

# Improvement Research on Electric Resistance Welding (ERW) Can-Hammering Mechanism Control of Three-Piece Can

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**Abstract**—Three-piece can is also known as SPTE three-piece can. Due to the whole can being composed of can body, bottom and cap, it is called three-piece can. It is the common metal container used in food, beverage and other industries. Three-piece can making technology has been applied and developed for almost nearly 200 years, from the early development of soldering to the current electric resistance welding. Based on the disadvantages of the existing electric resistance welding can-hammering mechanism, the welds quality problem caused by the disadvantages is analyzed and can-hammering mechanism control improvement method and specific solution are raised to promote the welds quality of electric resistance welding.

**Keywords**—SPTE three-piece can; automation control; electric resistance welding; can-making; can-hammering mechanism

## I INTRODUCTION

Three-piece can is also known as SPTE three-piece can. Due to the whole can being composed of can body, bottom and cap, it is called three-piece can. It is the common metal container used in food, beverage and other industries. Three-piece can making technology has been applied and developed for almost nearly 200 years, from the early development of soldering to the current electric resistance welding. In comparison with soldering, electric resistance welding is more environmentally friendly and energy-efficient, but its equipment composition is more complex, and the quality of welding is affected by many factors. The welds quality will affect not only the appearance of the whole can, but also the necking, flanging, sealing and other processes after electric resistance welding. Therefore, the electric resistance welding is the key to the whole production of three-piece can.

## II BASIC CONSTRUCTION OF ELECTRIC RESISTANCE WELDING

The work process of electric resistance welding for can-making contains: materials suctioning, materials feeding, circle forming, can-carrying, can-hammering, and welding.

Materials suctioning means that a small piece of iron sheet is pulled down and separated from rack into materials feeding track after suctioned by sucker; materials feeding mechanism pushes the iron sheet into circle forming mechanism after materials suctioning sucker vacuum is broken; circle forming mechanism rolls the flat iron sheet into a round can with end-to-end joint; can-carrying mechanism pushes this round can to the can-hammering location; can-hammering mechanism forces

this round can between upper and lower welding wheels. On upper and lower welding wheels, there is a moving copper wire which is transferred with the welding wheels and simultaneously passes the round can through the upper and lower welding wheels. In the process, the round can is welded together at the lap joint by the current that flows through upper welding wheel - copper wire - round can end-to-end joint - copper wire - lower welding wheel.

On the welding wheel and the copper wire, low voltage and high current are flowed through. The current reaches kiloampere constantly. End-to-end lap joint of the round can is welded together by instantaneous high heat.

Welding heat is based on  $Q=I^2R$ . Constant current is generated by inverter and relevant control circuit. R is determined by end-to-end lap joint amount. If lap joint area is oversized, resistance R is undersized. The smaller is calorific value, the easier to cause pseudo soldering separation. If lap joint area is undersized, R is oversized. If calorific value is too high, and lap joint area is small, it is easy to cause weld penetration.

## III DISADVANTAGES OF EXISTING CAN-HAMMERING MECHANISM

Common can-hammering mechanism now has the oscillatory hammering pawl-type and the translational pushing pawl-type.

During can-making continuously at high velocity, it is easy for the oscillatory hammering pawl-type to cause can-pressing and can-hammering not in place. Can-pressing shows, when can-hammering time is too early and the can is hammered into upper and lower welding wheels, the velocity of hammering pawl is still higher than that of copper wire, resulting in the can to be extruded or form a mark, or since the velocity of front-end movement is higher than that of copper wire, the amount of heat is not sufficient, resulting in pseudo soldering of front-end. Can-hammering is not in place, because the round can doesn't enter into the space between upper and lower welding wheels after can-hammering in place, or the entry depth is not sufficient. Since the lap joint amount of front-end welding is insufficient and resistance R of lap joint position is relatively large, calorific value is large; since the lap joint area is not sufficient, weld penetration is appeared or big end is welded. These will increase the rejection rate of can-making.

The translational pushing pawl-type resolves above problems to some extent. Structure is shown as Figure I.

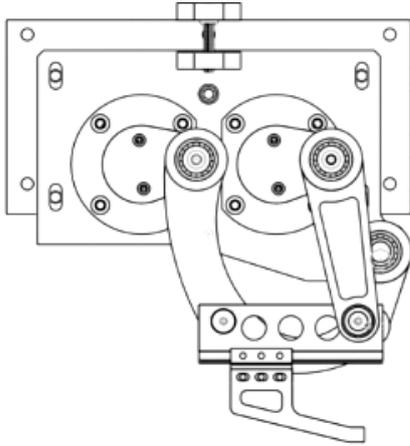


FIGURE I. TRANSLATIONAL PUSHING PAWL-TYPE CAN-HAMMERING MECHANISM

In Figure II, the elapsed time between each two adjacent points is fixed. As can be seen from Figure II, the distance of pushing pawl between each two adjacent points is varied, which can be seen that the motion of pushing pawl is not uniform.

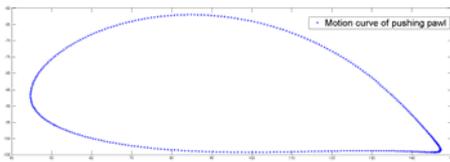


FIGURE II. MOTION CURVE OF PUSHING PAWL

The can-making velocity is set to 300 cans / min, the can height is 88 mm, and the interval over the copper wire is 2 mm. Then, the velocity of the copper wire is approximately 27 RPM. The fixed velocity of the driving wheel of pushing pawl is 300 RPM. Figure. 3 is the motion position curve and the motion velocity curve in the case that the fixed angular velocity of the driving wheel is 300 RPM, where x represents time. Y is horizontal displacement in the upper of Figure III, while y is horizontal velocity in the lower of Figure III.

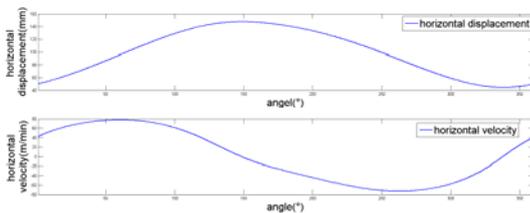


FIGURE III. MOTION DISPLACEMENT AND VELOCITY DIAGRAM OF PUSHING PAWL

When maximum positive horizontal displacement of pushing pawl is 147.5 mm, the horizontal velocity is 0 m/min. In the vicinity of maximum displacement, when the velocity is positive and 27 m/min, the horizontal displacement is 145.3 mm. Therefore, in the range of 2.2 mm, the velocity of pushing

pawl is lower than that of copper wire, i.e. pushing pawl doesn't play a role within this distance, the can performs inertial motion or the can has entered into the space between the welding wheels that are driven by the copper wire, so it is said temporarily that this distance is an invalid distance after the pawl pushes the can.

It is easy to keep the can height and the distance over the copper wire constant. No matter how to increase the can-making velocity, the distance is certainly invalid after the pawl pushes the can.

However, with the same can-making velocity, the can height or the distance over the copper wire is increased, and the velocity of the copper wire is increased, while the velocity of the driving wheel is unchanged, resulting in an increase of invalid distance after the pawl pushes the can. It has been calculated that, in the case of the can height (118 mm) and the distance over the copper wire (2mm), this distance has changed from 2.2 mm to 2.7 mm. In actual production, the quality problem of the welding head is caused by the difference of 0.5mm. It is said temporarily that 0.5mm is velocity compensation distance.

In actual operation, when the can height is changed a little, this velocity compensation distance can be eliminated by reducing the copper wire velocity, i.e. shortening the distance over the copper wire or moving the pushing pawl. However, these two methods have some limitations.

Firstly, reduction of the copper wire velocity is not unlimited. When the copper wire velocity falls too low, the distance between two adjacent cans will be too close and then these two cans will be welded together, resulting in the congestion of the production line, which will eventually increase the rejection rate.

Secondly, when the velocity compensation distance is eliminated by moving the pushing pawl, on the basis of the curve, the computation is made on the invalid distance after the pawl pushes the can. The curve is nonlinear, and the computation is very complex, so the computation of this velocity compensation distance is also nonlinear. In actual production, this distance doesn't appear as a reference for adjustment. During the can switching, the position of pushing pawl only changes the variation of the can height, then repeated attempts are carried out to change other equipment parameters to match the change caused by this velocity compensation distance.

In addition, when the can height is increased, the pushing pawl needs to move the increment of the can height horizontally and negatively, which can lead to press the can during the fall of the pushing pawl. As can be seen from Figure.2, when the pushing pawl is moved from the high position to the plane of the pushing pawl, the velocity is very low within a distance, because the pushing pawl needs requires a certain distance of movement to catch up with the material feeding facility. The longer is the distance of movement, the longer is the time that the pushing pawl spends to catch up with the can-carrier and the higher is the possibility of pressing the can.

Therefore, in order to eliminate these problems, while the calibration difficulty of operator is reduced, the change can be eliminated by the variable motion of the driving wheel.

#### IV THE DRIVING WHEEL VELOCITY CHANGE CONTROL OF TRANSLATIONAL PUSHING CAN-HAMMERING MECHANISM

The velocity change of the driving wheel is achieved by the servo. Motor acceleration and deceleration adopt the fixed acceleration change ways for the convenience of calculation. Initial servo control status is obtained from general control processor of electric resistance welding, and the real-time servo control calculation is completed within the servo.

A new IO connection is provided between the servos of the can-hammering mechanism and the can-carrying mechanism. At the fixed phase, the can-carrying mechanism transmits the signal to the servo of the can-hammering mechanism via this IO. After the rising edge of the IO signal is obtained by the servo, it is compared with its current phase, i.e. the phase difference between the actual phase and the target phase of the servo can be obtained. Later, on the basis of this phase difference, the servo control is adjusted to some degree, in order to ensure that the can-hammering mechanism and the can-carrying mechanism always tends to be synchronized.

Control is divided into three stages: correcting stage, translational pushing and entering stage, and translational pushing in place stage, as shown in Figure IV.

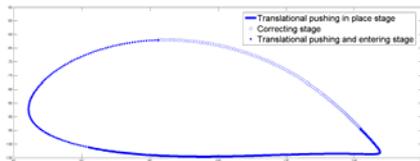


FIGURE IV. THE CONTROL STAGE DIAGRAM OF THE PUSHING PAWL AT THE CHANGING VELOCITY

##### A. Correcting Stage

At this stage, the servo will obtain the synchronization signal of the can-carrying mechanism via IO. The signal is used to correct the motion of the servo. When the signal appears, the servo control should be at a fixed phase. If the servo deviates from the phase at this moment, the angular velocity of the driving wheel is adjusted finely at the correcting stage, thereby reducing the error of the next cycle. In terms of time response, the correcting results are lagged one cycle. Therefore, in normal operation, the correcting ratio can't be too large, and the phase error at the time of signal synchronization should be within 2% during the cycle. If beyond the range, it is out of control. Intermittent control may lead to press the can and occur pseudo soldering or weld penetration of the can. This limit of phase difference can be neglected at start-up. After the velocity of multiple cycles has been corrected, if the phase difference at the synchronization time falls below 1% during the cycle, synchronization is successful, and materials suctioning can be launched.

##### B. Translational Pushing and Entering Stage

Assuming no error control, after the synchronization signal is got from the correcting stage, on the basis of the can-making

velocity, the fixed time of translational pushing and entering ( $t_1$ ), the initial time of translational pushing stage ( $t_0$ ), the initial angular velocity of the drive wheel ( $\omega_0$ ) and the initial angle ( $\theta_0$ ) are obtained. If the entering angle is  $\theta_1$  and the servo acceleration is  $a$ , the target angular velocity at the translational pushing stage is:

$$(t_0 - t_1 + (2 \times a \times \omega_1 - 2 \times a \times \omega_0 - 2 \times t_0 \times t_1 + t_1^2 + t_0^2 + a^2 \times \omega_0^2) / 2) / a$$

##### C. Translational Pushing in Place Stage

The angular velocity at the translational pushing in place stage is still fixed. Only if this angular velocity will ensure that it is pushed horizontally to maximum distance of 2mm, the horizontal velocity of pushing pawl is equal to the velocity of copper wire. Under this condition, on the basis of Figure III, the angular velocity at this time can be derived reversely. It is the angular velocity at the translational pushing in place stage.

#### V SUMMARY

If the better control performance is achieved, three-axis servo control can be used for the can-carrying mechanism, the copper wire movement mechanism and the can-hammering mechanism, and the three mechanisms are built under a control model, so the error control response will be more timely and the control Stability is better.

The shortcomings for the existing translational pushing type of can-hammering mechanism are discussed mainly. The shortcomings are remedied by the method of variable speed control. Ultimately, such a goal is achieved: after the can height is changed, the pushing pawl only needs to consider the actual variation of the can height, without the consideration of such a problem whether the velocity of pushing the welding wheel is not synchronized with the speed of the copper wire due to the change of the can height; this problem is resolved - when the can height is increased, since the pushing pawl is in the falling-after-rising position, there is a problem of pressing the can.

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