Simulation technique of multi-strokes stamping with high stroke rates

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Automation lines used widely in sheet stamping industry, which can stamp the part with higher stroke rates. Die temperature may rise for the deformation and frictional induced heat, which can trigger the crack or wrinkle of part, thus make the automation line unstable. Simulation techniques of multi-strokes stamping with high stroke rates is studied. Strain rate and temperature-dependent material properties, thermal properties of the blank and die components, sliding velocity, pressure and temperature-dependent friction coefficient etc. is incorporated in the simulation model. A secondary development software is developed to trigger the commercial software running and reading the calculate results. It can run multi-strokes simulation and save the required results. Simulation of a tube deep drawing with 100 strokes is carried out. The die temperature rise curve is obtained. And the thickness change in different strokes is compared. It showed the crack or wrinkle risk is changed for the die temperature rise. Method to decrease the failure risk is studied based on the simulation result, adjust the blank holding force or control the die temperature by cooling method can make the automation line more stable.

Keywords: Multi-strokes; High stroke rates; Cooling system; Simulation.

1. Introduction

The dwell time for a stainless-steel kettle base is 12.97 seconds per stroke, comprising 11.5 seconds of press waiting time, 0.167 seconds for mold closure, and 1.47 seconds of press running time. The mold closure height is 20mm, and the stroke rate is 120mm/s. To enhance stamping production efficiency and reduce costs, increasing the number of strokes per unit time is necessary. Automation equipment enables high-speed stamping production. Compared to low-speed stamping, high-speed stamping increases the strain rate of the sheet metal and raises localized mold temperatures, altering process parameters critical for proper part formation. Multiple consecutive stampings can lead to wrinkling and cracking issues, destabilizing production. Utilizing stamping process simulation methods allows for the prediction and proactive mitigation of wrinkling and cracking during forming processes, ensuring stable production. High-speed stamping process simulation, building upon traditional stamping simulations, accurately considers material strain rate effects within the simulation model and can simulate changes in mold temperature, thereby accounting for its influence on the forming process. Given the gradual increase in cold stamping mold temperature, continuous stamping simulations are necessary.

Through the development of continuous stamping simulation software, an analysis of the simulation results of stainless-steel kettle bottom plate components was conducted. As the number of stamping cycles increases and mold temperature rises, the thickness

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distribution on the sheet metal changes. Thinning areas experience increased thinning, thereby exacerbating the risk of cracking. Conversely, thickened areas see increased thickness, heightening the risk of wrinkling. The thickness distribution was examined across 100 simulations.

Based on the simulation model, improvements have been proposed to address wrinkling and cracking issues caused by changes in forming process parameters. For areas experiencing localized temperature increases, controlling the maximum temperature of the mold is recommended as a preventive measure. Additionally, adjusting the blank holder force dynamically can also yield positive results by maintaining stability throughout the stamping process.

2. Simulation principle

The commercial simulation software is used to simulate the parts of stainless steel kettle bottom dish. Appropriate constitutive model parameters should be adopted in the simulation, and the model parameters should be able to consider the effect of strain rate and temperature[1]. The heat of the material, friction[2] heat and heat transfer between the plate and the die should be considered in the simulation. The actual stamping time speed should be basically consistent with the actual, if not consistent, the speed scaling is carried out, and the corresponding scaling should be carried out in terms of strain rate and thermal conductivity. It is necessary to consider continuous stamping, develop continuous stamping software, and monitor changes in temperature rise at key points of the mold throughout the process

2.1. *Material property simulation*

In the process of material molding, the performance of the material itself is the key to affect the molding, for the same material, the environmental conditions affecting the molding are mainly molding speed and molding temperature. By analyzing and comparing the stress-strain curves of materials at different drawing speeds and at different temperatures, the parameters of material constitutive model can be obtained and the forming quality can be predicted, which has guiding significance for the design of continuous stamping die.

The test material in this paper is sus304, and the common tensile test model is adopted. The specific shape and size are shown in Figure 1. The simulation parameters are shown in Table 1.

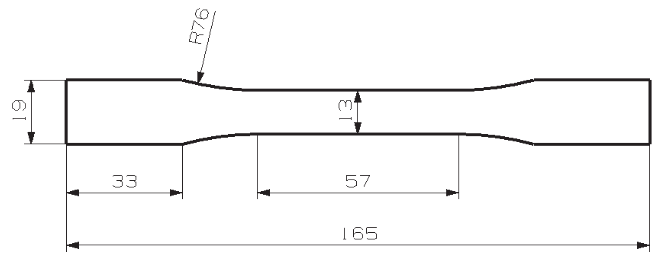

Fig. 1. Tensile test model.

Table 1. Simulation parameter setting.

Different temperature	Ratio	Different strain rate	Ratio
283K, 1mm/s	Base value 1.0	18° C, 0.033mm/s	Base value 1.0
291K, 1mm/s		18° C, 1mm/s	
318K, 1mm/s		18° C, 10mm/s	
333K, 1mm/s			

The simulation results of different temperatures and different strain rates are shown in Figure 2.

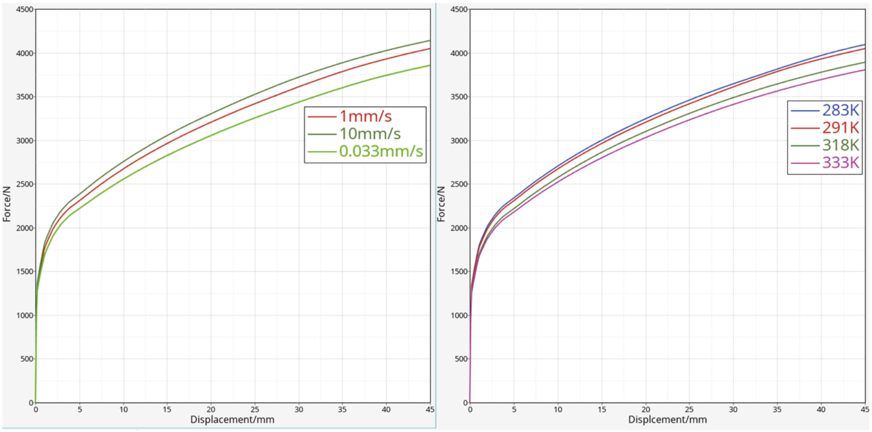

Fig. 2. Force-displacement curves at different strain rates (left) Force-displacement curves at different temperatures (right).

Based on the simulation results, it can be seen that, to a certain extent, the higher the strain rate, the greater the resistance of the same material at the same temperature; At the same strain rate, the lower the temperature, the higher the resistance. However, for the cold stamping process of the material, the resistance of the material can neither be too weak nor too strong, so the molding rate and temperature need to be reasonably selected according to the molding needs.

2.2. *Thermal performance simulation*

In the process of material forming, the heating caused by plastic deformation and the heating caused by friction[3] will be transferred between the sheet and the die. By analyzing the thermal properties of the sheet forming process, the forming situation of the sheet is predicted. At the same time, in order to ensure the accuracy of thermal performance simulation, considering the impact of strain rate and temperature on the material model, the material card was rewritten according to the material simulation results. The definition of the material model is shown in Table 2.

Table 2. Material model.

SUS304					
3D TABLE	Temperature	2D table	Strain rate0.033mm/s	Strain rate1mm/s	Strain rate10mm/s
	283K	998	0.9746	1.0130	1.0464
9999	291K	997	0.9621	1.0000	1.0330
	318K	996	0.9184	0.9546	0.9861
	333K	995	0.9067	0.9424	0.9735

The thermal performance simulation model adopts the common cold stamping model schematic diagram and simulation model as shown in Figure 3.

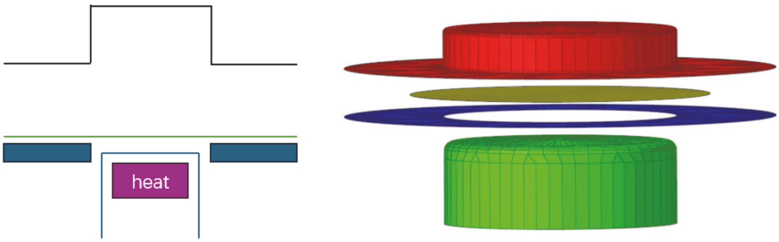

Fig. 3. Schematic diagram and simulation model of common cold stamping models.

In thermal performance simulation, heat transfer between the sheet metal and the mold was considered. Using Ls-Dyna preprocessing software, sliding velocities for the die, sheet metal, flange, and punch were defined. Friction coefficients related to pressure and temperature were also incorporated. By varying the initial temperature of the punch die, the forming conditions of the sheet metal were predicted. With an initial sheet thickness of 0.4mm, the initial temperatures of the punch die were set at 298K and 423K respectively. Simulation results are depicted in Figure 4.

Through simulation, the thickness of the sidewall after sheet metal forming can be determined. Observing sidewall thickness after forming with different initial temperatures of the punch reveals that excessive initial punch temperatures increase the risk of wrinkling and cracking during the forming process. Therefore, controlling the punch temperature in continuous stamping dies is crucial for maintaining the quality of sheet metal forming.

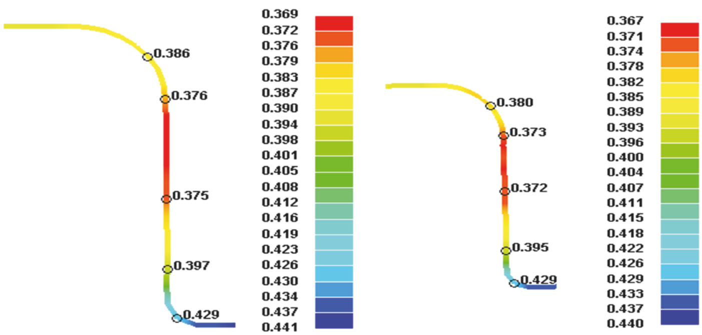

Fig. 4. Punch 273K(left), punch 423K (right) side drawing thickness of stamping sheet metal after forming.

3. Continuous stamping simulation

During continuous stamping processes, heat accumulation due to plastic deformation and friction can occur within the die[4]. This thermal buildup poses a critical challenge for continuous stamping dies. Therefore, this study focuses on addressing these issues by customizing commercial simulation software and monitoring temperature variations at key points within the die throughout the continuous stamping process. The developed interface is shown in Figure 5. Utilizing its solver, simulations were conducted to compute temperature changes within the die during 100 consecutive stamping cycles, as illustrated in Figure 6.

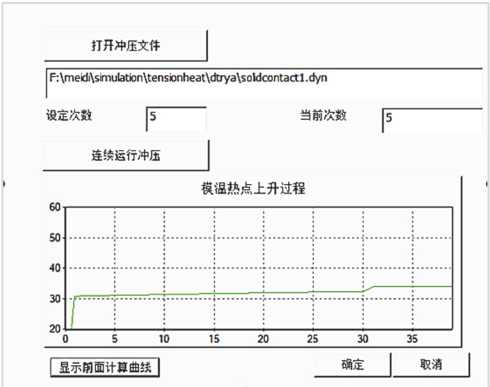

Fig. 5. Continuous stamping simulation software secondary development interface.

From the simulation results, it can be observed that the mold temperature gradually increases during continuous stamping. To better observe the effect of mold temperature rise on sheet metal forming, the side wall thickness after forming for the 1st and 100th consecutive stamping is shown in Figure 7.

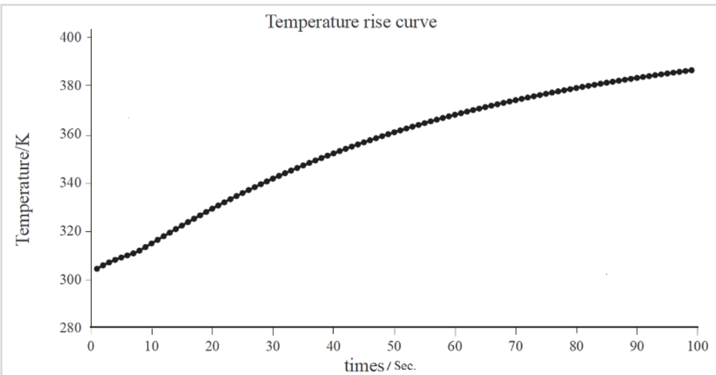

Fig. 6. Continuous die temperature rise process.

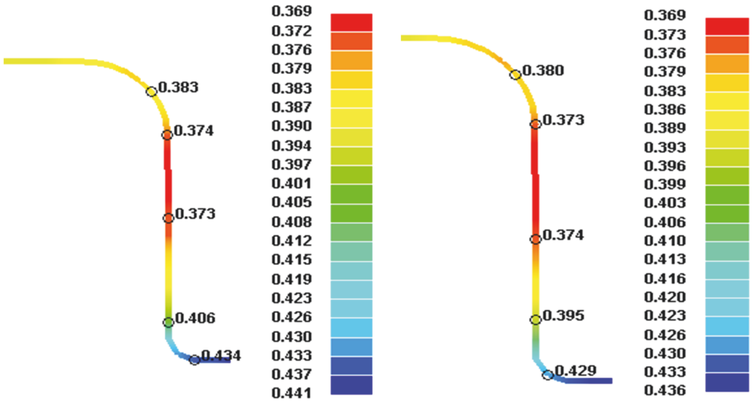

Fig. 7. Side drawing thickness after the 1st (left) and 100th (right) stamping sheet metal forming.

With an initial sheet thickness of 0.4mm, as the number of stamping cycles increases and mold temperature rises, there is a consistent trend of decreasing side wall thickness. The thinning rate at the same location increases continuously, posing higher risks of product cracking and wrinkling. Therefore, managing mold cooling in continuous stamping processes is crucial for enhancing product quality.

4. Discussion and solution

According to the simulation results of continuous stamping, continuous stamping will cause the mold temperature to continue to rise, and then the molding quality will deteriorate, which is mainly reflected in the thinning molding thickness, resulting in cracking and wrinkling risk. Therefore, a set of cooling system is designed in this paper, and the water channel design is used inside the punch to dissipate heat. The specific design structure is shown in Figure 8.

Fig. 8. Cooling water channel design.

The continuous stamping simulation calculation was carried out on the model with water channel installed. The mold temperature rise curve obtained by simulating 100 stamping processes and the mold temperature rise curve without water channel installed are shown in Figure 9.

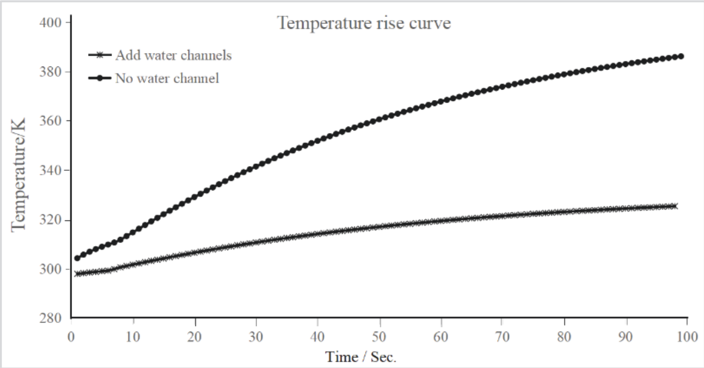

Fig. 9. Add water channel continuous stamping die temperature rise process.

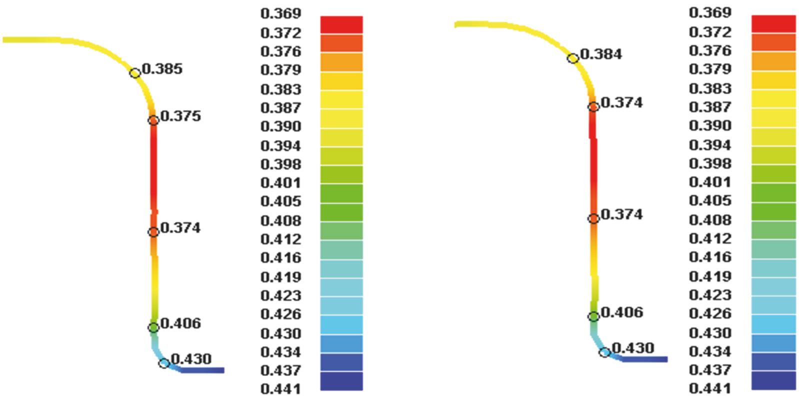

Fig. 10. Side drawing thickness after the 1st (left) and 100th (right) stamping sheet metal forming after the installation of water channel.

From the continuous stamping simulation results, it is evident that the mold temperature stabilizes after reaching 325K when water channels are installed. The side wall thickness after the 1st and 100th consecutive stamping cycles is shown in Figure 10.

According to the simulation results, the forming quality of the continuous stamping die with water channel is stable, and the drawing thickness of the sheet metal side is not continuously reduced. It is considered that the installation of water channel has a direct effect on the improvement of the quality of the continuous cold stamping die and has guiding significance for the design of the continuous stamping die.

5. Conclusion

During high-speed stamping processes, issues such as material strain rate increase and mold temperature rise can lead to cracking or wrinkling during continuous stamping, causing production interruptions. Based on an analysis of actual stamping processes, optimal simulation settings for addressing strain rate issues and mold temperature rise have been identified. Commercial software was custom-developed to simulate multiple continuous stamping processes, aiming to preemptively mitigate issues like cracking and wrinkling that arise post-production. Application of this simulation method using cylindrical stretching components illustrated its utility in analyzing mold temperature variations across multiple stamping cycles, evaluating section thickness variations among parts to compare their trends in wrinkling and cracking. This simulation approach enables proactive adoption of suitable process measures based on predictive forming issues, thereby safeguarding uninterrupted production workflows.

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