Influences of rolling method on deformation force in cold roll-beating forming process

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Abstract: In the process of cold roll−beating forming, as the research object，the gear rack was selected to study the influence law of rolling method on the deformation force. By the mean of the cold roll forming finite element simulation，the variation regularity of radial and tangential deformation was analysed under different rolling methods. The variation of deformation force of the complete forming racks and the single roll during the steady state under different rolling modes was analyzed. The results show: when upbeating and down beating, radial single point average force is similar, the tangential single point average force gap is bigger,the gap of tangential single point average force is relatively large. Add itionally,the tangential force at the time of direct beating is large, and the dire ction is opposite with down beating.With directly beating, deformation force loading fast and uninstall slow. Correspondingly,with down beating,deformat ion force loading slow and uninstall fast.

1. Introduction

In the machining, Cold roll-beating forming is a non-traditional near-net forming processing methods which is characterized by zero waste, high efficiency, low pollution, and near net shape, among other advantages. The forming technology can be widely used in many types of equipment, including machines, aircraft, ships, agricultural equipment, splines and gears[1-4].

In the cold roll-beating production process, the rolling wheel hit the workpiece each time withan extremely short time. Deformation of the workpiece occurred violent elastoplastic deformation, because process parameters and material properties may have great deformation. The force directly affects the surface shape and accuracy of the part during the forming process. The process ultimately affects the quality of the part, the wear and tear on the rolling equipment, and the service life of the rolling wheel [5-6]. Therefore, the process of cold roll forming deformation determines the rolling equipment development, the choice

of process parameters, and affect the quality of parts of the key factors. At present, in the analytical study of cold rolling deforming force, Zhang Lu and others analyzed the deforming force when the rolling wheel broke in and out from the stationary workpiece surface [7]; Wang Xiaoqiang and others finite element simulation and experimental methods to study the impact of processing parameters on the deformation force[8].

Therefore, in this paper, we establish a finite element simulation model of the cold roll forming process , and analyze the variation of radial and tangential deformation forces under different roll-off methods and deformation force deformation regularity of completely shaped rack and single rolling in stable stage. This method improves the accuracy of cold roll-beating spline forming a scientific value.

2. Established the Finite Element Simulation Model of Cold Roll Forming Rack

The deforming area where the rolling wheel touches the part uses a density meshing method. The grid cell's mean line length is 0.1mm. For the non-deformed area we use the coarse meshing method. The grid cell's mean line length is 1mm. The size of the making is set to be long, wide and high, which is 24mm, 10mm and 5mm respectively, The penetration depth is set to 0.5mm.The mesh partition of the manufacturing work piece is shown in figure 1. The number of units is 659,600.The roll-beating wheel set arouno rotational degrees of freedom and three translational degrees of freedom; The workpied the y-axis revolution constant angular velocity of 1180r/min, Constrain the remaining twce surface at the bottom of the set along the x-direction constant feed rate of 1mm/s.
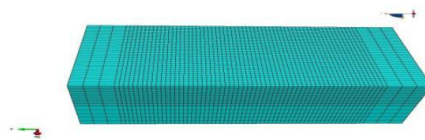

Fig.1 Divided grid work piece

3. Finite Element Simulation Analysis of Cold Rolling Racks

3.1. Roll-beating deformation force simulation

3.1.1. Radial deformation force. Cold roll-beating production process. The changes of radial forces during the up beating and down beating operations are divided into four stages: increasing, stabilizing, transitional and decreasing, as shown in picture 2.
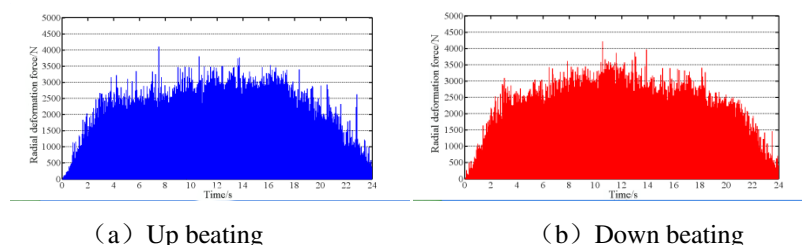

（a）Up beating   （b）Down beating

Fig.2 Radial deformation force force of up beating and down beating when whole cogging is formed

1) Increase stage: The making parts and roll-beating wheel contact constant speed continue to the approach. Between the two contact areas, roll-beating depth increases and

radial deformation force together increases. When up beating and down beating, it plays in the 0 ~4s speed of increasing similar,4 ~ 8.5s increasing speed decreases, which tends to be gentle.

2) Stable stage: between the make piece and the roll-beating wheel, within8.5 ~ 13s,it reachs the maximum contact area, Roll-beating depth reached the maximum. At the same time, radial force into the stable stage, and reached the maximum. The radial force is not absolutely stable at this moment. As the roll-beating process will appear hardening and resonance etc phenomenon, Roll-beating force will slowly increase, and will up and down fluctuate. After that, it is Closer to the actual situation deformation force reached the maximum, basic Maintain balance.

3) Transitional stage: When the tangential undeformed metal material is not sufficient to completely constrain the deformed portion of the material, Roll-beating is in the transitional phase. Among them, up beating the transition stage is between 13 and 18s. Deformation force after a slight bulge slowly decreases. With down beating, the transition stage is also between 13 and 18s. Deformation force began to slowly decrease.

4) Decreasestage: When the roll-beating wheel touches the other boundary of the part, the horizontal direction continues movement of make parts, gradually be away from the roll-beating wheel. The contact area is reduced and radial deformation force decreases, until the contact area is zero time and radial roll-beating force becomes zero. Among them, up beating the deforming force decreased from 18 ~24s later at a constant speed until it is zero; down beating the deforming force decreased between 18 ~22s at a slow22 ~24s, later decreases at a quickly speed until it is zero. It shows that with the up beating and down beating two forming methods, the variation of radial deformation force decrease stage during the whole forming process is rule exist differences.

When Up beating and down beating form, the deformation forces are fluctuating up and down. taking a single roll-beating deformation force compare sized is meaningless, the deformation force of a certain time period can not fully reflect the force size of two cold roll-beating under forming modes. According to the simulation result data as the characteristics of discrete points, it uses a single point average deformation force (the sum of the deformation forces corresponding to the collection points divided by the total number of the collection points) to compare a with b the deformation force size of the two forming modes. Then up beating the average deformation force of the single point is:1569.844N, down beating the average deformation force of the single point is:1541.24N,difference about 1.8%,so in the whole cold roll－beating production process, whether is up beating or down beating the way, the average radial deformation force is basically the same size.

3.1.2. Tangential deformation force. As shown in figure 3, Shun playing, down play cold roll forming process. Tangential force is also divided into three stages: increasing, stabilizing and reducing. The law of change is not completely similar. The regularity of the variation of the tangential force and the variation of the radial force are similar during the follow-up. But the direction of force is negative; With down force the tangential force 0 ~ 11s increase slightly faster, 11 ~ 17s basically are stable, and reach the maximum. After 17s it began to slow down, In 22s, it speeds up to reduce the speed until zero. It can be calculated along the tangent to the single point of the average deformation force size: 287.445N, The direction and the

movement of the opposite direction; down play a single point when the average deformation force: 129.5736N, A difference of about 55%.

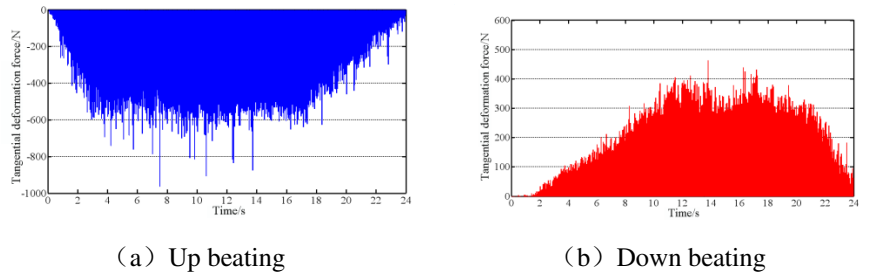（a）Up beating   （b）Down beating

Fig. 3 Tangential deformation force of up beating and down beating when whole cogging is formed

Shun hit. After playing the wheel and the workpiece contact, because it is the same movement, will inevitably increase the deformation of the bottom of the forming tank. The bottom of the force is required to produce deformation. Far greater than the force is required to produce deformation on the surface of the part. When against the fight, the opposite direction of motion increases the amount of deformation near the surface of the part. The force required to create the deformation is small relative to the bottom of the alveolus.

3.1.3. Resultant force. Due to the tangential force, relative to the radial force is small. The size and change of the resultant force is basically determined by the radial force. As shown in Figure 4,the magnitude and change of the resultant force of the cis and transboundary movements are basically the same as that of the radial force.
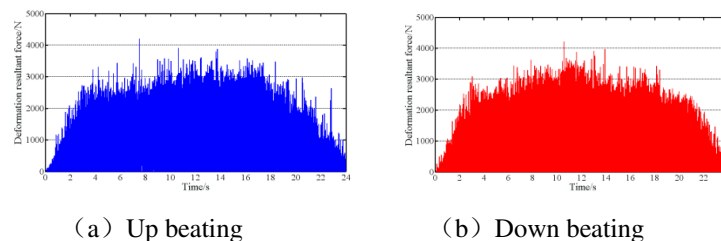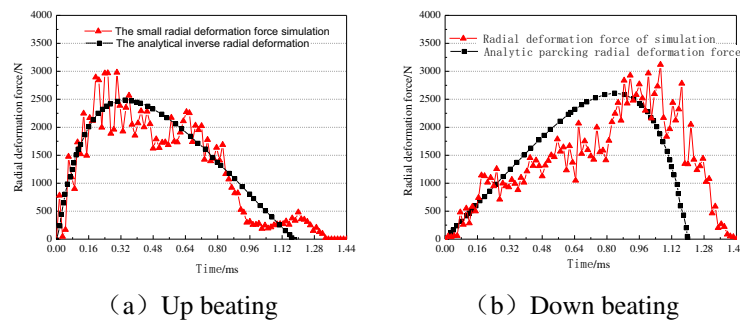

（a）Up beating   （b）Down beating

**Fig. 4** Resultant force of up beating and down beating when whole cogging is formed

3.2. Steady stage single roll deforming force changes

Taking cold roll－beating forming finite element simulation process of the stabilization phase, clockwise hit the time period 9.66516s-9.66660s and the down hit time period 9.65683s-9.65825s single roll radial deformation force, then the cis, inverse roll twice The length of time is about 1.4ms,Shown in Figure 5.Radial rolling deforming force varies with time, generally can be divided into rising（loading）stage and descending (unloading) stage. The resultant force and radial deformation force is similar and not do a separate analysis. However, the radial force, down loading and unloading time are the opposite, of which the clockwise loading time is about 1.2ms, unloading time is about 0.2ms; down loading time is about 0.2ms, unloading time is about 1.2ms.This is because no matter the cis, down, after the deformation, rolling wheel contact with the workpiece needs to overcome the maximum force closed to the cogging at the bottom. down hit, the rolling wheel from the last part of the workpiece forming the beginning of the tooth into the alveolar,

deformation force will reach the maximum (loading process),as the rolling wheel moves closer to the surface of the part, the deformation force gradually decreases and the deformation force becomes zero until it leaves the part surface (unloading process)；clockwise hit, the rolling wheel from the workpiece on the surface began to enter, with the rolling wheel into the workpiece surface gradually deepen, the deformation force also increases, reaching the bottom of the forming tooth, the deformation force to achieve the maximum (loading process)，after that, the rolling wheel quickly runs out from the bottom of the tooth gap, and the deformation force is rapidly reduced to zero (unloading process).For the tangential deformation force variation as shown in Figure 6, and the radial deformation force is basically the same, no longer separate analysis.

（a）Up beating   （b）Down beating

Fig. 5 The radial deforming impulse force during single up beating and down beating at steady stage

（a）Up beating   （b）Down beating
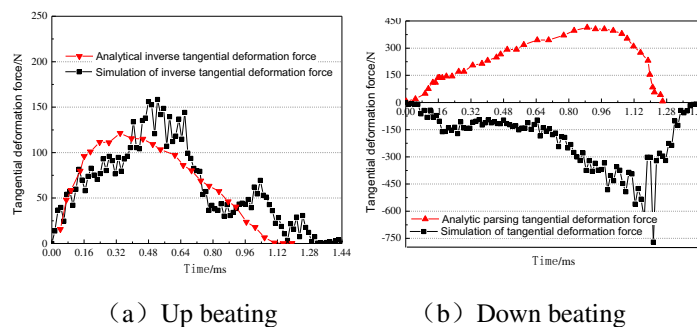
Fig. 6 Tangential deforming impulse force during single up beating and down beating at steady stage

The cold roll－beating production process in the rolling wheel and workpiece contact faster, speed of 1180r / min, the contact time between the two is about 1.4ms.In the process of non-precision machining, it can be approximated that a single cold roll－beating is an instantaneous dynamic loading process，along the fight, down punch forming can be undifferentiated. However, in the precision roll forming, along the fight, the fight against the formation of choice must be considered. When clockwise hitting the radial, tangential deformation force loading a long time, unloading a short time; down hit when the opposite. When the loading time is short, the impact of the rolling wheel on the surface of the workpiece is large, the deformation rate at the moment of contact is large, and the deformation amount also becomes larger, thereby affecting the profile shape of the alveolate formed on the workpiece.

4. Conclusion

Through the finite element numerical simulation, the whole forming process of the cold roll-beating of the rack was simulated and the following conclusions were obtained:Analysis of the simulation results shows that in the process of cold roll－beating forming a complete rack, the radial single-point average force during the normal and down operations is basically the same, but is a difference of about 1.8%，the average tangential single point average force difference is larger, a difference of 55%, of which the tangential force along the big hit, and the opposite direction and the inverse time.Through the cold roll-beating forming process in the steady stage single cold roll－beating deformation simulation results can be found，in the clockwise mode, the deformation force is loaded slowly and the unloading is fast，in the down mode, the deformation force is loaded fast and the unloading mode is slow. It shows that the down impact has a great influence on the parts and the cold roll-beating equipment.

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