Design Assessment and Parametric Study of Expansion Bellow

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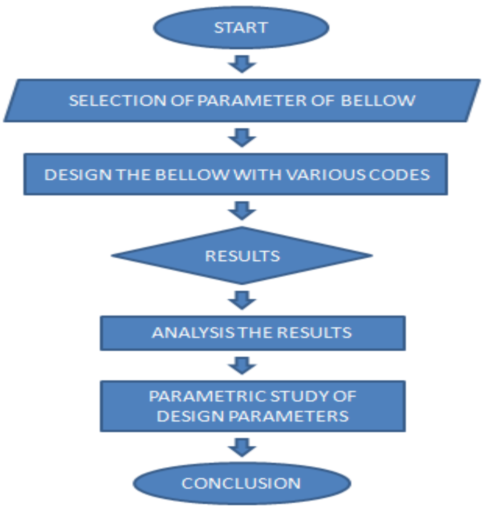
Abstract - Design of Expansion bellow is a very critical activity in the process of design of an Expansion Joints. Major difficulties arrive in research process because there are only few numbers of literatures, books and research papers are available to guide the researchers to develop new design with its complex shapes. For the purpose of safe and durable operation throughout the estimated working life it is necessary to consider various factors while design. To arrive at successful design of expansion bellow it is requires to change the numbers of design parameters and do a lots numbers of iterative calculation for a long time.

In this current research paper author developed the design of U shaped expansion bellow with the help of Expansion design codes like ASME and EJMA.A detail parametric study is carried out based upon the design output and verified through FEA process.

Key Words: Expansion bellow, EJMA,ASME,FEA

1. METHODOLOGY



1. This project methodology starts with the study of various literature s and journals related to the bellow and expansion joints.
2. Then select various design parameters as per the suitable conditions like applications, durations of applications, space available etc.
3. Then Design the bellow with the chosen parameters with various design codes and standards.
4. Then analyse the various design results to find the optimum one.
5. Then do the parametric study to ensure the impacts of the parameters on the stress values, life of bellow etc.
6. Finally conclude the entire process.

2. BELLOW DESIGN PARAMETERS

To design a simple Expansion bellow for certain Design Pressure with requisite certain minimum nos cycle of operation the designer need to consider certain input design parameters and material properties as mentions below

A. Essential Material properties for Bellow design.

PARAMETERS	NOTATIONS
Modulus of elasticity at Room Temp for Bellows	Eb(RT)/Eo
Modulus of elasticity at Working Temp for Bellows	Eb(dt)
Modulus of elasticity for ring at design temp	Er(DT)
Modulus of elasticity for collar at design temp	Ec(DT)
Modulus of elasticity at Working Temp for collar	Ebc /Eb(DT)
Modulus of elasticity (overall)	Eb
Yield strength at design temperature of the actual Bellows material after completion of Bellows forming and any applicable heat treatment	Sy

B. Design input parameters

PARAMETERS	NOTATIONS
Pipe outer dia	OD
Bellow ID	Db
Bellows Thickness	t
Number Of Plys	n

Mean radius of bellows convolution	rm
Pitch of Convolution	q
Number of Convolutions	No
Tangent Length	Lt
Bellows tangent collar thickness	tc
Collar Length	Lc
Length of the bellow convolution	Lb
Design Pressure	P
Design Temperature	T
Axial Compression	Xc
Axial Extention	Xe
Lateral Movement	y
Angular Movement	θ

Depending upon the above mentioned material properties and input parameter others auxiliary parameters can be find out from EJMA and ASME Codes .

3. STRESS CLACULATIONS AS PER EJMA:

1. Tangent Circumferential Membrane Stress Due to pressure (S1)
   $S1= P*(Db + n*t)^2 * Lt*Eb*K / (2 * (n*t*Eb*Lt(Db + n*t)) + (tc*K*Ec*Lc*Dc))$
2. Bellows Circumferential Membrane Stress Due to pressure (S2)
   $S2 = (P*Dm*Kr*q)/(2*Ac)$
3. Bellows Meridional Membrane stress Due to pressure (S3)
   $S3 = P*W / (2 * n * tp)$
4. Bellows Meridional Bending Stress Due to pressure (S4)

   $S4 = (P / 2n) * (W / tp)^2 * Cp$

EVALUATION

$S1$ & $S2 < Cwb * Sab$

$S3+S4 < Cm * Sab$

All the conditions should be satisfied

5. Bellows Meridional Membrane Stress due to deflection (S5)
   $S5 = Ebr * (tp)^2 * e / (2 * W^3 * Cf)$
6. Bellows Meridional bending Stress due to deflection (S6)
   $S6 = 5 * Ebr * tp * e / (3 * w^2 * Cd)$
7. Total Stress (St) = $0.7*(S3+S4)+S5+S6$
8. Cycle Life (Nc) = $(C/(St-b))^a$
   Where
   Where a=3.4,b =54000,c=1860000

4. STRESS CLACULATIONS AS PER ASME:

1. Tangent Circumferential Membrane Stress (S1)
   $S1=(P*(Db+(n*t))^2*Lt*Eb*k)/(2*(n*t*Eb*Lt*(Db (n*t))+(tc*k*Ebc*Lc*Dc)))$
2. The circumferential membrane stress due to pressure
   $S2= (P*Dm *q)/(2*A)$ for intermediate convolution
   $S2=(q*Dm+Lt(Db+nt))*P/2(A+n*tp+tc*Lc)$ for end convolution
3. The meridional membrane stress due to pressure (S3)
   $S3= P*w / (2 * n * tp)$
4. The meridional bending stress due to pressure
   $S4= (P*Cp/(2*n))*(w/tp)^2$

   EVALUATION

   $S3 + S4 \le Kf*S$

   Kf = 3.0 for formed bellows

   Kf=1.5 for annealed bellows
5. Meridional membrane stress (S5)
   $S5= Ebr * (tp)^2 * dq / (2 * w^3 * Cf)$
6. Meridional bending stress (S6)
   $S6= 5 * Ebr * tp * dq / (3 * w^2 * Cd)$
7. Total Stress (St) = $0.7*(S3+S4)+S5+S6$
8. Cycle Life (Nc) =$(k0/kg*(E0/Eb)St-S0))^2$
   Where
   $kg*(E0/Eb)St \ge 65,000$ psi
   St is expressed in psi, Ko=5.2 _ 106 and So=38,300

4. DESIGN RESULTS

STRESS	EJMA	ASME	UNITS
S1	3964.019	3964.019	Pa
S2	7312.319	5752.273	Pa
S3	1069.718	1069.718	Pa
S4	33597.47	33597.47	Pa
S5	1738.486	2210.82	Pa
S6	237959.2	343993.3	Pa
St	263964.8	370471.2	Pa
NC	1663.59	412.2956	Nos.

5. DESIGN ANALYSIS:

From the above design it is observed that though the input parameters are same for the both codal design method (ASME and EJMA), the output stress components are different because of their respective design philosophy. The nature of stress components distribution are shown through the graph bellow.

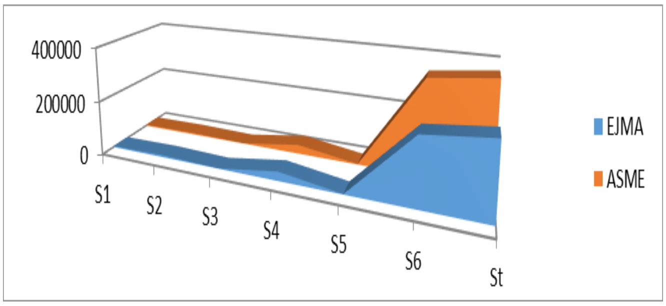


FIGURE: VIEW OF VARIOUS STRESS COMPONENTS

The above design can be analysed in that for the same design parameters

1. The value of

a) Tangent Circumferential Membrane Stress (S1)
b) Bellows Meridional Membrane stress (S3)
c) Bellows Meridional Bending Stress (S4)

Are same for both ASME and EJMA code basis Design

2. The value of

d) Bellows Circumferential Membrane Stress (S2) is higher in EJMA with respect to ASME code basis Design

3. The value of

e) Bellows Meridional Membrane Stress due to deflection (S5)
f) Bellows Meridional bending Stress due to deflection (S6)
g) Total stress (St)

Are lower in EJMA with respect to ASME code basis Design

4. The cycle life of bellow is higher in EJMA with respect to ASME code basis Design

7. PARAMETRIC ANALYSIS:

In the above design process the impacts of changes of design parameters on total stress in both the design process mentioned below –

With the initial rise in bellow convolution diameter, pitch, length, pressure & temp. increase the total stress increases as shown in below graph

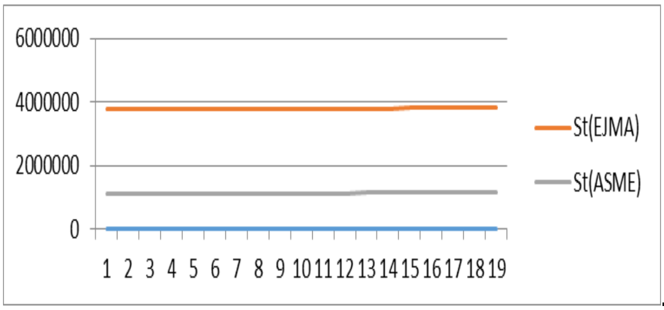


FIGURE : NATURE OF CHANGE IN TOTAL STRESS WRT DIAMETER, PITCH, LENGTH, PRESSURE & TEMP

With the increase of the depth of convolution the total stress vale decrease in both the design process as shown bellow

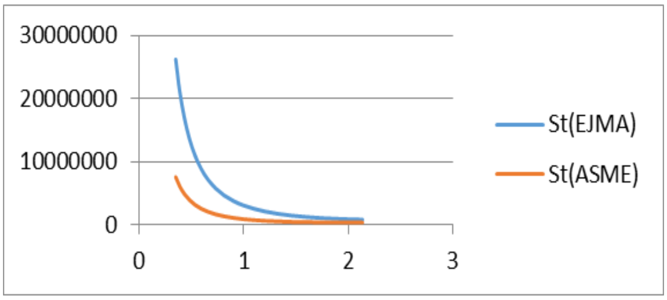


FIGURE : NATURE OF CHANGE IN TOTAL STRESS WRT BELLOW CONVOLUTION DEPTH

With the increase of the thickness of the bellow the total stress increase with higher rate as shown in the graph below

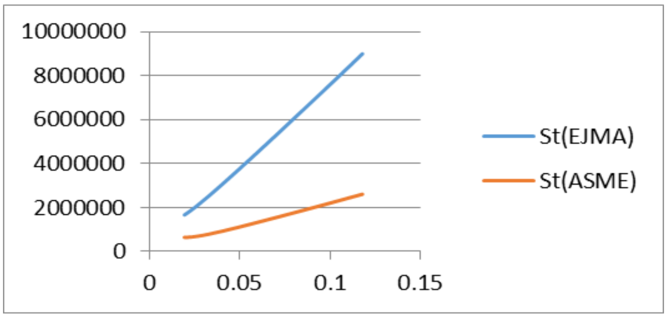


FIGURE : NATURE OF CHANGE IN TOTAL STRESS WRT BELLOW

CONCLUSION

[1] The total stress estimated from the design based on EJMA depends on the meridional membrane stresses and meridional bending stress due to the pressure and the total equivalent displacements in axial direction without considering the others effects like temperature etc. While in the design with ASME section VIII also considers the effects of operating temperature of bellows using the modules of elasticity both at room temperature and operating temperatures.

[2] Fatigue strength factor is neglected while designing with the EJMA design code but the considered while designing with the design code-ASME section VIII with its effecting factors like thickness changes, various surface factors and weld geometrics.

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