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NC Transformation of Shear in Preheater Heat Transfer Element

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Abstract

In order to solve the problem of low positioning accuracy, poor automation, less efficient that common shears work in the production of boiler air preheater heat transfer components, a new type of Double CNC shearing machine system is designed on the basis of common shears. The PLC, Ball screw and Servo system are used to control the feeding length accurately, a touch screen is applied as a display device and input system at the same time, the utility of system is improved greatly. In this article, the design process, basic structure and operating principle of the system are introduced, the design ideology and PLC program flow are described, there is a brief description about the system program debugging results as well. At the end, the rationality of the design is proved combined by the actual use.

1. Introduction

An air preheater is an important waste heat recovery equipment in a boiler system, heat carried by the flue gas in rear of the boiler flue is converted to the cold air required for combustion. Not only reducing the loss of energy of a unit, energy conservation, but also cooling the high temperature flue gas, reducing the dust content in smog and harmful gas [1, 2]. At present, commonly rotary air preheater in large thermal power plants exchange heat between smog and air by rotating fan warehouse of heat transfer components. Shears are used to cut heat transfer components in the production process, however, due to the fan-shaped arrangement of the heat transfer element in fan warehouse, lead to a different sheet length. There are some problems of low precision, inefficiency, tedious work about using common shears in artificial cutting. Aiming at this problem, common shears are remade by applying a PLC, a AC servo motor and a ball screw. Functions of upper and lower double synchronous feeding, synchronous cutting, manual synchronization trimming, any given number cropping, real-time display processing parameters are added, at the same time keeping the function of the original equipment. The working efficiency and the cutting accuracy are improved greatly. The system has been put into production, reliable, high control accuracy, ease of use and maintenance.

2. Structure and Principle

2.1. The General Design Requirements

The length of heat transfer elements is different, because heat transfer components of rotary preheaters are put in fan warehouse[5]. In order to reduce errors caused by manual adjustment, the shear system should feed and shear according to a group of predetermined number automatically, it has the function of pause and re-start cutting at any number. Heat transfer components in heat sink divide into the flat type and the embossed type. In order to increase the heat transfer area, a flat type and a embossed type heat transfer components are put together as a group. This requires that a consistent size of two cutting

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down plates must be ensured. The feeding platform of shears is designed to double layer structure, not only improve the efficiency, but also ensure the cutting accuracy. It is inevitable that the plate dislocation of upper and the lower layers caused by mechanical errors. The function of manual synchronous edge trimming is essential, two layer plate position is adjusted by the way of manual if it is necessary. In order to grasp the real-time current work and metal cutting status of shears, the upper and lower feed section need to be detected and controlled accurately. The state and the current processing parameters can be displayed and set at a real time. Figure 1 shows the placement diagram of preheater fan warehouse heat transfer element.

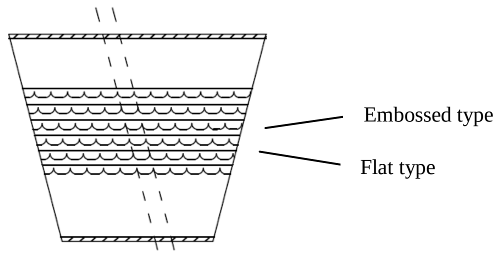
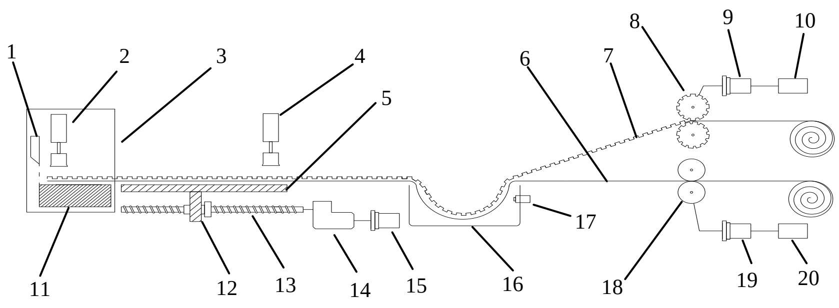


Figure 1. A Schematic Diagram of the Preheater Fan Compartment

2.2. The Basic Structure of the System

A CNC cutting system consists of a mechanical part and a control sections. The mechanical part assembled by a shear body, a feeding platform and a roll feeder. The control section consists of a PLC and related electrical components. A touch screen is applied as input and display module in order to facilitate parameter setting and display real-time data. Shears body includes a mounting bracket, a cutting blade for cutting sheet metal, a cylinder briquetting for fixing plate, position sensors for detecting blade position. Figure 2 shows the shearing system schematic.

The feeding platform is a key part to control the plate moving precisely, it consists of a cylinder briquetting, a platform, a fixing nut, a screw, a reducer and a AC servo motor. The AC servo motor controlled by PLC is connected with a screw by the reducer, the screw is connected with platform by fixed nut.



1.Shear Blades 2.Clamping Cylinder 3.Shears Bracket 4.Transfer 5.Feeding Platform 6.Flat Plate 7.Embossing Plate
8.Embossed Rollers 9.Feeding Motor Converter 10.Up Feeding Converter 11.Cut 12.Screw nut 13.Ball 14.Reducer
15.Servo Motor 16.Buffer Pit 17.Photoelectric Switch 18.Flat Rollers 19.Drive Motor 20.Down Feeding Converter

Figure 2. The Shearing System Schematic

2.3. The System Works

The stuff is transported by two roll feeder at the same time, after embossing rollers, two plates are pressed to the required plate type respectively, after a buffer pit, two plates are arrived at feeding platform. Aligning two plates is required by an artificial trimming when the system first runs. The clamping cylinder clamping when the plate reaches it, stop feeding simultaneously, manual controlling shears cutting. After completion, the feeding platform drives the transfer cylinder moving backwards to a default length, clamping cylinder after reaching the specified position, lifting it, then the plate is send to clamping cylinder, clamping, cutting. This process is cycled by shears according to the sequence and length of setting, automatic cutting, until a stop command is received. Shears control system flow chart is shown in Figure 3.

First of all, the system is initialized, after the functions of each part are monitored properly, the system works in normal operating cycle. If the system function is detected abnormality, stop signal is sent immediately, alarming, this is done by the PLC and sensors. The work of feeding motor and embossing roller motor is controlled by the PLC, whether a manual trimming is needed depending on the setting. If it is necessary, the manual mode is switched, to trim, otherwise into the automatic mode directly, the distance setting in the touchscreen is read, automatic circular cutting.

3. System Design and Selection

3.1. The Structural Design

This design is reformed on the basis of existing shears, the production cost is greatly reduced. The cutting part of shears are retained, feeding platform is transformed, a plurality of clamping cylinders and corresponding sensor is fixed on the platform. The moving part of platform consists of two linear guides and ball screws. The rotary motion is converted into linear motion by the ball screw, a small friction, high accuracy ensure the platform moving more precisely. The ball screw is connected to the gear motor,then connected to AC servo motor by couplings.

Servo motors, compression cylinder and frequency converters are controlled by PLC, sensors of the system are also connected to PLC respectively. The status of device which is monitored is reflected to PLC to judge the current work status. Using the touch screen as a display and input device, data is input conveniently, the current working status of the system is understood intuitively [7].

3.2. The Component Selection

The component selection is essential for the system, the system efficiency is improved and the system life is increased by a right choice, unnecessary costs are reduced [6]. In this paper, the component selection is about the ball screw and the servo motor. Main parameters needed by the ball screw selection include screw pitch (mm), axial draw load (P_{m}), average speed(N_{m}), basic dynamic rating load(daN), dangerous speed(N_{c}), buckling load(P_{k}) and screw length. The ball screw selection process shown in Figure 4. The BSS3232-1238 is used by the ball screw type of CNC cutting machines.

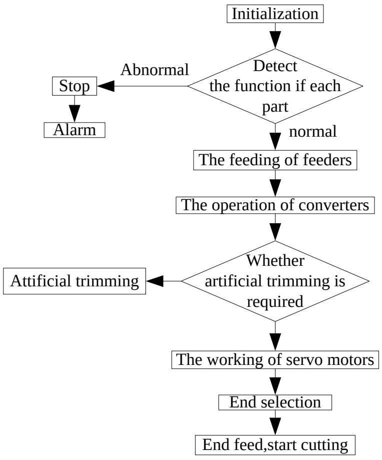


Figure 3. The Control System Flow Chart

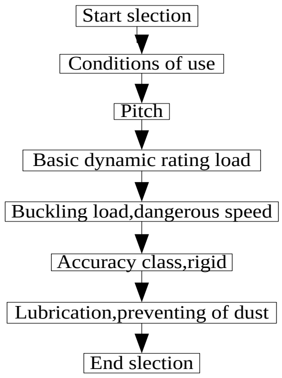


Figure 4. The Ball Selection Process

When a type of servo motors is selected, the margin load which applied in the output of a motor shaft must be ensured. The inertia torque of applying to the motor output shaft can be started and stopped basing on the desired pulse rate, there is a enough time constant for acceleration and deceleration of it[8].

The total torque of the motor output shaft consists of a constant speed torque and a acceleration torque of output shaft.

$$T_1 = \left(\frac{PL}{2\pi\eta} + T_P \frac{(3P_L - P)}{3P_L} \right) \frac{Z_1}{Z_2} \tag{2-1}$$

$$P = F + uMg \tag{2-2}$$

In the formula: T_1 $(N \cdot m)$ is the output torque when speed is constant. P (N) is the axial external load. L is the pitch of ball screw. η is the total mechanical efficiency. T_P is the friction torque caused by a preliminary pressure load, means that the torque is generated when there is a pressure, a preliminary pressure nut of the preliminary pressure load of is released, the preliminary pressure friction torque is decreased with the increase of the external load also. P_L is a preliminary pressure load. Z_1 / Z_2 is the gear ratio of the transmission gear[9].

Accelerating torque of the motor output shaft can be calculated by the following formula[10].

$$T_2 = J_M \omega = J_M \frac{2\pi N}{60\,t} \times 10^{-3} \tag{2-3}$$

$$J_M = J_1 + J_4 + \left(\frac{Z_1}{Z_2} \right) \left\{ (J_2 + J_3) + M \left(\frac{L}{2\pi} \right)^2 \right\} \tag{2-4}$$

$$J_i = \frac{\pi\gamma}{32} D^4 \ell (i = 1,2,3,4) \tag{2-5}$$

The above formula: T_2 is driving torque during acceleration ($\mathrm{N \cdot m}$). ω is the angular acceleration of the motor shaft ($\mathrm{rad/s^2}$). N is the motor speed ($\mathrm{r/min}$). t is the acceleration time(s). J_M is the inertia torque of the motor($\mathrm{kg/cm^2}$). J_1 is the inertia torque of a small gear (kg/cm^2). J_2 is the inertia torque of a large gear (kg/cm^2). J_3 is the inertial torque of ball screw (kg/cm^2). J_4 is the inertia torque of motor rotor (kg/cm^2). M is the weight bench and sheet (kg). L is ball screw pitch (cm). D is the outer diameter of the cylinder. ℓ is the cylinder length. γ is the proportion of material $\gamma = 7.8 \times 10^{-3}$.

The total torque of the output shaft motor can be obtained.

$$T_M = T_1 + T_2 = \left(\frac{PL}{2\pi\eta} + T_P \frac{(3P_L - P)}{3P_L} \right) \frac{Z_1}{Z_2} + J_M \frac{2\pi N}{60t} \times 10^{-3} \quad (2\text{-}6)$$

Based on the above results obtained, the motor selection software is used to calculate the required motor power. According to the calculation result, the ASMT30M250AK is chosen as a servo motor, the ASD-A3023M is used as a servo driver.

4. Hardware and Software Design

4.1. The Main Circuit Design

The work of servo motor is completed by the control of the servo driver, the speed and the direction of the servo motor are controlled by servo drivers according a request of the PLC [3]. A main wiring diagram of the system is shown in Figure 5. The left side of the main circuit is a wire of the servo driver, the R, S and T are the servo drive power supply terminal, the L1, L2 terminal are the control power of a servo driver.

The output terminals of the U, V, W are the input terminal of a servo motor power. The PE terminal is the ground terminal. The right of the main circuit is protection and control loop of servo system and AC-DC converter circuit. The traditional circuit-breaker is replaced by QM1 that is a new motor protection switch. The TC1, TC2 are controlled circuit transformer, ordinary three-phase power supply is converted to the AC and DC power supply for controlling, for servo drives and other external devices [4]. The contactor KM1 is a servo controller power switch. The QF1, QF2, QF3 are breaker for protecting the unidirectional power circuit. The SB1 is a normally closed button as the switch control circuit, as the system emergency stop button at the same time. The SB2 is a normally open push button for a detection system and a coil normally or not. The LT1 as a light is used to display the working status of main circuit. The KA13 as a switch used to drive the coil KM2, controlling the cut material electromagnet working in the manual mode. As shown in Figure 5.

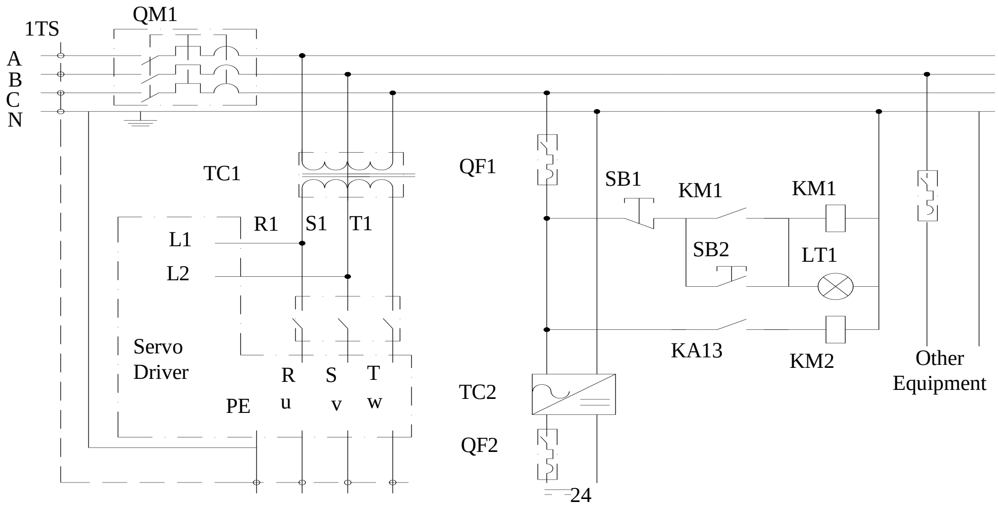


Figure 5. The System Main Wiring Diagram

4.2. The Servo Drive Port Allocation and Software Design

The PLC servo drive terminal assignments include: emergency stop button SB1, servo motor operation button SB3, SB4, SB5, SB6, mode switch SA7, servo motor automatically run button SB8,SB9,SB10,SB11,SB12. Figure 6 shows PLC servo terminal assignments.

The software design of the PLC includes two parts, the manual mode and the automatic mode. The structure of programs become simple and clear, easy to check and analyze because of using the modular structure in the program. Programs include a initialization process, the manual / automatic mode switching program, a aligned cutting process, the counter program, the emergency stop procedures and so on. The servo system and the cylinder are controlled directly by external buttons and switches, the corresponding procedure is relatively simple when the system working in manual mode. When the system works in automatic mode, a work cycle of the servo motor, a operation time of the cylinder and a cutting frequency are calculated according to the input data. Figure 7. shows the software flow chart.

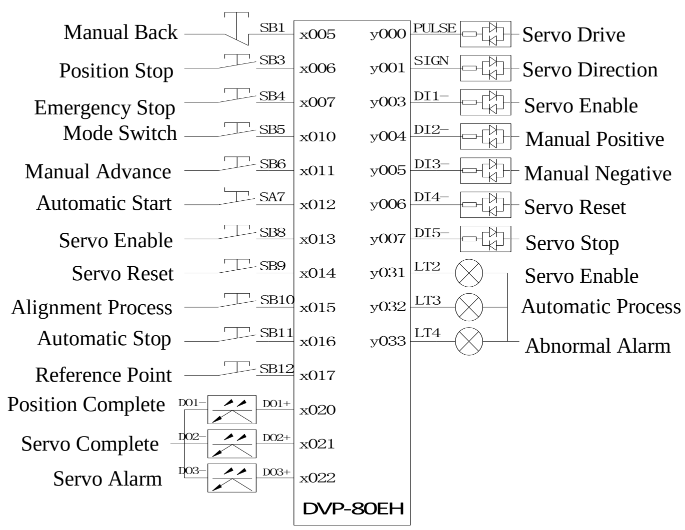


Figure 6. Input and Output Port Assignment Map of PLC

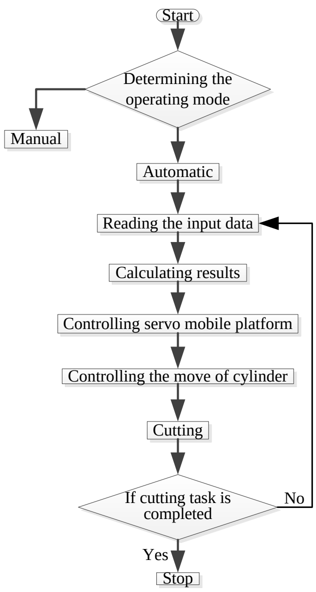


Figure 7. The Software Process

The move of the feeding platform is adjusted according to the needed data of shears automatically cut fixed-length program. After entering the automatic operation mode, the M202 coil is conducted, the M20 coil is energized, the movement valve is controlled to clamp. The K1 is the number of steps needed to cut, D3300 is running steps currently. The D4010 indicates that the difference distance currently. The D3300 is compared with K1, calculating the required moving distance currently. The data is stored to D5000.

The mobile cylinder clamping or not is controlled by the Y16. After the Y16 is closed, clamping cylinders after the moving cylinder clamping. The T90 is the delay register, the data of the K15 is delay time. After the delay, the M22 coil is reset, clamping cylinder relax, after the moving the cylinder clamp (Y16 closed), clamping cylinder relax (Y20 closed). The T71 timer starts counting, time the K12 is timing, the required moving distance(D5000) is sent to pulse counter.

(D3000). The platform is moved, positioned after servo enable until the fixed-length program is completed. The mobile valves return the specified location based on the traveled distance, cycling, automatic feeding task is completed. Figure 8 is a fixed-length program when cutting automatically.

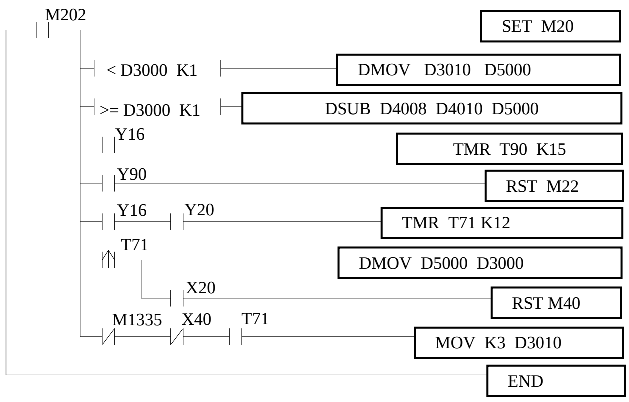
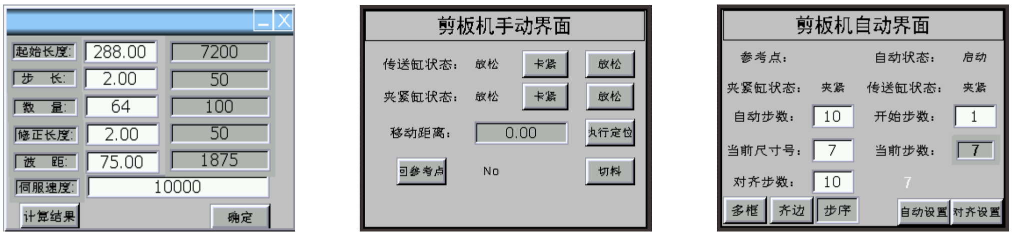


Figure 8. The Fixed-Length Program

5. Run and Debug

A Delta touch screen and a PLC are adopted in the shears system, the ScrEdit software can be used to design touch-screen interface and connected to PLC by a emulator, the PLC program is debugged. The work status of the transfer cylinder and clamping cylinder are controlled by shears manual control interface. The cutting material of shears can be controlled as well.

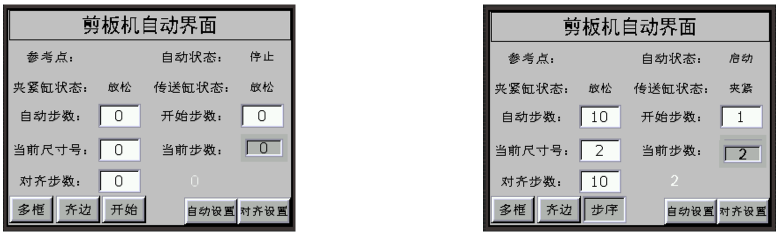
The moving distance of platforms be read directly. The manual cutting can be completed at the end. In the automatic interface, the status of transfer cylinders and running steps currently is displayed, specify the number of steps are input that the system starts to run from the specified location. The automatic settings interface is entered by the auto setup button, after entering the actual parameters, the corresponding results are calculated according to the program by a PLC. The operating parameters of the servo motor are set. Figure 9(a) and Figure 9(b) shows shears controlling interface. Figure 9(c). shows automatic setup interface.



(a) (b) (c)

Figure 9. The Manual Control ,Automatic Control and Automatic Settings Interface

When the program is debugged, parameters are added. The parameters of Figure 11 are common parameters of the actual production, for *example*: the initial length, the step, the quantity, *etc*. Align parameters are set in alignment settings page in order to reduce cutting error. Selecting cutting types depending on the circumstances later, multi-frame or single frame cutting. Finally, click the start, the system enters the automatic working state. Figure 12 and Figure 13 show the two work states of shears during program debugging.



(a) (b)

Figure 10. The Automatic Work Status

In the simulated automatic work process, the automatic steps are set to 10, the start step number to 1, the alignment step number to 10. Figure 10(a). Shows the work status of shears running to the second step. In this case the transfer cylinder is clamped, the clamping cylinder is relaxed, the system is in the second step of conveying plates. Figure 10(b). is a 7th step in the automatic process, at this point the clamping cylinder and transfer cylinder are in the clamped state, the system is in the 7th step of cutting plates.

6. Conclusions

The problems of low efficiency, large errors in traditional boiler air preheater heat transfer components production are solved. Ball screws, a servo system, a PLC and other equipments are used to reform ordinary shears, and the conventional single-layer structure is instead by the two-layered structure. Not only the productivity and accuracy of equipment are provided greatly but also production costs are reduced. There are manual mode and automatic mode in the system. The mode can be free changed in order to meet the various needs of different situations. The current work status can be displayed by a touch screen. The touch screen is used as an input module for setting up easier. The correctness of the design is proved by the ScrEdit software running on the system debugging. There are already some manufacturers began to use this shearing system, systems are working properly, the cutting tasks can be completed quickly and accurately in accordance with the requirements. Depending on the application, the system is not only suitable for the production of pre-heater heat transfer components, but also for other the occasion that needs often change sheer size.

References

[1] J. Zhou, B. Song, S. Chen, D. Zhao and C. Tian, "Application of Plate Air Preheater[J]", Petro-Chemical Equipment, vol. 01, (2007), pp. 68-70.
[2] Z. Wang, "Energy-saving Transformation of Rotary Air Heater in the Boiler of Power Plant and Utility Analysis[J]", Energy Technology and Economics, vol. 05, (2010), pp. 50-53, 66.
[3] Z. Wang and J. Hao, "Design of Control System of Industrial Steam Turbine Based on PLC and Touch Screen[J]", Journal of Harbin University of Science and Technology, vol. 06, (2007), pp. 107-109, 116.
[4] Y. Zhong, J. Hao, Y. Wang and L. Han, "The Control System of Small Industrial Steam Turbine Based on P LC[J]", Journal of Harbin University of Science and Technology, vol.02, **(2007)**, pp. 56-58, 62.
[5] X. Xiong, "Design of Automatic Cutting Plate Machine System Based on PLC[J]", Programmable Controller & Factory Automation, vol. 12, **(2002)**, pp. 70-71, 73.
[6] Y. Hai and L. Sun, "Design of Shears Automatic Control System Based on PLC[J]", Electric Age, vol. 08, **(2012)**, pp. 100-102.
[7] G. Shen, Q. Shi, Q. W. Shi, "PLC controlled automatic shears[J]", Journal Of Jiamusi University(Natural Science Edition), vol. 02, **(2000)**, pp.148-150.
[8] S. Chen, Q. Zheng, Y. Yuan, "Design and Implementation of Automatic Control Shears[J]", Modern Electronics Technique, vol. 19, **(2009)**, pp. 157-160.
[9] R. Pei and J. Miao, "Synchronously Running Control Method for Four Machines of Double-Side Shear. Industrial Electronics and Applications", 2006 1ST IEEE Conference on, **(2006)**, pp. 1–3.
[10] Y. Li an H. Gao, "On-line Calculation for Thermal Efficiency of Boiler", Power and Energy Engineering Conference (APPEEC), 2010 Asia-Pacific. **(2010)**, pp. 1-4.