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STUDY ON TECHNOLOGY OF MULTI-WEDGE CROSS-WEDGE ROLLING OF AUTOMOBILE SEMI-AXIS SHAFTS

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With rapid development of automotive industry, the demand of automobile semi-axis is increasing. However, it increases the cost investing in dies as automobile semi-axis are stile produced with single-wedge cross-wedge rolling. Therefore, the study on deformation of MCWR forming automobile semi-axis is of great significance. The software PRO/E is adopted in setting up three-dimensional model, with the advanced explicit dynamic finite element DEFORM, the simulation of rolling automobile semi-axis with MCWR was analyzed systematically. The influence of rolling parameters on rolling force were attained by a practical computed method. It was shown that side wedge forming angles and side wedge transition angles had little influence on the force, the coefficient friction had critical influence on force.

Keywords: multi-wedge cross wedge rolling (MCWR), automobile semi-axis, force parameter.

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ИССЛЕДОВАНИЕ ТЕХНОЛОГИИ ПАРАЛЛЕЛЬНОЙ ПОПЕРЕЧНО-КЛИНОВОЙ ПРОКАТКИ ПОЛУОСИ АВТОМОБИЛЯ

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С ускоренным развитием автомобилестроения возрастает потребность в полуосях для автомобилей. Однако это повышает расходы на инструмент, так как до сегодняшнего дня полуоси изготовляются методом традиционной поперечно-клиновой прокатки. Поэтому изучение деформирования параллельной поперечно-клиновой прокатки автомобильных полуосей имеет большое значение. В данной работе освоено применение программного обеспечения PRO-E для создания трехмерной модели, подробно описано применение усовершенствованного программного обеспечения DEFORM на основе динамичного метода конечных элементов, систематично проанализировано моделирование прокатки автомобильных полуосей методом параллельной поперечно-клиновой прокатки. Влияние параметров прокатки на усилие прокатки оценено методом практических вычислений. Это показало, что углы формирования боковых клиньев и углы перехода боковых клиньев не оказывают большого влияния на усилие прокатки, а коэффициент трения существенно влияет на усилие прокатки.

Ключевые слова: параллельная поперечно-клиновая прокатка, полуоси автомобилей, усилие прокатки.

Instructions. Automobile semi-axis shafts are drive shafts of driving wheels, which are power transmission shafts as shown in the Fig 1. Two driving wheels move at the different speeds of rotation in the process of driving, therefore, the two driving wheels cannot be connected by one driving shaft but driven by two semi-axis shafts which are connected with differential mechanism. Automobile semi-axis shafts which not only transmit torque from engine are an important force transmission part of the car, also withstand the vertical force and lateral force generated from the wheel, as well as traction force and longitudinal force generated from braking force. Therefore, the automobile semi-axis shafts are an important carrier transmission system, and one of the vulnerable parts of the automobile. Currently, the popular methods of producing automobile semi-axis shafts in domestic and abroad are forging and single-wedge cross-wedge rolling forming. Single-wedge cross-wedge rolling forming has lots of advantages like high production efficiency, material utilization, high quality and low cost compared to forging method. However, the investment of mold is large by single-wedge cross-wedge rolling, hence, it will

Fig. 1. Automobile Semi-axis shafts

further reduce the costs and weight of the mold and equipment by applying MCWR technology [1, 2].

MCWR is one kind of plastic forming technology which conducts radial pression and axial extension on the raw shafts simultaneously by couples of wedges called main wedge and side wedges. And MCWR is an advanced precision long shaft parts near net shaping technology which has many advantages like saving roll surface, reducing weight of the equipment, high efficiency, saving materials and is low cost compared with single wedge CWR. This technology is one of the most effective technologies to produce long shafts professionally and economically in addition [3–6].

Therefore, studying new effective and energy saving technology on producing large-scale long shafts meets the urgent requirement of the development of society and the market.

At present, the research study of automobile semi-axis shafts by MCWR is almost vacant all over the world. Therefore, the paper has established the three dimensional rigid-plastic finite model of automobile semi-axis shafts by MCWR based on the Deform-3D software and ANSYS/LS-DYNA on the basis of the model construction. The influence rolling parameters on rolling force were attained by a practical computed method, it has shown that side-wedge forming angles and side-wedge transition angles have little influence on the force, the coefficient friction has critical influence on force. Above research results provided theoretical basis for realizing professional and mass production of the MCWR automobile semi-axis.

As a conclusion, the study of automobile axle MCWR on automobile semi-axis shafts has critical significance.

Design the mold and establish the finite element model

Design the mold. There are three ideas to design the mold for automobile semi-axis shafts by MCWR. One is rolling simultaneously the side short parts and the middle long parts, and the advantage of this idea is that the surface of mold is shorter than other designation, while the disadvantage is the force is not symmetric in the process of rolling. And another idea is rolling the side short parts of shafts after having rolled the middle long parts of shafts, therefore, the mold could be designed symmetrical, while the length of die surface is too long. And the last idea is to length one of the side wedges to rolling the one side short part of shaft on the base of the second idea.

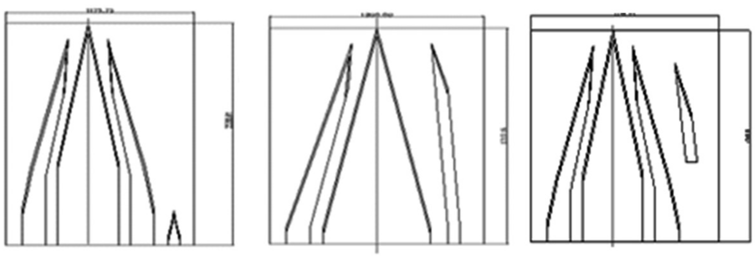
One can design a mold called No.1 for automobile semi-axisas shaft as is shown in Fig. 2, *a* from the first idea, and this mold length is 2313.16 mm, which could works on H800 rolling machine.

And one can design a mold called No.2 for automobile semi-axis shaftas as is shown in Fig. 2, *b* from the second idea, and this mold length is 2538.81 mm, which could works on H1000 rolling machine. Then one can design a mold called No.3 for automobile semi-axis shafta as is shown in Fig. 2, *c* from the second idea, and this mold's length is 2320.00 mm, which could works on H800 rolling machine.

As a conclusion, we selected the No.1 mold to do simulation analysis.

Establish the finite element mold. To simplify the problem, make the assumption as following:

1. Since rolling is carried out at high temperature, the elastic deformation of shafts in rolling is much smaller than the plastic deformation, so the flattening deformation of the mold and the elastic deforma-



a *b* *c*

Fig. 2. Benz rear axis mold

tion of die could be ignored to some extent, and the die could be deemed as rigid which will reduce the amount of calculation in the analysis, and the elastic modules $E = 210$ GPa.

2. The weight of shafts is ignored and deemed as plastic, and the plastic modules $E = 90$ GPa.

3. Since the whole rolling process is completed in 3to 4 seconds, and the time of heat transfer between dies and shaft with air is intensely short, rolling temperature could be deemed as constant during the process.

4. Simplify the friction between the dies and shafts is coulomb friction, assuming the friction between dies with shaft is the same in all the contact portions.

5. The shaft is not contacted with rolling guides in the process of rolling, and the rolling condition of rolling dies are perfectly symmetrical. The final finite element model is shown in Fig. 3.

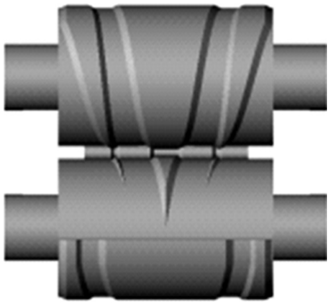


Fig. 3. Finite element simulation mold by multi-wedge cross-wedge rolling

The rules of technological parameters on force parameters

Process parameters by mult-wedge cross wedge rolling. Using the finite element model which has been established to do finite element simulation under the condition of typical process parameters. Process parameters by multi-wedge cross-wedge rolling were as follows: diameter of dies 800 mm; side forming angles 25°, 30°, 35°; side transition angles 25°, 35°, 45°; coefficient of friction 0.3, 0.4, 0.5; rolling temperature 1050 °C.

Influence rule of side forming angles on force. In the condition of side transition $\alpha_z = 25°$ and friction coefficient $\mu = 0.5$, the variation of force parameters effected by different sides wedge angles in the process of rolling is shown in Fig. 4. As can be seen from Fig. 4, with the side wedge forming angles increase, the force is going to increase, however, the extent is not large.

Influence rules of side transitionanl angles on force parameters. In the condition of side wedge forming angles $\alpha_i = 30°$, and the coefficient friction $\mu = 0.5$, the variation of force parameters effected by different side wedge transition angles in the process of rolling is shown in Fig. 5. As can be seen from Fig. 5, with the

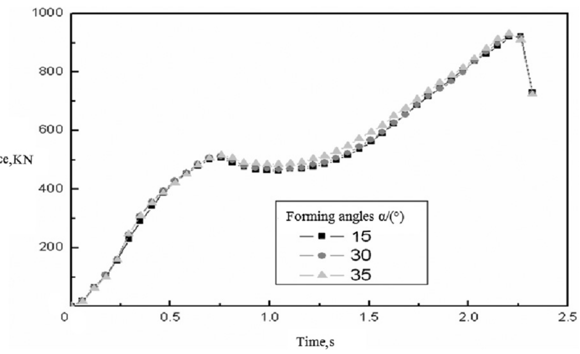


Fig. 4. Influence rule of side forming angles on force

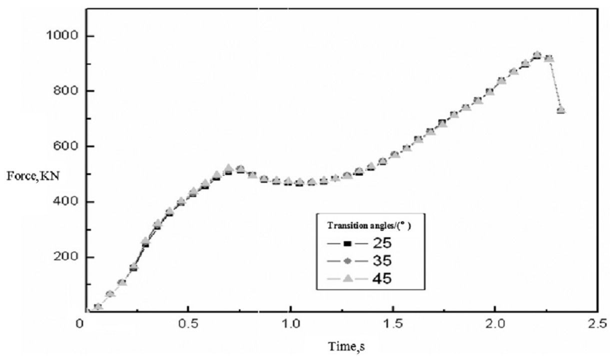


Fig. 5. Influence rule of side transition angles on force

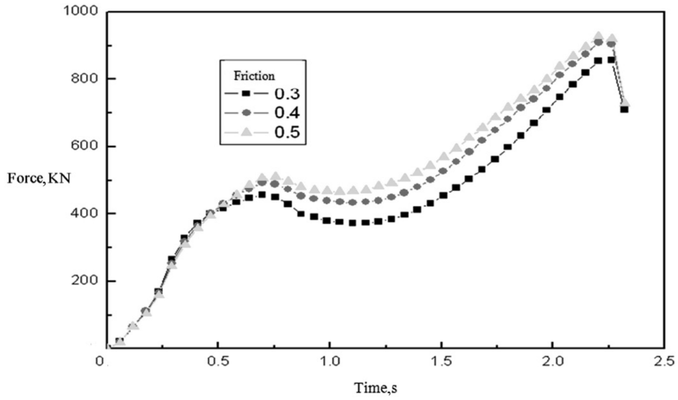


Fig. 6. Influence rule of friction on force

side wedge transition angles increase, the force is not effected actually. Therefore, changing the transition angles has not obvious effects on the variation of force.

However, the transition angles will influence the surface quality of shafts in the rolling transition section. In conclusion, in the terms of surface quality of transition section, we should choose small transition angles.

Influence rule of coefficient friction on force parameters. In the condition of side transition α_z = 25° and side-wedge forming angles α_i = 30°, the variation of force parameters effected by different coef-

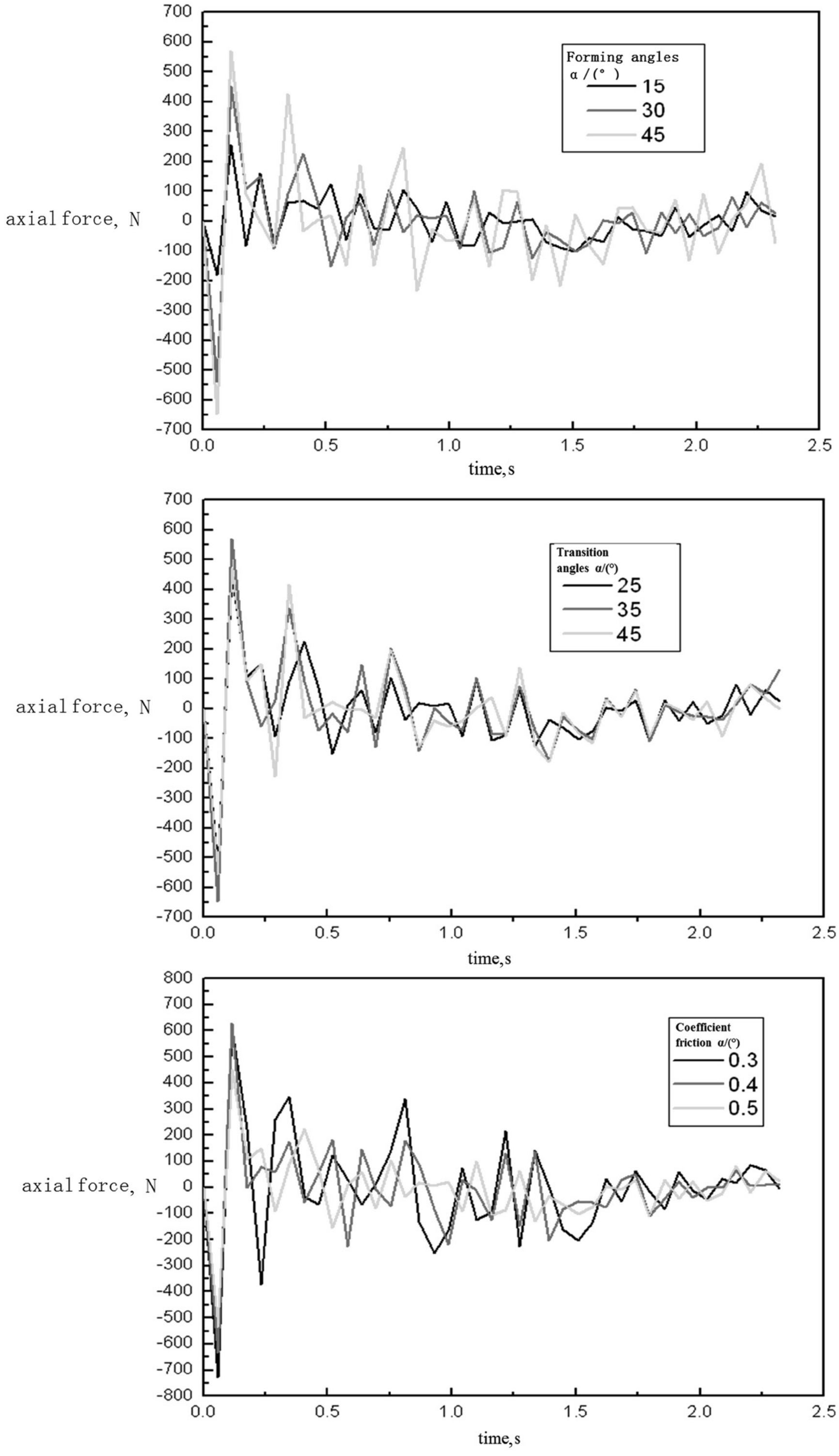


Fig. 7. Influence rules of axial force

ficient friction in the process of rolling is shown in Fig. 6. As can be seen from Fig. 6, with the coefficient friction increase, the force is going to increase, and the extent is large, considering the force parameters practically, the coefficient friction should be considered necessarily.

Influence rules of axial force

The influence rules of the axial force are shown in the Fig. 7. It can be seen from the figure that different side forming angles, different side transition angles and different coefficient friction have same effects on the axial force to a certain extent. Considering the axial force is extremely smaller than radial force and tangential force, the axial force could be almost negligible. Besides, during the process of rolling forming, the axial force generated is almost balanced from a general analysis, in other words, it means that the mold is balanced from the axial direction. And asymmetric rolling just generate imbalance which can be resolved by the plastic deformation of the shafts in a little moment.

Conclusion. Based on the finite element simulation, the law of automobile semi-axis shaft force influenced by technological parameters are studied, it has obtained a conclusion as well:

1. Side-wedge forming angles and side wedge transition angles have little influence on the force.
2. The coefficient of friction has critical influence on force.
3. Different side transition angles and different coefficient of friction have same effects on the axial force to a certain extent. During the process of rolling forming, the axial force generated is almost balanced from a general analysis.
4. Those results will provide theoretical basis for realizing professional and mass production of the MCWR automobile semi-axis.

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