

STRAIGHT PIPES UNDER INTERNAL PRESSURE EFFECT OF INITIAL NON-CIRCULARITY ON MAXIMUM STRESS

1. NOTATION

a	initial amplitude of circumferential waves (see Figure 1)	m	in
E	modulus of elasticity of pipe material	N/m ²	lbf/in ²
f_n	maximum circumferential stress in non-circular pipe	N/m ²	lbf/in ²
f_0	maximum circumferential stress in circular pipe, pR/t	N/m ²	lbf/in ²
n	number of circumferential waves (see Figure 1)		
p	uniform internal pressure	N/m ²	lbf/in ²
R	radius to mid-wall of undeformed pipe	m	in
t	thickness of pipe wall	m	in
ν	Poisson's ratio		

Both SI and British units are quoted but any coherent system of units may be used.

2. NOTES

The maximum stress in an initially non-circular pipe under internal pressure is given by

$$f_n = f_0 \left\{ 1 + \frac{6a/t}{1 + 12pR^3(1 - \nu^2)/[Et^3(n^2 - 1)]} \right\}.$$

Provided that $R/t > 5$ this equation is accurate to within 10 per cent. The ratio f_n/f_0 is plotted against pR^3/Et^3 for various values of n and a/t where Poisson's ratio is taken as 0.3.

It is assumed that the pipe is long, straight and unrestrained and that the stresses remain within the elastic range. The pipe is of uniform thickness and deviations about the mean radius are of sinusoidal form. Under pressure the initial amplitude a is reduced but the wave form remains the same.

Further data on the effect of geometrical inaccuracies on the maximum stresses in cylindrical pipes under internal pressure may be located by reference to the Engineering Sciences Data Index.

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3. DERIVATION

1. HAIGH, B.P. An estimate of the bending stresses induced by pressure in a tube that is not initially quite circular. *Proc. Instn mech. Engrs*, Vol. 133, 1936.

4. EXAMPLE

It is required to find the maximum stress in a pipe of radius $R = 1.25$ in and thickness $t = 0.05$ in. The modulus of elasticity of the material is 29×10^6 lbf/in² and the working pressure is to be 1000 lbf/in². Tolerances are such that an ovality in which the major and minor diameter are $2R + t$ and $2R - t$ is permissible.

In this case $n = 2$

and
$$a = R - \left(\frac{2R - t}{2} \right) = 0.5t.$$

Therefore from Figure 1 when

$$\frac{pR^3}{Et^3} = \frac{1000 \times 1.25^3}{29 \times 10^6 \times 0.05^3} = 0.539 \text{ and } \frac{a}{t} = 0.5,$$

$$\frac{f_n}{f_0} = 2.02.$$

Since
$$f_0 = \frac{pR}{t} = \frac{1000 \times 1.25}{0.05} = 25\,000 \text{ lbf/in}^2,$$

$$f_n = 2.02 \times 25\,000 = 50\,500 \text{ lbf/in}^2.$$