inner radius to a wall thickness in the gas pipe in question is $\frac{4}{0.765} = 5.23$, that is why the thin-walled cylinder equations are no longer taken and solutions are referred to a thick-walled cylinder assumption.(Mechanics of Materials 2007). The stresses produced by internal pressure are shown in Figure 2.

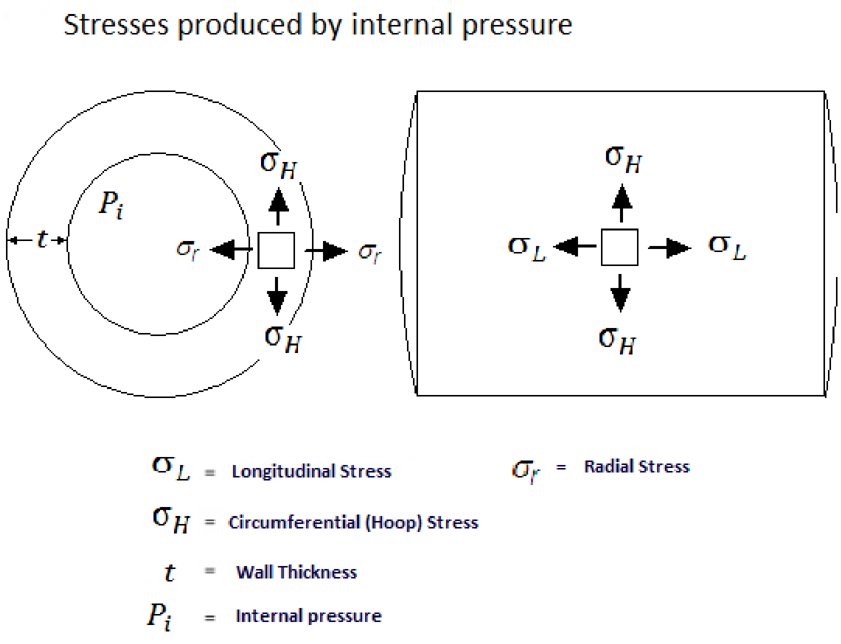

Figure 2 Stresses produced by internal pressure (Engineeringtoolbox 2016).

5.2.1 Circumferential (hoop) stress

The hoop stress is calculated two times, on the outside surface, where the radius r to point in cylinder wall is equal to R_o, and on the inside surface, where the radius r to point in cylinder wall is equal to R_i.

$$\sigma_H = P_i * \frac{\left(\frac{R_o}{r}\right)^2+1}{(R_o/R_i)^2-1} \qquad (2)$$

(Mechanics of Materials 1997 p.220)

$$\sigma_H = 0{,}034 * \frac{\left(\frac{4{,}765}{4{,}765}\right)^2 + 1}{\left(\frac{4{,}765}{4}\right)^2 - 1} = 0{,}16\ MPa$$

$$\sigma_H = 0{,}034 * \frac{\left(\frac{4{,}765}{4}\right)^2 + 1}{\left(\frac{4{,}765}{4}\right)^2 - 1} = 0{,}2\ MPa$$

r = radius to point in tube or cylinder wall (mm) (R_i < r < R_o)

On the inner surface the hoop stress is equal to 0.2 MPa and on the outer surface is equal to 0.16 Mpa.

5.2.2 Longitudinal stress

Calculating the longitudinal stress

$$\sigma_L = \frac{P_i * R_i^2 - P_o * R_o^2}{R_o^2 - R_i^2} \qquad (3)$$

(Mechanics of Materials 1997 p.221)

$$\sigma_L = \frac{0{,}034 * 4^2 - 0}{4{,}765^2 - 4^2} = 0{,}081 MPa$$

5.2.3 Radial stress

Radial stress formula:

$$\sigma_r = -P_i * \frac{\left(\frac{R_o}{r}\right)^2 - 1}{(R_o/R_i)^2 - 1} \qquad (4)$$

(Mechanics of Materials 1997 p.220)

$$\sigma_r = -0{,}034 * \frac{\left(\frac{4{,}765}{4{,}765}\right)^2 - 1}{\left(\frac{4{,}765}{4}\right)^2 - 1} = 0$$

There is no radial stress on the outside surface of the pipe.

$$\sigma_r = -0{,}034 * \frac{\left(\frac{4{,}765}{4}\right)^2 - 1}{\left(\frac{4{,}765}{4}\right)^2 - 1} = 0{,}034MPa(c)$$

“The radial stress for a thick-walled cylinder is equal and opposite to the gauge pressure on the inside surface, and zero on the outside surface.” (Liquisearch 2016)

5.2.4 Shear stress

The maximum shear stress can be calculated by formula, where hoop and radial stresses are at the certain point of cylinder.(Mechanics of Materials 1997)

$$\tau_{max} = \frac{\sigma_H - \sigma_r}{2} \qquad (5)$$

(Mechanics of Materials 1997 p.221)

Putting Hoop stress and radial stress formulas in formula of maximum shear stress.

$$\tau_{max} = \frac{1}{2} * \left(\left(A + \frac{B}{r^2}\right) - \left(-A + \frac{B}{r^2}\right)\right) = \frac{B}{r^2}$$

(Mechanics of Materials 1997 p.221)

“The greatest value of τ_{max}thus normally occurs at the inside radius where r = R_i” (Mechanics of Materials Volume 1 p.221 1997)

Constant $B=\frac{(P_i - P_o)*(R_i^2 * R_o^2)}{R_o^2 - R_i^2}$

$$\tau_{max} = \frac{(P_i - P_o)*(R_i^2 * R_o^2)}{R_i^2 * (R_o^2 - R_i^2)} = \frac{(0.034)*(16*4.765^2)}{16*(4.765^2 - 16)} = 0.11MPa$$

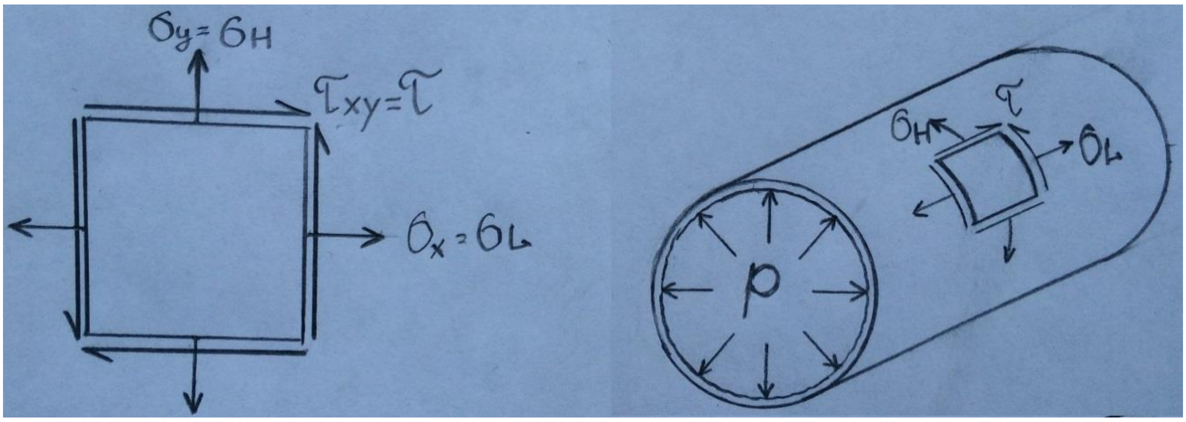

Figure 3 Shear, longitudinal and hoop stresses.

(Wall thickness and diameter of pipelines 2005)

6 Finite Element Method

Finite Element Method (FEM) divides the whole model into a lot of small pieces, which are having simple shapes and called elements, which are effectively replaces a complex problem by a lot of simple problems that need to be solved together. Elements are sharing common points, which are called nodes. The process of dividing the model into small pieces is called meshing. Finite element method uses elements with different shapes. (Help.solidworks 2016).

The SolidWorks programme uses Solid mesh, Shell elements and Beam or Truss elements, which are used for meshing different objects. When meshing is done with solid elements, SolidWorks generates parabolic and linear tetrahedral elements. “A linear tetrahedral element is defined by four corner nodes connected by six straight edges. A parabolic tetrahedral element is defined by four corner nodes, six mid-side nodes, and six edges. In general, for the same mesh density (number of elements), parabolic elements yield better results than linear elements because: 1) they represent curved boundaries more accurately, and 2) they produce better mathematical approximations. However, parabolic elements require greater computational resources than linear elements.” (Help.solidworks 2016). Linear and parabolic tetrahedral elements are shown below.

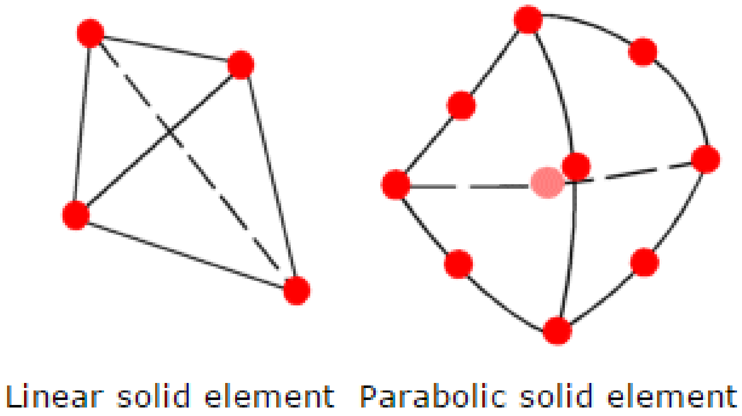

Figure 4 Tetrahedral solid elements

7 Analyzing stresses with SolidWorks and ANSYS

7.1 The material and dimensions

Both programmes use the copper tube as the gas pipeline, with internal pressure of 0.034 MPa. (The pressure of natural gas in buildings). The inner diameter is 8mm and the wall thickness is 0.765 mm. The characteristics for copper tube are taken from the Copper Tube Handbook. E=17,000,000 psi =117210.87 MPa and the Poisson's ratio is 0,37. The dimensions of the pipe are shown in Figure 5.

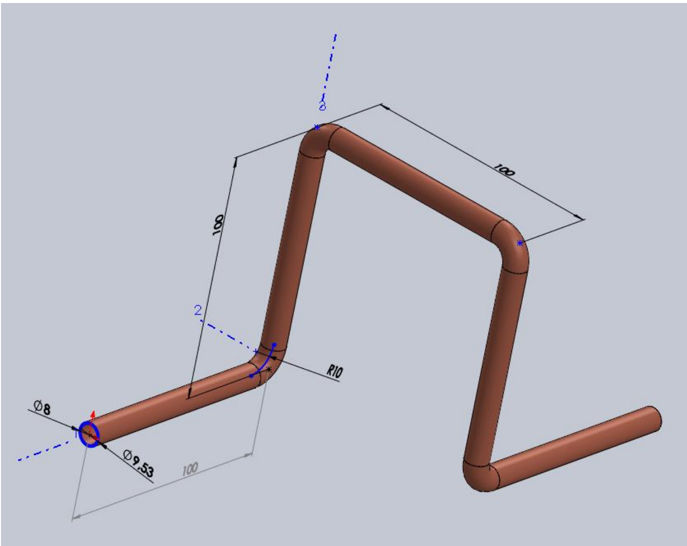

Figure 5 Dimensions of pipe

The radius of rounding is 10 mm. The whole pipe is divided into 9 sections: 5 sections of straight pipeline and 4 sections of bended pipe.

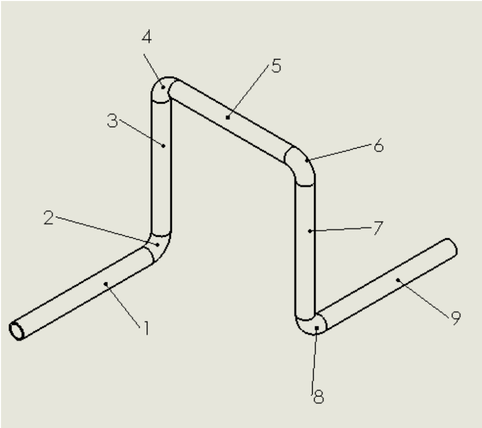

Figure 6 Sections of pipe

7.2 Meshing

In solidworks a parabolic tetrahedral element is used for meshing, because it's yield a better results than a linear solid element. Two elements are used in the thickness direction of pipe.

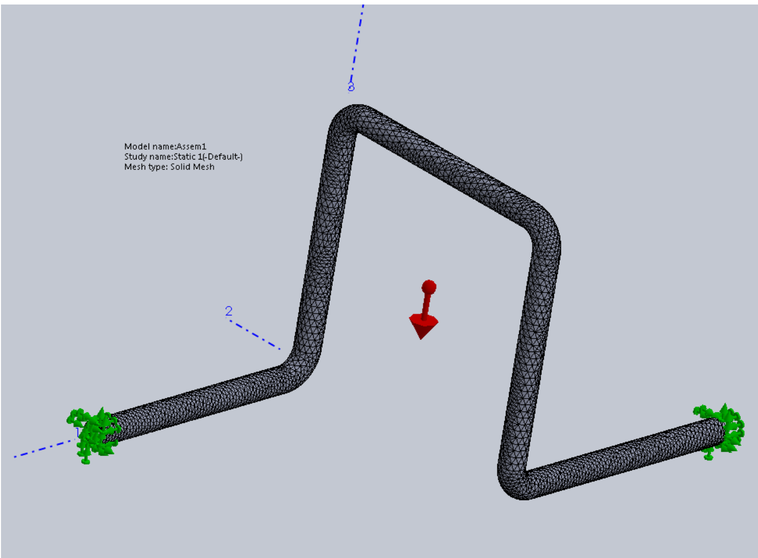

Figure 7 Mesh (Linear solid tetrahedral element) of 2 mm in Solidworks

The shell 281 was used in ANSYS programme, which is suitable for analyzing thin to moderately-thick shell structures. Shell 281 is an eight-node linear shell element which has six degrees of freedom at each node. Those are translation in x, y, z direction and rotation about x, y, z axis.

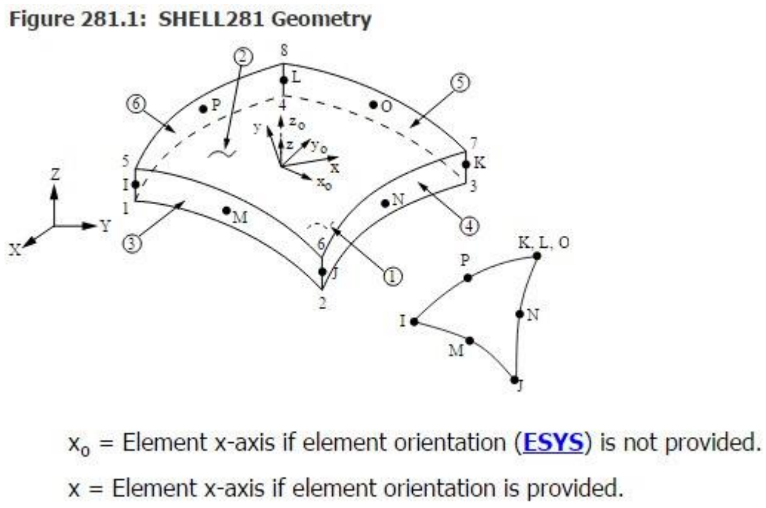

Figure 8 SHELL 281

Element coordinate system (ESYS) is oriented relative to the axis of the element.

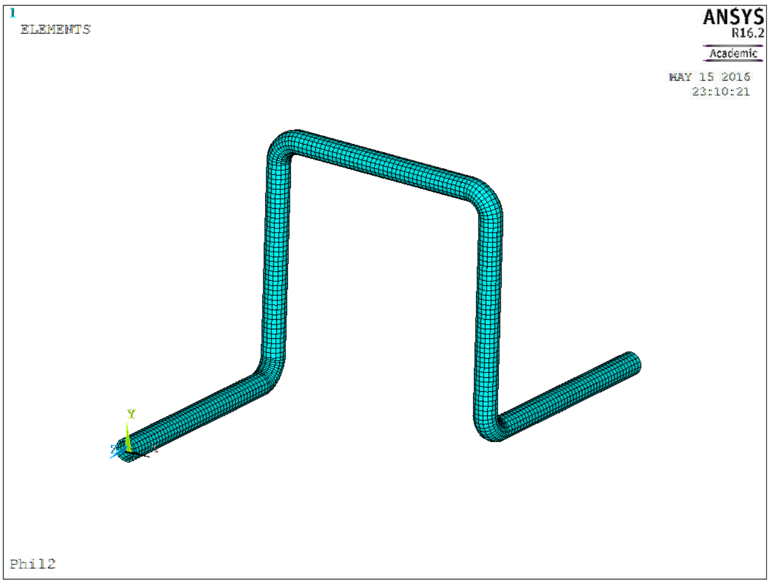

Figure 9 Mesh (SHELL 281) of 2 mm in ANSYS

There is no displacement of all degrees of freedom on the pipe endings. For the analyzing only a regular part was taken to compare the results of the analytical solution to the results with calculations of FEM in ANSYS and Solidworks programmes. The initial parameters for pressure is 34000 Pa =0.034 MPa and the pressure is uniformly distributed along the whole pipe.

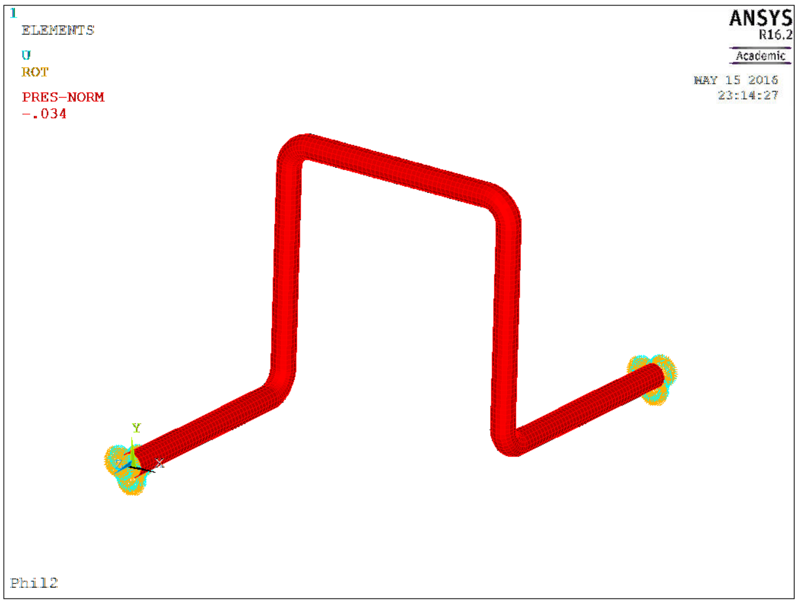

Figure 10 Boundary condition and Internal pressure of 0.034MPa

7.3 The maximum Von-Mises stress

The criterion of maximum von Mises stress is based on the theory of Mises-Hencky, also known as the theory of distortion energy.

For principal stresses σ1, σ2, σ3, von Mises stress is expressed as:

$$\sigma_{vonMises} = \left\{\frac{[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_1-\sigma_3)^2]}{2}\right\}^{1/2} \quad (6)$$

(Help.solidworks2016)

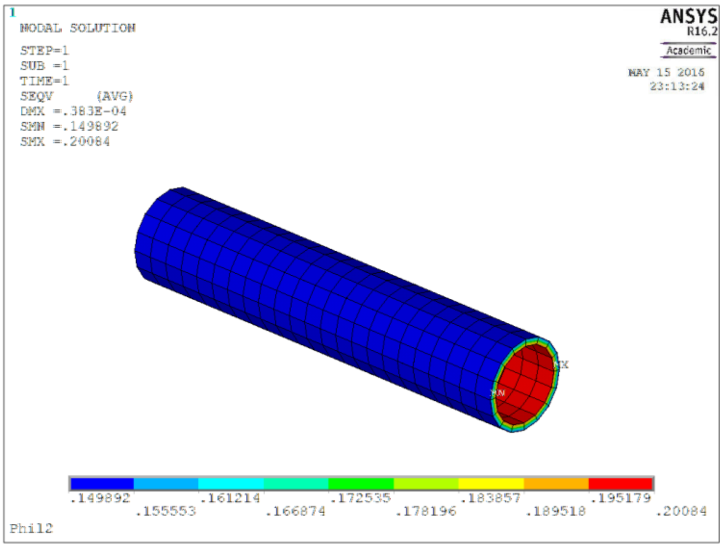

Figure 11 Von-Mises stress of the section 1-ANSYS [MPa]

It can be easily seen, that the results in ANSYS and SolidWorks are approximately the same for von Mises stress in the pipe section 1 and section 3.

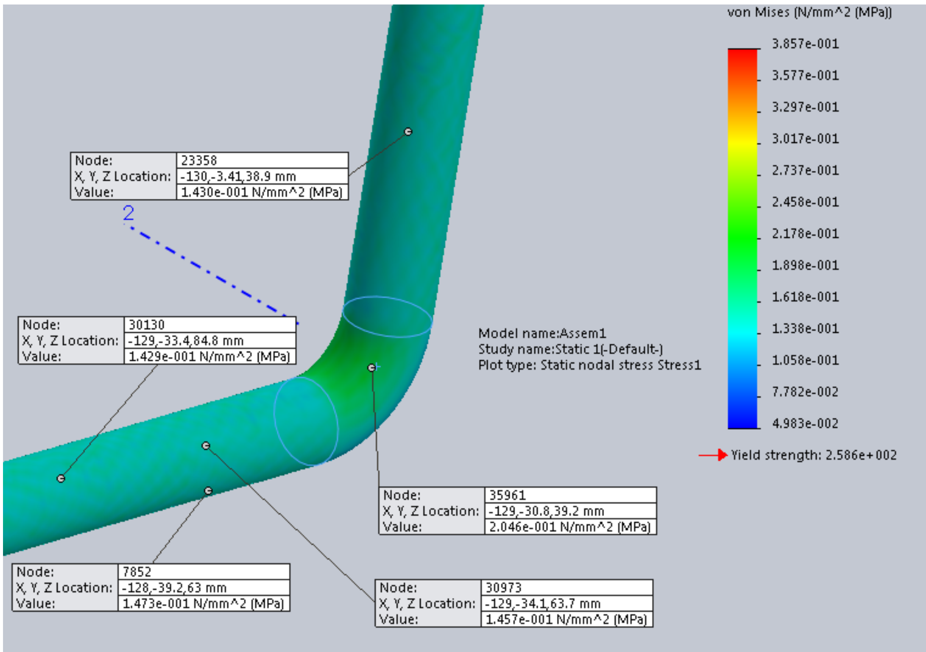

Figure 12 Von Mises stress of the section 1-SolidWorks [MPa]

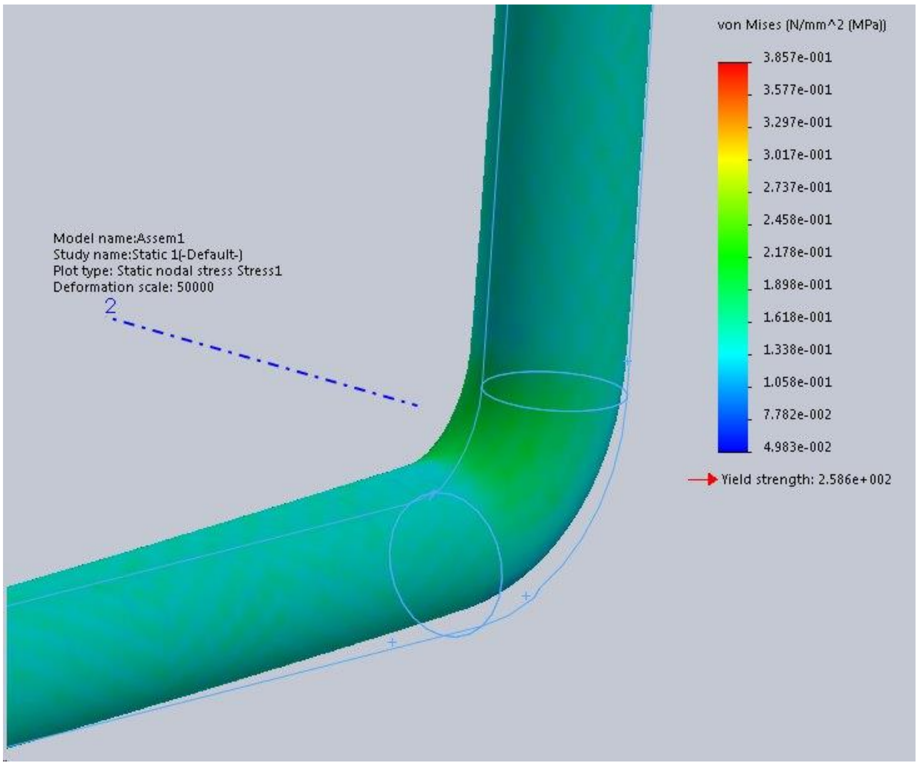

Figure 13 Von Mises stress (deformed result) -SolidWorks[MPa]

Due to the bend of the tube, the occurrence of local increased stresses in the sections of sharp changes in pipe shape (curvature, on the section of bending).

7.4 Hoop stress

"Hoop stress is the stress in a pipe wall, acting circumferentially in a plan perpendicular to the longitudinal axis of the pipe and produced by the pressure of the fluid in the pipe." (Oil and Gas Pipelines 2015)

From the analytical calculations in equation (2) the hoop stress on the outside surface is $\sigma_H = 0.16\ MPa$ and on the inside surface is $\sigma_H = 0.2\ MPa.$ The results are approximately the same.

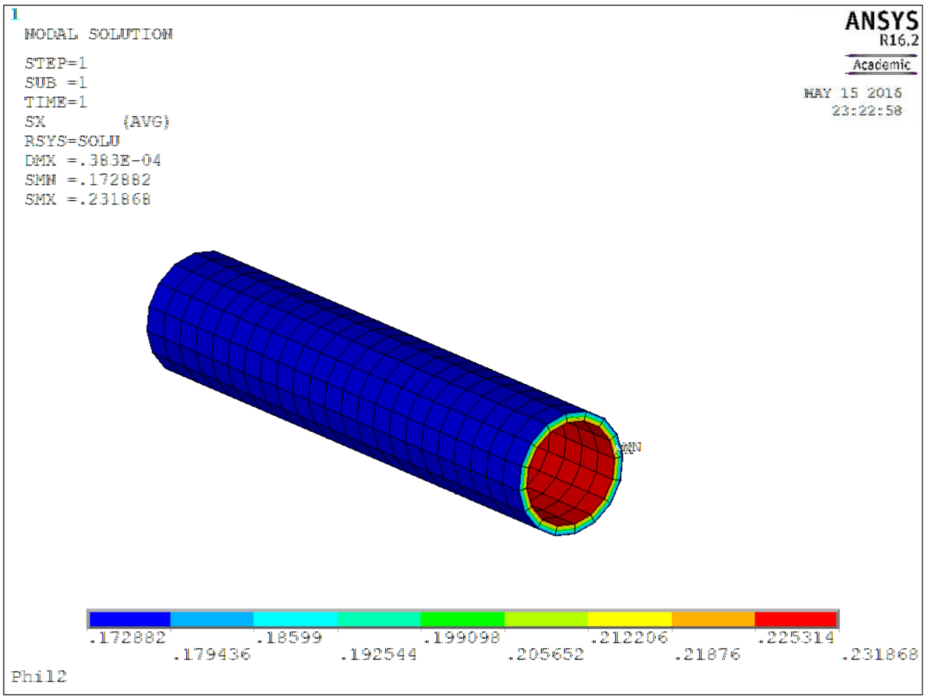

Figure 14 Hoop stress [MPa]

7.5 Longitudinal stress

Figure 15 shows the longitudinal stress in the gas pipeline.

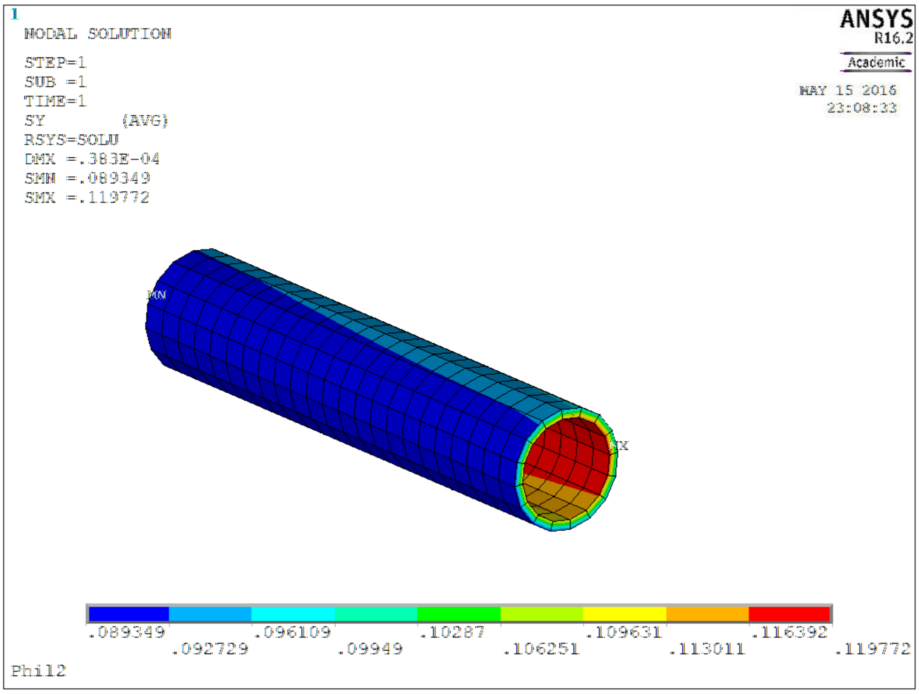

Figure 15 Longitudinal stress [MPa]

The first section of the pipe was used to show the Longitudinal stress, which develops in the pipe walls and compared to analytical calculation. The stress is increasing rapidly, as closer to bend angle. From the calculations in equation (3) the longitudinal stress $\sigma_L = 0.081\ MPa$. On the pipe section below the longitudinal stress along the pipe is approximately 0,089 MPa. The results are approximately the same.

7.6 Displacement

The maximum displacement calculated by SolidWorks programme is $3{,}67 * 10^{-6} m$, which is occurs for the top section of the pipeline. The minimum displacement is at the sections 1 and 9, at the ends of the pipe, where there is no displacement of all degrees of freedom.

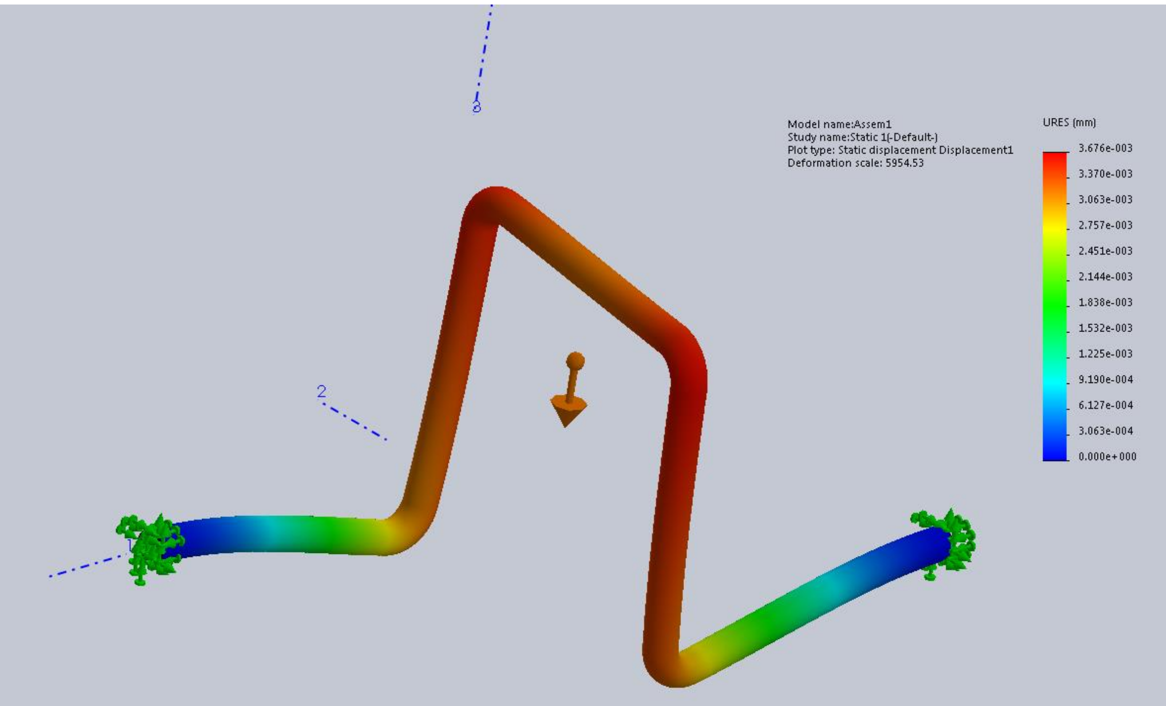

Figure 16 Resultant displacement of pipeline in SolidWorks [mm]

8 Advantages and disadvantages of copper tubing

An important property of copper is its versatility. Copper is a naturally corrosion-resistant metal and it is also lightweight, which makes it easier to work with, and also easier to extend over long stretches without supports. Copper tubes and fittings with a single standard are applied to all types of engineering communications. The copper pipes are used in the heat exchanger of gas water heaters, brake systems of vehicles, aircraft hydraulics and it shows the reliability of copper. Copper is almost entirely subjected to recycling. Copper has an exceptionally long lifetime and a high wear resistance. The very important advantages of copper using for gas pipes are a very simple technology of installation and connections of pipes with use of press fittings, which greatly reduces the time of installing of the gas supply system, the durability of copper tubing and its presentable appearance, as well as a high resistance to corrosion. One of the main disadvantages of copper pipe is a smaller mechanical strength than in a steel pipe, also the cost of the copper is little more expensive. (Tuckersac 2014) (Coper.org 2016). “Strong, flexible, small diameter copper tube and fittings are a cost-effective solution to deliver natural in both residential and non-residential buildings. From single-family homes to multi-story, multi-family dwellings and commercial properties copper's flexibility, long lengths and larger internal flow area per outside dimension allows the installation of gas distribution systems in areas where piping space is at a premium."(Copper 2016). The copper compression fittings are shown in Figure 17.

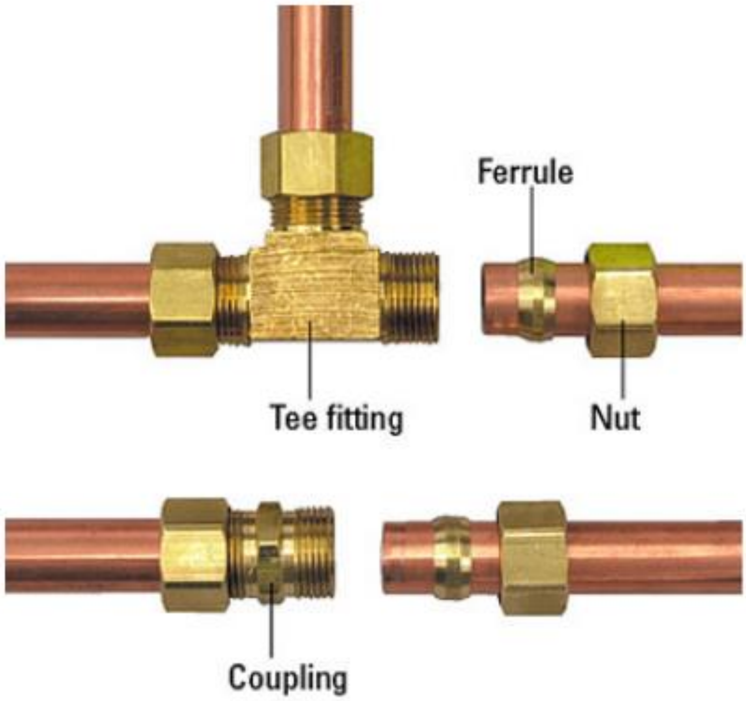

Figure 17 Copper Compression Fittings (Morton-il 2014)

9 Conclusion and future work

In this thesis, the part of a gas pipeline in the living quarters was considered. The natural gas (consisted of methane (CH_4) 93.32% and other impurities such as ethane, propane and butane) created an internal pressure, which is equal to 0,034 MPa, which is uniformly distributed along the entire length of the pipeline. The pipeline was made of copper (Type L standard ASTM B280), and the copper pipeline uses the press technology, which does not require any welding in the place of pipe connections, as well as adapters and elbows can be used which makes it very easy to use for gas pipelines. At the same time an analytical calculation of the pipeline section and calculations by the finite element method in ANSYS and SolidWorks were done. The results of the calculations in programmes were agreed with the analytical calculation, by showing the correctness of the obtained results.

Although the results demonstrated in the thesis are of relatively good accuracy, they could be further developed by means of:

1. Shell elements usage in SolidWorks for a more precise calculation;
2. Taking into account the vibration;

These shortcomings are a good incentive for the continuation of the more deep future study of the topic in question as well as finite element method.

Figures

Tables

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