Design of Universal Expansion Joint under Axial and Transverse loading as per EJMA Code

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Abstract - Bellow is a flexible seal/expansion joint, whose convoluted portion is designed to flex when thermal movements occur in the piping system. The number of convolutions depends upon the amount of movement the bellows must accommodate or the force that must be used to accomplish this deflection. The convoluted element must be strong circumferentially to withstand the contraction and thermal expansion of the system. This strength with flexibility is a unique design problem that is not often found in other components in industrial equipment. Bellows are frequently used in the pressure vessels or piping system, aerospace, etc. it has the function to absorb regular or irregular expansion and contraction in the system. Since bellows require high strength as well as good flexibility, we prefer SS 316 l alloy to design and manufacture a bellow. The design, manufacturing and analysis of bellows are more complicated than other general tubes. A journal related to design and manufacturing of bellows can be discussed. In this research, we planned to design, modelling and detailing of bellows under axial and transverse loading using EJMA code. By using this EJMA code one can predict the circumferential membrane stress, meridional membrane stress, movement per convolution and fatigue life cycle of the bellows

Keywords: Bellows, Convolution, EJMA code, Expansion joint.

I. INTRODUCTION

The flexible element of an expansion joints consisting of one or more convolutions and the end tangent with the ratio of length of the bellows to the diameter of the bellows must be lesser or equal to 3 with no more than five plies. Any device containing one or more bellows used to absorb dimensional changes such as caused by thermal expansion or contraction of pipe system. Tubular bellows are one of the most efficient energy-absorbing elements for engineering systems. An expansion joint or movement joint is an assembly designed to safely absorb the heat-induced expansion and contraction of various engineering materials, to absorb vibration, to hold certain parts together. The bellows is the flexible element of the expansion joint, it must be strong circumferentially to withstand the pressure and flexible enough longitudinally and laterally to accept the deflections for which it was designed, and as repetitively as necessary with a minimum resistance. This strength with flexibility is a unique design problem that is not often found in other components in industrial equipment. Metal bellows have wide application in aerospace, micro chemical plants, power system, automotive vehicle parts, refineries, heat exchangers, piping system, electromechanical system, petrochemical plant, power stations, district heating installations, HVAC systems etc. and wherever piping systems or ducts are subjected to movement through the effects of temperature, pressure or external forces etc.

II. SELECTION OF TYPE OF EXPANSION JOINT

In our problem, we recommend the universal type expansion joint because it’s having the intellectual properties such as the universal expansion joint is applicable for any type of applications in the piping system.

The universal expansion joint is mainly used for absorbing the combination of three basic loads (Axial, Lateral, and Angular). These are used to absorb the large amount of lateral deflections. And it is completely differ from double expansion joint.

Advantages of universal expansion joint are in the following**:**

- It’s having simple and robust construction.
- It’s having the tendency to absorb large amount of axial, lateral and angular movement.
- It is comparatively inexpensive.
- The installation of the universal expansion joint is easier
- Maintenance of this kind of expansion joint are lower.

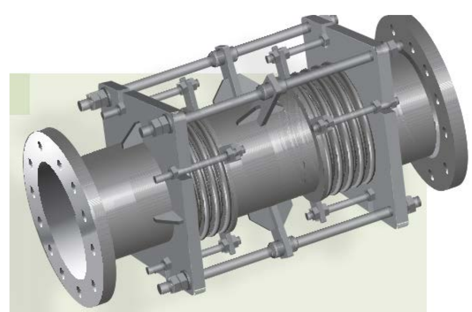

Fig. 2.1 Univrsal Expansion joint

III. LITERATURE SURVEY

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. 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 modelling and FEM analysis [1]. Investigation of the relationship between maximum stresses produced and cycle life of different shaped bellows expansion joints (U-shape, Ω-shape and disc-shape) using MATLAB. U-shaped bellow has smaller internal pressure-induced stress, longer fatigue life, and is more suited for higher internal pressure situations. The most essential bellow design factor is the correct specification of the bellow movement requirements [2]. The failure of bellows expansion joints made of SS 304 has been analysed. Over pressure, Vibration of steam in piping are responsible for the failure. After complete observation of the bellows, found that the wrong design data are assumed at the time of bellows manufacturing and finally these bellows are fail within 1 year of service. Based on these design data, improve the design and re-design the metal expansion bellows by using EJMA code adding with inner liner. A finite element analysis (FEA) of bellows proposed in this paper to for the validation of the software results and EJMA design calculated results bellows with the inner liner. Finally the validation of results of EJMA design calculated value and FEA value shows a very good agreement. Here by adding the inner liner in the bellows gives the better results and performance achieved then the conventional bellows [3]. The review on flexible element of an expansion joints consisting of one or more convolutions with no more than five plies and the end tangent with length to diameter ratio not more than three and any device containing one or more bellows used to absorb dimensional changes such as caused by thermal expansion or contraction of pipe line, duct or vessel or heat exchangers. Finally the author have been found out the development of bellows, Forming Technology, analysis of movement test, buckling, Mechanical behaviour, Design concept, Effective parameters and Analysis of the bellow by using commercial available software [4]. The experimental investigation and performance evaluation of hydro formed tubular bellows in INCONEL 625 alloy can be performed. Tubular Bellows are generally formed by hydroforming process is to achieve the uniformity in structure with adequate dimensional accuracy. The flexibility and the fatigue property of the bellows were evaluated by using the spring rate test and life cycle test. The cross-sectional SEM (Scanning Electron Microscope) images were perfectly identifying the defects which presence on the surface of the convolutions of the bellows expansion joints [5]. The expansion joints are used to dissipate the energy during contraction or expansion in pipes. Different types of expansion joints are widely used in piping industries. This covers detailed calculation from EJMA (Expansion Joint Manufacturers association), Design, Modelling, Thermal and Structural analysis of axial type expansion joint. All design process will be performed with aid of FE analysis using ANSYS software [6]. Anew method has been proposed for manufacturing of the metal bellows and important parameters such as initial length of tube, internal pressure, axial feeding and velocity, mechanical properties and the type of materials were investigated by finite element (FE) analysis (LS-Dyna) and experimental tests. Finally, the results of finite element method (FEM) and experiments show a very good agreement. The results of the present work could be used as a basis of designing a new type of the metal bellows [7].A bellows, or a closed thin-walled elastic tube with corrugated walls, undergoes longitudinal extension when subjected to internal fluid pressure. Investigated herein is the mechanical behaviour of several pressurized bellows in clusters, which are designed to bend and twist as well as to extend and compress longitudinally. For torsion, the bellows are clustered in a cylindrical helix whose angle is chosen to produce the desired load–displacement relationships, for instance the highest rotation for a given torque. For both bending and torsional limbs, experimental results are included that exhibit the predicted mechanical behaviour [8].

IV. PROPOSED METHODOLOGY

SELECTION OF TYPE OF BELLOW

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SELECTION OF MATERIAL

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DESIGN CALCULATION AS PER EJMA

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3D MODELLING BY CATIA V5 R21

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DESIGN DETAILING

V. RESULTS AND VALIDATION AS PER EJMA

The axial and transverse movement's calculations of the metallic bellow with the material type SS 316 L to be calculated using

EJMA code. The total stress rate of the bellows can be calculated using the circumferential membrane stress and meridional membrane stresses of the bellows, bellows tangent and collar attached to the bellows due to pressure and deflections. And finally the fatigue life cycle of the bellows to be calculated as per EJMA code.

The analytical calculation of universal expansion joint recommended for the piping system having 1500 nominal bore to be calculated as per EJMA code for input parameter shown in TABLE 1:

TABLE 1. INPUT PARAMETERS FOR DESIGN CALCULATIONS OF BELLOWS AS PER EJMA CODE.

S.no.	Parameters	Values
1.	Internal design pressure	7.251 psi
2.	External design pressure	14.625 psi
3.	Design Temperature	158 F
4.	Axial movement	50 mm
5.	Lateral movement	15 mm
6.	Inside diameter	1490 mm
7.	Outside diameter	1534 mm
8.	Length of the collar	50 mm
9.	Tangent length	50 mm
10.	Number of convolutions	4+4

For that recommended type of bellows and the material, the stress calculations and fatigue life cycle for both internal and external design pressure of the expansion joint are calculated as per EJMA code is shown in TABLE 2.

TABLE 2. STRESS CALCULATIONS OF BELLOWS AS PER EJMA CODE.

S.no.	Parameters	Calculated Values
1.	Bellows tangent circumferential membrane stress due to Internal design Pressure	1382.27 psi
2.	Bellows tangent circumferential membrane stress due to External design Pressure	2801.32 psi
3.	Collar circumferential membrane stress due to Internal design Pressure	1387.27 psi
4.	Collar circumferential membrane stress due to external design Pressure	2811.08 psi
5.	Bellows circumferential membrane stress due to internal design Pressure	4675.01 psi
6.	Bellows circumferential membrane stress due to External design Pressure	9474.45 psi
7.	Bellows meridional membrane stress due to internal design pressure	192.385 psi
8.	Bellows meridional membrane stress due to External design pressure	390 psi
9.	Bellows meridional bending stress due to pressure	6578.49 psi
10.	Bellows meridional bending stress due to pressure	13596.48 psi
11.	Bellows meridional membrane stress due to deflection	386.55 psi
12.	Bellows meridional bending stress due to deflection	62558.22 psi
13.	Total stress range of bellows at internal pressure	67682.58 psi
14.	Total stress range of bellows at external pressure	72735.21 psi
15.	Fatigue life cycle of bellows at internal pressure	17921418.95 cycles
16.	Fatigue life cycle of bellows at external pressure	6156323.58 cycles

After the stress and fatigue life cycle calculations for the recommended expansion joint, the design of the expansion joint is undergone stress validation process. The stress validation process is a analytical calculation which is to be made to conclude that the design of an expansion joint made by EJMA standard code is to be safe or not. The stress validation process also carried out with use of EJMA standard code as shown below:

1) $S_1 \leq C_{wb} S_{ab}$ = 18802.68 Psi …………I

2) $S'_1 \leq C_{wc} S_{ac}$ = 18802.68 Psi ………...II

3) $S_2 \leq C_{wb} S_{ab}$ = 18802.68 Psi ………....III

4) $S_3 + S_4 \leq C_m S_{ab}$ = 46536.79 Psi ……..IV

Where,

S_1, Bellows tangent circumferential membrane stress due to design Pressure,

S'_1, Collar circumferential membrane stress due to design Pressure,

S_2, Bellows circumferential membrane stress due to Pressure,

S_3, Bellows meridional membrane stress due to pressure,

S_4, Bellows meridional bending stress due to pressure,

C_{wb}, Longitudinal weld joint efficiency factor for Bellows

C_{wc}, Longitudinal weld joint efficiency factor for Collar,

S_{ab}, Allowable materials stress for Bellows,

S_{ac}, Allowable materials stress for Collar,

C_m, Material strength factor

VI. DESIGN AND DETAILING OF BELLOWS

The bellow is to be modelled for the input parameters already discussed in above section using CATIA V5 R21 software. The isometric view of the modelled bellow is shown below:

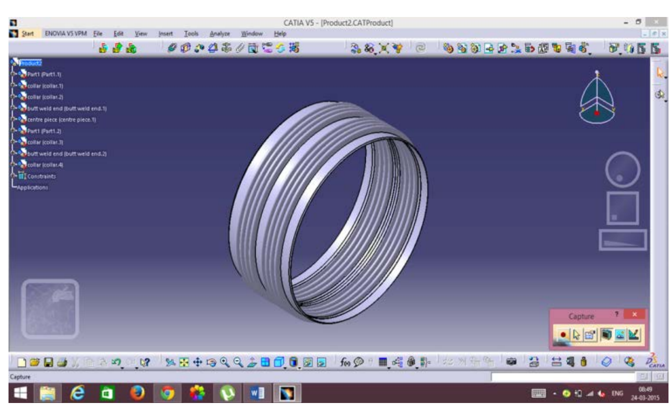

Fig. 4.1 Iso metric view of Univrsal Expansion joint

The design detailing and the fabrication drawing can be performed in the drafting workbench of the CATIA V5 R21 software with the sectional cut of the universal expansion joint. Geometrical Dimensioning & Tolerancing (GD&T) is used to give the tolerances of the universal expansion joint. The detailed design of universal expansion joint is shown below:

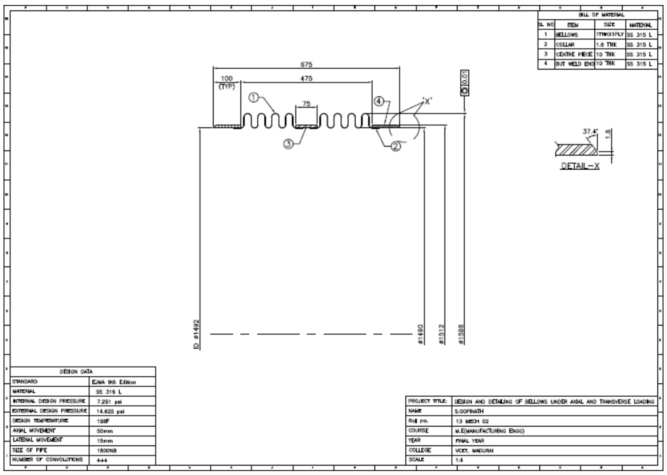

Fig. 4.2 Fabrication drawing for Univrsal Expansion joint

VII. CONCLUSION

The analytical calculation for the bellows design has been done as per EJMA standards and different stress values has been determined.

Analytical validation for Bellows design has been done as per EJMA standards and it has been validated for the different stresses for the total thickness of 1mm having 1 ply as per standards and it is observed that all stress values are in the safe limit.

The following observation can be made from above analytical calculation a as per EJMA standards;

1. The Bellows Tangent Circumferential Membrane stress due to pressure (S1)for external is found to be 2801.32Psi and has been validate as per condition given in Eq I ($S1 \leq CwbSab$) and is found to be safe.

2. The Collar membrane Circumferential stress due to pressure (S'1) is found to be 2811.08Psi and has been validate as per condition given in Eq II ($S'1 \leq CwcSac$) and is found to be safe.

3. The Bellows Circumferential Membrane stress due to pressure (S2) is found to be 9474.45 Psi and has been validate as per condition given in Eq III ($S2 \leq CwbSab$) and is found to be safe.

4. The Bellows Meridional Membrane Stress due to pressure (S3) and Bellows meridional bending stress (S4) is found to be of value 390 Psi and 13596.48 Psi respectively and has been validate as per condition given in Eq IV ($S3 + S4 \leq CmSab$) and is found to be safe.

5. The number of fatigue life cycles (N) observed to be 6156323.58cycles

VIII. FUTURE SCOPES

The FEA analysis can be used for validating the design of the bellow, already calculated by using EJMA standard. In other words, it is used to justifying the calculated stresses and cycle life by EJMA standard could be equal to the value of the stresses and cycle life done by FEA analysis. And the FEA analysis is used to show the impact of loads in the universal expansion joint in real time.

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