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A numerical study of the effects of roller paths on dimensional precision in die-less spinning of sheet metal

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Roller path parameterization

- **Die-less spinning**: directly formed by the roller freely.

- In this study, the roller paths including concave, linear, convex and combined curves are all defined as three times Bezier curves:

$$P(u)=\sum_{i=0}^{3}B_{i,3}(u)V(i)=\sum_{i=0}^{3}C_3^i u^i(1-u)^{3-i}V(i)$$

- All the Bezier curves used in the study have been parameterized by the ratio of chord height to length(RHL):

$$RHL=(\pm)\frac{M_1M_2}{P_1P_4}$$

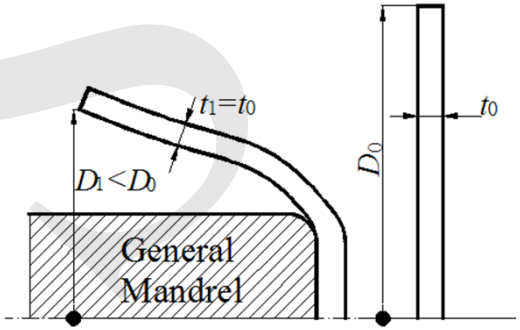
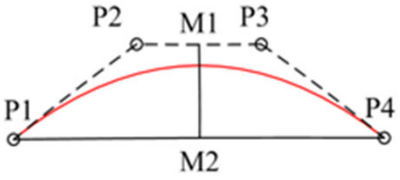


Fig. 1 Diagram of die-less spinning



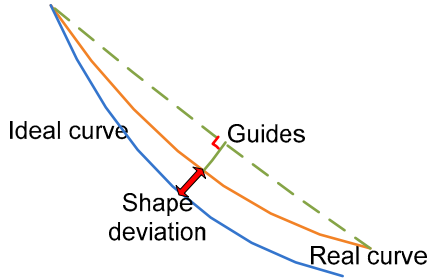
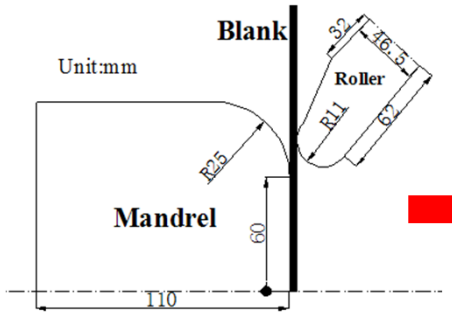
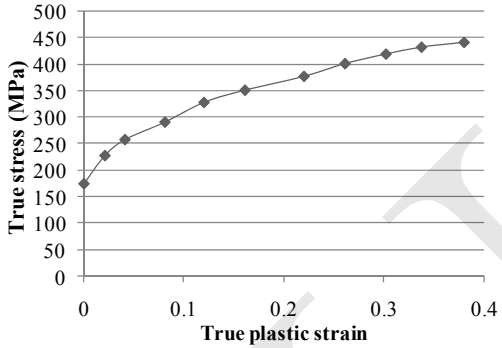


Fig. 2 Schematic diagram of roller paths and shape deviation definition.

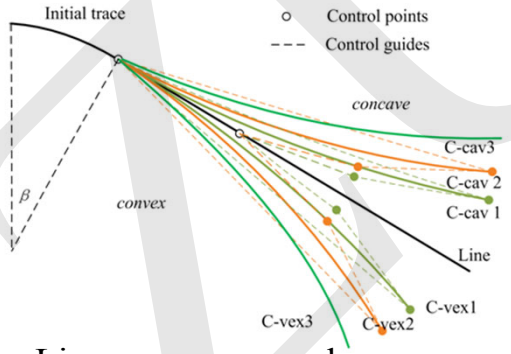
Simulation Model



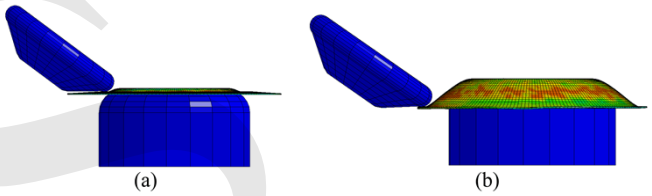
Schematic diagram of the spinning experiment



True stress-strain curve of mild steel



Linear, concave and convex roller paths used



FE simulation model of die-less spinning

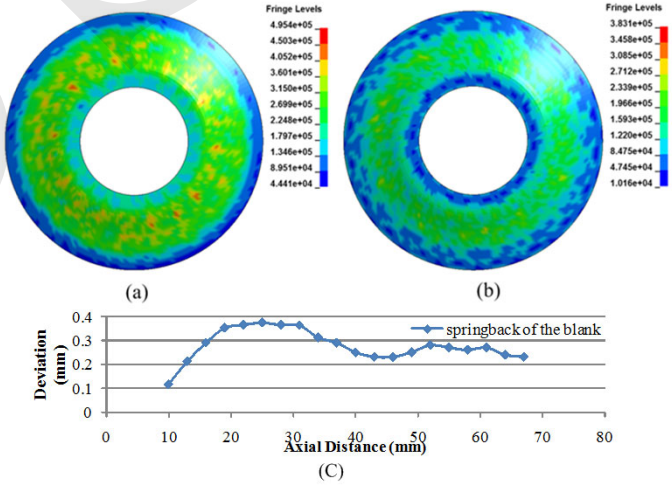


Illustration of springback condition of the final product

Model used in the experiments → **Initial conditions of the experiments** → **Final results of the experiments**

Dimensional precision results

- **The thickness and shape variations of the deformed metal plate with the designed roller paths.**

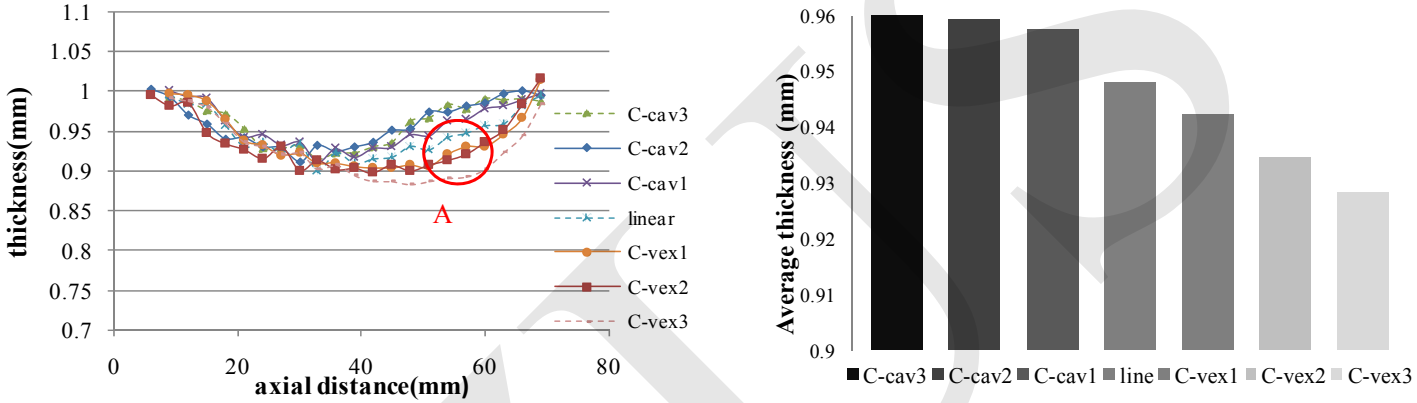


Fig. **3 Thickness variation** with different roller paths. (a) Thickness variations along the blank and (b) average thickness in each roller path

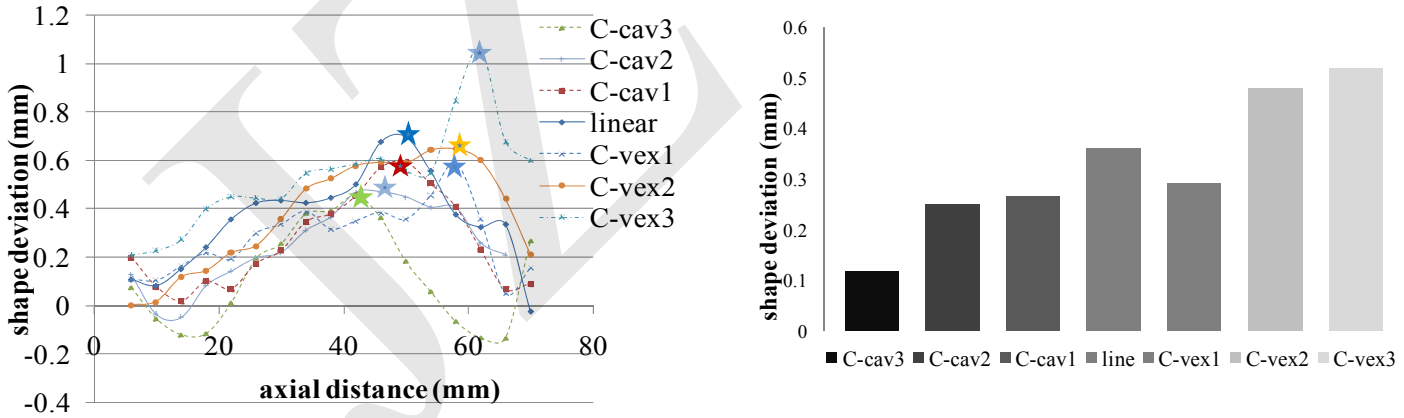


Fig. **4 Shape variation** with different roller paths. (left) Shape deviation along the blank and (right) average shape deviation in each roller path

Conclusions

- For concave roller paths, the greatest thinning and shape deviation area is located mainly in the middle of the blank, and a low RHL could result in little shape deviation, while for the convex roller paths, the same areas are located mainly in the back part of the area and a low RHL leads to both low thickness reduction and low shape deviation.
- The results in this study indicate the relationship between the parameterized roller paths and the dimensional precision in the first pass of die-less spinning. The effectiveness of the FE models has been shown, and that can be a foundation for further research on roller path compensation strategies and multi-pass planning methods in the die-less spinning of complex products.

Table.1 Influence of the bending degree (RHL) of roller paths on the forces and dimensional precision

	Forces			Precision	
	Axial	Radial	Tangential	Thickness	Shape
Concave-RHL	-	Negligible	-	-	+
Convex-RHL	++	+	++	--	++
Combined		Not available		Optimum exists	

-slightly negative; --: significantly negative; +: slightly positive; ++: significantly positive