CAD Program for Design of Metal Bellows

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Received: 15 December 2012 Accepted: 31 December 2012 Published: 15 January 2013

Abstract
Metal bellows is a precision component that is welded along the peripheries of both inside and outside diameters. A development of computer aided design program for the three kinds of welded metal bellows has been studied by Auto LISP language of AutoCAD in this thesis. In this study, this program is sequentially constructed dialog boxes, with which the expected shape of the metal bellows would be obtained quickly and exactly by input of the basic data that the initial radius, inner and outer diameters, pitch, thickness of plate and land length is given. The effects on stress distribution of the bellows can be estimated using a commercial FEM code of ANSYS Workbench when altering some design variables. As a result, this program studied in this paper revealed the advantages as follows, users can obtain the shape of the bellows more easily by input the variables or adding more information, moreover, this program can be revised simply by changing the variables according to the demands in industry and the drawing of metal bellows can be connected to other CAD programs for modeling and FEM analysis

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Index terms— metal bellows, autocad, autolisp, diaphrgm, ansys workbench, pro/engineer.

1 Introduction

etal bellows is an elastic element that consists of very thin metal plate with ring ripple, it can absorb vibration in direction of axis and radius to avoid damaging system. 1,2 Welded metal bellows is a precision component welded along the peripheries of inside and outside diameters, therefore, it is more flexible and compressive than other bellows and widely used for connection pipes, protection device and heat abstractor for protecting system through itself deformed and absorbing vibration. 3 Recently, the demands for the metal bellows are rapidly increasing. Welded metal bellows is not only used in general industry, such as automobile, Ships and pump, but also used in aircraft and other space field, in addition, the study of bellows is active in biological, such as artificial heart. 4,5 The need of domestic metal bellows is gradually increasing in production, but the design principle has not been established and it would waste of time to design different dimensions of metal bellows by using AutoCAD. So the auto program is needed by just entering some main data of the bellows by using the program of AutoLISP.

In this paper, in order to meet the demand for the automatic design, three kinds of welded metal bellows would be designed and the diaphragm of bellows would be developed by using AutoLISP in AutoCAD, finally, the designed bellows would be examined by using ANSYS Workbench program.

2 II.

3 Background Theory

Metal bellows is consisted of many convolutions, one of which is very important because it determines the whole design of diaphragm and it is a precision component which is welded along the edge of peripheries both inside and outside diameters as shown in Fig. 1. Therefore, elastic 6,7 and plastic 8 theory is used as a foundation for the design of the bellows. The shape of bellows in this paper is more flexible than others because it consists of up and low thin plate. Although the principle of three waves of bellows has been confirmed, the inter side of bellows bears too large stress. In this paper, not only three waves bellows has been optimized, but also the shape of four and five waves bellows has also been developed. The system is much effective and simple as shown in Fig. 3.

Loading the main program which is made up of three kinds of bellows that are three, four and five waves shapes. The main program was loaded in AutoCAD. There are three kinds of bellows which users can choose. Every window is a subroutine program. Users

4 Design and Analysis Program

In this paper, the AutoCAD and Pro/ENGINEER program were needed to verify the bellows diaphragm. Finally, FEM program of ANSYS Workbench will be used to analyze it.

After running program, the shape of 2D bellows is shown in Fig. 2 and save it as the format of Dxf file in AutoCAD. Then insert 2D CAD file to 3D design program of Pro/ENGINEER. Create Modeling in Pro/ENGINEER and save it as Parasolid file which would be used in ANSYS Workbench. AutoLISP has a lot of functions with great computing ability. It loads from the file that was saved before, and then computing the data, and all of the commands are able to AutoCAD. Moreover, all institutions modeling can be achieved by using commands of AutoLISP language in AutoCAD and the auto program is developed by using AutoLISP language. The 3D shape of bellows also can be used for other programs or outputs. In this way it will help users more effectively.

5 Design and Analysis Program

In this study, three kinds of welded metal bellows diaphragm were designed by using AutoLISP language in AutoCAD. The expected shape of bellows would be automatically obtained by just inputting the basic data of bellows. The analysis of deformation and stress is very difficult because the shape of bellows is complex. Therefore the deformation and stress is analyzed by using FEM program ANSYS Workbench.

In order to know how the various of initial radius, the diameters of both inside and outside, the pitch and thickness affect to the shape of bellows, many types of bellows were simulated according to different dimensions of bellows.

6 a) CAD Program

After running program the right shape of bellows would be automatically created according to the design principle.

In order to get welded metal bellows, the plasma laser is needed, so the design program includes welded bead. The input data includes the bead of the line. The shape of bead of inner bellows is fully created, and the outer one is half created and the size of the bead is three times of the bellows's thickness. Finally, the analysis of the bead is carried out by using FEM tool.

Diaphragm would not be generated if the value of initial radius is too small or too large, when inputting data of the bellows in AutoCAD. Errors would appear when using the program as follows. For the initial radius, such as shown in Fig. 2, if radius of C1 and C5 is six times longer than L1, C2 and C4 would not be created, for the length of line, it should be longer than bead and for the pitch, it should be longer than three times of thickness.

From above we can see that if the input data is too large or small the shape of bellows would not be created, users should input the proper data because the diaphragm is based on the design principle.

The dimensions of three, four and five waves bellows are shown in Fig. 4(a), (b) and (c). The AutoCAD program developed in this paper can generate the appropriate value, it is possible to create drawings output as well as to the file to the finite element analysis. Welded metal bellows was simulated by using ANSYS Workbench a finite element analysis program, and modeled Y-axis symmetry, with 1/360° a shape in order to shorten the time of the analysis. The fixed lower and gave the axisymmetric conditions, and was compressed bellows by lowering the plate above. Designed according to the displacement of the bellows, the stress and strain were calculated. Bellows designed to investigate interference during compression the bellows through modification of the shape and designed.

The property of welded metal bellows is SUS304, poisson's ratio is 0.3 and young's module is 2.1E+05 MPa. Both the axis and welded end of bellows bears pressure and tension. In order to analyze the shape of bellows, the part of bellows was modeled form one convolution to four convolutions. The stress of pressure and tension was given to the face of end of up. The mass of face value is 10 kg and the pressure is as follows:( ) { } 2 0 2 0 , L R R A A F p ? ? × = = ? (1)

Where, 0 R is external radius and L is the end length of upper plate. A is the end area of up total bellows. According to the end of bellows the area is different. The reflect stress is the same as the stress of pressure.

Boundary condition based on the condition of pressure. The below of bellows is fixed and the upper portion of bellows was pressed make it just could move up and down.

The condition of tension is same with the pressure. However, both inner and outer lines are not contacted with each other. So the face contact is not used.

In order to consider the design parameters of the bellows, the value of different bellows of initial radius, external diameter, inner diameter, pitch, thickness and length of line are shown in Table 1. There are three models and the basic dimensions of model are as follows M01. The dimensions of the M02 and M03 are the same as the dimensions of four and five waves bellows. The dimensions of model have been confirmed but convolution has been not yet. The convolution determines deformation and stress, so the result is different with other convolutions. In order to get correct result, the effect on the number of convolution to model was examined.

Fig. 6 shows the spring constant and stress graph according to different convolution from 1 to 7. Tension is 115 MPa and pressure is 107 MPa when the convolution is four. According to the above, the convolution of model is confirmed over four. The bellows constant is obatined as based on the pressure and tension 10 kg.N F K r × = ? (2)

Where, K is spring constant and ? is the maximum deformation. r F is reflect of stress and N is the number of convolution.

The tension and pressure of spring constant of basic model are 113.56 N/mm and 102.08 N/mm. The pressure of deformation is bigger than the tension of deformation.

The spring constant would be small when the initial radius is big, and the pitch, thickness and strength of line would be big when the spring constant is small and especially the thickness is significant to the spring constant.

7 c) Deformation and Stress Analysis

The design parameters of all models are listed in Table 1. M01 is three waves bellows and the long length of line is two times longer than the short length of line. M02 is four waves bellows and M03 is five waves bellows. The von Misses stress is as shown Fig. 7 2, when these three models are given the same pressure of 10 kg. The stress of M01 is 682.78 MPa and the stress of M02 is 582.94 MPa and the stress of M03 is 640.92 MPa. All the maximum stresses appear in inside part of welded.

The design principle of four waves bellows is asymmetry and the initial radius are the same before. M04 and M05 are the design optimization models of three and five waves bellows. All dimensions are the same but initial radius is three times larger than before.

Table 3 shows that the value of pressure stress of M04 and M05 are 72.22 MPa and 42.59 MPa that are smaller than M01 and M03. The value of tension stress of M04 and M05 are 32.14 MPa and 57.42 MPa that are smaller than M01 and M03. The design principle of four waves bellows is asymmetry and the initial radius are the same before. The stress of bellows M06, M07 and M08 are examined when the thickness is changed from 0.15 mm to 0.2 mm.

8 Conclusion

In this paper, metal bellows is developed by using AutoLISP in AutoCAD and the deformation, stress of bellows has been analyzed through ANSYS Workbench, the results were as follows ? Three kinds of welded metal bellows has been developed automatically in CAD program. Inputting the basic design of 2D and 3D bellows is easy using the basic data in dialog box.

? Unskilled person can be accessed easily in the design. The 3D or 2D shape bellows design can easily draw in the printer or plotter form AutoCAD drawing.

? The dimensions of three, four and five waves bellows have the each characteristic. It must be suitably selected in consideration of the sizes and the process of machining the actual field.

? The spring constant of five waves bellows is bigger than three waves of bellows when the same parameter of bellows was defined.

? When applied to the field bellows designed, it is possible to reduce time and cost during production of the product.

VI. [1]

1

Figure 1: Figure 1 :

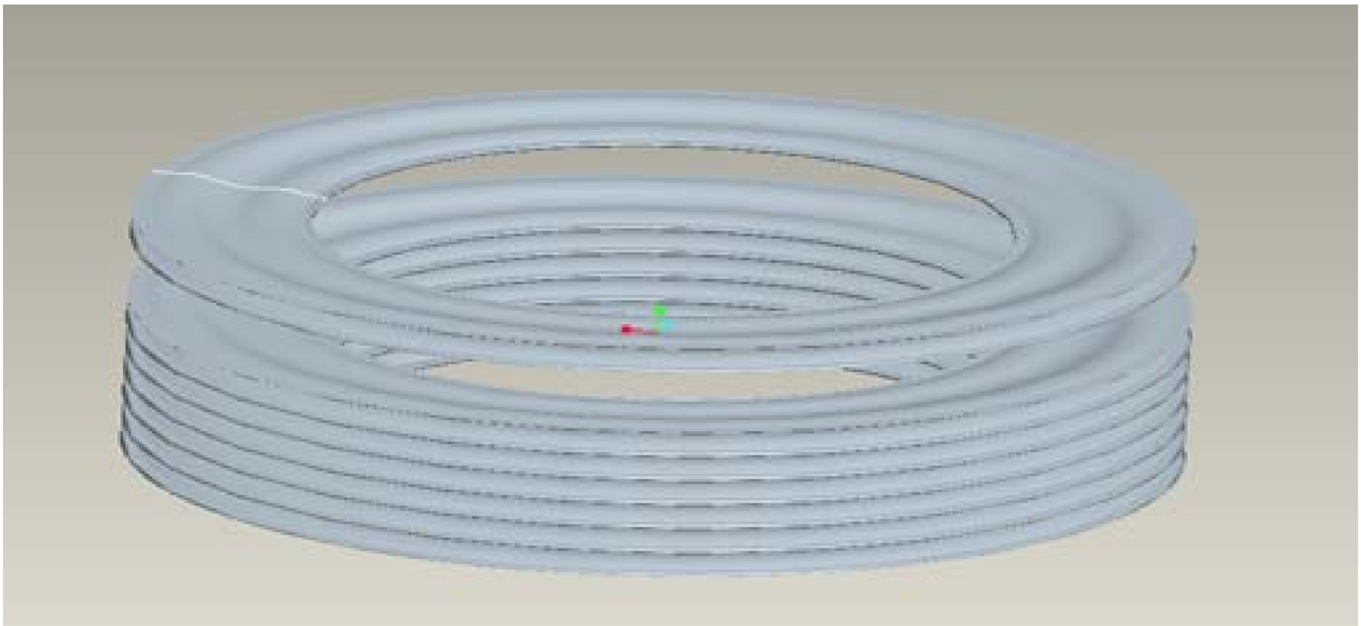


Figure 2:)

2

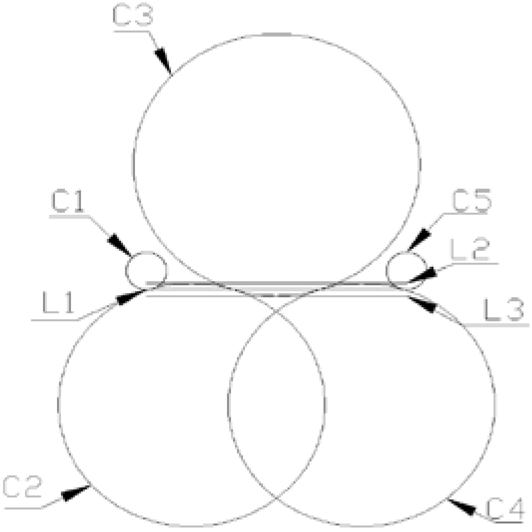


Figure 3: Figure 2 (

2

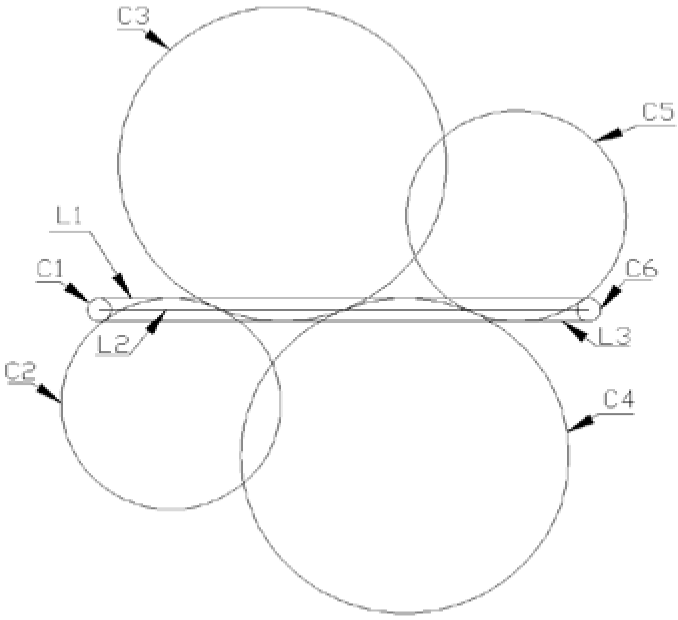
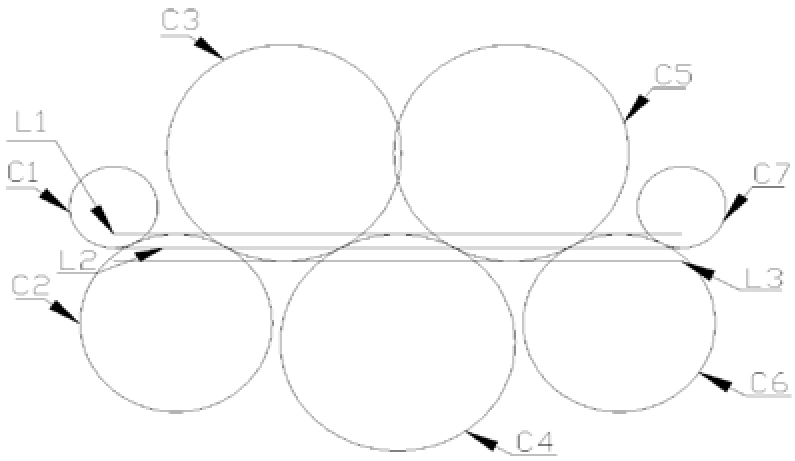
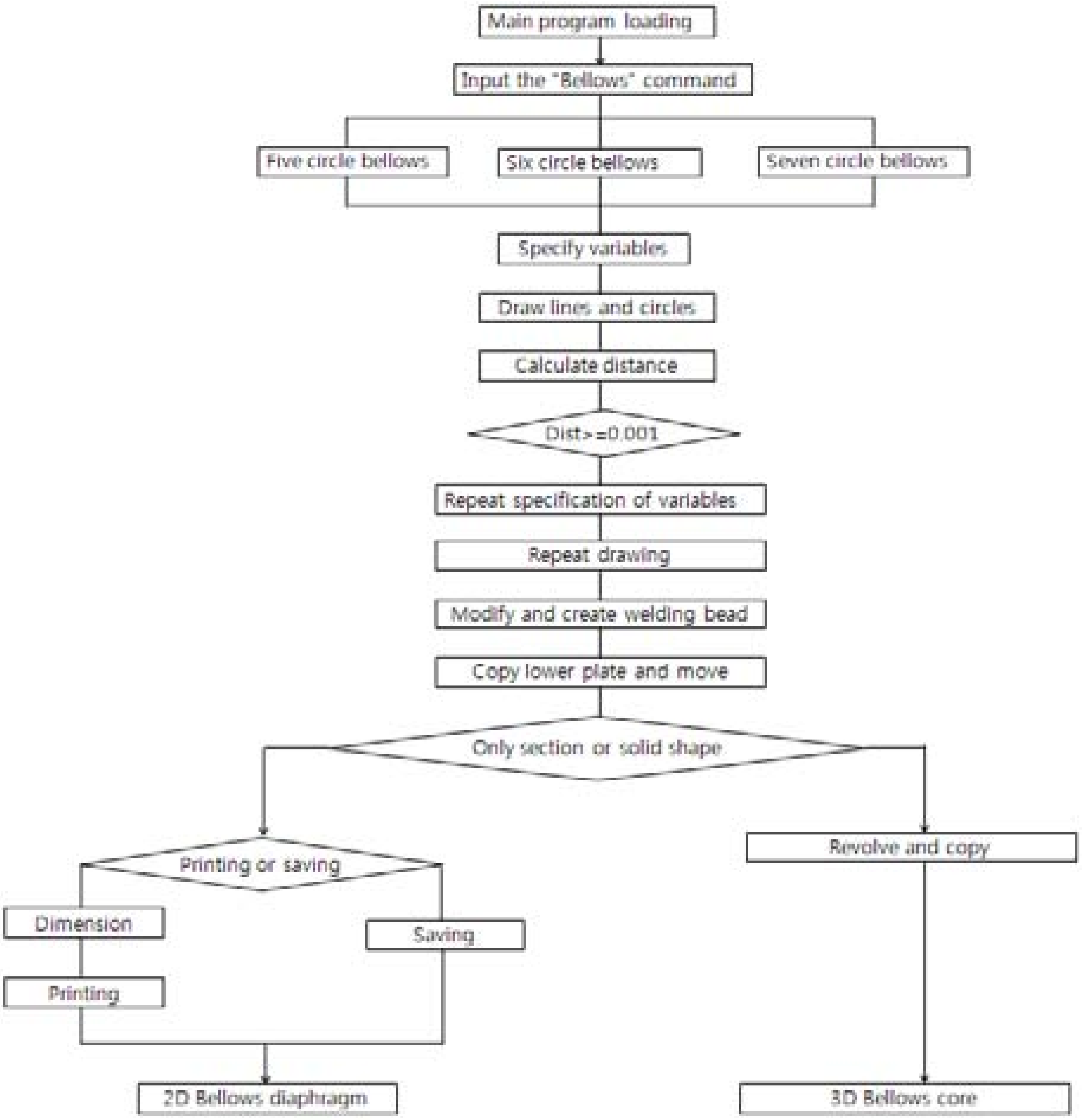


Figure 4: Figure 2 (



3

Figure 5: Figure 3 :



4

Figure 6: Figure 4 (

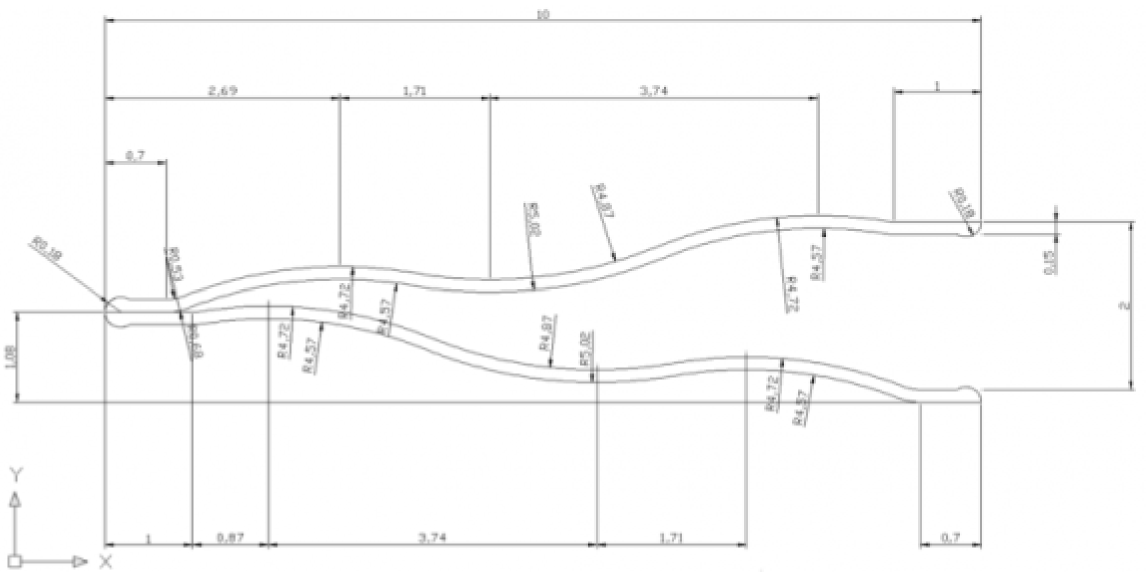
5


Figure 7: Figure 5 :

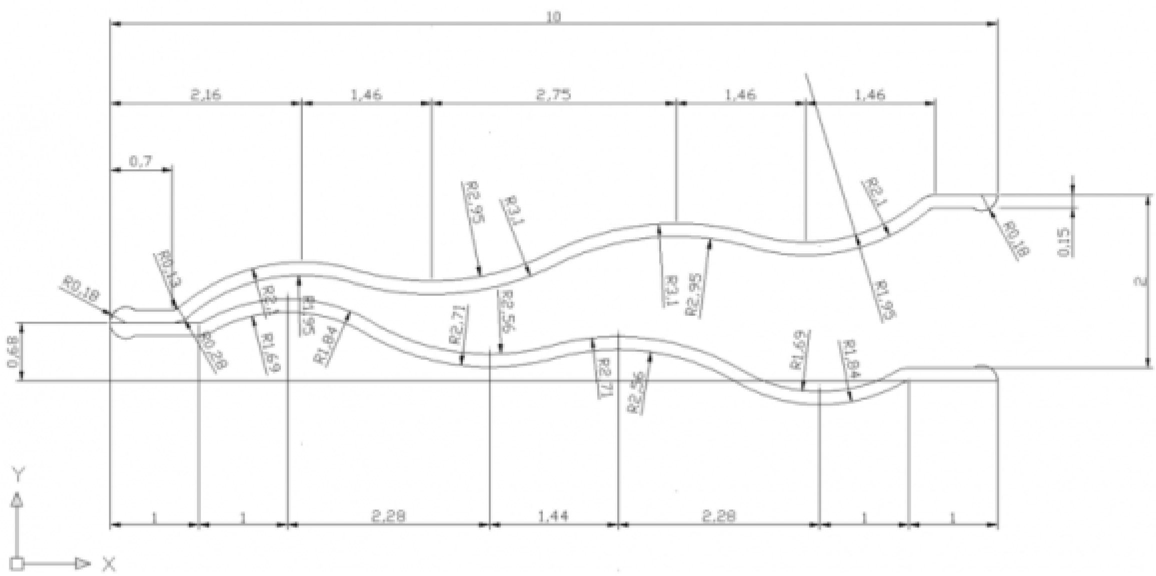
6


Figure 8: Figure 6 :

7

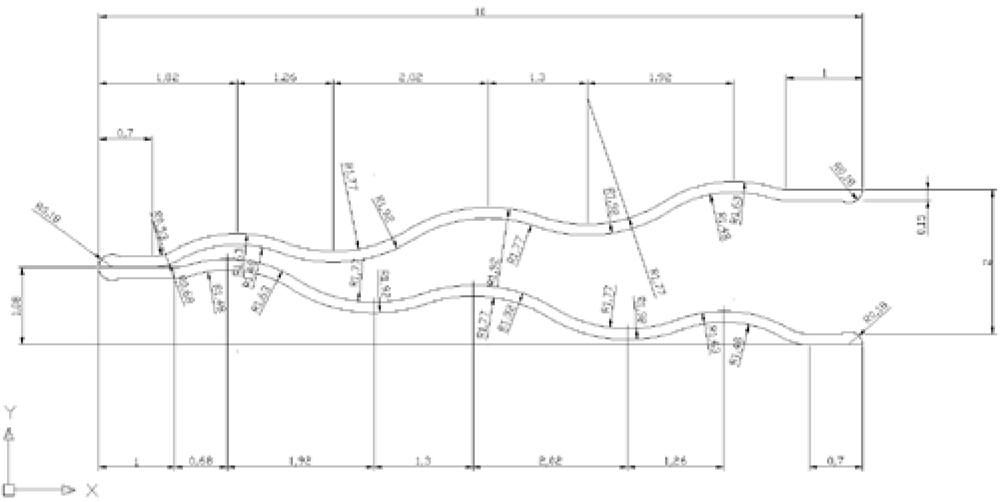


Figure 9: Figure 7

1

Model	Initial Radius (mm)	Diameter (mm) Inner	Outer	Pitch (mm)	Thickness (mm)	Short length (mm)	Long length (mm)
M01	0.2	39	59	2	0.15	0.7	1
M02	0.2	39	59	2	0.15	0.7	1
M03	0.2	39	59	2	0.15	0.7	1
M04	0.6	39	59	2	0.15	0.7	1
M05	0.6	39	59	2	0.15	0.7	1
M06	0.6	39	59	2	0.2	0.7	1.1
M07	0.6	39	59	2	0.2	0.7	1.1
M08	0.6	39	59	2	0.2	0.7	1.1

Figure 10: Table 1 :

2

Model	Load		Time (s)	Displacement (mm)	M ax imum (MPa)
	Compression	10Kg (98.06N)	1	1.0091	682.78
M01	Tension	10Kg (98.06N)	2	0.65369	489.75
M02	Compression Tension	10Kg (98.06N) 10Kg (98.06N)	1 2	0.90249 0.9117	582.94 582.83
M03	Compression Tension	10Kg (98.06N) 10Kg (98.06N)	1 2	0.95309 0.98523	640.92 485.94

Figure 11: Table 2 :

3

Model	Load		Time(s)	Displacement (mm)	Maximum (MPa)
M04	Compression Tension	10Kg (98.06N) 10Kg (98.06N)	1 2	0.95531 0.86303	610.56 457.61
M05	Compression Tension	10Kg (98.06N) 10Kg (98.06N)	1 2	1.0894 0.95626	598.33 428.52

Figure 12: Table 3 :

4

Figure 13: Table 4

4

Model	Load	
Compression Tension Compression Tension M08 Compression M06 M07 Tension V.	10Kg (98.06N) 10Kg (98.06N) 10Kg (98.06N) 10Kg (98.06N) 10Kg (98.06N) 10Kg (98.06N)	

[Note: © 2013 Global Journals Inc. (US) CAD Program for Design of Metal Bellows]

Figure 14: Table 4 :

[Koh et al. ()] 'A Finite Element Analysis and Shape Optimal Design with Specified Stiffness for U-typed Bellows'. B G Koh , Y J Seo , G J Park . *Transactions of Korea Society of Automotive Engineers* 1995. 3 (6) p. .

[Lee et al. ()] 'A Study on the Dynamic Characteristics of Bellows'. W Lee , J Oh , T W Kim . *Transactions of the Korean Society of mechanical engineers* 1988. 12 (6) p. .

[Hirata et al. ()] 'Fatigue Life of Welded Bellows (Effect of Configuration of Corrugated Plate)'. O Hirata , A Nakajima , K Okada , S Sasaki , Y Ogawa . *Journal of the JSME* 1995. 61 (587) p. .

[Hirata et al. ()] 'Fatigue Life of Welded Bellows (Effect of Test Speed)'. O Hirata , A Nakajima , K Okada , S Sasaki , Y Ogawa . *Journal of the JSME* 1995. 61 (589) p. .

[Kim ()] 'Plasticity" Seoul University 2009. 9'. D H Kim . *EG&G Seoul Industrial Division* 2002. (Bellows Talk)

[Ugural ()] *Stresses in plates and shells*, C Ugural . 1981. McGraw-Hill. p. .

[Choi et al. ()] 'The Analysis of Welded Metal Bellows'. B G Choi , W D Kim , H J Lee , C S Woo . *Korea Institute of Machinery & Materials* 1991. 21 p. .

[Troitsky and Sc ()] M S Troitsky , D Sc . *Stiffened Plates Bending, Stability and Vibrations*, 1976. Elsevier Scientific Publishing Company. p. .