Primary sensing element III

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Bellows Element

- The bellows element is a thin walled cylindrical cup-like structure with a number of folds for its cylindrical surface along the axis of the cup as shown in Fig.
- The fold are known as corrugations or convolutions .The formation of the convolution for a thin walled seamless tubing or cup is complex process, an hence welded bellows are manufactured by welding separately stamped annular diaphragms with a large hole at the center as shown in Fig.
- Precision bellows are normally of special metallic alloy used for generating much larger displacement with pressure than the other elastic elements.
- They are also made from plastic material and rubber for use at much lower pressure, and do not require much precision.
- Bellows are axially stretched or compressed by forces developed due to the difference in pressure between the inside and outside of the element.
- Bellows differing widely in their sizes are available for a variety of applications in instrumentation.

Bellows Element

- The diameter of the bellows ranges from 7mm to 150mm ,while the wall thickness ranges fro 0.08 mm to 0.3mm.
- The merits of a bellow element are its low spring rate, low flexural rigidity, and a near-linear characteristics between pressure and displacement.
- But the limitation in their application to measurement is due to their lack of zero stability. To some extent, this difficulty is minimized by using it in conjunction with a high quality helical spring at the cost of its spring rate.
- Sensitivity of the bellow depends on various parameters such as the fold angle α, ratio m of the radius of curvature of the fold, R to internal radius Ri, and the ratio,c of the external radius Re to Ri.
- However, the axial deflection

Bellows Element

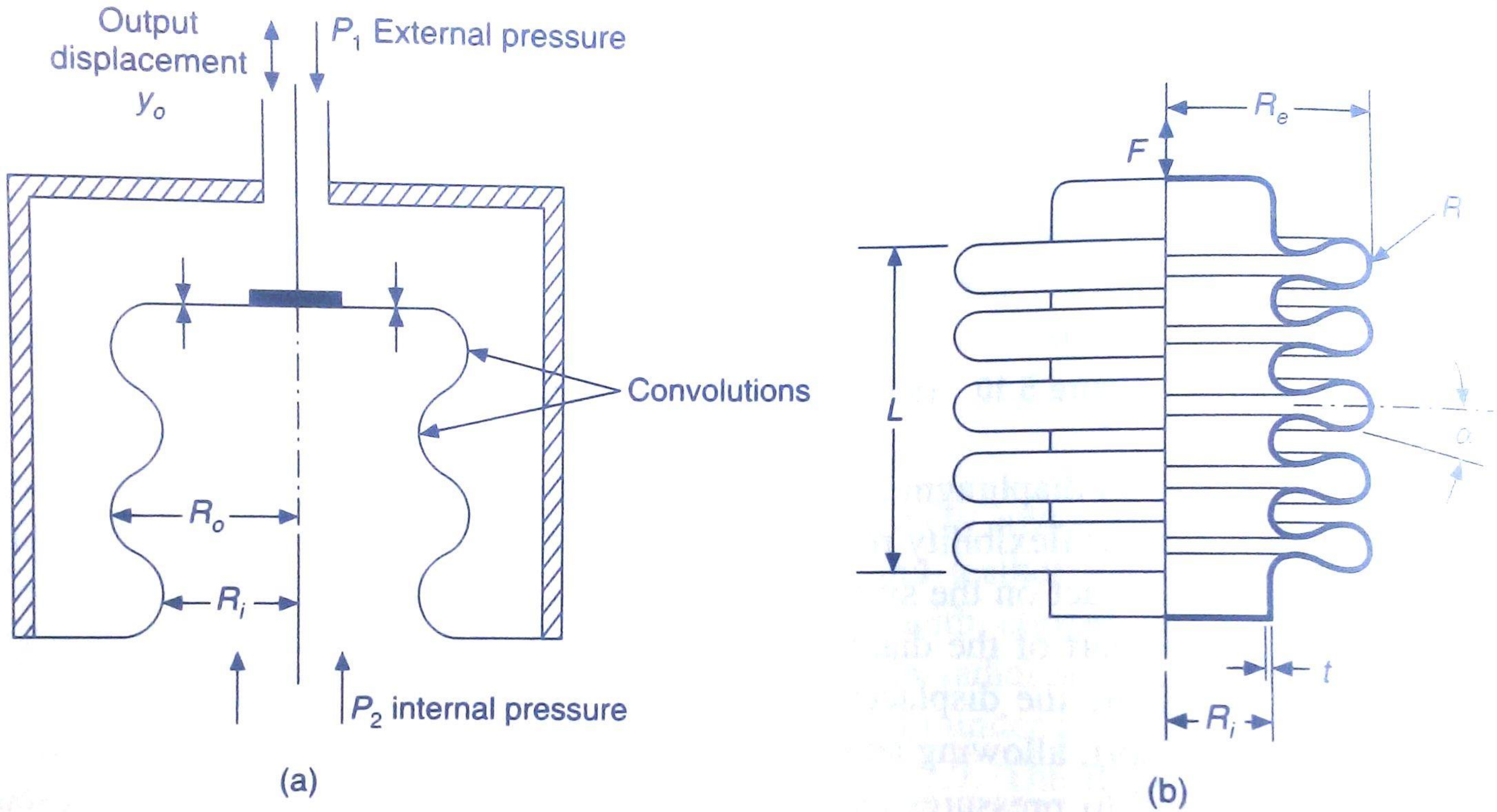

Figure 5.11 (a) A simple bellows element; (b) cut-away section showing formation of corrugations

Bellows Element

... radius R_e to R_i.

However, the axial deflection y_m for the case with $\alpha = 0$ is given by

$$y_m = \pi R_m^2 \, \Delta P \, \frac{1-\mu^2}{Et} \, \frac{n}{A_0 + B_0 \dfrac{t^2}{R_i^2}} \tag{5.16}$$

where,

n = No. of convolutions

R_m = mean radius $\dfrac{R_e + R_i}{2}$ m

P = pressure difference N/m^2

μ = Poisson's ratio of the material

E = Young's modulus N/m^2

t = thickness of walls m

R_i = internal radius m

A_0, B_0 = constants depending on m and c

Bourdon tube element

- Bourdon tube is the most favoured mechanical elements for the measurement of pressure and constitute an important group of primary transducer for converting pressure into linear and angular displacements.
- The simplest and the best form of bourdon tube element consist of thin-walled tube of an oval and flat sided cross-section, bent into circular arc of central angle ranging from 200 to 270 degree (hence known as C-type bourdon tube)
- One end is connected to rigid base to communicate with the source of pressure, while other end is closed and sealed having freedom of movement
- Due to pressure difference between inside and outside of the tube, the cross-section of the tube is deformed and the tube bent to circular cross section, the resulting effect being the displacement of the free tip

Bourdon tube element

- The initial coiling angle ψo decreases to ψ as shown and the difference of these two angles $\Delta\psi$ and the consequent displacement of the free tip y is linearly related to the pressure difference ΔP.
- The net displacement is 3-4mm for tube of 10cm diameter with $\Delta\psi$ of 10 degree.
- Thin walled tube have the ratio of t/b of less than 0.6, where t is thickness of the wall and b half breadth of the tube are used for the pressure up to 35kN/m2
- Thick walled tube with higher ratio above 0.6 is used to handle higher pressure.
- Expressions for $\Delta\psi$ and y for thin walled tube is given as follows

Bourdon tube element

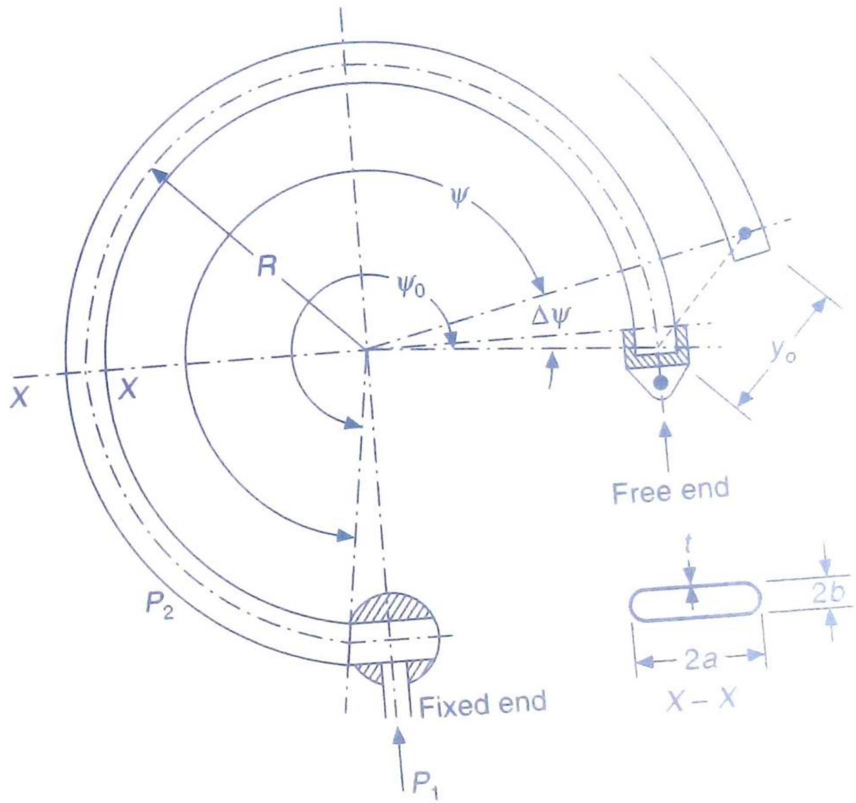

Figure 5.12 Bourdon tube element.

Bourdon tube element

$$\frac{\Delta\psi}{\psi_0} = \Delta P\left[\frac{1-\mu^2}{Ebt} R_0^2\right]\left(1-\frac{b^2}{a^2}\right)\left(\frac{\alpha}{\beta+\chi}\right) \tag{5.17}$$

$$y_{\text{radial}} = \frac{\Delta\psi}{\psi_0} R_0(1-\cos\psi_0) \tag{5.18}$$

$$y_{\text{tangential}} = \frac{\Delta\psi}{\psi_0} R_0(\psi_0 - \sin\psi_0) \tag{5.19}$$

$$y = \sqrt{(y_{\text{rad}}^2 + y_{\tan}^2)} \tag{5.20}$$

where

ΔP = pressure difference, N/m^2
R_0 = radius of the arc, m
μ = Poisson's ratio of the material
E = Young's modulus of the material, N/m^2
a = semi-major axis of the tube, m
b = semi-minor axis of the tube, m
t = thickness of walls of tube, m
χ = $R_0 t/a^2$, a dimensionless constant
α, β = dimensionless constants obtained from Table 5.5
$\Delta\psi, \psi_0$ = angles, radians