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Effect of Die Cavity Configuration on the Stress Distribution in Tube Hydroforming Process with and without Rubber

Hani Aziz Ameen , Kadhim Mijbel Mashloosh, Rusul Abdel Kareem Salman

**Original Article*

Abstract— In this work three dies (square, cosine and conical) are considered to investigate the effect of media either hydraulic fluid or rubber on hydroforming material applied in tube bulging using ANSYS code.
Ansys APDL is used to simulate the bulging process and to observe the effect of media of the internal pressure on the equivalent stress distribution in the tube. It is found that the stress decreases about 16.54% when the rubber is the media of the internal pressure in case of cosine die and 4.01% in case of conical die and 4.20% in case of square die. So it can be concluded that the rubber media used in bulging tube is much better than the hydraulic fluid.
Index Terms— Tube Hydroforming, Finite element method, ANSYS, Bulging, Square, cosine and conical profile cross section Tube, Rubber, Stress analysis .

1.INTRODUCTION

Tubes hydroforming is one of metal forming processes by which it can produce several complex shapes in mid or at any place along the length of straight or bent tubes depending on the shape of a very rigid die cavity that in which the tube is placed and clamped tightly. This process is done by applying high internal pressure towards the inner wall of the tube to force it to take the final shape of the die cavity, using hydraulic fluid or rubber media. Hani Aziz Ameen ,et al,[2016] [1] presented the optimum loading path to prevent the wrinkling which is applying axial ramp load separately then increase the internal pressure . Xianghe X et al., 2009[2] used square hydroforming die to study friction coefficient, and the anisotropic coefficient (r) on the thickness distribution. Abdelkefi Abir, et al, 2015[3] also used square hydroforming die to study the friction conditions which are responsible for the thickness distribution in a part realized by tube hydroforming. Djavanroodi F., et al, 2008[4] using cosine profile of bulging tube to study the influence of friction between die's wall and tube, springback of formed tube ,and tube material properties and the results observed that the strain hardening coefficient which has the significant influence on the formability of the tube. Selvakumar A. S. , et al ,[2012][5] used the conical shape's die for bulging tube to study deformation characteristics on tubular materials before and after heat treatment in hydroforming process. The parameters considered were axial feed, fluid pressure, and fluid medium. Due to the effect of axial feed, the pressure during forming and expansion of tube were analyzed. When pressure exceeds at a certain value, failures of wrinkling and bursting types occurred. Girard A A.C. et al., 2006 [6] using conical profile of bulging tube with urethane as a media of internal pressure. Mikael Jansson, et al, [2007][7] used the conical shape's die for bulging tube to study the results of a hydroforming process which depend large extent on the choice of process parameters, i.e. the combination of material feeding and exerted inner pressure.
In this work three ANSYS models are presented for three types of bulging tube using hydraulic fluid and rubber as a media to apply the internal pressure.

2- Theoretical Approach

The hydroforming process can be divided into three stages during forming : yielding of tube's metal , free forming process (i.e. before tube wall reaching the inner's die wall) , the last stage is the contact of the tube wall with the inner's die wall. Several assumptions are considered for the theoretical analysis are : homogenous deformation , thin wall tube and isotropic material. The theoretical analysis will be on the free forming process (i.e. before the contact of the tube wall with the inner's die wall).

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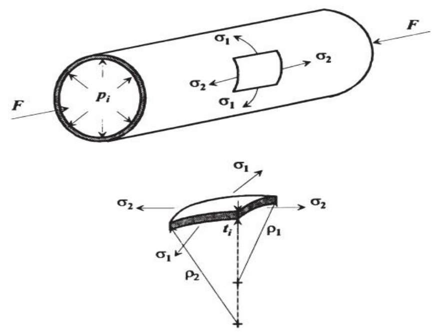

Figure(1) Stresses on the element of tube wall.

Figure(1) illustrated that the internal pressure P_i caused by the axial load F. From the equilibrium condition of the element , it can be get [8],

$$\frac{\sigma_1}{\rho_1}+\frac{\sigma_2}{\rho_2}=\frac{P_i}{t_i} \quad (1)$$

From equilibrium forces in the longitudinal it can be concluded [9],

$$\sigma_2=\frac{\rho_1 P_i}{2t_i}-\frac{F}{2\pi\rho_1 t_i} \quad (2)$$

And according to the Von Mises yield criteria , the effective stress and strain will be :

$$\bar{\sigma}=(1-\alpha+\alpha^2)^{0.5}\cdot \quad (3)$$

$$\bar{\epsilon}=[\tfrac{4}{3}(1+\beta+\beta^2)]^{0.5}\cdot\epsilon_1 \quad (4)$$

where

$$\alpha=\sigma_2/\sigma_1 \quad (5)$$

$$\beta=\epsilon_2/\epsilon_1 \quad (6)$$

$$\epsilon_1=\ln(\rho_1/\rho_0) \quad (7)$$

$$\epsilon_3=\ln(t_i/t_0) \quad (8)$$

where ϵ_1 and ϵ_3 are the circumferential and radial strain, ρ_0 and ρ_1 are the initial and instantaneous radius of tube and t_0 and t_i is the initial and instantaneous wall thickness.

When the Levy Mises equation is applied, the following relation can be obtained:

$$\alpha=(2\beta+1)/(2+\beta) \quad (9)$$

$$\beta=(2\alpha-1)/(2-\alpha) \quad (10)$$

Combining equations 1,2,3 and 5 , it can be get :

$$P_i=\frac{\bar{\sigma}}{(1-\alpha+\alpha^2)^{0.5}}\cdot t_i\cdot\left(\frac{1}{\rho_1}+\frac{\alpha}{\rho_2}\right) \quad (11)$$

$$F=Pi\cdot\pi\cdot{\rho_1}^2\cdot\left(1-\frac{1\alpha}{1+\alpha\cdot\rho_1/\rho_2}\right) \quad (12)$$

If the following data are taken for equations (11) and (12)

$\rho_1=(d_0-t_0)/2$, $\rho_2=\infty$, $t_i=t_0$, $\bar{\sigma}=\sigma_y$

Where d_0 is the outer diameter of tube and σ_y is the yield stress of the material, hence Eqs.11,and 12 will be:

$$P_{iy}=\frac{\sigma_y}{(1-\alpha+\alpha^2)^{0.5}}\cdot\frac{2t_0}{(d_o-t_0)} \quad (13)$$

$$F_y=P_i\cdot\pi\cdot\frac{(d_0-t_0)^2}{2}\cdot(1-2\alpha) \quad (14)$$

So, it can be treated the free bulging for the tube wall by putting $\rho_2=\infty$. referring to equations (1) and (2) , Equation (11) and (12) will be

$$P_i=\frac{2t_i}{d_i-t_i}\cdot K\cdot\left(\frac{2}{2-\alpha}\right)^n\left(\sqrt{1-\alpha+\alpha^2}\right)^{n-1}\left(\ln\frac{d_i-t_i}{d_0-t_0}\right)^n \quad (15)$$

$$F=P_i\cdot\pi\cdot\left(\left(\frac{1-\alpha}{2}\right)\cdot(d_i-t_i)^2-t_0\cdot\frac{(2d_0-3t_0)}{4}\right) \quad (16)$$

3- Hyperelastic Materials

The purpose of this paper is to use the rubber(which is a hyperelastic material) as a media instead of hydraulic fluid in the tube hydroforming process. Rubber like materials, which are characterized by a relatively low elastic modulus and high bulk modulus, are used in a wide variety of structural applications. These materials are commonly subjected to large strains and deformations. In 1951, Rivlin and Sunders developed a hyperelastic material model for large deformations of rubber [10].

This material model is assumed to be incompressible and initially isotropic.

The form of strain energy potential for a Mooney-Rivlin material is given as : [11]

$$W=c_{10}(I_1-3)+c_{01}(I_2-3)+1/d(J-1)^2 \quad (17)$$

Where

W is strain energy potential.

c_{10} , c_{01} are material constants

I_1 is first deviatoric strain invariant .

I_2 is second deviatoric strain invariant .

d is material incompressibility parameter.

J is determinant of the elastic deformation gradient F.

4- Loading Path

Referring to equations (15) and (16), several Loading Paths were attempted to avoid wrinkling, from Ref.[1]which it can be concluded that the behavior of the loading path as shown in Figure(2) prevent the wrinkling.

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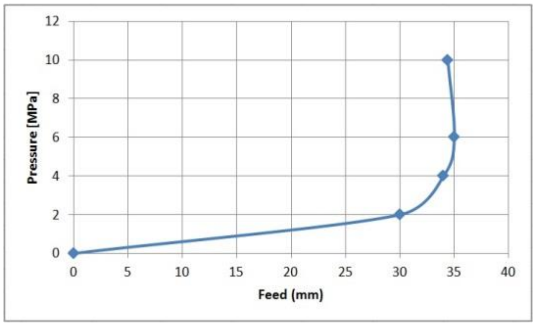


Figure(2) Load Path using for bulging process

In our work , the loading path presented in Ref[1] is used.

5- Finite Element Model

ANSYS, finite element analysis, software package with capability to analyze a wide range of different problems is a powerful numerical technique, has been applied in the past years to a wide range of engineering problems. Although much FE analysis is used to verify the structural integrity of designs, more recently FE has been used to model fabrication processes. When modeling fabrication processes that involve deformation, the deformation process must be evaluated in terms of stresses and strain states in the body under deformation including contact issues[12]. A numerical control algorithm is used for the loading path as in Fig.(2) to give maximum formability of circular tubes during the bulging using hydraulic and rubber media . In this type of analysis, loading (Figure2) can cause large deformation, permanent deformation beyond the material yield point and residual stresses. However, contact between parts of a mechanism or among independent parts can be handled. Nonlinear transient stress analyses produce more accurate stress results than linear static stress analyses. The die represented by (Target 170), and defined as a very rigid body and the tube blank material represented by (solid186), which is defined by eight nodes having up to three degrees of freedom at each node(u_x,u_y,u_z). The contact interface between die and the deformed material is represented by (Contact 174), which has three degrees of freedom at each node. Due to symmetry quarter model is meshed[13].

6- Model Construction

6-1 Case -one- Cosine Bulging Die

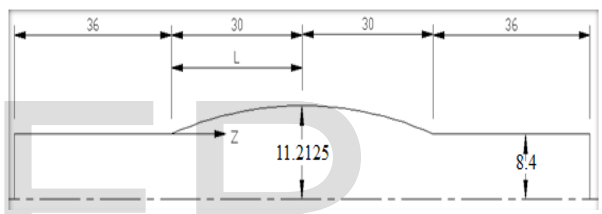
For studying the tube hydroforming process and its parameters a complex bulge shape with “cosine profile” was designed depending on an equation used to design dies [14].

$$R = \left[\frac{1}{2}(R_1 + R_2)\right] + \frac{1}{2}(R_1 - R_2)cos\left(\frac{\pi \times Z}{L}\right) \qquad (18)$$

where R is a die radius at any section along die length.
R_1: Maximum radius of die =11.2125 mm ,
R_2: Minimum radius of die =8.4 mm
Z: length of section on die length = 5 mm cumulative distance for each section
L: bulging die length = 60 mm
The results arranged in Table(1) and Figure(3) shows the cosine profile

Table(1) The cosine profile dimensions

R mm	**8.4**	**9.05**	**9.48**	**10.058**	**10.634**	**11.057**	**11.2125**
Z mm	**0**	**5**	**10**	**15**	**20**	**25**	**30**



Figure(3) Half cosine die profile dimensions

6-2 Case -two- Conical Bulging Die

Other shape with “conical profile” was designed depending on the tube diameter (18.8mm) as shown in Figure(4).

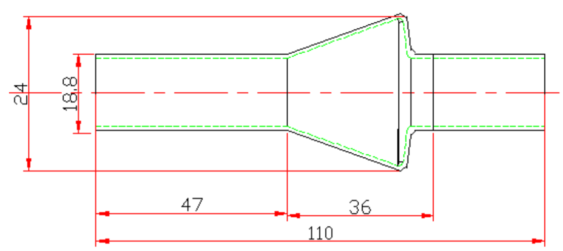


Figure (4) Conical die profile dimensions

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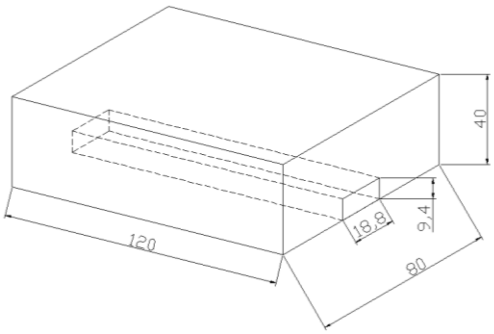
<u>6-3 Case -three- Square Bulging Die</u>

The square dimensions of the die was :length of the die = 120 mm, width of the die = 80 mm, Height of the upper and lower part = 40 mm. hence, the dimensions of the cavity (square section) will be length=110, width=18.8 and height of the upper and lower part= 9.4mm, as shown in Figure(5).



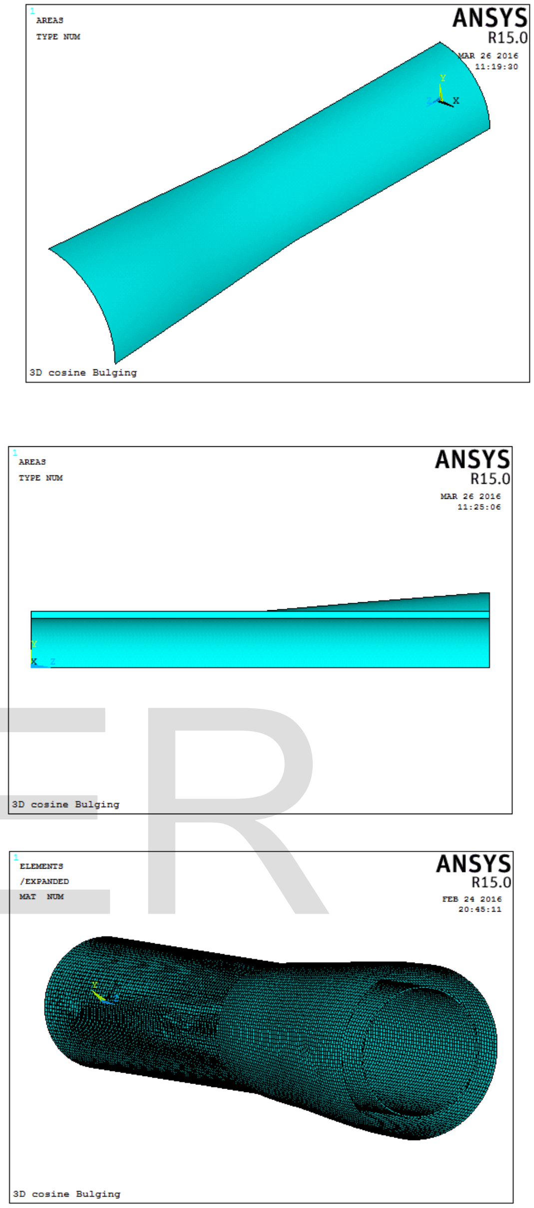
Figure(5) Square die profile dimensions

There are several types of data which must be fed to numerical finite element software to simulate tube hydroforming process and to study its parameters. Isotropic Hardening Plasticity model was used. The plastic response was modeled using the Von Mises Yield Criterion, with the material properties listed in table (2).

Table(2) The mechanical properties of copper tube material

Modulus of Elasticity (E)	124 GPa
Tangent Modulus of Elasticity (E_T)	0.8 E GPa
Yield Stress (σY)	105 MPa
Poisson's Ratio (υ)	0.34
Friction Coefficient	0.15

In cosine bulging, first, the line is drawn according to Figure(3) , then rotate by 90° to consist three dimension model where the quarter hollow cylinder is drawn as a tube. In this modeling Mapped meshing was used, as shown in Figure(6).



Figure(6) Model of cosine bulging

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The following is the APDL of ANSYS that model without rubber

```
/title,3D cosine Bulging
!-----------------------
/view,1,1,1,1
/prep7
!Die
!k,1,0,,0
k,2,8.4/1000,,0
k,3,8.4/1000,,36/1000
k,4,9.05/1000,,41/1000
k,5,9.48/1000,,46/1000
.
.
spline,3,4,5,6,7,8
spline,8,9
lcomb,1,2
lcomb,1,3
lcomb,1,4
lcomb,1,5
.
.
arotat,1,,,,,,10,11,90
!tube
cyl4,0,0,8.4/1000,0,7.4/1000,90,66/1000
allsel,all
numcmp,all

!mesh tube
!========
Et,1,186      !element type solid186
Mp,ex,1,124e9  ! 124 GPa
MP,nuXY,1,0.34  ! possion ratio=0.34
.
.
!meshing the tube
type,1
mat,1
real,1
esize,0.5/1000    ! set meshing size
.
.
!/COM, CONTACT PAIR CREATION - START
CM,_NODECM,NODE
CM,_ELEMCM,ELEM
CM,_KPCM,KP
CM,_LINECM,LINE
CM,_AREACM,AREA
CM,_VOLUCM,VOLU
!/GSAV,cwz,gsav,,temp
MP,MU,1,0.15
MAT,1
MP,EMIS,1,7.88860905221e-031
R,3
REAL,3
ET,2,170
ET,3,174
.
.
```

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```
!B.C
!====
Asel,s,,,7   !L7
nsla,s,1
D,all,ux,0
!D,all,Roty,0

!D,all,Rotz,0
allsel,all
Asel,s,,,6   !L8
nsla,s,1
.
.
!1
!==
Asel,s,,,2    !L5
nsla,s,1
D,all,uz,0
!D,all,Rotx,0
!D,all,Roty,0
allsel,all
.
.
```

The following is the APDL of ANSYS that model with rubber:

```
/title,3D cosine Bulging with Rubber
! ---------------------------------
/view,1,1,1,1
/prep7
! Die
!k,1,0,,0
k,2,8.4/1000,,0
k,3,8.4/1000,,36/1000
k,4,9.05/1000,,41/1000
k,5,9.48/1000,,46/1000
.
.
spline,3,4,5,6,7,8
spline,8,9
lcomb,1,2
lcomb,1,3
lcomb,1,4
lcomb,1,5
.
.
arotat,1,,,,,,10,11,90
```

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```
!tube
cyl4,0,0,8.4/1000,0,8/1000,90,66/1000
!Rubber
cyl4,0,0,8/1000,0,2/1000,90,66/1000
!Vovlap,2,1
!=======
allsel,all
numcmp,all
!mesh tube
!=======
Et,1,186        !element type solid186
Mp,ex,1,124e9  ! 124 GPa
MP,nuXY,1,0.34  ! possion ratio=0.34
.
.
!meshing the tube
type,1
mat,1
real,1
esize,1/1000    ! set meshing size
.
.
!Mesh rubber
ET,2,186        !element type solid186
MP,eX,2,2.87e6     ! 2.87 Mpa
MP,nuXY,2,0.499    ! possion ratio=0.499
tb,hyper,2,,,mooney
tbdata,1,0.293e6
.
.
!meshing the rubber
type,3
Amesh,8
type,2
Mat,2
.
.

! contact between die and tube
!====================
!/COM, CONTACT PAIR CREATION - START
CM,_NODECM,NODE
CM,_ELEMCM,ELEM
CM,_KPCM,KP
CM,_LINECM,LINE
CM,_AREACM,AREA
CM,_VOLUCM,VOLU
!/GSAV,cwz,gsav,,temp
MP,MU,1,
MAT,1

MP,EMIS,1,7.88860905221e-031
R,3
REAL,3
```

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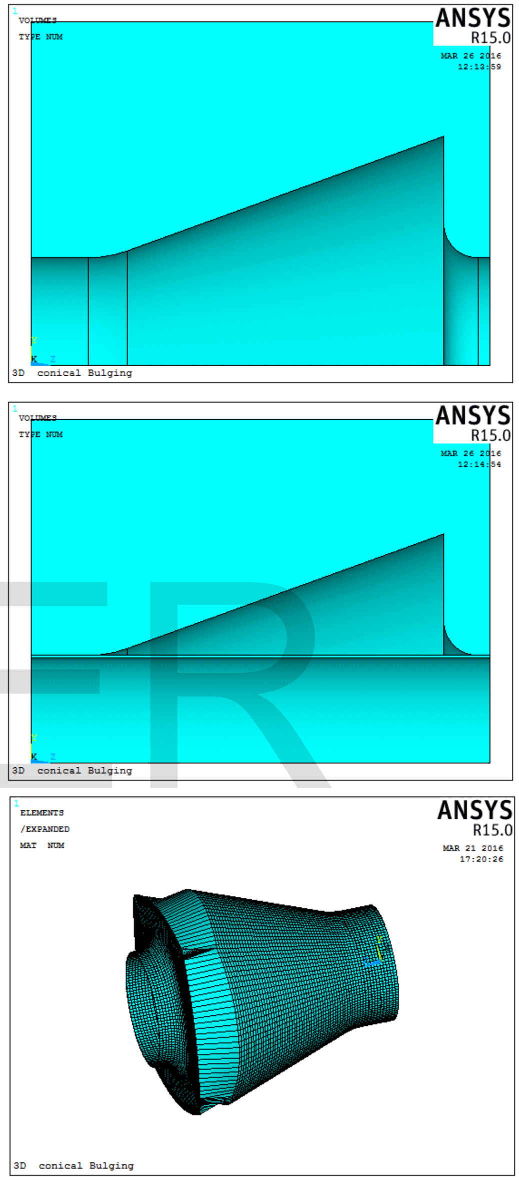
```
ET,4,170
ET,5,174



R,3,,,1.0,0.1,0,
.
.
!B.C
!===
Asel,s,,,7   !L7

Asel,a,,,1
nsla,s,1
D,all,ux,0
allsel,all
.
.
!1
!==
Asel,s,,,3    !L5
asel,a,,,9
nsla,s,1
D,all,uz,0
allsel,all
Asel,s,,,11
nsla,s,1
.
.
```

In conical bulging, first, the line is drawn according to Fig.(4) , then rotate by 90° to cover three dimension model where the quarter hollow cylinder is drawn as a tube. In this modeling Mapped meshing was used, as shown in Figure(7).



Figure(7) Model of conical bulging

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The following is the APDL of ANSYS that model without rubber:

```
/title,3D  conical Bulging
!-----------------------
/view,1,1,1,1
/prep7
!Die
!k,1,0,,0
k,2,9.4/1000,,0
k,3,9.4/1000,,6.7/1000
k,4,12/1000,,30/1000   !36
.
.
!mesh tube
!=======
Et,1,186        !element type solid186
Mp,ex,1,70e9  ! 124 GPa  !70e9ok
.
.
!meshing the tube
type,1
mat,1
real,1
.
.
!contact
!========
!*
!/COM, CONTACT PAIR CREATION - START
CM,_NODECM,NODE
CM,_ELEMCM,ELEM
CM,_KPCM,KP
CM,_LINECM,LINE
CM,_AREACM,AREA
CM,_VOLUCM,VOLU
!/GSAV,cwz,gsav,,temp
‘MP,MU,1
MAT,1
R,3
.
.
!B.C
!===
Asel,s,,,17   !L7
nsla,s,1
D,all,ux,0
.
.
!1
!==
Asel,s,,,12    !L5
nsla,s,1
D,all,uz,0
allsel,all
Asel,s,,,15
nsla,s,1
sf,all,pres,0.5e6
.
.
```

The following is the APDL of ANSYS that model with rubber:

```
/title,3D  conical Bulging
!-----------------------
/view,1,1,1,1
/prep7
```

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```
!Die
!k,1,0,,0
k,2,9.4/1000,,0
k,3,9.4/1000,,6.7/1000
k,4,12/1000,,30/1000
.
.
!Tube
cyl4,0,0,9.4/1000,0,9.2/1000,90,40/1000 !t8.4-8.2ok
allsel,all
numcmp,all
!mesh tube
!=======
Et,1,186        !element type solid186
Mp,ex,1,70e9  ! 124 GPa  !70e9ok
.
.
!meshing the tube
type,1
mat,1
real,1
.
.
!Contact
!========
!*
!/COM, CONTACT PAIR CREATION - START
CM,_NODECM,NODE
CM,_ELEMCM,ELEM
CM,_KPCM,KP
CM,_LINECM,LINE
CM,_AREACM,AREA
CM,_VOLUCM,VOLU
!/GSAV,cwz,gsav,,temp
‹MP,MU,1
MAT,1
R,3
REAL,3
ET,2,170
ET,3,175
KEYOPT,3,9,0
KEYOPT,3,10,2
R,3,
.
.
!Rubber
cyl4,0,0,9.2/1000,0,3/1000,90,40/1000 !t8.4-8.2ok
!Mesh rubber
ET,12,186       !element type solid186
MP,eX,12,2.87e6     ! 2.87 Mpa
MP,nuXY,12,0.499    ! possion ratio=0.499
tb,hyper,12,,,mooney
.
.
!meshing the rubber
type,13
Amesh,19
type,12
.
.
!B.C
!====
Asel,s,,,17   !L7
```

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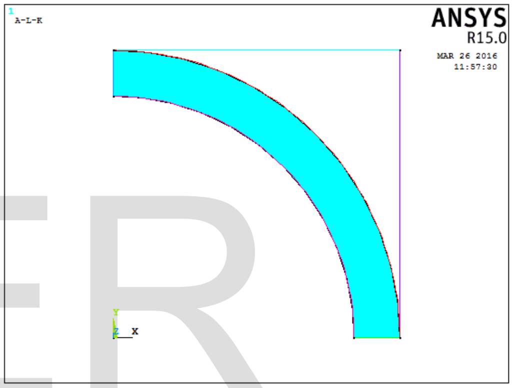
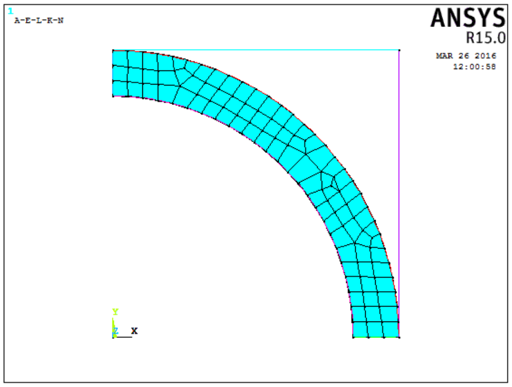
```
asel,a,,,23
nsla,s,1
D,all,ux,0
allsel,all
.
.
!contact tube and rubber
!=================
!/COM, CONTACT PAIR CREATION - START
CM,_NODECM,NODE
CM,_ELEMCM,ELEM
CM,_KPCM,KP
CM,_LINECM,LINE

CM,_AREACM,AREA
CM,_VOLUCM,VOLU
!/GSAV,cwz,gsav,,temp
MP,MU,1,0
MAT,1
MP,EMIS,1,7.88860905221e-031
R,4
.
.
!1
!==
Asel,s,,,12    !L5
asel,a,,,18
nsla,s,1
D,all,uz,0
allsel,all
Asel,s,,,21
nsla,s,1
sf,all,pres,0.1e6
allsel
.
.
```

In square bulging, the line quarter of cylinder is drawn with two line represented the die in a two dimension model. Then meshing was used, as shown in Figure(8).





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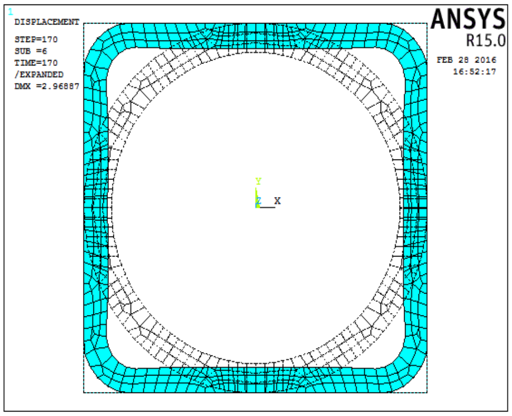

Figure(8) Model of square bulging

The following is the APDL of ANSYS that model without rubber:

```
prep7
!Die
k,1,0,,0
k,2,9.4,0
.
.

l,4,3
.
.

! Blank
cyl4,0,0,9.4,0,(9.4-1.5),90
!blank
ET,1,182
KEYOPT,1,3,3
.
.
!meshing the Blank
type,1
mat,1
real,1
!contact
!======
!/COM, CONTACT PAIR CREATION - START
CM,_NODECM,NODE
CM,_ELEMCM,ELEM
CM,_KPCM,KP
CM,_LINECM,LINE
CM,_AREACM,AREA
CM,_VOLUCM,VOLU
!/GSAV,cwz,gsav,,temp
MP,MU,1,0
MAT,1
R,3
REAL,3
ET,2,169
ET,3,172
KEYOPT,3,9,0
KEYOPT,3,10,2
R,3,
RMORE,
RMORE,,0
.
.
finish
/config,nres,10000
/solu
lsel,s,,,4
nsll,s,1
D,all,ux
lsel,s,,,6
nsll,s,1
D,all,uy
```

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```
!1
!==
lsel,s,,,5
nsll,s,1
sf,all,pres,1
allsel
nlgeom,on
outre,all,all
outpr,all,all
.
.
```

The following is the APDL of ANSYS that model with rubber:

```
/prep7
!Die
k,1,0,0
k,2,9.4,0
.
.
l,4,3
l,3,2
!Blank
cyl4,0,0,9.4,0,(9.4-1.5),90
!blank
ET,1,182
KEYOPT,1,3,3
R,1,120
.
.
tbdata,1,45,0.8e3
!meshing the Blank
type,1
mat,1
.
.
amesh,1        !  mesh area no.1
allsel,all
!contact
!======
!/input,quarter-R,txt
!/COM, CONTACT PAIR CREATION - START
CM,_NODECM,NODE
CM,_ELEMCM,ELEM
CM,_KPCM,KP
CM,_LINECM,LINE
CM,_AREACM,AREA
CM,_VOLUCM,VOLU
!/GSAV,cwz,gsav,,temp
MP,MU,1,0
.
.
allsel,all
!rubber
!=====
cyl4,0,0,9.4-1.5,0,,90
MP,eX,20,2.87      ! 2.87 Mpa
MP,nuXY,20,0.499     ! possion ratio=0.499
.
.
```

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```
!*
!/COM, CONTACT PAIR CREATION - START
CM,_NODECM,NODE
CM,_ELEMCM,ELEM
CM,_KPCM,KP
CM,_LINECM,LINE
CM,_AREACM,AREA
CM,_VOLUCM,VOLU
!/GSAV,cwz,gsav,,temp
MP,MU,1,0
MAT,1
MP,EMIS,1,7.88860905221e-031
R,4
REAL,4
ET,4,169
ET,5,172
R,4,,,1.0,0.1,0,
RMORE,,,1.0E20,0.0,1.0,
.
.
finish
!/config,nres,10000
/solu
lsel,s,,,4
nsll,s,1
.
.
!1
!==
*do,i,1,25,1
lsel,s,,,8
nsll,s,1
D,all,ux,i!
.
.
```

5-Results and Discussion

The results presented in this paper are the distribution of stresses and strains during bulging process with different configuration (cosine, conical, square) die's shape and different pressure media which are hydraulic fluid and rubber. It was found that in the case of cosine die the maximum equivalent stress without rubber 278MPa Pa and maximum equivalent strain 0.289432 as shown in (Fig. 9) and when the rubber is used the maximum equivalent stress 232MPa and maximum equivalent strain 0.23395 as shown in (fig. 12). In the conical die the maximum equivalent stress without rubber 224MPa and maximum equivalent strain 0.224223 shown in (Fig. 10)and when the rubber is used the maximum equivalent stress was 215 MPa and maximum equivalent strain 0.690767 as shown in (Fig. 13). In the square die the maximum equivalent stress without rubber 309MPa and maximum strain 0.344567 as shown in (fig. 11) and when the rubber is used the maximum equivalent stress 296 MPa and maximum strain 0.315487 as shown in(Fig. 14)From that it can be shown that

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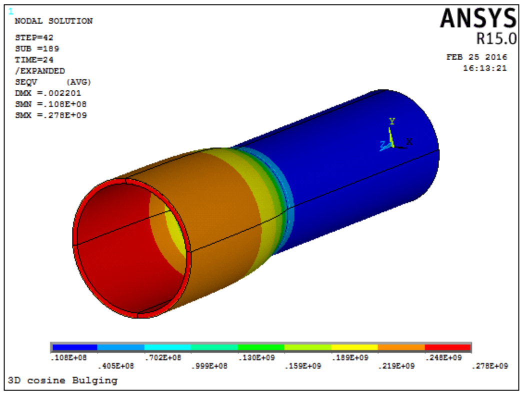
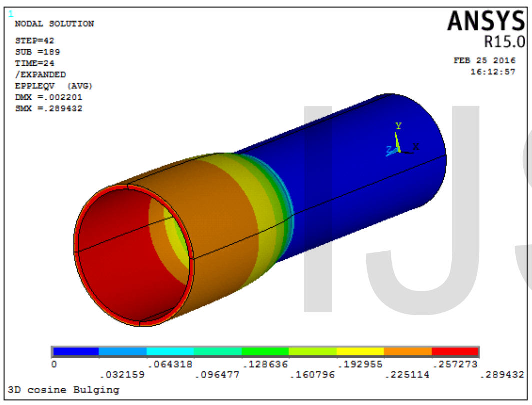
the wall tube's stress with the rubber media is about 12.84% smaller than with a hydraulic fluid as shown in table 3 .

5-1-1 case -1- cosine without rubber



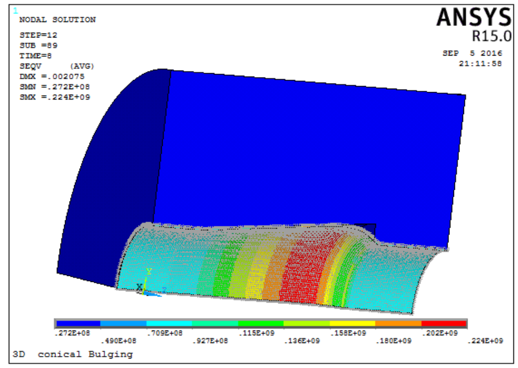
Figure(9) - (a)



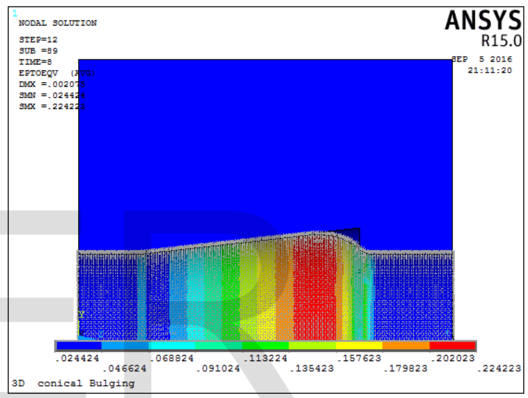
Figure(9) - (b)

Figure(9) cosine die a: equivalent stress b: equivalent strain

5-1-2 case -2- conical without rubber



Figure(10) – (a)



Figure(10) – (b)

Fig.(10) conical die a: equivalent stress b: equivalent strai

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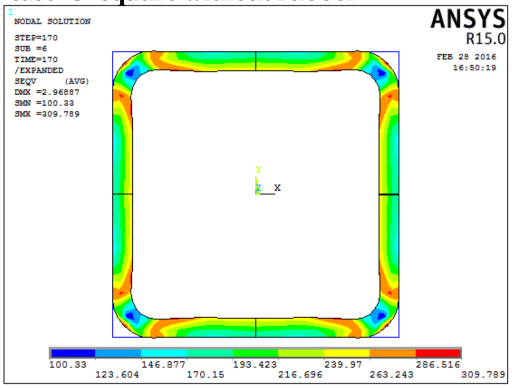
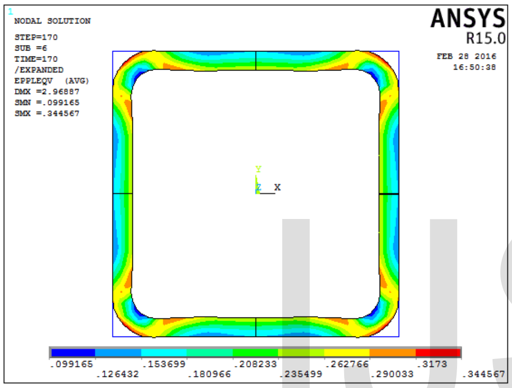
5-1-3 case -3- square without rubber



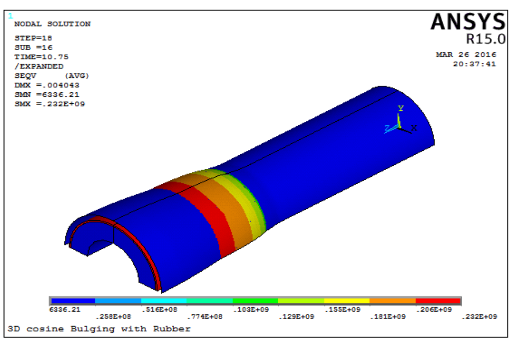
Figure(11) - (a)



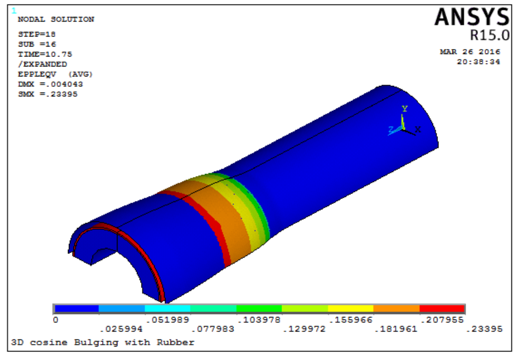
Figure(11) - (b)

Figure(11) square die a: equivalent stress b: equivalent strain.

5-2-1 case -1- cosine with rubber



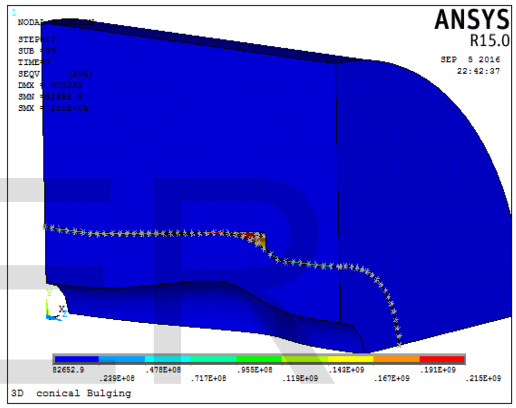
Figure(12) – (a)



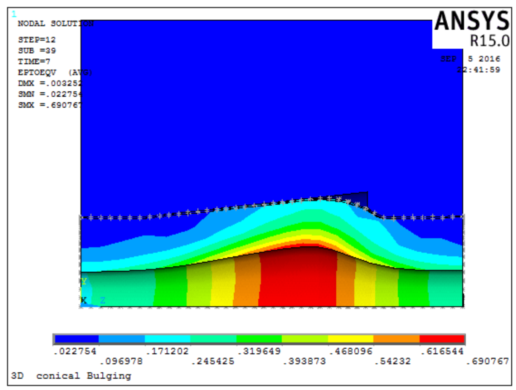
Figure(12) - (b)

Figure(12) cosine die a: equivalent stress b: equivalent strain.

5-2-2 case -2- conical with rubber



Figure(13) - (a)



Figure(13) - (b)

Figure(13) conical die a: equivalent stress b: equivalent strain.

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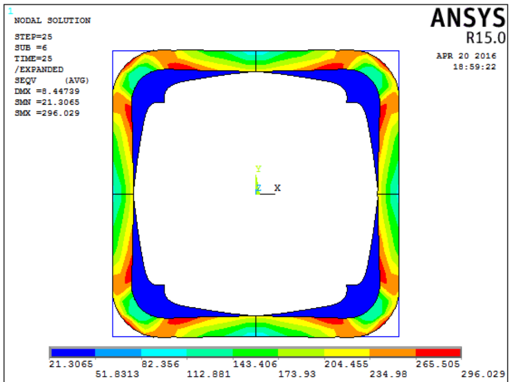
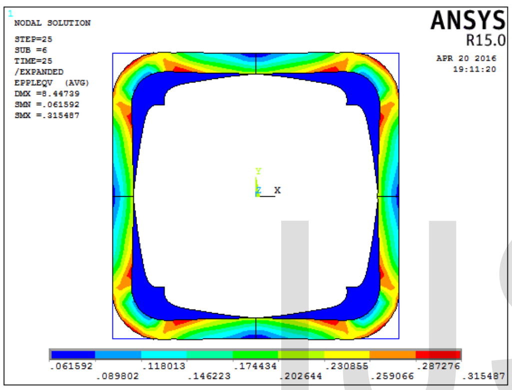
5-2-3 case -3- square with rubber



Figure(14) - (a)



Figure(14) - (b)

Figure(14) square die a: equivalent stress b: equivalent strain.

Table (3) shows the differences in equivalent stresses with and without rubber.

Bulge configuration	Equv. stress without rubber [MPa]	Equv. Stress with rubber [MPa]	Discrepancy%
Cosine	278	232	16.54
Conical	224	215	4.01
square	309	296	4.20

6-Conclusions

In this study the ANSYS is used to design and simulate the three dies configuration(square ,cosine and conical) to observe the media effect of hydraulic and rubber material that caused the internal pressure on the bulging tube .It's found the stress is decreased about 16.54% when the rubber is the media of the internal pressure in case of cosine die and 4.01% when the rubber is the media of the internal pressure in case of conical die and 4.20% when the rubber is the media of the internal pressure in case of square die .So it can be concluded that using the rubber media to produce the internal pressure in tube is much better than the hydraulic in bulging process. .

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