experimental results.

8. A Study on the Static and Elastic Behaviour of Bellows

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The bellows are usually utilized in piping system, pressure sensor, and temperature controller of refrigerator and cooling system of automobiles. Bellows used in piping system are designed to absorb axial movement and another deformation of pipe. Internal pressure on the side-wall convolution and end collar introduces an axial load and tends to push the collar away from the convolutions. The bellows are idealized by series of conical frustum-shaped elements, as it is an axi-symmetric shell structure.

To find out static deformation behaviour of bellows subjected to internal pressure, axial load, non-symmetrical load, shearing load and bending moment, the axi- symmetrical shell theory using the finite element method is adopted in this paper. The 6-degree of freedom element is adopted on axi-symmetrical load, while the 8-degree of freedom element is adopted on non-symmetrical load. In case of on 8-degree of freedom element, Fourier series are employed to derive load-displacements relations under non-symmetrical load. As the non-symmetrical load and displace ments of axi-symmetric body are generally periodic functions of angle θ, the nodal load and nodal displacements can be expanded in Fourier series. The series of cosine and sine can be converted into exponential series. With the principal of virtual work, the element stiffness matrix and element load vector are obtained. The element of stiffness matrix and load vector are complex numbers in each order and the stiffness matrices are square and skew- symmetric.

In this study, four kind of experiments which are compression load test, internal pressure test, shearing load test and eccentric load test are performed. The load required to deflect bellows is the function of the dimensions and the materials of the
bellows. The displacements of nodal points due to small increment of force are calculated by the finite element method and the calculated nodal displacements are added to r-z cylindrical coordinates of nodal points. The new stiffness matrix of the system using the new coordinates of nodal points is adopted to calculate the another increments of nodal displacements with step by step method.

Numerical solutions by the finite element method and experimental values are comp--ared in load-displacement graphs. The results of the finite element method are fairly well agreed with those of various experiments. Spring constants and various stresses are analyzed according to the changing geometric factors of U-shaped bellows. Using FORTRAN program developed in this paper, spring constants and stresses can be predicted by input of a few factors.

The geometrical non-linearity in application of finite element method must be delibrated,

because bellows are manu- factured with thin plate and external shape are very large, pliability and deflection are also large compared with thickness of bellows. In the case of bellows subjected to axial load and internal pressure, maximum stresses are induced at valley of wave. The width and slope of ring-plate have an important effect on stiffness and static behaviour of bellows.

Bellows subjected to non-symmectric load can be analized by Fourier series, because non-symmectric load is the periodic fuction of period 2π. The deflection of bellows subjected to non-symmetric loads as shearing load, bending load, and eccentric load are measured and compared with those of calculation results by the computer program developed in this paper. Good coincidences between two results are confirmed.