

THE GENERAL CHARACTERISTIC CURVE OBTAINED IN THE CASE OF PRESSURED PIPES BENDING PROCESS

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Abstract: The paper presents the characteristic curves obtained in the case of experimental researches concerning the pressured pipes bending process. These curves allowed the tracing of the general characteristic curves of process.

Keywords: pressured pipes bending process, general characteristic curve

1. INTRODUCTION

The pressured pipes bending process has the technological advantage compared to the other process because it avoids the energy and time consuming processes.

It is well-known the fact that in the case of the pipes bending, in the compressed zone different waves appear, the pipe section become oval and the variation of the wall thickness occurs.

The concurrent action of the two loads – inner pressure and bending – during the pressured pipes bending process avoid the waves occurrence, maintains the circularity of section and the variation of the wall thickness within acceptable limits.

2. RESULTS OF THE EXPERIMENTAL RESEARCHES

By using the data obtained as results of the experimental researches, the characteristic curves in the case of pipes bending under different conditions related to the geometrical, mechanical and technical parameters were traced.

In fig. 1 the characteristic curves obtained in the case of $\Phi 18 \times 16$ pipes bending are presented. The pipes were made in 1.4541 stainless steel (table 1). The working conditions were as follows: without/with pressure ($p = 25$ MPa and $p = 36$ MPa). The two pressures represented $0.5 p_L$ (p_L – the limit pressure when the flattening of inner pressurized pipes occurs). If we mark the points under which the curves from the figure keep their linearity with a sufficient accuracy, we can appreciate the behaviour of the pipe material in the three cases of bending.

In the elastic stage, the evolution of load is described by the linear portion, from the axis origin till the marked points. Above this limit, the deviation from the linearity shows that the material entered in the plastic deformation zone. The curve no. 1 obtained in the case of pipe bending without inner pressure express only the bending load. Since the test was performed by respecting the pure bending conditions, the relation of Navier could be applied:

$$\sigma_{\text{mac}} = M/W_z. \quad (1)$$

$$\sigma_{\text{max}} = (Fl)/4W_z \quad (2)$$

Material, dimensions, mechanical properties and working parameters for the tested pipes

Table 1

Pipe data			Mechanical properties according to the standard			Working parameters					
No.	Material	Pipe dimensions Dxd-L [mm]									
			σ_c [MPa]	σ_r [MPa]	ε_r	p_L [MPa]	p [MPa]	M_L [Nm]	Bending angle 2α [grade]	Bending radius R [mm]	Support length l [mm]
1	Stainless steel 1.4541	18x16-1200	230	540-740	0,366	76,6	0	75,22	15	100	539
2							25		50		
3							36		50		

From the pipe loading according to the physical model presented in fig. 1a, it results $M = Fl/4$ and in conjunction with the above relation we can determine the value of the bending maximum normal stress:

Remarks:

1. For the bending moment determination the following relation was used:

$$M_L = \sigma_c S_p$$

1. For the static moment (S_p) determination the following relation was used:

$$S_p = 2 \left(\frac{\pi D^2}{8} \cdot \frac{2D}{3\pi} - \frac{\pi d^2}{8} \cdot \frac{2d}{3\pi} \right) = \frac{D^3 - d^3}{6}$$

where: D – the outer diameter of pipe;
 d – the inner diameter of pipe

3. For the limit pressure p_L determination, the following relation was used:

$$P_l = \sigma_r \frac{2}{(\sqrt{3})^{1+\lambda}} \frac{h}{r_i}$$

where: h – the thickness of the pipe wall;
 r_i – the inner radius of pipe;
 $\lambda = \ln(1 + \varepsilon_r)$

Taking into account that the coordinates of point that mark the end of the curve linearity are $F = 450$ N and $2\alpha = 2^\circ$, the length of support is $l = 53.9$ cm and the axial section modulus proper to the $\Phi 18 \times 16$ pipe is $W_z = 0.1215$ cm², the values of stress could be calculated: $\sigma = 2820$ daN/cm².

The ratio $2820/2300 = 1.22$ ($\sigma_e = 2300$ daN/cm², the tensile yield strength of the pipe material according to the standard) confirms the higher availability to bending than tensile concerning the yield strength of material.

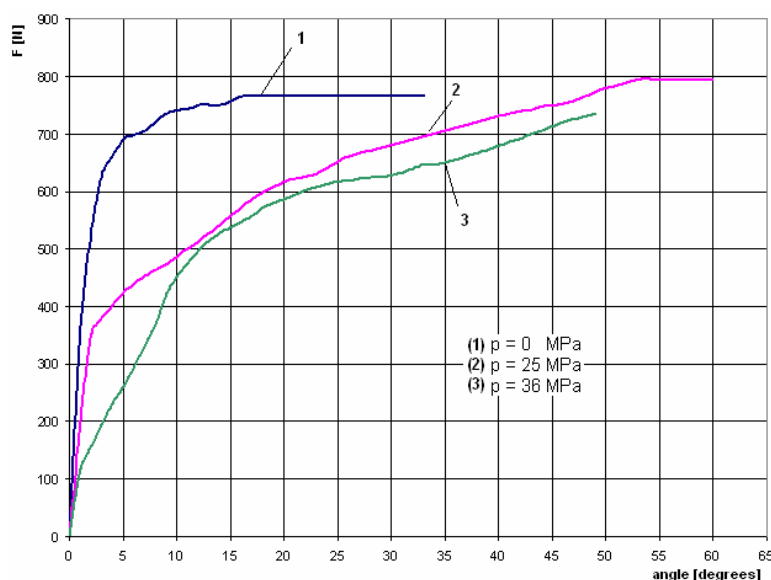
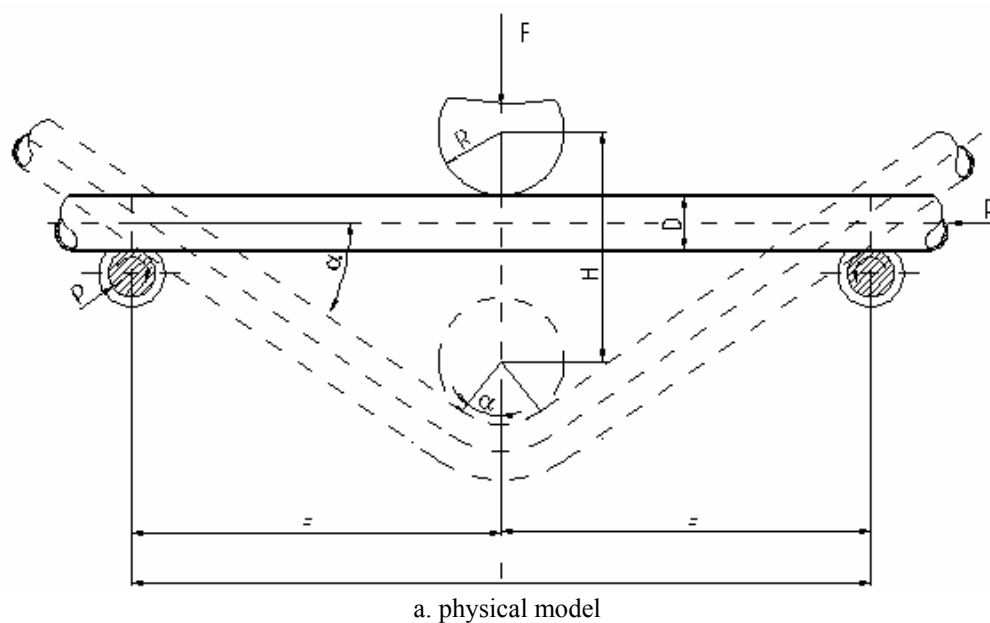


Fig. 1 Physical model and characteristic curves

For the angle $2\alpha = 2^\circ$, the values of displacement on vertical direction was calculated [1]: $H = 9.5$ mm. Over this limit, to the continuous increasing of force, the material of pipe passes in the plastic deformation zone.

From the diagrams obtained in the case of pipe bending by using an inner pressure $p = 25$ MPa (curve 1) it results that the losing of pipe stability (pipe flattening) occurs for the force value $F = 765.14$ N, the vertical displacement $H = 36.89$ mm corresponding to the angle $2\alpha = 16^\circ$ and the length of support $l = 46.26$ mm. Being at limit, the value of the bending moment can be determined by using the following relation:

$$M_L = \sigma S_p \quad (3)$$

where S_p represents the sum of absolute values of the static moments calculated in rapport with the neutral axis for the plastic zones.

Under these conditions, by using the relation (2), the value of the normal stress at flattening (without break) was determined: $\sigma = 3062$ daN/cm².

In the case of the inner pressurized pipes with $p = 25$ MPa and $p = 36$ MPa, the passing in the plastic zone occurred for $F = 355$ N and $F = 110$ N, respectively. It results that the reserve of elasticity decreases along with the inner pressure increasing.

Based on the analysis of the characteristic curves obtained in the case of the anterior described bending operations as well as in the case of other bending operations, described in [1] and considered to be correct performed, the following conclusions can be stated:

- The general aspect of the characteristic curves, in coordinates $F - 2\alpha$, respective force – bending angle, is the one presented in fig. 2.
- After the pipe bending by using a bending angle of $20 \div 25^\circ$, the material hardening process begins to attenuate.

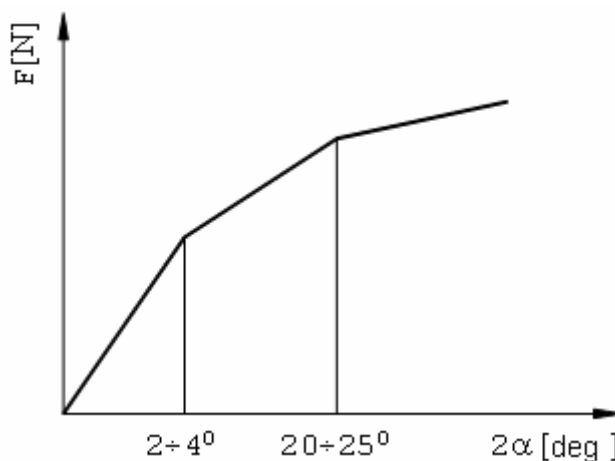


Fig. 2 The general characteristic curves obtained in the case of pipes underpressure bending process

3. REFERENCES

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