OPTIMIZATION OF PROCESS PARAMETERS FOR THE PRODUCTION OF SEAMLESS ROCKET MOTOR TUBE BY FLOW FORMING PROCESS

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ABSTRACT

'Flow Form Tube', is used as a Casing in various missiles to withstand generated thrust. It encases propellant and plays a vital role in missile thrust technology. The tube is supposed to with stand high temperature and pressures and should have high mechanical properties with more factor of safety. The aim of this work is to study the effect of various parameters like roller radius, stagger, hardness and feed on the final flow formed tube dimensions at different reduction rates on flow forming process of Rocket Motor Tube for various application in aerospace engineering and missile technology. The material chosen for study is MDN 250 (Maraging Steel). Ovality of the tube, Mean diameter, Surface finish and Thickness variation were also studied and it is found that in three stages of forming for the final pass to flow form for desired size .The MDN250 (Maraging Steel) for obtaining better Mechanical properties and its geometry, thickness and mean diameter.

KEY WORDS: MDN 250 (Maraging Steel), Preform, CNC flow forming machine, Ovality, Mandrel, Mean diameter, Surface quality, Roller radius, Stagger, Hardness and Feed.

INTRODUCTION

Flow forming technology has emerged as the most advanced metal forming technique due to its manifold advantages over conventional metal forming techniques such as extrusion and tube drawing. It is equally difficult to control thickness variations in the final product to less than about 25% of the blank thickness. From the above it will be seen that spinning is based on "LAW OF EQUAL AREAS" i.e. the superficial area of finished spun article should be the same as the area of blank from it is made Flow forming means shaping a product of sheet metal, tube or draw piece in one are more passes of the forming roll or rolls. The magnitude of wall thinning depends on the properties of the input material and the number of passes.
Flow forming is an effective method of manufacturing short series of precision tubular products of hard-to-deform materials, as well as short series of toothed products and profiled disks. The flow forming process requires smaller forming forces as compared to other metal forming processes. The pre-form is locked to the mandrel with serrations and rotates at the same speed along with it. In flow forming, the pre-form is elongated on the rotating mandrel

by means of mechanically guided rollers. The forming roller follows the contour of the mandrel with a preset gap. The gap between the rotating mandrel and the roller acts as an orifice through which the metal flow occurs. The machine stretches the preform on a rotating cylindrical mandrel by means of mechanically guided rollers from the initial wall thickness ‘t’ to final wall thickness ‘t_1’ in one or several working cycle. The relative changes in shape is defined there by as

% reduction in thickness

$R=\{(t_o- t_1)* 100\%\}/to$

Relative changes in shape of more than 85 to 95% can be achieved. The inside diameter of the preform & finished parts

METHODOLOGY

In flow forming, as shown schematically in Fig (1) & (2), the blank is fitted into the rotating mandrel and the rollers approach the blank in the axial direction and plasticize the metal under the contact point. In this way, the wall thickness is reduced as material is encouraged to flow mainly in the axial direction increasing the length of the work piece. The flow of metal directly beneath the roller consists of two components, axial and circumferential in two methods forward and Reverse direction as shown below.

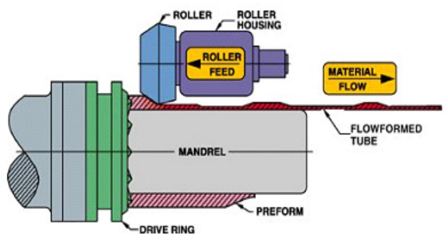


Fig 1: Reverse Flow Forming

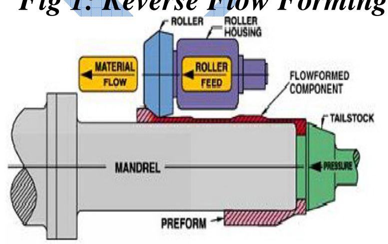


Fig 2: Forward Flow Forming

Experimental investigations have been carried out with the object of establishing process parameters related to MDN 250 Maraging Steel. The experiments have been carried out on LEIFEILD WEST GERMANY make, three roller flow forming machine .The mandrel rotates at a speed, S rpm. The roller travels parallel to the axis of the mandrel with a feed rate, F mm/min and decreases the wall thickness of pre-form when a thickness reduction t (%) is given by radial feed. The thickness reduction is effected by maintaining gap between the mandrel and the roller less than the thickness of the pre-form. The axial and radial feeds are maintained by hydraulic power pack through servo motors. The preform is reduced to a final wall thickness by elongating it without change in the inside diameter of the tube. Due to volume constancy, this reduction in thickness of the pre-form leads to an increase in length of the tube.

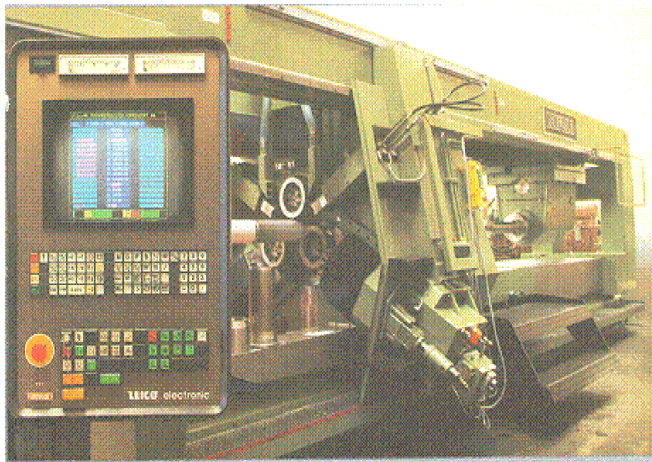


Fig 3: Flow-forming Machine

DESCRIPTION OF EQUIPMENT

It is a three roller CNC flow forming machine, Model ST 56-90, Leifeild make of West Germany.

The specifications of the machine are as follows.

1. Machine model : ST 56-90 CNC
2. Length of bed : 8150mm
3. Min. flow forming dia : 30mm
4. Max. Flow forming dia : 660mm
5. Max. flow forming length (Forward) : 2000mm
6. Max. flow forming length (Reverse) : 4000mm
7. Stroke of Tail stock cylinder : 2400mm
8. Total connected load of the machine : 375KVA

The CNC machine program used given as appendix – 1

The control panel which is fitted in the CNC control switch cabinet contains all switches and keys required for programming and for the programmed control of the machine.

The machine control form is

N3 G2 X +/- 3.2 Z+/- 3.2 W 100 R5 S150 F160 M3

Where,

N	:	Record No
G	:	Path function
X Y, Z, and W	:	Desired value of position
F	:	Feed mm/min
S	:	RPM of spindle
M	:	miscellaneous function
R	:	Radius

APPENDIX-1 (Program)

N 00	G	X	Y	Z	W	F	S	M
50	1	60	60	60	580	1200	-----	21
51		60	60	60	580	1200	----	----
52		60	60	60	580	1200	100	O3
53		60	60	60	580	1200	100	60
54		60	60	60	580	1200	100	68
55		20	20	20	580	800	100	----
56	01,64	9.81	11.04	14.45	540	200	100	----
57		9.81	11.04	14.45	530	100	100	----
58		9.00	12.15	15.3	520	50	100	----
59		9.00	12.15	15.3	332	50	100	----
60		60	60	60	332	1200	100	----
61		60	60	60	900	1200	100	----
62		10	10	10	900	500	110	----
63		5.18	6.21	9.59.	750	500	110	----
64		5.18	6.21	9.59	720	100	110	----
65		3.95	5.6	7.5	710	50	110	----
66		3.92	5.6	7.5	362	50	110	----
67		60	60	60	362	200	110	----
68		150	150	150	362	1200	110	O5
69		150	150	150	362	1200	-----	61
70		150	150	150	362	1200	-----	69
71		150	150	150	362	1200	-----	----
72		150	150	150	362	1200	-----	22

PLAN OF EXPERIMENT

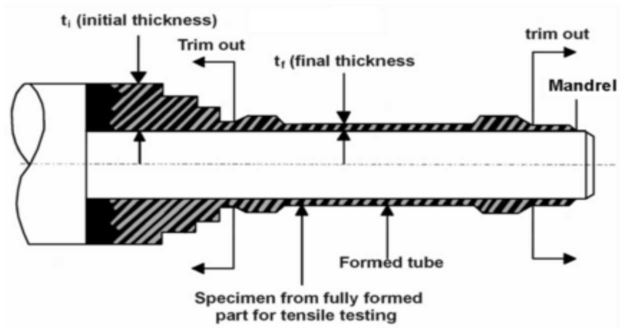
The total reduction in thickness is about88 to 90% and the reduction in each pass is limited to 50-60%. It is decided to carry out the flow forming operation in three passes.

The percentage reduction in each pass is given below

Sl No.	Pass No	Initial Thickness	Final Thickness	Initial hardness (HRC)	Final hardness (HRC)	Percentage Reduction
1	First	18.5	9.5	21	28	48.6
2	Second	9.5	4.6	28	30	51.5
3	Third	4.6	2.1	30	31	54.3

Table: 1 the percentage reduction in each pass

The approximate flow forming process parameters are set from theoretical data available. That data is then suitably adjusted based on the experimental results to give the required mean diameter, Ovality and thickness of the tube. Fig 3 shows the tubes at various stages of reductions.



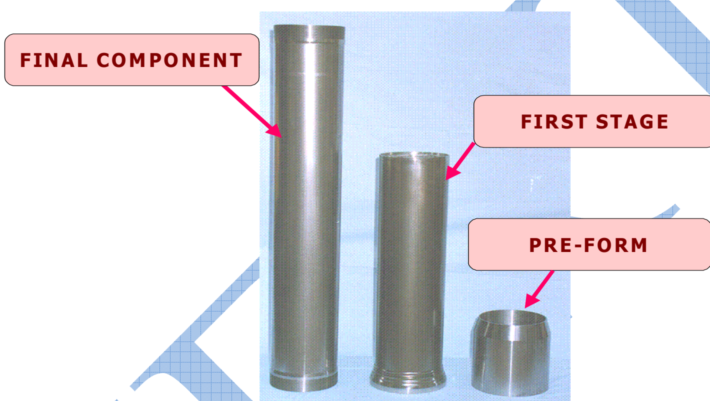


Fig 4: Machined Preform and its finish

RESULTS AND DISCUSSION:

This experiment was carried out to know the effect of feed rate on the surface finish, thickness and Ovality. The experiments were conducted with different feed rates in final pass. The other parameters that are kept constant are shown in appendix – 2.

APPENDIX – 2

Sequence of pass	Roller configuration			Stagger		Mandrel Speed (rpm)	Roller in Feed		
	X	Y	Z	X-Y	Y-Z		X	Y	Z
1	30 8 10	20 12 10	15 12 10	6.8	9	100	9	12.5	15.3
	30	20	30						

2	8 10	12 10	12 10	6.8	9	110	3.95	5.6	7.5
3	30 4 10	20 4 10	30 8 10	5.3	3	130	1.11	2.43	3.65

After flow forming of the components with different feed rates, the measured values of surface finish, Ovality and the thickness are tabulated in the table 4.9.

Expt no	Feed rate Mm/ Min	Surface Finish (inside) µm	Surface Finish (outside) µm	Mean dia In mm	Ovality Mm	Thickness In mm
1	40	0.59 0.58 0.61 0.57 0.59	2.8 2.7 2.9 3.2 2.9	202.3	0.35	2.0
2	45	0.63 0.61 0.65 0.62 0.63	3.03 3.04 3.02 3.05 3.03	202.2	0.25	2.05
3	50	0.68 0.69 0.67 0.69 0.68	3.2 3.3 3.1 3.4 3.2	202.1	0.2	2.1
4	55	0.74 0.73 0.75 0.76 0.74	3.3 3.1 3.5 3.2 3.3	202.2	0.23	2.15
5	60	0.78 0.77 0.75 0.76 0.77	3.46 3.47 3.45 3.48 3.47	202.25	0.3	2.2

Table:4.9 Variation of parameters with feed rate

MEAN DIAMETER

The effect of finishing roller radius against mean diameter on the finished tube was observed and results are shown in figure 5.3. It is observed that large nose radius of the roller will tend to increase mean diameter of the tube. Since larger nose radius of the roller will have larger contact and hence the roller will tend to increase the circumferential dimension. This is due to larger forces when the roller radius is high and which will create more spring back effect. It is also observed in figure 5.4 that change in stagger spread will also affect the mean diameter.

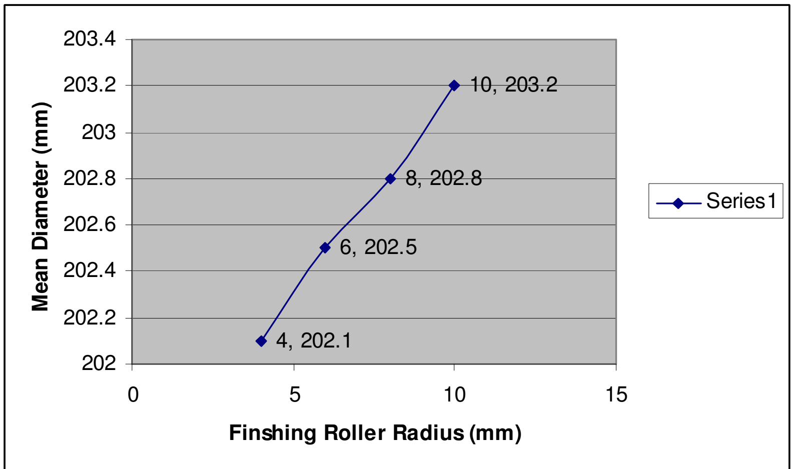


Fig 5: Variation of Mean Diameter with Roller Radius

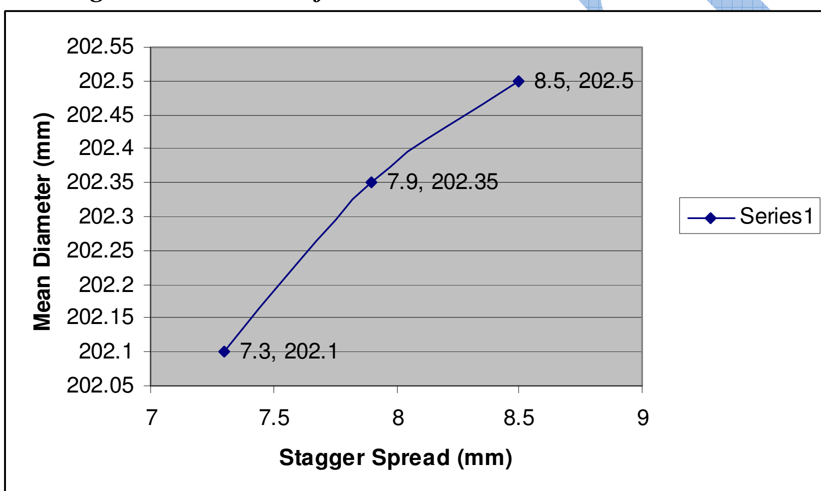


Fig 6: Variation of Mean Diameter with Stagger

THICKNESS VARIATION

The effects of hardness variation in the preforms against the thickness variation along the length of the tube were observed and results are mentioned in Fig 5.5. It is observed that large variations in hardness in the preforms will result in large thickness variations in the finished tube. The hardness variation in pre-form should be minimized (5 to 10 BHN) to avoid thickness variation and Ovality. This is because in homogeneity (hard sports, inclusions, uneven rate of cooling) in the material.

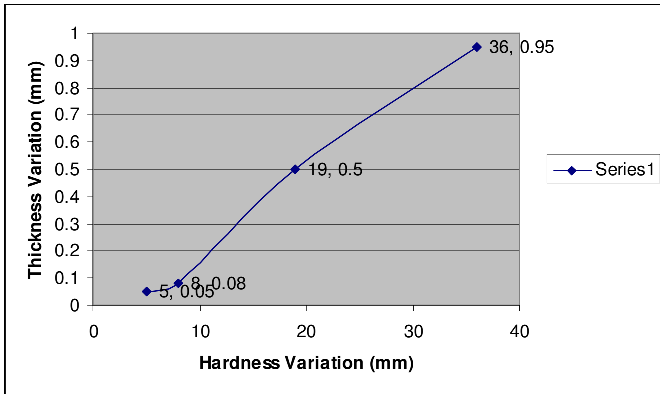


Fig 7 : Hardness Variation vs. Thickness Variation

OVALITY

Fig 5. 6 represent the effect of finishing roller radius against the Ovality of the tube. It observed that for smaller roller radius the Ovality is less when compared to the Ovality of tubes formed with large roller radius.

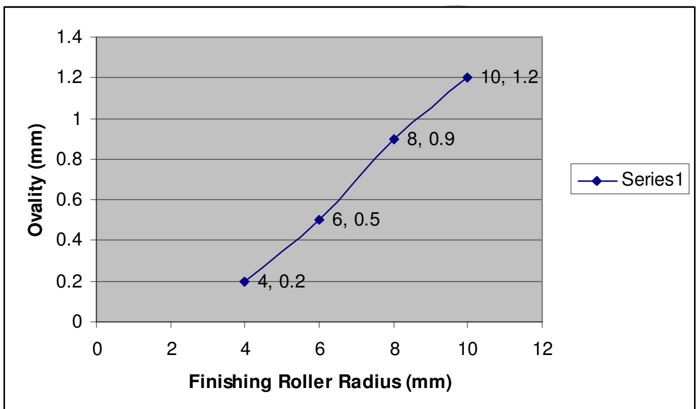


Fig 8: Variation of Ovality with Finishing Roller Radius

The effect of stagger spread against the Ovality of the tube was observed and results are mentioned in Fig. 8 it observed that when stagger spread is less the Ovality is less and increases with increase in stagger spread. The roller radius should be fixed at 4 mm to have uniform mean diameter and reduction in Ovality. It is observed that the increase at high feed rates the ovality is more and decreases up to a point and again starts increasing gradually feed this is due to non flow formed residual stresses.

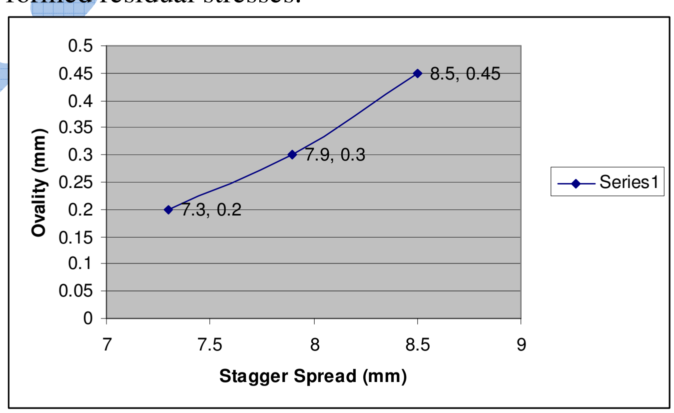


Fig 9: Variation of Ovality with Stagger Spread

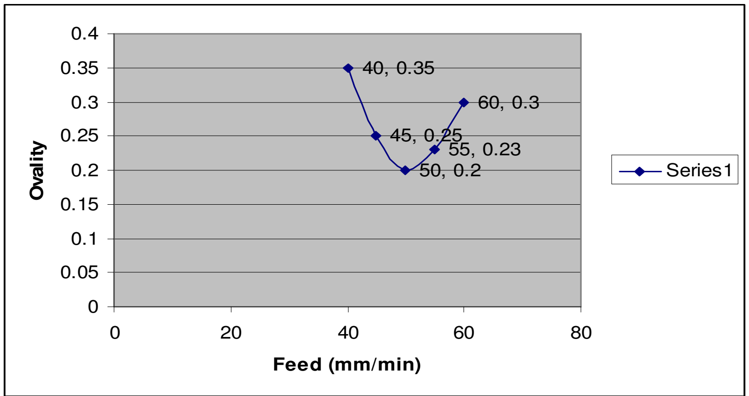


Fig 10: Variation of Ovality with Feed

SURFACE FINISH

The effect of feed against surface finish (inside and outside the tube) observed and results are shown in Fig 10 and 11. It is observed from the result, that the increase in feed the surface roughness (inside and outside the tube) increases. Lower feed rates improve the surface finish, but ovality and variation in mean diameter increases. Therefore feed is optimized at 50 mm/min.

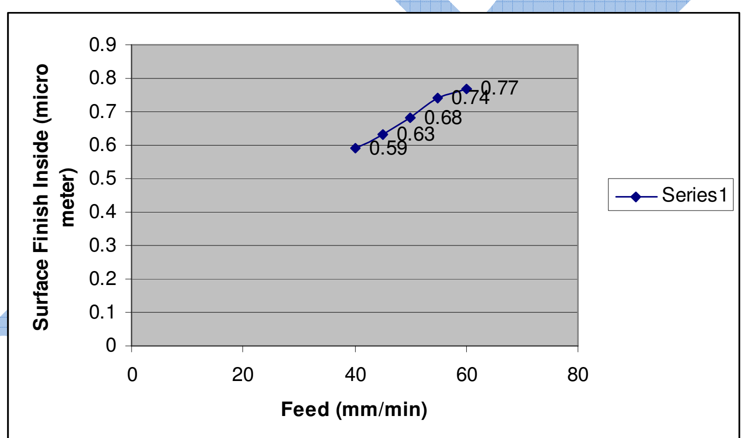


Fig 11: Feed vs. Inside Surface Finish

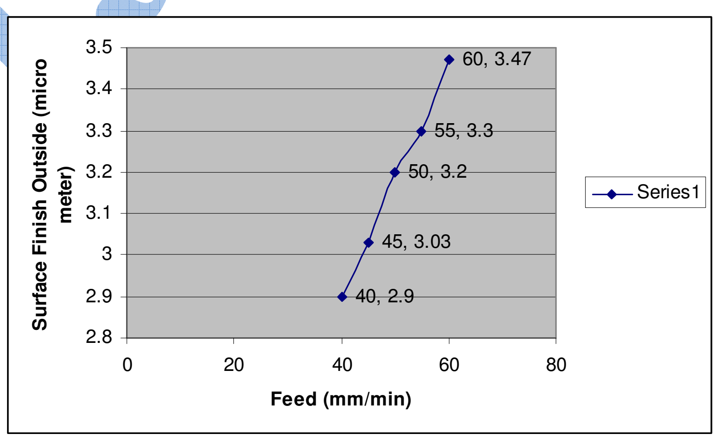


Fig 12: Feed vs. Outside Surface Finish

THICKNESS

The effects of feed against thickness are observed and results are present on Fig 12. It is observed that the effect of feed on thickness is very small i.e. with increase in feed rate the uncut chip thickness which will increase the thickness of the formed tube. Lower feed rates improve the surface finish, but ovality and variation in mean diameter increases. Therefore feed is optimized at 50 mm/min

Thickness reduction is optimized at 30% to Manu-facture tubes with good dimensional characteristics and surface qualities.

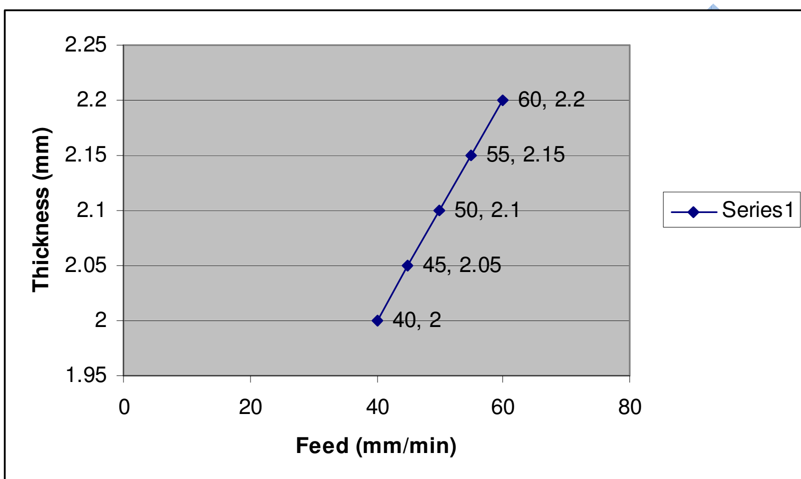


Fig 13: Feed vs. Thickness

HARDNESS

The hardness variation in pre-form should be minimized (5 to 10 BHN) to avoid thickness variation and ovality. The effect of percentage reduction in material against the hardness along the axial direction of the tube was measured and observed results are mentioned in Fig.13. It is observed from stage reduction the hardness is increase gradually. It is observed that after certain percentage of reduction there is no increase in hardness. The increase in hardness is due to continuous work hardening effect. Beyond certain reduction there is not much work hardening.

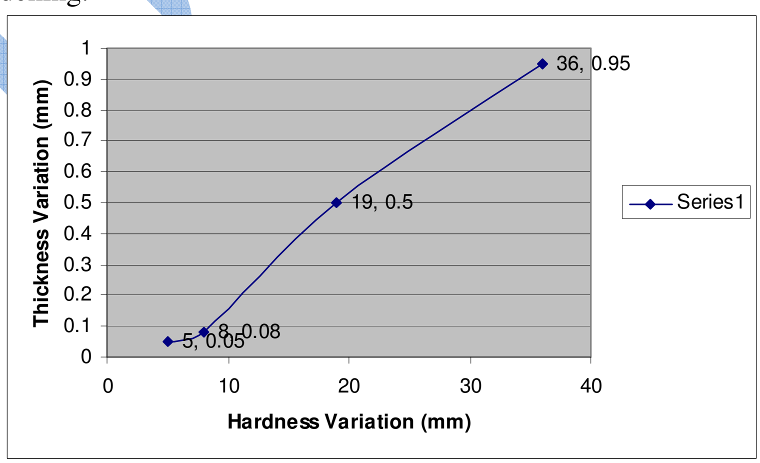


Fig 14: Hardness Variation vs thickness variation

CONCLUSIONS

Based on the experimental results and analysis made in the earlier chapter on flow forming tubes of MDN250 Maraging Steel, the following conclusion are drawn.

- The finishing roller radius should be lower than other two rollers to have uniform mean diameter and reduction in ovality. The roller radius should be fixed at 4 mm to have uniform mean diameter and reduction in ovality.
- The hardness variation in pre-form should be minimized (5 to 10 BHN) to avoid thickness variation and ovality. The hardness is increased up to 25-30% for 88% of thickness reduction. The geometrical accuracy becomes worse with the increment of thickness reduction.
- Lower feed rates improve the surface finish, but ovality and variation in mean diameter increases. Therefore feed is optimized at 50 mm/min. The speed of the mandrel is arrived at 100-130 rpm to produce the tubes with good surface qualities.
- Thickness reduction is optimized at 88% to manufacture tubes with good dimensional characteristics and surface qualities. The roughness of tube surface increases with increment of thickness reduction. Increase of the thickness reduction results in crystals refinement.
- The hardness variation in the preforms tube should be as less as possible to avoid thickness variation and ovality. Yield and tensile strength increment are 14% and 30% for 88% thickness reduction.
- The staggering of the rollers should be kept in such a way that there is a mini\mum of thickness of preforms tube.
- The feed rate is arrived at 50 mm/min on MDN250 (Maraging Steel) to obtain better ovality, thickness and mean diameter.
- Though reduction in feed rate improves surface finish, but its effect is there on ovality and mean diameter, therefore it is optimized at 50 mm/min

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