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Stress Analysis of Mandrel Used In Pilger Technology

Ruchil A. Patel[1], Apurvkumar Patel[2], Rajesh Kumar[3], Dr. D. V. Patel[4]
[1, 2, 3,4]*Mechanical Engineering, GTU, Ahmedabad*

Abstract—Cold pilgering is one type of metal forming process in which the thickness and diameter of the tube reduces up to 65 to 70 percentage. It is generally chosen for its dimensional accuracy controlled by ratio of diameter to thickness reduction. In pilgering process, the profile of the roller die and mandrel is very important because the outer diameter surface finish depends on the roller die profile and inside diameter surface depends on the mandrel profile. This article focuses on the stress analysis of different profiles of mandrel like: Linear (Taper) and Parabolic (Quadratic) Profiles.
Keywords—Analysis of mandrel Profiles, Linear, Parabolic, Quadratic, Pilger Technology, Tube Drawing, Stresses

I. INTRODUCTION

In current scenario, pilgering process is used in most of all the tube manufacturing industries. Its usefulness because of its high dimensional accuracy. In pilger machine minimum two roller die running in opposite direction and mandrel is tangent to these two dies. Outer diameter of tube depends upon the roller die and the inner diameter depends upon the mandrel diameter. Pilger machine can produce outer diameter up to 8mm to 230mm and thickness of tube up to 0.5mm to 30mm. Pilgering process can reduce the 90% of the cross section of copper material, 75% of stainless steel and 70% of high strength alloy like titanium alloy. In metal forming process compressive force is required which is provided by two roller die pressing the mother tube. There is a semi-circular groove on the circumference of the roller die. Radius of the curvature of this groove reduces continuously over the circumference. Generally the geometric shape of the mandrel is taken tapered. Working principal of the pilgering process is shown in the “Fig 1”, mother tube is continues fed over the mandrel. When the mother tube comes to working zone the roller die compresses the mother tube and translates in the forward direction also. It completes the forward stoke then it comes to the staring position of the working zone which is called backward stroke. When it completes one cycle 70-75% reduction of the diameter as well as thickness of tube is obtained .After performing number of small forming steps we get the desired product of tube.

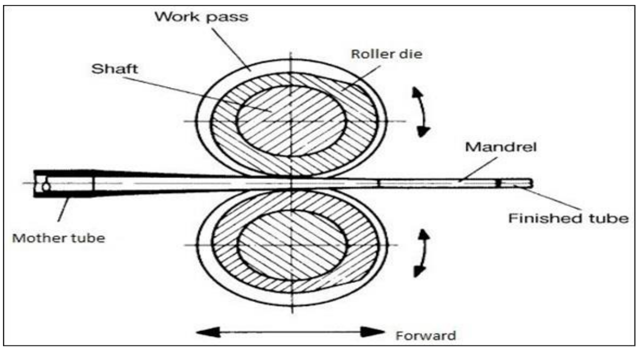

Fig 1: Working Principle of Pilger]

II. DETAILS OF MANDREL

Internal diameter and surface roughness of the Seamless tube depends on the mandrel. In the pilgering process the compressive force is applied by the two roller die to form the shape of mother tube as finished seamless tube required. There are mainly three types of geometric shapes:

1. Linear profile/Taper profile
2. Quadratic profile/Parabolic profile
3. Cosine profile

But mostly we use the tapper profile and quadratic/parabolic profile [1]. There is a direct contact between Roller Dies and the mother tube and tube is in the direct contact of mandrel, the relative motion between the tube inner surface and the mandrel causes friction between two surfaces. The value of proper coefficient of friction is very important [2]. In pilgering processes the mother tube continuously passes over the mandrel. The feed rate also affects the surface finishing [3]. Tool steel materials like H11, M4, D2, and H13 are preferred in design of mandrel. A taper mandrel profile is shown in the "Fig. 2". There are two zones in whole process of pilgering one is working zone in which 90% reduction occurs and another is Sizing zone which reduces remaining 10% of the diameter and the thickness. Sizing zone assures the accuracy of the surface finish. Normally more than 30KN compressive force is required to form a tube in the pilgering process applied by the roller. In the paper the geometric shape of mandrel optimize and applied force causes various effect on mandrel like deformation, surface wear, fatigue failure, stress produced in the mandrel, bending moment etc. In this paper we focus on these effects by analyzing the different parameters with the help of Ansys Software Package.

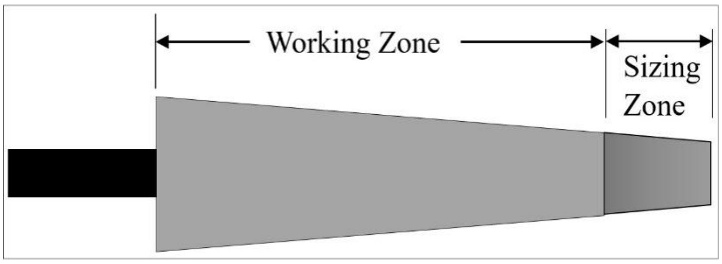

Fig 2: Different Zones of Mandrel

III. LOAD CALCULATION

Here the drawing stress produces due to tube draw. Use to slab method and find the drawing stress.

$$\sigma_d = \left(\frac{2\sigma_0}{\sqrt{3}}\right)\left(\frac{1+\beta}{\beta}\right)\left[1-\left\{\frac{h_2}{h_1}\right\}^{\beta}\right] + \sigma_b\left\{\frac{h_2}{h_1}\right\}^{\beta}$$

σ_d = Drawing stress
σ_b = Back pull tension
h_1 = Intial thickness tube
h_2 = Final thickness tube
μ_1 = coefficient of friction between ring die and tube
μ_2 = Coefficint of friction between tube andmandrel
α = Mandrel taper angle

Take $\sigma_0 = 290\,\frac{N}{mm^2}$, for steel

$$\sigma_b = \frac{\alpha*\sigma_0}{2\sqrt{3}} = \frac{2*280}{2\sqrt{3}} = 161.658\,\frac{N}{mm^2}$$

$$\beta = \frac{\mu_1+\mu_2}{\tan\alpha} = \frac{0.2+0.06}{\tan 2} = 7.445$$

Put the all value in above stress equation,

$$\sigma_d = \left(\frac{2\sigma_0}{\sqrt{3}}\right)\left(\frac{1+\beta}{\beta}\right)\left[1-\left\{\frac{h_2}{h_1}\right\}^{\beta}\right] + \sigma_b\left\{\frac{h_2}{h_1}\right\}^{\beta}$$

$$\sigma_d = [(334.863 * 1.134)(1-0.00241)] + [161.658 * 0.0024]$$

$$\sigma_d = 379.207\frac{N}{mm^2}$$

Area of cross section at exit $= \pi dt = \pi * 19.05 * 1.78$
$= 106.52mm^2$

Drawing load $=$ Drawing stress $*$ Area of exit
$= 379.207 * 106.52$
$= 40393.197\ N$

IV. STRESS ANALYSIS OF MANDREL

Here using the Ansys workbench 15.0 the analysis of mandrel geometric shape and optimize the geometric shape. Ansys software gets very high accuracy result of analysis. Mandrel deformation, stress, fatigue and safety factor analysis use the software. In FEA analysis involve the three phase
(1)Pre-processor phase
(2)Solution phase
(3)Post processor
Using the "Creo 2.0" to generate the geometry of mandrel and this geometry use in Ansys. In Ansys the mandrel both geometry meshing and approximate divide the 6050 elements of mandrel show in "Fig.3"

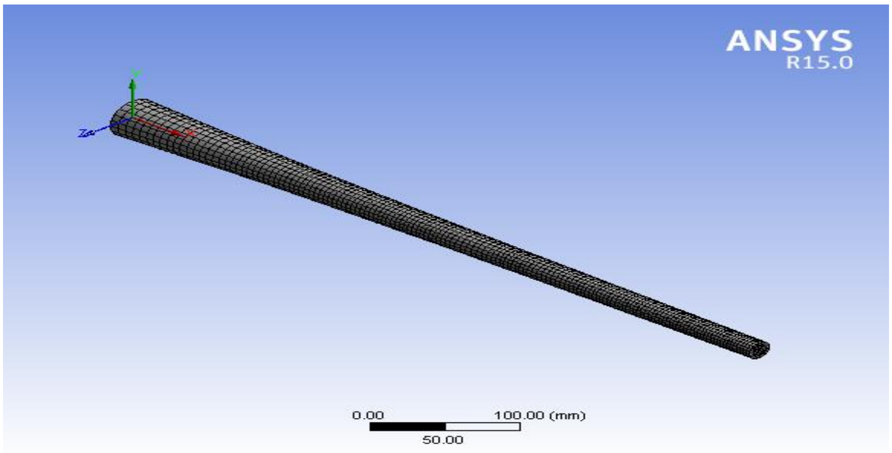

Fig 3: Meshing of Mandrel

After the meshing and the compressive load applying on the mandrel.

4.1 Analysis of linear profile mandrel

Table: 1 Geometry data (linear)

Length X (mm)	Length Y,Z (mm)	Mass (kg)	Volume (mm^3)	Element	Node
590	42.05	2.75	3.527E+05	6063	28914

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Analysis result table for linear profile mandrel.

Table: 2 Stress analysis results data for linearprofile mandrel

Sr. no.	Analysis type	Minimum	Maximum	Figure no.
1.	Equivalent (von-Mises) Stress (MPa)	1.2407	309.28	4
2.	Maximum Principal Stress (MPa)	-25.234	97.265	-
3.	Minimum Principal Stress (MPa)	-381.38	7.5444	-
4.	Maximum Shear Stress (MPa)	0.71138	178.07	-
5.	Normal Stress (MPa)	-226.88	82.74	5
6.	Shear Stress (MPa)	-172.75	170.86	-
7.	Maximum Principal Elastic Strain (mm/mm)	-3.1976e-005	8.4679e-004	6

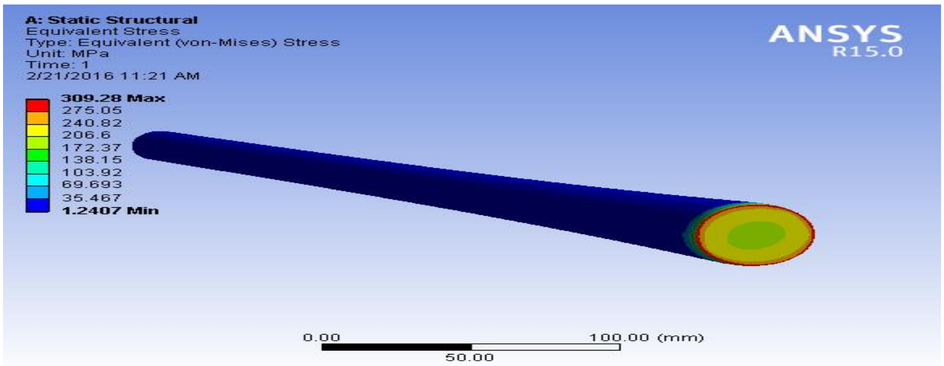

Fig 4:Equivalent (von-Mises) Stress in Mandrel(linear)

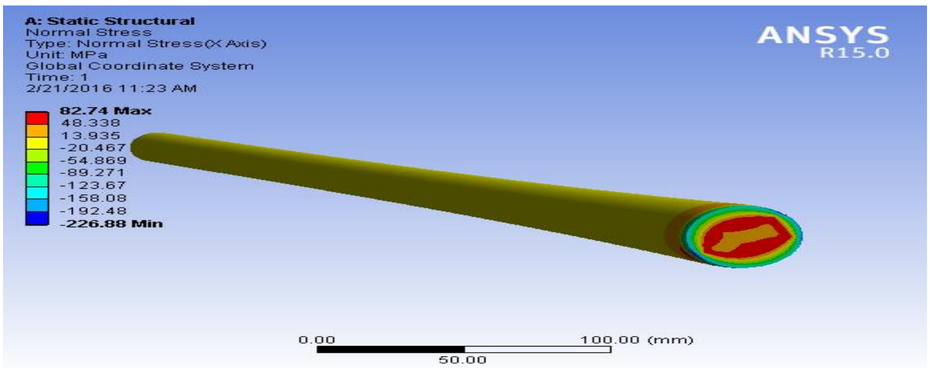

Fig 5:Normal Stress

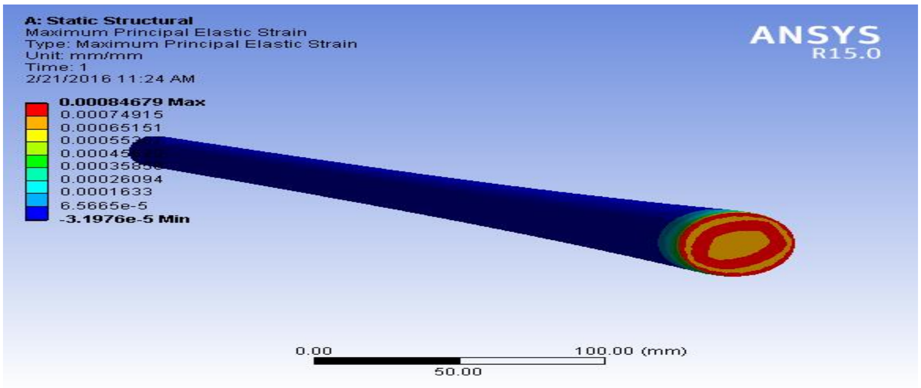

Fig 6:Maximum Principal Elastic Strain

4.2Analysis of Parabolic profile mandrel

Table: 3 Geometry data (Parabolic)

Length X (mm)	Length Y,Z (mm)	Mass (kg)	Volume (mm^3)	Elemen t	Node
590	42.05	2.64	3.3866E+005	6108	29118

Analysis result table for paraboli profile mandrel.

Table: 4 Stress analysis results data for parabolicprofile mandrel

Sr. no.	*Analysis type*	*Minimum*	*Maximum*	*Figure no.*
1.	*Equivalent (von-Mises) Stress (MPa)*	*0.20674*	*5.4463*	*7*
2.	*Maximum Principal Stress (MPa)*	*-0.79742*	*4.6291*	*-*
3.	*Minimum Principal Stress (MPa)*	*-5.8103*	*-0.32453*	*-*
4.	*Maximum Shear Stress (MPa)*	*0.11169*	*2.827*	*-*
5.	*Normal Stress (MPa)*	*-2.0782*	*3.3231*	*8*
6.	*Shear Stress (MPa)*	*-0.68582*	*0.75606*	*-*
7.	*Maximum Principal Elastic Strain (mm/mm)*	*1.051e-007*	*2.2289e-005*	*9*

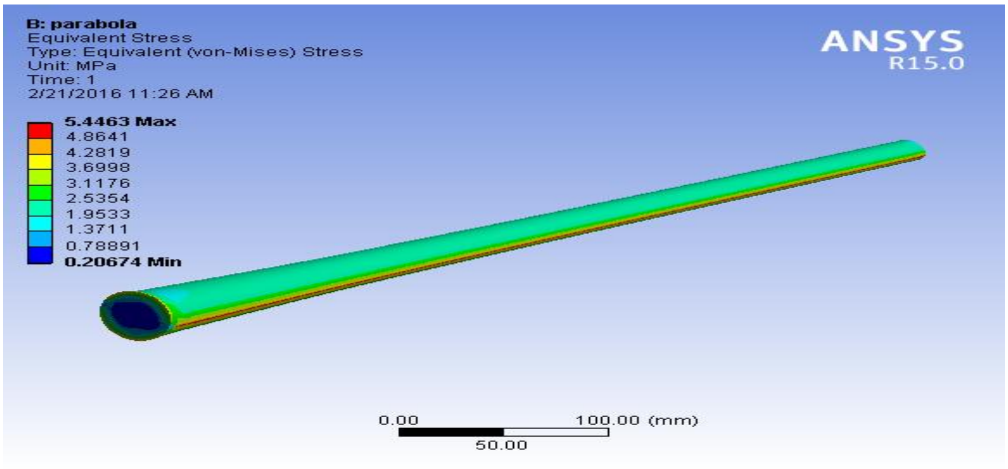

Fig 7:Equivalent (von-Mises) Stress in Mandrel(linear)

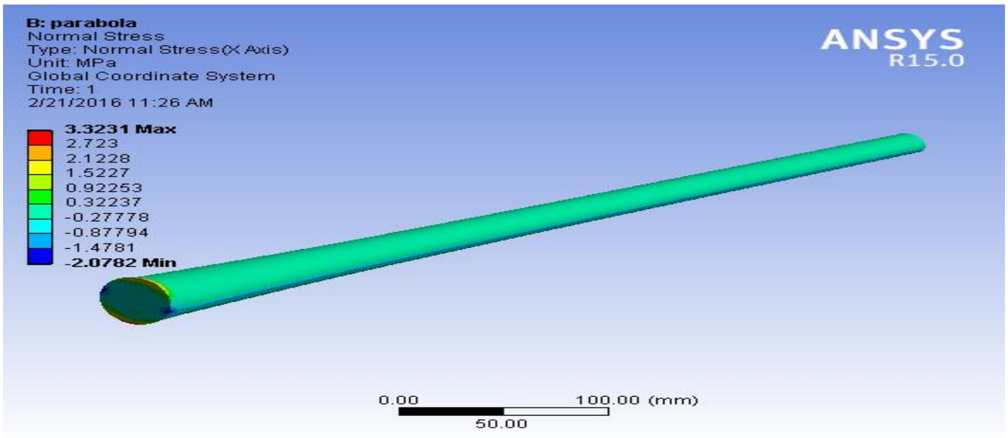

Fig8 :Normal Stress

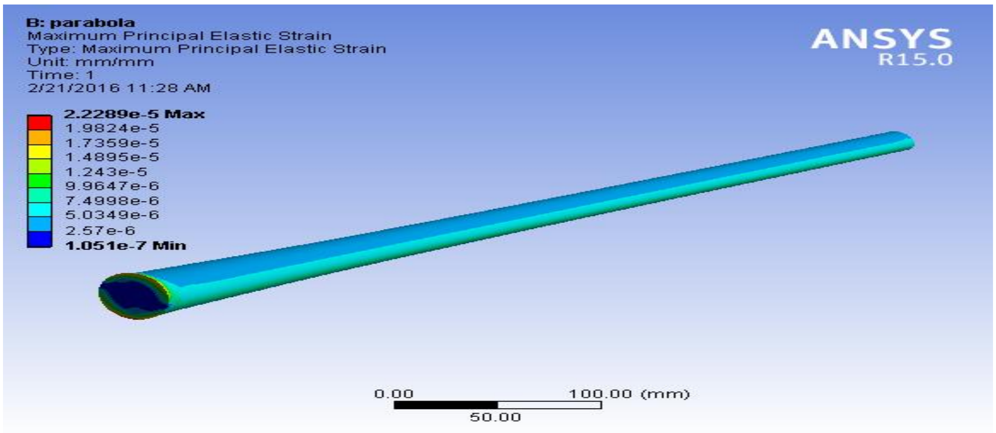

Fig 9:Maximum Principal Elastic Strain

V. CONCLUSION

Table: 5Comparison of results

Sr. no.	Analysis type	Linear profile		Parabolic profile	
		Minimum	Maximum	Minimum	Maximum
1.	Equivalent (von-Mises) Stress (MPa)	1.2407	309.28	0.20674	5.4463
2.	Maximum Principal Stress (MPa)	-25.234	97.265	-0.79742	4.6291
3.	Minimum Principal Stress (MPa)	-381.38	7.5444	-5.8103	-0.32453
4.	Maximum Shear Stress (MPa)	0.71138	178.07	0.11169	2.827
5.	Normal Stress (MPa)	-226.88	82.74	-2.0782	3.3231
6.	Shear Stress (MPa)	-172.75	170.86	-0.68582	0.75606
7.	Maximum Principal Elastic Strain (mm/mm)	-3.1976e-005	8.4679e-004	1.051e-007	2.2289e-005

- In the article, we compare both geometric profile of mandrel and we get stress result the most suitable geometric shape of mandrel is parabolic profile. The parabolic profile have long working life the compare of linear profile.
- The total deformation of parabolic profile less then compare of linear profile.
- The mass of parabolic profile is also less compare to linear profile.

REFERENCES

i. J. park, a, s. s. kim, “optimum design of a pilger mill process for wire forming using cad/cae”material science forum vols (475-479),p3275-3278.
ii. Dr.tecn.oachin danckert, dr.benny endelf, “analyze the drawing of precision tubes” 7th European ls-dyna conference.
iii. S.muot, hacquin, p.Montmitonner” a fully 3d finite simulation of cold pilgering”journal of material processing technology, 60(1996)505-512.
iv. B.L.Juneja,”Fundamentals of Metal Forming Processes “, new age international publishers, 2009 second edition.
v. Swadesh kumar sing,”production technology” made easy publication frist edition 2012
vi. Haideri farazdak, “CAD/CAM and automation” 6th edition, nirali prakashan 2009
vii. P.C.Sharma” a textbook of production engineering “S.chand publication, 2007, 7th edition