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Retraction

Retracted: Numerical Simulation of Fine Blanking Die Wear and Die Performance Analysis

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] Y. Li, Y. Zhao, and Y. Hao, "Numerical Simulation of Fine Blanking Die Wear and Die Performance Analysis," *Journal of Chemistry*, vol. 2022, Article ID 9893356, 7 pages, 2022.

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Research Article

Numerical Simulation of Fine Blanking Die Wear and Die Performance Analysis

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In order to study the die wear law of rotary fine blanking helical cylindrical gear, a three-dimensional rigid plastic finite element model of rotary fine blanking helical cylindrical gear is established on the Deform-3D software platform. Based on the Archard wear model, this paper analyzes the die wear in the fine blanking process, obtains the wear distribution of each point on the working surface of the die, determines the maximum wear area, and makes a comparative analysis with the fine blanking die wear of spur gear. Through the single factor variable method, this paper studies the effects of reverse jacking force, blank holder force, blanking speed, punch and die clearance, die fillet radius, and die initial hardness on die wear. The test results show that when the punch reduction is the same, the wear of the female die of fine blanking helical cylindrical gear is greater than that of fine blanking spur cylindrical gear. When the counter jacking force increases from 100 kN to 200 kN, the maximum wear of the die gradually increases from 6.91×10^{-6} mm to 9.38×10^{-6} mm; when the blank holder force increases to 3/4 of the blanking force, the die wear decreases with the increase of blank holder force; it is ideal when the blanking clearance is 0.5% t (0.02 mm). *Conclusion*. The wear model can accurately predict the relationship between main process parameters and wear in the process of rotary fine blanking, and the measures to reduce die wear are put forward from the aspect of process design.

1. Introduction

Using fine blanking technology to replace the current cutting processing to manufacture precision plate parts can greatly promote the production of automobile, electronic instruments, and other industries; drive the development of the whole machinery manufacturing industry in China; and achieve better economic and social benefits [1]. Fine blanking die is not only the key equipment for producing fine blanking parts but also the core of fine blanking technology, which directly determines the precision of fine blanking parts and the productivity of the factory. The die life is one of the important indicators to measure the die quality. With the rapid development of China's industrial modernization, the structure of fine blanking parts is becoming more and more complex, the accuracy requirements are higher, the application range is wider and wider, and higher requirements are put forward for the service life of fine blanking die. The large-scale, complex, high-precision, and high-efficiency of molds all depend on the improvement of mold life [2]. However, the structure of fine blanking die is complex. Engineers often design a set of die according to experience, resulting in unqualified product quality, low die life, low production efficiency, and greatly improved production cost. Therefore, the simulation analysis and estimation of fatigue life of fine blanking die has important scientific and practical significance for improving the design level of fine blanking die, improving the accurate theoretical basis for engineers to design die, improving the service life of die, improving factory production efficiency, and reducing production cost.

Fine blanking is the abbreviation of precision blanking, which belongs to noncutting processing technology. Precision blanking technology is to cut and separate the sheet along the required contour under three-dimensional pressure on a special press or a modified general press through a precision blanking die and finally obtain a plate-like precision contour part with smooth section, good perpendicularity, flatness, and high-precision [3]. Using precision blanking process instead of cutting process to manufacture plate-shaped precision contour parts, the main technical indexes of parts can reach or even exceed cutting and other machining methods, and the machining efficiency can be increased more than ten times, which greatly reduces the production cost. It is one of the development directions of manufacturing technology at present.

2. Literature Review

In terms of fine blanking process optimization, the common means are as follows: improving the design structure of fine blanking press or die, using orthogonal experiment, or finite element simulation to obtain the optimal results of different process parameters. Fine blanking press needs high strength, high stiffness, and good dynamic performance to ensure fine blanking accuracy. Ji used finite element simulation and topology optimization technology to optimize the structure of 12000 kN fine stamping machine and finally realized the improvement of performance while reducing the weight of the press [4]. Lubis analyzed the theoretical mechanism of stamping sheet metal with stepped punch without V-shaped blank holder by experiment and finite element simulation. The stepped punch structure increases the hydrostatic stress and material flow in the shear zone, so a bright shear surface can also be obtained. For precision gear parts with high dimensional requirements, the problem of fine punching collapse angle can be solved by using negative punch and die clearance. The larger the negative die clearance is, the smaller the part collapse angle is until it tends to a fixed value [5].

There are many factors affecting the wear of fine blanking die, including blank holder force, reverse jacking force, blanking speed, die chamfer, punch and die clearance, die hardness, and other physical parameters. It is difficult to determine the relationship between these physical parameters and die wear through experiments. The correlation between wear and these physical parameters can be obtained through finite element simulation. Zheng, combined with Archard model and using DEFORM-3D simulation, concluded that die wear is positively correlated with blank holder force, reverse jacking force, blanking speed, and die chamfer and negatively correlated with punch die clearance and die hardness [6]. Liu further trained the internal relationship between these main parameters and wear through neural network and then calculated the total wear through MATLAB platform. The total wear was obtained through the superposition of single wear. After each wear, the fillet, hardness, and clearance of punch and die are updated. Under the condition of wear, the next wear is calculated. The results are in good agreement with the experiment. The fine blanking process is studied by the finite element method, and the simplified model of undamaged punch is generally used [7]. Zhang compared the undamaged punch with the worn punch by finite element method. It is concluded that the stress and strain of the simplified model are relatively more concentrated, so the proportion of bright bands on the shear surface of parts obtained by undamaged punch is higher and there are fewer burrs [8].

In this paper, the DEFORM-3D wear analysis module is used to analyze the die wear in the rotary fine blanking process, obtain the wear distribution diagram of each point on the die surface, and determine the die wear distribution and the maximum wear area. Through comparative analysis, the effects of reverse jacking force, blank holder force, blanking speed, punch and die clearance, die fillet radius, and die initial hardness on die wear were studied. The research results show that the wear model accurately reflects the relationship between the main process parameters and wear in the process of rotary fine blanking, as shown in Figure 1, which provides a theoretical basis for die design.

3. Research Methods

3.1. Basic Concept of Fatigue. The load of most mechanical parts used in engineering varies with time, and fatigue is the main failure form. Fatigue refers to the process that parts or structures gradually produce local permanent structural or performance changes at a certain point or some points under cyclic load, form cracks after a certain number of cycles, and continue to expand under load until complete fracture.

The process of fatigue failure can be summarized as follows: under the action of cyclic load, microcracks are formed on the local maximum stress and the weakest and most stressed grains and then develop into macrocracks, which continue to expand and eventually lead to fatigue fracture. From the fracture of fatigue failure, we can find that the fatigue failure of parts has experienced three stages as follows: crack formation, propagation, and instantaneous fracture. Starting from the process of fatigue failure, we divide the fatigue life into fatigue crack formation life and fatigue crack propagation life.

From the characteristics of fatigue failure, it can be seen that, in the actual working conditions, fatigue is often difficult to detect, and it is very sensitive to the performance and processing of the material itself. Therefore, fatigue analysis is a very important part in part design and manufacturing. A complete fatigue analysis should include fatigue stress analysis, fatigue failure form analysis, antifatigue performance measurement, and the theory of estimating fatigue life, including fatigue cumulative damage theory and fatigue crack growth theory [9]. The fatigue analysis needs to collect the structural shape, material properties, and loading of relevant parts and obtain the estimated value of the working life of parts through theoretical analysis and calculation on the basis of actual working conditions. For the study of material properties, tensile and fatigue tests need to be carried out to obtain the basic parameters of the material. On the basis of consulting relevant books and calculating through empirical formula, the load situation is mainly based on the actual loading history.

Damage refers to the change degree or damage degree of material performance under fatigue load. When the material bears the stress higher than the fatigue limit, a certain amount of damage will be produced on the material every

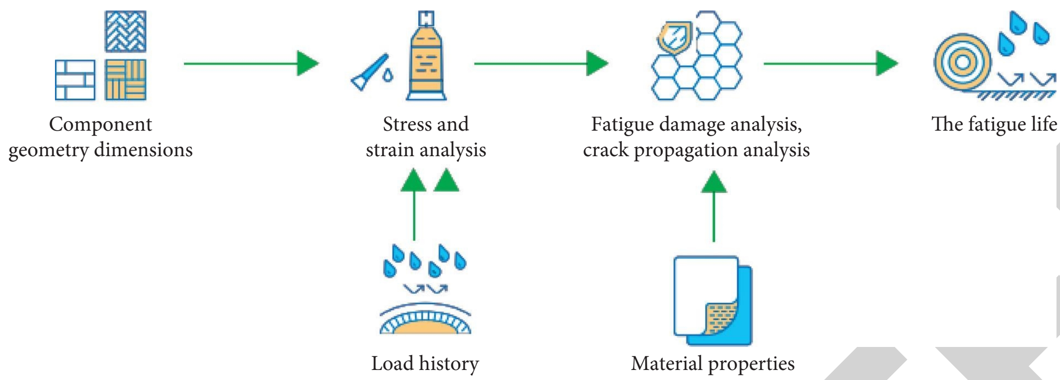

Figure 1: Wear performance analysis of fine blanking die.

cycle, and this damage can be accumulated. When the damage accumulates to the critical value, the material will undergo fatigue failure, which leads to a variety of fatigue cumulative damage theories.

3.2. Establishment of the Wear Model. In order to study the die wear law of rotary fine blanking helical cylindrical gear, this paper selects a helical cylindrical gear (geometric parameters are shown in Table 1) for finite element analysis [10] and analyzes and calculates the gear ring pressing and punch rotary blanking process. The blank material is 45 steel, and the die is D2 steel (corresponding to the domestic brand Cr12Mo1V1). The material model in DEFORM-3D software is used for analysis and calculation in the simulation. In order to improve the precision of rotary fine blanking calculation, the total number of grids of the blank is 200000, and the shear zone is locally refined.

Archard wear model predicts the wear amount of die in the forming process, and the expression is as follows [11]:

$$\omega = \int K \frac{P^a v^b}{H^c} \mathrm{d}t, \tag{1}$$

where ω is the wear depth; P is the positive pressure on the die surface; v is the sliding speed; and a, b, and c are standard constants. For steel, a and b are 1 and c is 2; K is the constant related to material properties, $K = 2 \times 10^{-8}$; H is the initial hardness of the mold (HRC); and t is the blank thickness.

Enter the Deform-3D preprocessing module to set the simulation control, select the heat conduction mode and Lagrange incremental algorithm, check the tool wear item in the data definition between objects, and select the Archard model to provide a theoretical algorithm for subsequent calculation. After the simulation analysis, select the tool wear item in the analysis option of the postprocessing module to analyze the wear results of the die. The size of each parameter can be determined according to the empirical formula of fine blanking parameters. Table 2 shows the basic conditions of finite element simulation. In this model, $t = 4$ mm.

4. Result Analysis

4.1. Comparative Analysis of Wear Amount. The precondition of fine blanking die wear is the friction between the die and the material working surface during fine blanking [12], but the severity of die working surface wear mainly depends on the normal force acting on the die surface, sliding speed, the state of the friction surface, and the hardness of the die surface according to the Archard wear model.

Through the comparative study, it is found that the wear of fine blanking die is mainly in the edge area, whether spur cylindrical gear or helical cylindrical gear. This is because in the process of gear fine blanking, the plastic deformation is mainly concentrated in the gap area at the edge, the range of plastic deformation is narrow, the stress is highly concentrated in the die edge area, the new shear area is first formed in the edge area, and the local high temperature caused by plastic deformation is also concentrated here. Therefore, the working conditions of the die edge are the worst in the process of fine blanking. Under such very bad conditions, friction with materials is easy to cause wear, so the wear of fine blanking die is mainly concentrated on the end face and side around the die edge.

Outside the cutting edge area, although the pressure acting on the end face of the working surface of the die is very large, there is no material relative displacement and friction, so there is no wear [13]. The lateral deformation of the die is much smaller than that of the die due to the friction force on the side of the die. If there are good lubrication conditions, there will be little or no wear.

The maximum wear of straight and helical teeth is shown in Figure 2. For the fine blanking model of spur gear, when the reduction of male die is 1, 2, 3, and 4 mm, respectively, the maximum wear of female die is 1.84×10^{-6}, 3.42×10^{-6}, 5.74×10^{-6} and 7.13×10^{-6} mm, respectively. For the fine blanking model of helical cylindrical gear, when the reduction of male die is 1, 2, 3, and 4 mm, respectively, the maximum wear of female die is 3.11×10^{-6}, 4.56×10^{-6}, 7.05×10^{-6}, and 8.39×10^{-6} mm, respectively.

For helical cylindrical gears, when the punch reduction is the same, the wear of fine blanking helical cylindrical gear die is greater than that of fine blanking spur cylindrical gear die. This is because in the fine blanking process of helical cylindrical gear, due to the increased rotation movement of the die, the material flow in the fine blanking process of helical cylindrical gear is more intense [14].

4.2. Analysis on the Relationship between the Change of Process Parameters and Wear. The wear of fine blanking die is the result of the comprehensive action of many factors,

Table 1: Geometric parameters of reference helical cylindrical gear.

Parameter	Number of teeth, z	Normal modulus, mm	Pressure angle, $\alpha/(^{\circ})$	Helix angle, $\beta/(^{\circ})$	Tooth width, b/mm
Numerical value	18	2.5	20	10	4

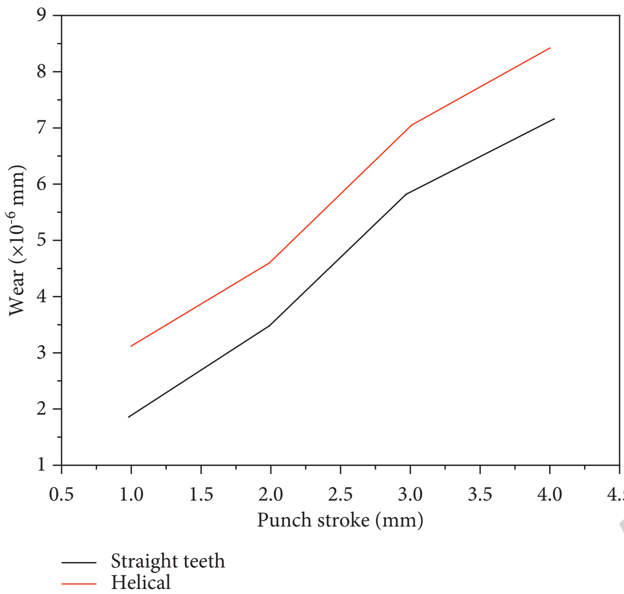

Figure 2: Comparison of wear amount of straight tooth and oblique tooth dies under different punch stroke conditions.

Table 2: Basic conditions of finite element model simulation.

Name	Description
Part type	Workpiece: plastic body V-shaped blank holder: rigid body Punch/die: rigid bodies Antiroof: rigid body
Workpiece material	AISI-1045
Die material	AISI-D2
Fillet radius of die edge (mm)	R_p, 0.01; R_d, 0.2
Blanking clearance (mm)	0.5% t (0.02 mm)
Blank holder force (kN)	500
Counter jacking force (kN)	150
Feed rate (mm·s^{-1})	10
Initial hardness of dieHRC	62
Rotation speed (RAD·s^{-1})	0.077
Friction factor	0.12
Fracture criterion	Oyane
Critical fracture value	2.5
Wear model	Archard wear model

including part material, die material, die structure, fine blanking process, and lubrication [15, 16]. From the perspective of process parameters, blank holder force, reverse jacking force, and blanking speed not only affect the section quality of blanking parts, but also affect the wear of dies [17]. In the rotary fine blanking model, six factors such as blank holder force, reverse jacking force, blanking speed, die fillet radius, blanking clearance, and die initial hardness are selected for analysis (Table 3), and the influence law of each factor on wear is studied. The selected method is single factor variable method. When one parameter is changed, the size of other process parameters is determined by Table 3.

4.2.1. Influence of Antijacking Force. In order to study the influence of antijacking force on the wear of the rotary fine blanking die, the wear of the die was simulated when the antijacking force was 100,125,150,175, and 200 kN. When the counterjacking force increases from 100 kN to 200 kN, the maximum wear of the die gradually increases from 6.91×10^{-6} mm to 9.38×10^{-6} mm, as shown in Figure 3.

4.2.2. Influence of Blank Holder Force. Figure 4 shows the influence of blank holder force on the wear amount of die. It can be seen that the wear amount of die increases with the increase of blank holder force. When the blank holder force increases to 3/4 of the blanking force, the wear amount of die decreases with the increase of blank holder force. This is because when the blank holder force increases, the three-dimensional hydrostatic stress increases, and the quality of the blanking section becomes better. But when the blank holder force exceeds a certain amount [18], it will cause the change of the stress direction, and the material is prone to fracture, in the case of material tearing earlier, the relative friction between the material and the die becomes smaller and the wear degree of the die decreases [19].

4.2.3. Influence of Punch Feed Speed. The influence of punch feed speed on die wear is shown in Figure 5. With the increase of punch feed speed, the wear amount of die also increases. This is because, under the condition of a certain blank holder force and reverse jacking force, the increase of punch feed speed requires a greater blanking force. As a result, the surface pressure of the blank and the die increases, and the flow speed of the blank and the die also increases. According to the Archard wear model, the wear amount increases [20].

4.2.4. Impact of Blanking Clearance. One of the main differences between fine blanking and ordinary blanking lies in the difference of blanking clearance. The blanking clearance of fine blanking is much smaller than that of ordinary blanking. With the increase of blanking clearance, the wear amount of the female die decreases [21–23] as shown in Figure 6. This is because the blanking clearance increases and the hydrostatic pressure in the fine blanking process decreases, so the positive pressure on the inner side of the die and the edge decreases. According to the Archard wear model, the wear amount decreases. However, if the blanking

Table 3: Model process parameters and numerical settings.

Blank holder force (kN)	Counterjacking force (kN)	Feed speed ($mm \cdot s^{-1}$)	Blanking clearance, % (t)	Die fillet radius (mm)	Initial hardness of die, HRC
400	100	6	0.1	0.2	58
450	125	8	0.3	0.3	60
500	150	10	0.5	0.4	62
550	175	12	0.7	0.5	64
600	200	14	0.9	0.6	66

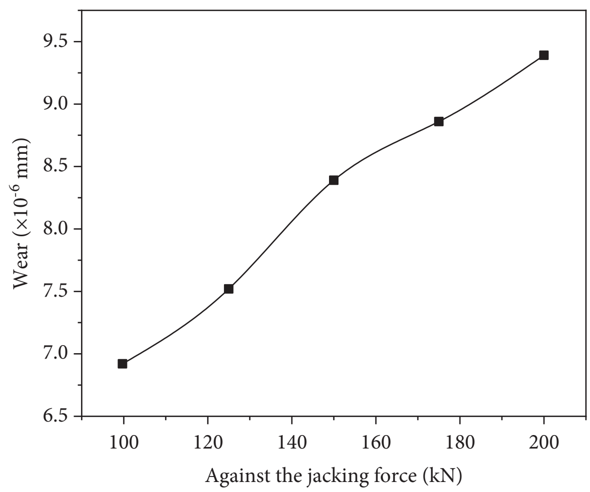

Figure 3: Effect of antijacking force on die wear.

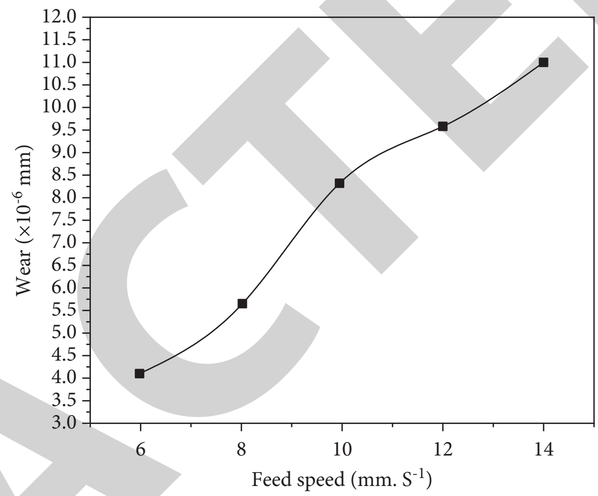

Figure 5: Effect of punch feed speed on die wear.

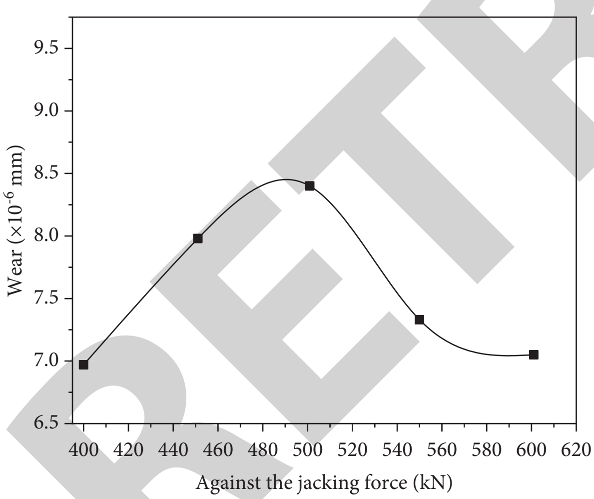

Figure 4: Effect of blank holder force on die wear.

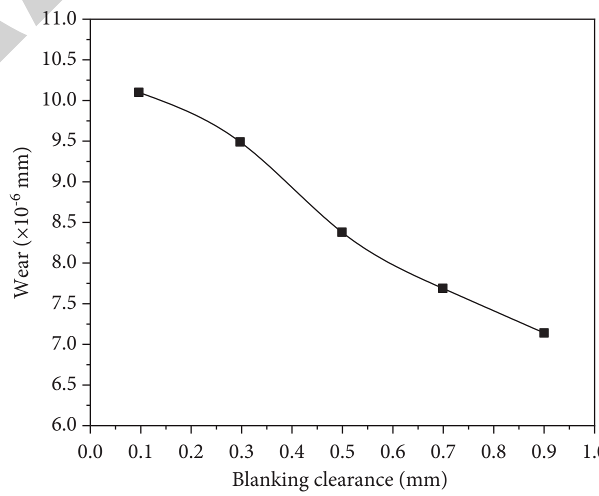

Figure 6: Effect of blanking clearance on die wear.

clearance is too large in the process of fine blanking, the surface quality of fine blanking parts will become worse. Therefore, selecting the appropriate blanking clearance is a key factor to improve the service life of the die and ensure the quality of fine blanking parts. For this model, considering the die life and blanking quality, it is ideal when the blanking clearance is 0.5% t (0.02 mm).

4.2.5. Influence of Die Fillet Radius. In the process of fine blanking, the fillet radius of the die is another factor affecting the quality of fine blanking parts. Through research, it is found that the fillet radius of the die also has an important impact on the service life of the die, as shown in Figure 7. As can be seen from the figure, with the increase of the fillet radius of the die, the wear amount of the die increases. This is because the increase of the fillet radius of the die improves the stress state of the material at the transition fillet, so as to reduce the plastic deformation degree of the material and prolong the plastic deformation time, resulting in the longer wear time of the die. According to the Archard wear model, the wear amount increases. As the increase of the fillet radius of the die will increase the step angle of the workpiece

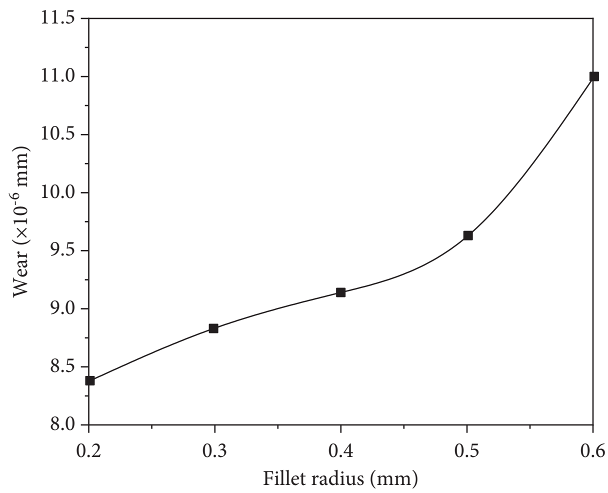

FIGURE 7: Effect of die fillet radius on die wear.

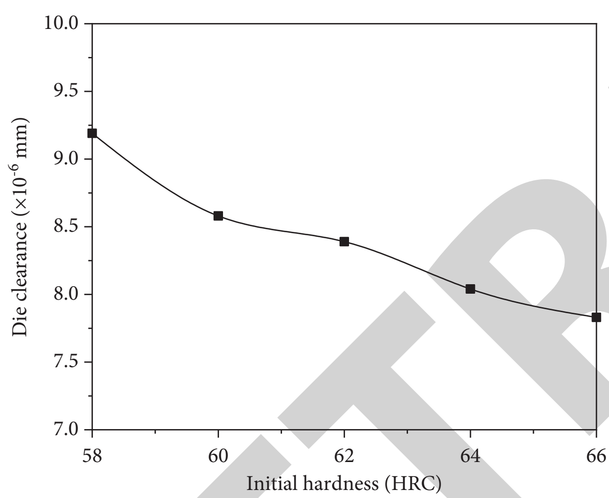

FIGURE 8: Effect of initial hardness of die on die wear.

accordingly, considering the die wear, section quality and step angle, it is ideal to take 0.2 mm as the fillet radius of the die.

4.2.6. Effect of Initial Hardness of Die. Die hardness is an important factor affecting die life. Figure 8 shows the effect of initial die hardness on die wear. It can be seen from the figure that the maximum wear of die decreases with the increase of initial die hardness. Therefore, the service life of the die can be improved by increasing the initial hardness of the die. At the same time, in order to prevent edge collapse and die fracture, the die also needs to have certain toughness. At present, the surface hardness of the die is generally provided through surface treatment technology, and the matrix has certain toughness, such as coating TiN or TiAlN coating on the die surface, so as to increase the die hardness within a certain range, so as to reduce the wear of rotary fine blanking die and increase its service life [24, 25].

5. Conclusion

No matter the spur gear or helical gear, the most worn part in the die blanking process is the die edge. For helical cylindrical gears, in the fine blanking process of left-hand helical cylindrical gears, the material flow is mainly concentrated on the right side of the spiral teeth of the die, and the wear on the right side of the tooth top circle of the spiral teeth of the die is more serious than that on the left side. Increasing the reverse jacking force, punch feed rate and die fillet radius will aggravate the wear of rotary fine blanking die and reduce its service life. Increasing the blanking clearance and the initial hardness of the die can reduce the wear of the die and increase the service life of the die.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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