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Analysis of Mandrel use in Pilger Technology

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***Abstract*—Cold pilgering is one type of metal forming process and complex tube making process in which the diameter and thickness of the tube reduces up 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 design and optimization of mandrel geometric shape the mandrel. In the paper use to linear profile and parabolic profile of mandrel and made of H11 material with the help of ANSYS software package.**

Keywords- Pilger; mandrel; quadratic; FEA

I.INTRODUCTION OF PILGER PROCESS

Now a day's all tube manufacturing industries use the pilgering process. The pilgering process is one of the metals forming process to make high dimensional accuracy of tube. In pilger machine there is two roller die and a mandrel tangent to these two rollers. 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.

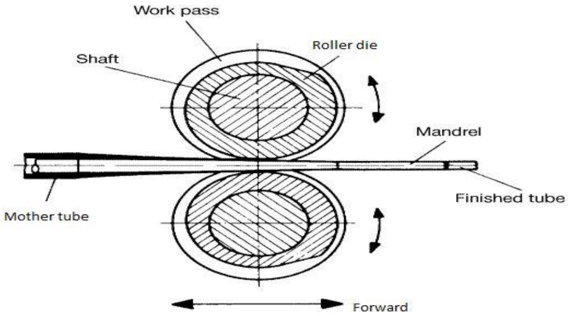

Fig.1 Working of Pilgering Process

II.ABOUT 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, 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 10KN 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.

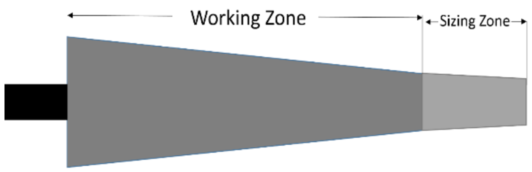

Fig.2 Mandrel Zone

III. CALCULATIONS

- DrawiHere 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 and mandrel
α = Mandrel taper angle

Take $\sigma_0 = 280 \frac{N}{mm^2}$, 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,

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

$$\sigma_d = [(323.316 * 1.134)(1-0.00241)] + [161.658 * 0.0024]$$

$$\sigma_d = 366.14 \frac{N}{mm^2}$$

$$\text{Area of cross section at exit} = \pi d t = \pi * 19.05 * 1.78 = 106.52 mm^2$$

$$\text{Drawing load} = \text{Drawing stress} * \text{Area of exit} = 366.14 * 106.52 = 39001.753 \text{ N}$$

IV. 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 6000 elements of mandrel show in "Fig.3"

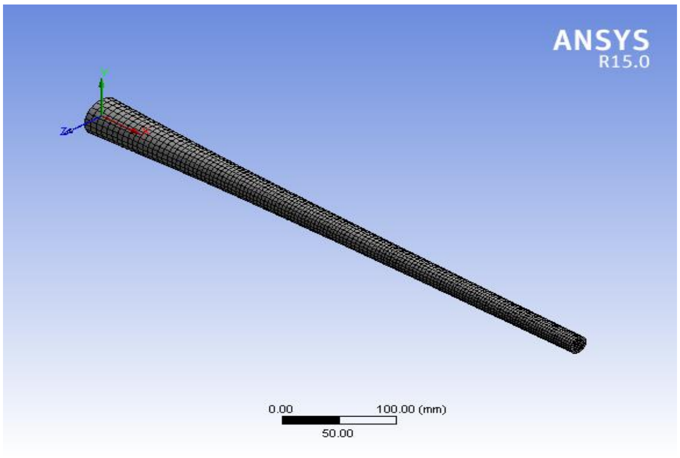

Fig.3 meshing of mandrel

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

A. Analysis of linear profile mandrel

- Geometry data 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

- Analysis result table for linear profile mandrel.

Table 2 Analysis result data (linear)

Analysis type	Minimum	Maximum	Figure no.
Total Deformation(mm)	0	0.00179	4
Equivalent Stress(Mpa)	0.21441	5.2351	5
Life(cycle)	42276	1E+006	6
Equivalent Alternating Stress(Mpa)	7.1471	174.5	-
Safety Factor	0.49397	12.06	-

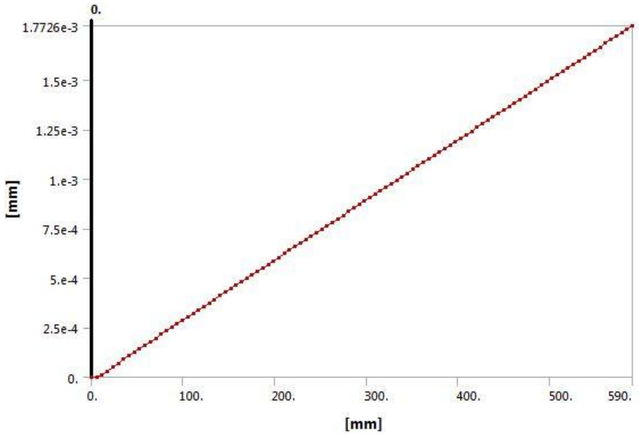

Fig.4 Total deformation (linear)

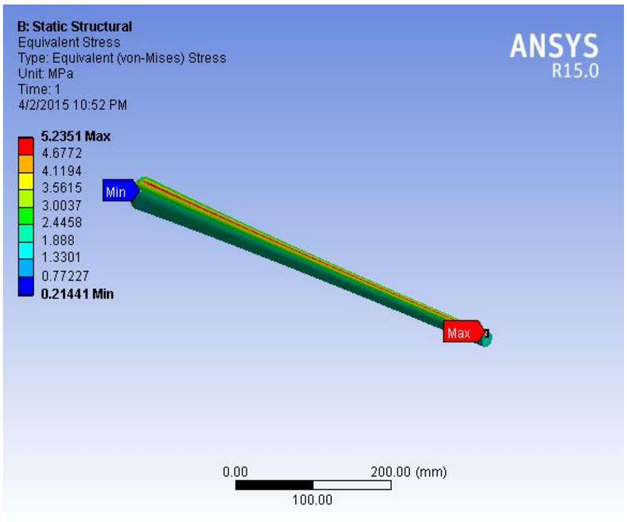

Fig.5 Equivalent Stress (linear)

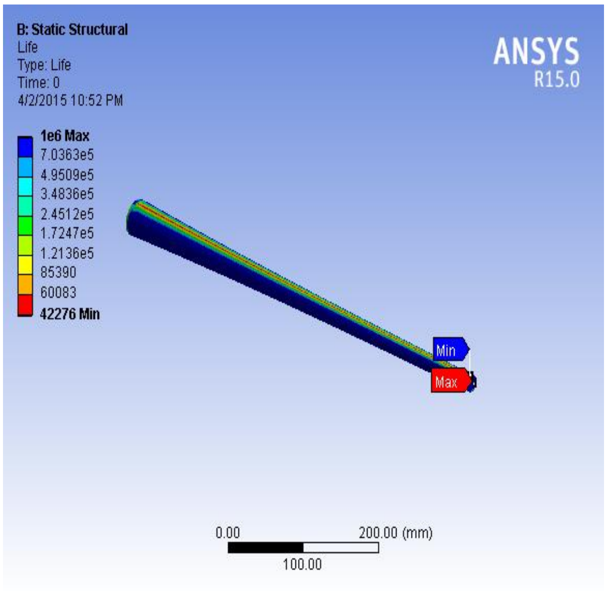

Fig.6 Life (linear)

B. Analysis of parabolic profile mandrel

- Geometry data of parabolic profile mandrel.

Table 3 Geometry data (parabolic)

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

- Analysis result table for parabolic profile mandrel.

Table 4 Analysis result data (parabolic)

Analysis type	Minimum	Maximum	Figure no.
Total Deformation(mm)	0	0.00180	7
Equivalent Stress(Mpa)	0.21846	5.3253	8
Life(cycle)	39708	1E+006	9
Equivalent Alternating Stress(Mpa)	7.282	177.5	-
Safety Factor	0.48561	11.387	-

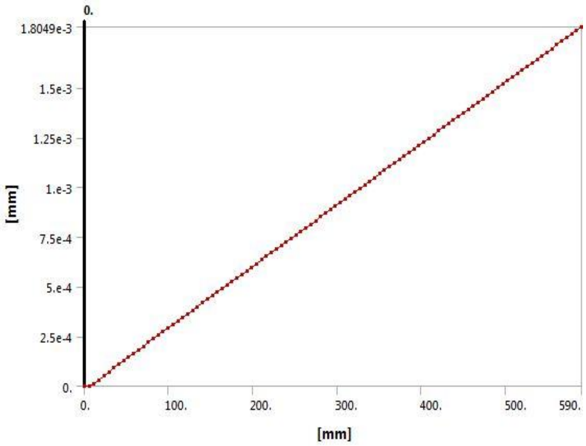

Fig.7 Total deformation (parabolic)

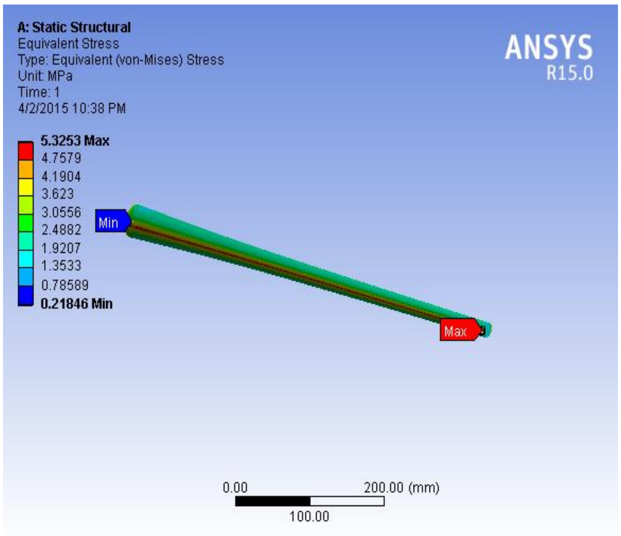

Fig.8 Equivalent Stress (parabolic)

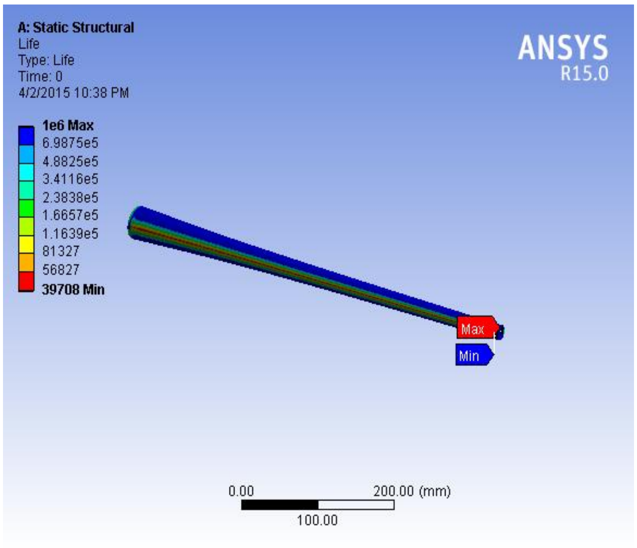

Fig.9 Life (parabolic)

ACKNOWLEDGMENT

Table 5 comparison of result

	Parabolic profile		Linear profile	
Analysis type	Minimum	Maximum	Minimum	Maximum
Total Deformation(mm)	0	0.00180	0	0.00179
Equivalent Stress(Mpa)	0.21846	5.3253	0.21441	5.2351
Life(cycle)	39708	1E+006	42276	1E+006
Equivalent Alternating Stress(Mpa)	7.282	177.5	7.1471	174.5

- In the paper the both geometry shape compare and get the result the linear profile shape of mandrel have better working life to compare the parabolic profile shape.
- The total deformation of linear profile geometry small to compare the parabolic geometry.
- The linear geometry to easy design and manufacture to compare parabolic profile shape.

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