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Flexibility Analysis of Industrial Piping Through Finite Elements And Photoelasticity Methods

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ABSTRACT

The industry needs predictability to work on a large scale without complications, only this way you can ensure your productivity. The piping flexibility analysis provides a prediction of future problems and proposes applicable solutions, with the objective of preventing pipes to suffer collapses, that can impact the production process and costs, and provide safety to workers and the environment, while avoid leaks and possible contamination. The aim of this study is analyse the flexibility of industrial piping through the finite elements and photoelasticity methods. For stresses analysis, using a computerized body of proof, it`s possible to find, through finite elements and photoelasticity`s practical project, the values of the stresses and the places where they are being applied. To guarantee that the computerized and practical models are consistent with reality, a mathematical model, already tested and proved, will also be implemented and compared to the others, so there are evidences that all models used are really reliable and can be used in large-scale industrial projects, with complex studies. A comparison of a mathematical model through balanced guided beam, a finite elements model using the software ANSYS® and a photoelasticity of a resin pipe will show that the method with better applicability in industries is the computational, showing trustable stress, reaction and deformation values as well as a detailed visualization of them distribution along the object of study.

Keywords: Elements, FEM, Finite, Flexibility, Photoelasticity, Piping.

I. INTRODUCTION

Complexes industrial projects needs to be created using effective and reliable methods of stress and reactions analysis, where that effectiveness could be obtained through the comparison of these three techniques: FEM, Photoelasticity and mathematical through guided balanced beam.

1. Piping Flexibility

Is the piping capacity to absorb thermal expansion by simple deformation of its various sections through changes of direction, curves, bends and torsions. A piping arrangement is more flexible when smaller stresses are derived from such strains, as well as the forces and reaction moments about the anchor points or movements restriction. The piping is considered sufficiently flexible when these tensions and reactions do not exceed their maximum permissible values [1].

2. Finite Elements

The objective of the finite elements method is to obtain a formulation that allows the analysis of complex and / or irregular systems through computer programs, automatically. To achieve this goal, the method considers the global system as being equivalent to a group of finite elements, in which each of these is a simple continuous structure.

Although the finite element method considering the individual elements as continuous, is in essence is a discretization procedure, which aims to transform an infinite-dimensional problem in finite-dimensional, ie a system with a finite number of unknowns.

The resolution of the problem consists in decomposing or discretizes the area under study into small subdomains called "finite element" which are connected by means of discrete points, termed "nodes". The set of elements used in discretization is called mesh [2].

3. Photoelasticity

Photoelasticity is defined as the experimental technique for the analysis of stress and strain through the use of models made of transparent polymers which exhibit optical anisotropy or birefringence when deformed, exhibiting a phenomenon of double refraction. These phenomena are observed by plane polarized light or circular [3].

II. INDENTATIONS AND EQUATIONS

The material properties and configuration of the studied model follows [1]:

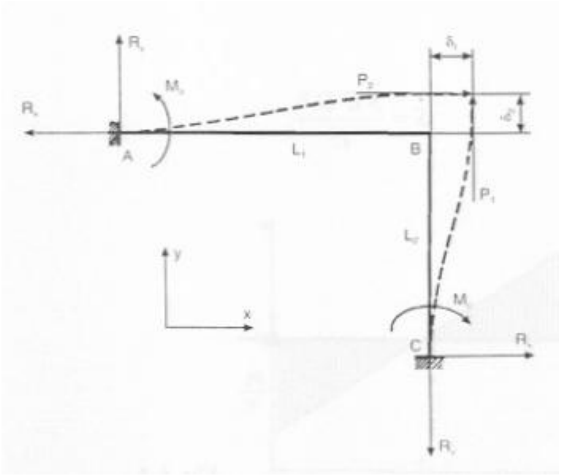

Figure 1 – Configuration of mathematical model

First must be calculated the maximum stress allowed in the most extended fibers (Sa), which according to ASME B13.3, is found by

$$Sa = f[1{,}25(Sh + Sc) - \sum Seql \tag{1}$$

Where:

f = variable according to the number of working cycles.

$\sum Seql$ = Variable that considers stresses exerted by the tube own weight and internal pressures of work.

Sa = Stress at the maximum allowed distended fiber.

Sh = Stress at the distended fiber at room temperature

Sh = Stress at the distended fiber at maximum working temperature

The dilatations are:

$$\delta_1 = L_0 \; x \; \alpha \; x \; \Delta T \tag{2}$$

$$\delta_2 = L_0 \, x \; \alpha \; x \; \Delta T \tag{3}$$

Where:

ΔL = Variation in length, bending.

ΔT = Temperature range

L_0 = Initial length of side.

α = Expansion coefficient

The maximum tension S_1 and S_2 on both sides are:

$$S_1 = \frac{3E_C D \delta_2}{L_1^2} \tag{4}$$

$$S_2 = \frac{3E_C D \delta_1}{L_2^2} \tag{5}$$

Where

E_C = Modulus of elasticity at ambient temperature

D = External diameter of pipe

L = Initial length of side.

To avoid a collapse, S_1 and S_2 must not exceed the value of Sa.

The reaction moments M_a and M_C are the maximum values of the bending moments applied at each side.

$$M_a = \frac{2IS_1}{D}\frac{E_h}{E_c} \tag{6}$$

$$M_c = \frac{2IS_2}{D}\frac{E_h}{E_c} \tag{7}$$

Where:

E_h = Modulus of elasticity at project temperature

The reactions R_X e R_y will be:

$$R_X = P_2 = \frac{2M_c}{L_2} \tag{8}$$

$$R_y = P_1 = \frac{2M_a}{L_1} \tag{9}$$

III. FIGURES AND TABLES

In this study was used an "L" symmetric configuration, and the properties are listed in table 1.

Table 1 – Configuration properties

GENERAL PROPERTIES		
Ø 1" pipe according to stardard ASME B36.10		
Norma de fabricação ASTM A 106 Grau B		
Ø External (mm)	*Ø Internal (mm)*	*Thickness (mm)*
33,4	26,64	3,38
"L" configuration within L1 = L2 = 200mm		
Yield stress (kgf/cm² - MPa)		
2450,00 - 240,26		
Rupture stress (kgf/cm² - MPa)		
4200,00 - 411,87		
Expansion coefficient (°C^(-1))		
12 x 10^(-6)		
Inercia moment (cm^4)		
3,6346		
Maximum temperature stress (Sh) (204°C) (kgf/cm² - MPa)		
1406,00 - 137,88		
Minimum temperature stress (Sc) (38°C)(kgf/cm² - MPa)		
1406,00 - 137,88		
at 22 °C		
Elasticity modulus (kgf/cm²)		
2,1 x 10^6		
Poisson coefficient		
0,30		
at 100 °C		
Elasticity modulus (kgf/cm²)		
1,9 x 10^6		
Poisson coefficient		
0,30		
at 200 °C		
Elasticity modulus (kgf/cm²)		
1,85 x 10^6		
Poisson coefficient		
0,30		

According to these properties, it was possible to create a model using the software ANSYS®.

As Fig. 2 shows, the body of proof has its ends anchored.

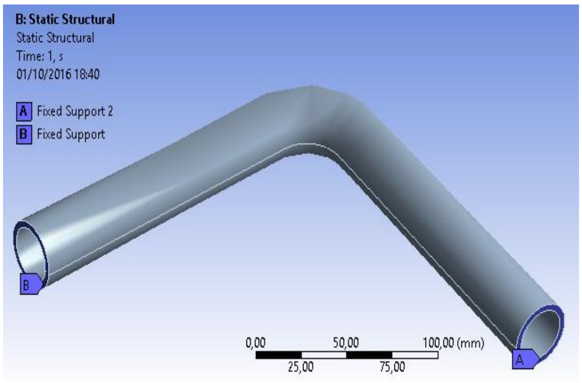

Figure 2 – Fixed supports location

Applying a thermal condition of 200C, the body of proof suffered a deformation and stresses in consequence of the anchored ends, this stress distribution is shown in Fig 3.

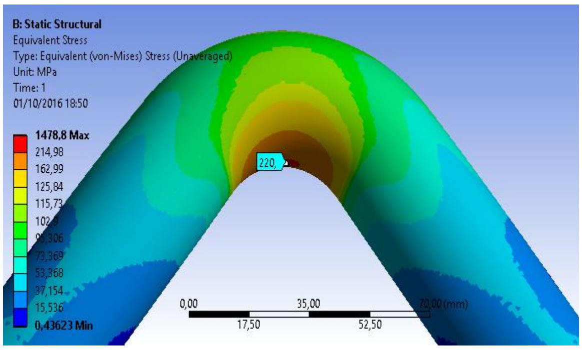

Figure 3 – Equivalent Stress von-Mises

For a comparison of the deformation curves, was made a photoelasticity method that consists in a polarized light hitting a body of proof made of resin using the same dimensions of the original, a tension was applied at its ends and as shown in Fig. 4.

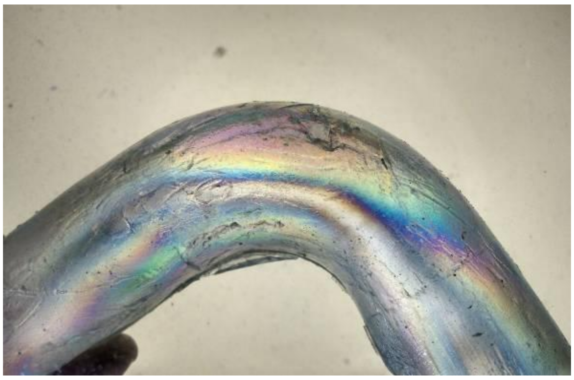

Figure 4 – Deformation curves in a resin sample

Results were obtained according to table 2.

Table 2 – Comparison of numerical results

Comparison of the results			
	Mathematical model according to standard ASME B31.3	Mathematical model out of standard ASME B31.3 and using deformation of FEM model	FEM model
δ (mm)	0,4272	0,4383	0,4383
S (Mpa)	220,38	199,70	220,00
M (N.m)	422,54	433,15	358,71
R (N)	4225,40	4331,5	3311,60

IV. CONCLUSION

After analysis of the numerical results, it is possible to note the effectiveness of the finite elements model made using ANSYS® software, which compared to the mathematical model according to ASME B13.3 obtained similar results, particularly in relation to the maximum stress present at the most extended fiber of the body of proof.

The photoelasticity model on the other hand only shows effectiveness for a visual analysis of the distribution curves of stress along the body of proof, but the values are quite difficult to obtain because of the difficult to obtain the resin elastic modulus and because the difficult visualization of the stresses on a specimen like a pipe, where a face hinders visual of the opposite face.

In industry the computational model shown the best to be applied for being possible several analyzes in different complexities, since the photoelasticity model is restricted to the complexity and even the size of the object of study.

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