Design and application of a new type of transmitting mechanism for advanced manufacturing

Yanzhong He\textsuperscript{1,*}, Zhongliang Huo\textsuperscript{1}, Xingsong Wang\textsuperscript{1}, Jing Chen\textsuperscript{2} and Chunlei Tu\textsuperscript{1}

\textsuperscript{1}School of Mechanical Engineering, Southeast University, 211189, China
\textsuperscript{2}eTrust Power Group Ltd., CITIC Private Equity Funds Management Co., Ltd., 212132, China

*Email: 18136819996@163.com

Abstract. The speed change of the press slider in the tensile region should be slower and the full load operation time should be longer to adapt to the stretching process. By analyzing structure and motion characteristics of the existing mechanical press, changing the main drive gear of the press, a new press with a slide part added near the bottom dead centre (BDC) with low speed characteristic was designed, which is very suitable for advanced manufacturing. According to the working principle and main features of the new combined press, the parametric design of the mechanical model was established by using ADAMS simulation analysis software. Through the parametric design of the pendulum length, several groups of sliding motion curves were obtained, and the influence of the rod length on the motion characteristics of the slider was compared and analyzed.

1. Introduction

At present, the main configuration of mechanical press in domestic and foreign is the crank-slide mechanism. The working part (tool) of the crank press is a stamp, whose fixed part is mounted on the table of the press and whose movable part is mounted on the press slide. The slide is moved by the crank-slide mechanism. In one turn of the crank the connecting rod makes a complete pass; the stamping takes place during the forward motion of the slide. This structure is simple and easy to manufacture and maintain. It satisfies stamping process, cutting edge, shaping, and local forming without special kinematic requirement. Its motion characteristics are shown as sinusoidal curves. Moving speed of slider varies greatly near the bottom dead centre (BDC) and the working stroke is not uniform. When the mechanism works, it has great impact, vibration and noise. Especially in the drawing process, parts are prone to tear or wrinkle defects, which can not guarantee the accuracy and quality of the drawing parts. In order to meet some requirements of deep stamping and deep drawing, it is necessary to change the speed of slider slowly near the lower dead point, and the working area of full load is longer. In order to adapt to the above slider motion characteristics, the existing method is to transform the crank-slider press into six-bar, eight-bar and ten-bar press, which can meet the technological requirements of deep drawing and stretching, but the main transmission structure of this kind of mechanism is more complex, and the requirements for processing, assembly and debugging are higher. Moreover, the multi-link structure leads to poor rigidity and low precision of the whole machine. In order to ensure the quality of the whole machine, the processing and manufacturing requirements of the machine tool are further improved, thus the production cost is increased. However,
the drawbacks of the hydraulic drawing machine are insufficient. In this paper, a new type of mechanical stretching pressure mechanism is designed for the deficiencies of deep drawing and stretching technology in the existing crank-slider press, and the kinematic and structural characteristics of the new structure are described in detail [1-2].

2. Working principle and structure scheme

2.1. Working principle

Figure 1 shows a schematic diagram of the slider motion of a new mechanical drawing press with new configuration. The working principle of the mechanical drawing press is as follows: The eccentric wheel is rotated by the transmission mechanism, and the pendulum rod moves up and down in a straight line while swinging with the eccentric wheel. The center of mass of the pendulum rod moves in the same straight line. The other end of the pendulum rod is connected with the slider, which moves up and down with the pendulum rod. Assuming that the eccentricity of eccentric wheel is $e$ and the length of pendulum rod is $L$, its structural characteristic is that the relationship between eccentric wheel and pendulum rod should satisfy $e < L$. On the premise of satisfying the relationship between the length of the rod, different slider operating curves can be obtained according to the design of different lengths of $L$, and different slide technological motion characteristics can be obtained. In addition, the noise of crank press is lower than that of common crank press because of the lower working speed and the lower impact force. By changing the length of the pendulum rod, the speed of the slider at the end of the working stroke can be greatly slowed down, and it can stay at the limit working position for a period of time, so that the press can have the movement characteristics of tension and holding pressure.

![Figure 1. New type mechanical press slide motion diagram.](image)

(a) Slider running to top dead centre (TDC) condition  
(b) Slider running process condition  
(c) Slider running to bottom dead centre (BDC) condition

The structure of the new mechanical tension press includes the fuselage and the transmission part. The eccentric wheel is mounted on the fuselage and driven by the transmission system. One end of the pendulum rod 2 is hinged with the eccentric wheel 1. With the rotation of the eccentric wheel 1, the pendulum rod 2 performs a compound motion of swing and linear reciprocating motion. The other end of the pendulum rod 2 is connected with the slider part 3, which follows the pendulum rod in reciprocating motion in the fuselage guide rail. The stroke of the press is $H=2e$, and the condition of $e < L$ must be satisfied [3-4].

2.2. Structure scheme

As shown in figure 2, the scheme structure of a new drawing mechanical press for the new configuration is presented. In order to ensure the balance of force and smooth transmission of the main transmission mechanism, the eccentric gears and eccentric wheels are symmetrically installed in the layout of the whole machine. The eccentric gear is rotated by the gear shaft, and the pendulum rod moves in a straight line while swinging with the eccentric wheel. The center of mass of the pendulum rod always moves in a straight line. The other end of the pendulum rod is connected with the middle axis of the slider. When the pendulum rod moves up and down, the slider moves up and down with the
pendulum rod. As shown in figure 3, the eccentric gear and the eccentric wheel in this mechanism are characterized in that the central axis of rotation of the eccentric portion and the central axis of rotation of the large gear are coaxial, which is different from the eccentric gear structure in eccentric gear press.

![Figure 2. Scheme structure of a new drawing mechanical press.](image)

![Figure 3. Eccentric gear structure.](image)

The specific working process of the key parts installation in figure 2 is as follows: the eccentric wheel part of eccentric gear 4 is installed in the copper sleeve 9 of the fuselage 1, the large gear part of eccentric gear 4 meshes with the gear shaft 3, and the gear shaft 3 transmits power by the flywheel 2; the one end of the swing bar 5 is rotated and connected with the eccentric gear 4 through the copper sleeve through the connecting shaft 8. With the rotation of eccentric gear 4, the swing bar 5 oscillates and reciprocates with the upper and lower straight sports. The other end of the pendulum rod 5 is connected with the slider 10 through the rotation of the central axis 7. The slider 10 follows the pendulum rod 5 to reciprocate on the guide rail 11 of the fuselage 1. The structure of the eccentric wheel at the other end is the same as that of the side eccentric gear in the way of power transmission and connection of the slider.

3. Mechanism simulation and analysis
The rigid body simulation analysis model of the transmission mechanism of the new mechanical tension press is established by ADAMS simulation analysis software. Simplified model of main transmission mechanism is established. Simplified model of pendulum, eccentric wheel and slider of main transmission mechanism is created in ADAMS to analyse, which ensures that simulation analysis of main transmission mechanism is not distorted. As shown in figure 4a, the main characteristic parameters are eccentricity of eccentric wheel \( e = 150 \text{mm} \), and length of pendulum rod \( L = 180 \text{mm} \). figure 4b is the simulation operation condition of the main transmission mechanism slider when it goes down. It can be seen that when the slider goes down near the bottom dead centre (BDC), the pendulum rod gradually presents a vertical position, and the angle between the pendulum rod and the
slider running speed decreases gradually. The smaller the angle is, the better the force condition of the pendulum rod is.

![ADAMS simulation analysis model](image1)

![Slide down movement simulation condition diagram](image2)

Figure 4. ADAMS simulation experiment of slider motion.

Figure 5 is the motion characteristic curve of the main drive mechanism with new configuration obtained by ADAMS simulation. When the slider runs to the bottom dead centre (BDC), the speed of the slider changes slowly within a certain range of rotation angle, and the speed and acceleration are smaller, which is very suitable for sheets with low drawing rate.

Figure 6 is the displacement curve of the pendulum rod in X and Y directions, which can clearly show the position of the pendulum rod in a working cycle. In order to study the force variation law of the pendulum rod in the main transmission mechanism, the bottom of slider is assumed to bear the vertical force of F=1000N.

![Main transmission mechanism movement simulation curve](image3)

Figure 5. Main transmission mechanism movement simulation curve.

![Displacement curve of the pendulum rod at the X and Y direction](image4)

Figure 6. Displacement curve of the pendulum rod at the X and Y direction.

Figure 7 is the curve of the vertical direction force at the connecting point of the pendulum rod in the main transmission mechanism simulated by ADAMS. From figure 7a and figure 7b, it can be seen that the force on both sides of the pendulum rod is equal in size and opposite in direction when the slider
goes down. The common point is that when the bottom of the slider is subjected to constant load, the force on the connecting position of the pendulum rod increases gradually as the slider goes down, but when the specific angle is reached, the force law changes, and the force on the connecting position of the pendulum rod decreases gradually with the slider approaching the bottom dead centre (BDC). Because the force of the pendulum rod has such characteristics, it is necessary to consider the angle position of the slider starting to stamp in order to optimize the force conditions at the pendulum rod connection, which is also the basis for checking the strength and stiffness of the pendulum rod.

4. Parametric design of the transmission mechanism

In order to more accurately analyse the influence of the relationship between rod length and eccentricity on the motion characteristics and force properties of the main transmission mechanism, the simulation analysis model in ADAMS is parameterized. Through the transmission simulation of parameterized rod length, the motion characteristics of slider and the force variation curve of pendulum rod under different rod length conditions are further investigated. The motion and force curves under various rod lengths are compared and analysed, and the rules are summarized, which provides a theoretical basis for the design of optimum parameters of the rod lengths of mechanisms.

4.1. Simulation analysis model parameterization

Based on the above simulation and analysis model created in ADAMS, its characteristic parameters are taken as the initial values of parametric analysis. The eccentricity of eccentric wheel $e = 150 \text{ mm}$, the length of the pendulum rod $L = 180 \text{ mm}$. The length of the pendulum rod is parameterized and the value is $L = [160, 170, 180, 190, 200] \text{ mm}$.

There are several parametric design models commonly used in ADAMS: parameterized POINT location, parameterized MARKER POINT location, parameterized geometry and parameterized drive. For the parameterization of the length of the pendulum rod, it can be transformed into the parameterization of the coordinates of the end point of the pendulum rod. When creating a connecting rod that needs to be parameterized, first create geometric points (two geometric points need to be parameterized at both ends, and one geometric point needs to be parameterized at one end), then select the two points when creating the connecting rod. Because the connecting rod is related to the geometric points, the parameterized connecting rod is indirectly realized by the position of the parameterized geometric points, the parameterized connecting rod is indirectly realized by the position of the parameterized geometric points.

The specific methods of parameterization are as follows: Open the simulation analysis model created by the ADAMS. A variable dialog box pops up after clicking on the menu [build] – [Design Variable] – [New]. According to the parametric analysis of the length of the pendulum rod, the design

![Figure 7. Force variation curves of the pendulum rod.](image-url)
variables are 160, 170, 180, 190 and 200, and the standard value is 180. According to the coordinate position relationship of the simulation analysis model, the initial coordinate values of the parameterized points are (0, 330, 0). If the Y coordinate is parameterized instead, the coordinates are (0, (DV_1), 0), and the Y coordinate value (DV_1) is taken as [310, 320, 330, 350, 350]. After setting the parameterized coordinate point, the pendulum rod is correlated with the coordinate of the point. As shown in figure 8, the list of values of the parameterized design variable DV_1 is created. After defining the design variables, we need to define the objective function.

Firstly, the stroke, velocity, acceleration curve, X, Y displacement curve, centroid velocity curve and force curve of the slider in the main transmission mechanism are measured as the optional values of the objective function. Then, the design variable length L of the pendulum rod is correlated with the corresponding objective function curve. As shown in figure 9, after clicking on the menu [simulate] – [Design Evaluation], the dialog box for correlation analysis of defining objective function and design variables is popped up. After defining the correlation function, clicking the [Start] button for parametric simulation analysis and calculation, the corresponding motion curve, displacement curve, centroid velocity curve and force curve of the slider under five different pendulum rod lengths can be obtained. Figure 10 shows the parameterized lines of the length of each pendulum rod.

4.2. Curve analysis

Figure 11 shows the parametric simulation curve of the transmission mechanism. As can be seen from the curves shown in figure 11a, all curves have a common point that the change is relatively gentle.
near the bottom dead centre. With the increase of the length of the rod, the smooth range increases, and different length of the pendulum will get different stroke curves of the slider. In this way, the required process stroke curve can be obtained by the length of the control rod.

As can be seen from the curves shown in figure 11b, the velocity curves of the pendulum rod are obviously different with the length of the pendulum rod. The common point is that the velocity near the bottom dead centre is small, but as the rod length increases, the speed decreases. In this way, the length of the control rod can be used to obtain a very suitable drawing speed for a certain material.

From the curve of figure 11c, it can be seen that the acceleration curves are also significantly different due to the length of the rod. The change of velocity near the bottom dead centre is slower, but with the increase of the length of the rod, the change of velocity is slower [5-9].

![Image](a) Curve of the slide stroke  
(b) Curve of the slide velocity  
(c) Curve of the slide acceleration  
(d) Displacement curve of the pendulum rod at the X direction  
(e) Displacement curve of the pendulum rod at the Y direction  
(f) Force variation curves of the pendulum rod is connected with the eccentric  
(g) Force variation curves of the pendulum rod is connected with the slide wheel  
(h) Velocity curve of the pendulum rod mass center

**Figure 11.** Transmission mechanism parameterized simulation curve.

From the curves in figure 11d and 11e, it can be seen that with the increase of the length of the pendulum rod, the displacement space of the pendulum rod in the direction of X and Y has greater influence on the downward and upward process of the slider, but less influence near the bottom dead centre.
From the curves in figure 11f and 11g, it can be seen that with the increase of the length of the pendulum rod, the force at the junction of the two ends of the pendulum rod decreases, and the effect is most obvious near the maximum value of the force at a specific turning angle, when the effect is less near the bottom dead centre.

From the curves in figure 11h, the velocity characteristics of the centre of mass of the pendulum bar can be obtained. When the slider goes down, the speed increases gradually. After reaching a certain time, as the slider goes down to the bottom dead point, its speed decreases gradually, and the speed of reaching a certain time decreases gradually to zero. When the slider goes down and goes up, the sudden change of velocity at a specific time point is affected by the length of the pendulum rod. The longer the length of the pendulum rod is, the slower the sudden change of velocity is.

5. Conclusion
A new type of transmission mechanism of mechanical press suitable for deep stamping and drawing process is designed. The slider speed changes slowly near the bottom dead centre, and the working area of full load is longer. The mechanism can obtain different slider operating characteristic curves by changing the length of the pendulum rod, which has good versatility.

The working principle and main characteristics of mechanical drawing press are described in detail, and the scheme structure is designed. The key technology and working process of the drawing mechanical press are illustrated with an example.

With the help of ADAMS software, a simulation analysis model is created. The motion characteristics of the main transmission mechanism and the force characteristics of the pendulum rod are simulated and analysed, and the corresponding variation curve is obtained. By parameterizing the length of the pendulum rod in ADAMS, the corresponding slider motion curve, the displacement curve, the centroid velocity curve and the force curve of the pendulum rod under the condition of the length of the pendulum rod are obtained. The relationship curves are evaluated and analysed to provide theoretical basis for the design of the optimum rod length and the optimum technological motion curve of the main transmission mechanism.

This kind of mechanical stretching press has the advantage of sufficient stretching compared with hydraulic stretching press. In addition, the structure can greatly reduce the height of the press body and the weight of the whole machine. While the cost is reduced, the stiffness of the fuselage is increased and the precision of the whole machine is improved, which improves the precision of the parts and the life of the die. It provides an important reference for the design of mechanical press with this configuration.

References
[1] JIER Machine Tool Group Co., LTD. Design of Crank Press. [M]. Jinan: Publishing House of Jinan, 1973.
[2] D. Y. He. Crank Press [M]. Beijing: China Machine Press, 1989.
[3] Y. D. Lu, Y.Z.He, J.M.Huang, etc. Novel mechanical pressing machine [P]. China invention patent: CN201010562724.7.2010.11.25.
[4] Y. Z. He, J. M. Huang. Mechanical press with novel structure [P]. China patent for utility model: CN201020694554.3.2010.12.30.
[5] J. R. Zheng. Introduction and improvement of ADAMS virtual prototype technology [M], Beijing: mechanical industry press, 2002.
[6] MCS. Software. MSC. ADAMS/View advanced training course [M]. Beijing: tsinghua university press, 2004.
[7] L.G.Pu, M.G.Ji. Mechanical design [M]. Beijing: higher education press, 2004.
[8] "handbook of forging and pressing technology". Handbook of forging technology [M]. Beijing: defense industry press, 1988.
[9] Alexander Moser.Metalworking’s Mechanical Press Handbook [M].Boston: Metalworking Magazine, 1960.