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Numerical investigation to predict the geometrical and mechanical properties of a flow-formed workpiece using 1.7220 steel

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Introduction

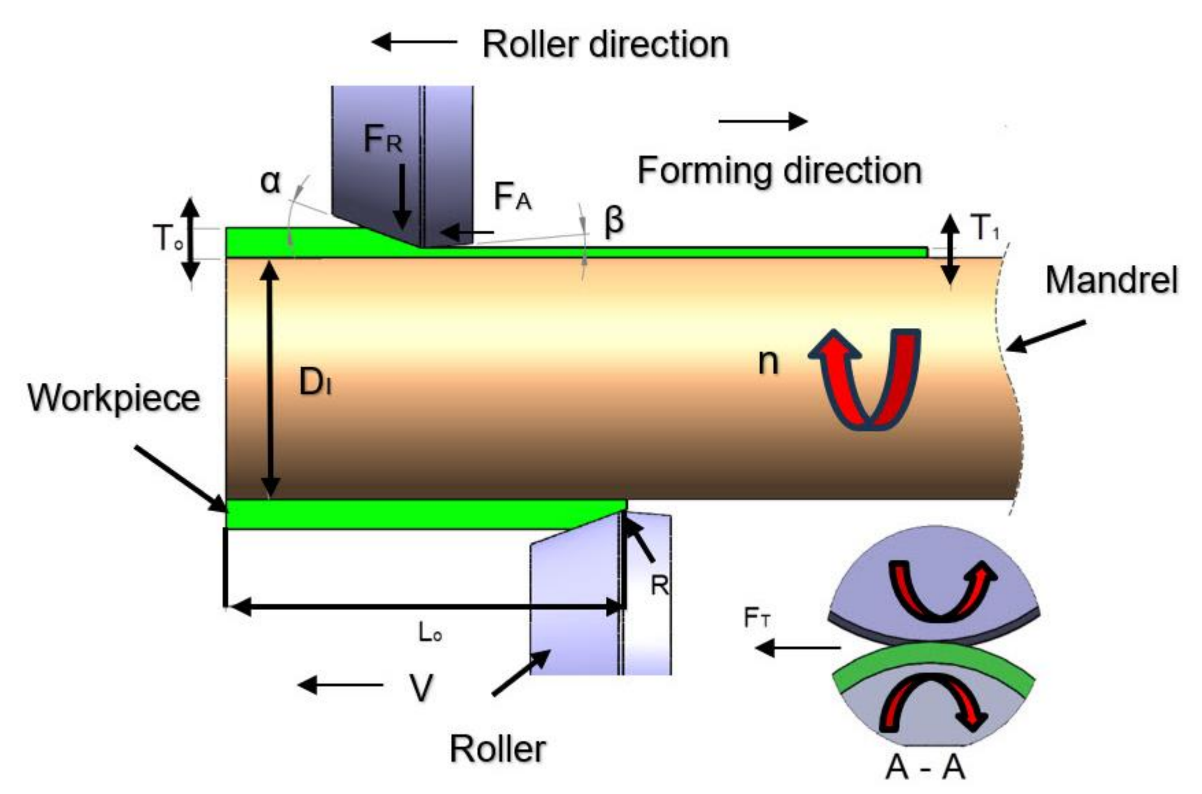

Figure 1 Principle of backward flow forming

Table 1 Descriptions of flow forming process parameters

S_O Starting wall thickness (mm)	γ Leading angle (degree,°)	F_A Axial force (N or Kg)
S_1 Finished wall thickness (mm)	δ Trailing angle(degree,°)	F_R Radial force (N)
L_O Starting length (mm)	R Nose radius(mm)	F_T Tangential force (N)
D_I Inside diameter (mm)	V Feed rate (mm/minute)	n Spindle Speed (rpm)

Finite Element Model

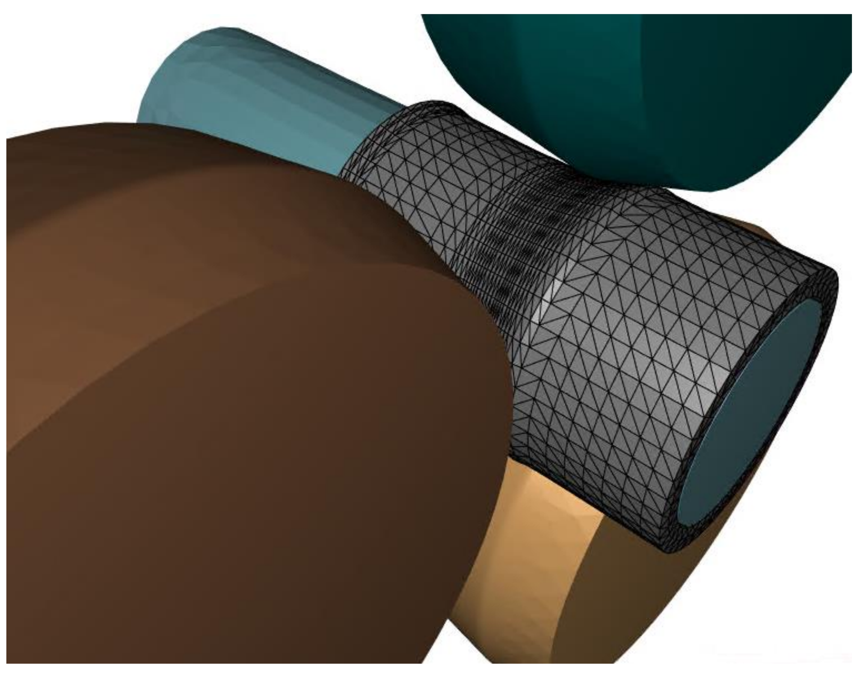

Figure 2 Mesh demonstration of the workpiece, roller, and mandrel

Re-meshing Model

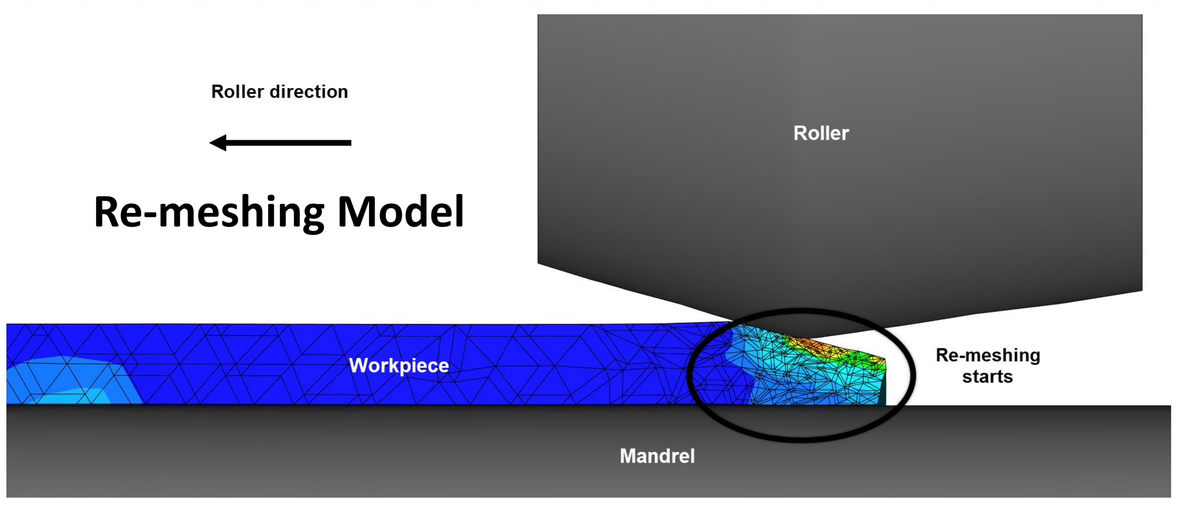

Figure 3 ALE re-meshing generation under the roller

Equations

Law Limited Tresca friciton model

$$\tau = \mu\sigma_n \quad \begin{cases} If & \mu\sigma_{n<\bar{m}} \frac{\sigma_0}{\sqrt{3}} & then & \tau = \mu\sigma_n \\ If & \mu\sigma_{n\geq\bar{m}} \frac{\sigma_0}{\sqrt{3}} & then & \tau = \bar{m}\frac{\sigma_0}{\sqrt{3}} \end{cases}$$

$$C_{CR} = \int_0^{\bar{\varepsilon}_f} \left(\frac{\sigma_{max}}{\bar{\sigma}}\right) d\bar{\varepsilon}$$

Von Mises Stress

$$\sigma_{eq} = \frac{1}{\sqrt{2}}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_1 - \sigma_3)^2]^{\frac{1}{2}}$$

$$\tau = \mu(\Delta' v\sigma_n)\Delta v$$

$$m = m_0 + m_1 T$$

$$\varphi_c = h(T - T_0)$$

$$\dot{W} = \eta c_{ij}\dot{\varepsilon_{ij}} = \eta K\sqrt{3}\bar{\varepsilon}^{m+1}$$

FEA Method

Table 2 FEA model contact features

Process parameters	
Roller-preform btw friction cof	0.075 – 0.15
Mandrel – preform btw friction cof	0.075 – 0.15
Interaction roller-mandrel-preform	20000 W/m2.k
Ambient (cooling)	5500 W/m2.k

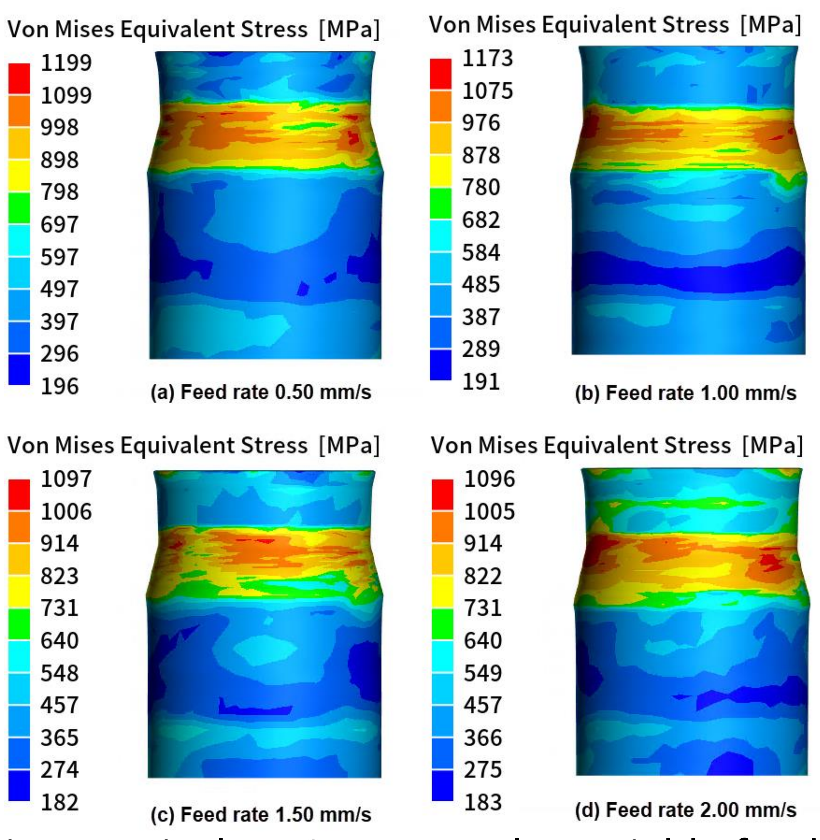

Figure 4 Von Mises Equivalent Stress results variable feed rates

FEA Results

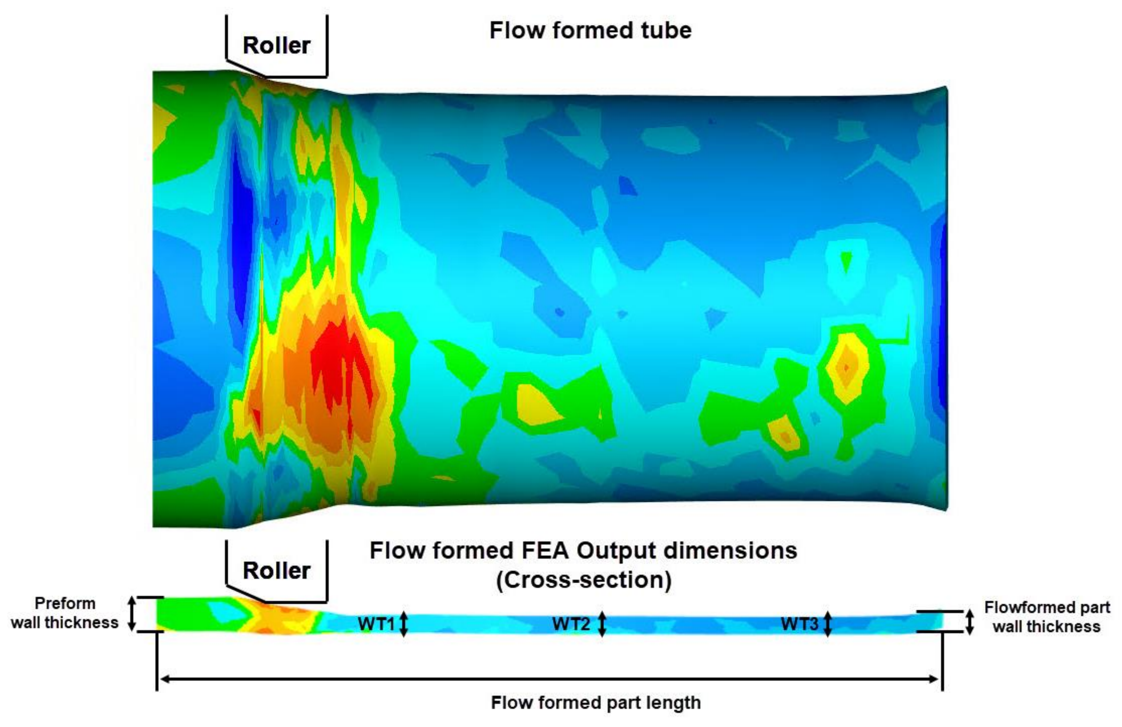

Figure 5 Flow formed part length and wall thickness measurement designation.

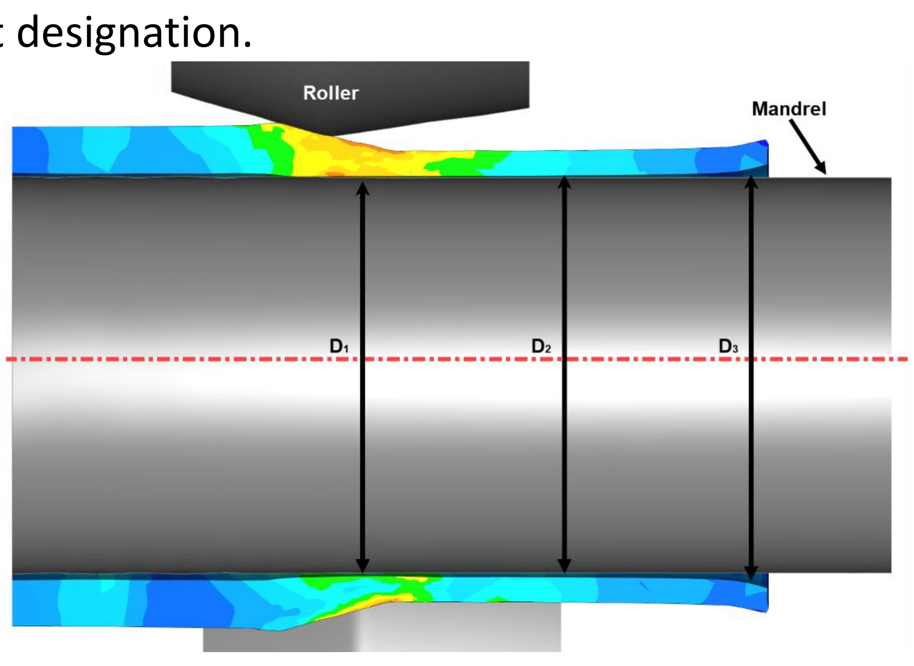

Figure 6 Cross section of the flow formed parts using variant feed rates from 0.25 mm/s (1) to 2 mm/s (8)

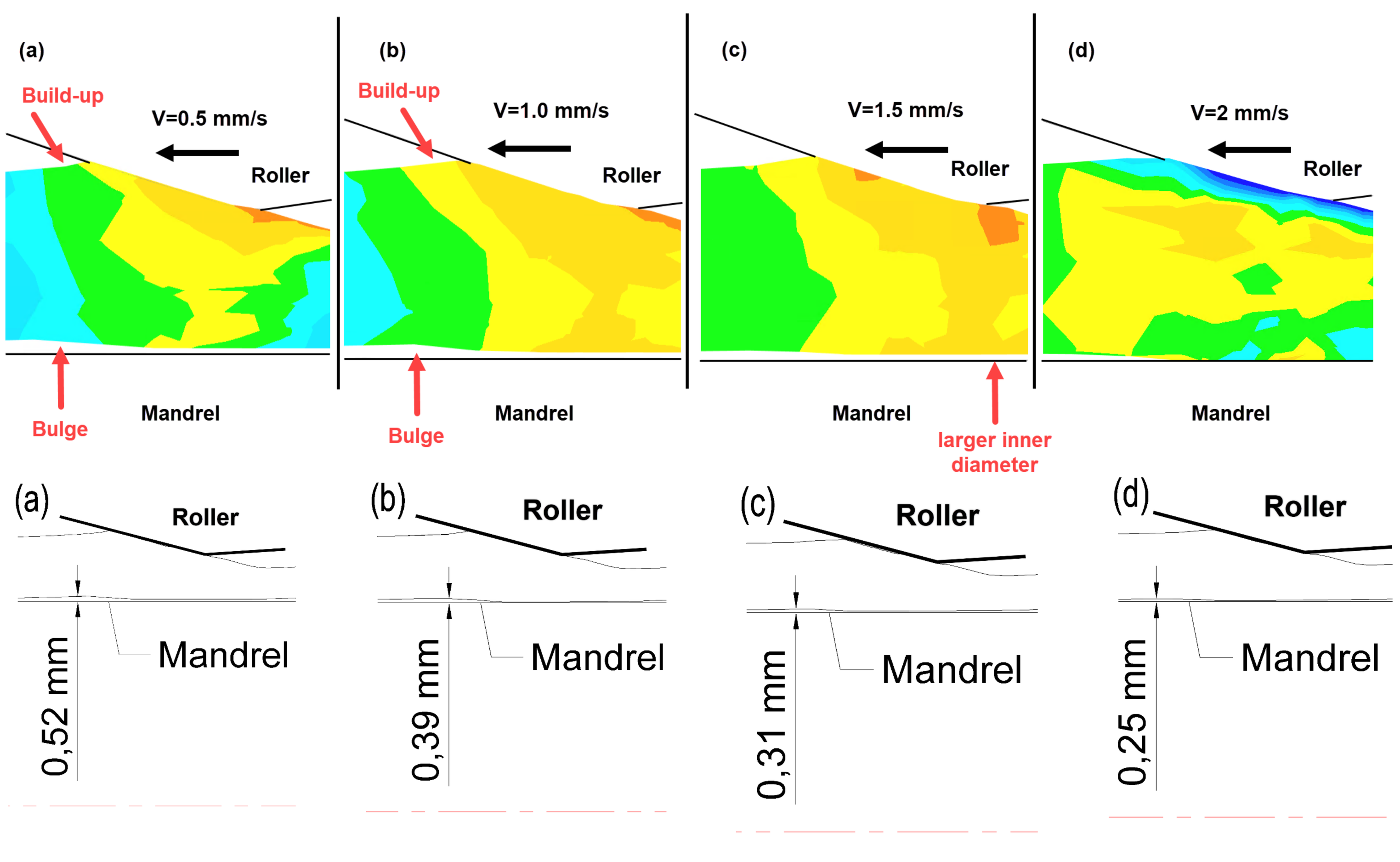

Figure 7 Bulge dimensions according to different feed rates

Samples	Input		Flowformed FEA Output	
	Feed rate (mm/s)	Mandrel (rpm)	Wall thickness (mm)	Mean inside diameter (mm)
1	0.25	220	2.97	50.83
2	0.5	220	3.00	50.70
3	0.75	220	3.05	50.63
4	1.00	220	3.08	50.53
5	1.25	220	3.11	50.44
6	1.50	220	3.12	50.31
7	1.75	220	3.13	50.21
8	2.00	220	3.14	50.17

Table 3 Wall thickness and mean inside diamater results

Conclusions

- It was observed that the outer surface of the workpiece exhibited higher strain values, which gradually decreased towards the inner diameter.
- The flow forming process frequently faces defects like built-up edges, bell-mouth formations, and diameter growth, which are heavily influenced by feed rate. These factors affect process accuracy, surface quality, and bulge formation.
- Lower feed rates cause greater radial deformation and diameter growth, whereas faster roller movements minimize plastic deformation defects, leading to smaller inner diameters and bulges in flow-formed tubes with short roller feed strokes.

References

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