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The Research of Ultrasonic Equipment Applied In Non-woven Welding

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Abstract. In the paper, an ultrasonic atomization welding system is discussed, which composed of the high frequency ultrasonic power supply and the transducer. The high frequency ultrasonic power supply provides appropriate electric for the transducer, and the transducer transforms the electric energy into the ultrasonic kinetic energy. This paper is focus on the theory analysis and the design of the power supply. Based on the analysis and argument of ultrasonic welding power, for ultrasonic welding of the specific requirements, designed the rectifier filter circuit, power amplifier, frequency track circuit, matching circuit, drive and protection circuit. In addition, analyzed the main part of the rectifier filter circuit, power conversion and other parts, gave the parameters of calculation and choice of methods.

Keywords*:* Ultrasonic Automatic Welding System, Ultrasonic Power Supply, Convert, Frequency Tracing

1. Main text

With the people's life quality improving and the life rhythm speeding up, the early Non-woven Fabrics processing method already cannot satisfied the requirements, and cannot correspond with demand of the automation or the standardization, so the Ultrasonic Automatic Welding System has widely prospect and application. This paper is focus on the theory analysis and the design of the power supply.

2. Main text

The system[5] of Ultrasonic power mainly consists of driving circuit, power amplifiers, matching circuits, transducer and feedback circuit components. Ultrasonic power supply theory as shown in figure 1. shows.

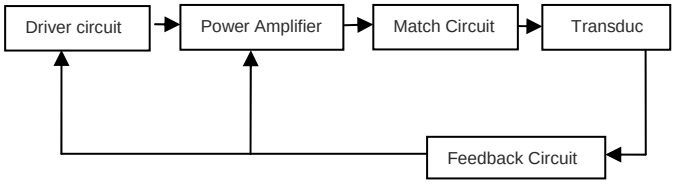

Fig. 1: Principle of Ultrasonic Generator

In the practice[3], switching power supply tends to adopt the converter with transformer isolation. While in ultrasonic power field, from safety and practicality, control and impedance converting angle, need to adopt the converter with transformer isolation.

3. The Design Rectifier Filter Circuit

Rectifier filter circuit is the role of communication, converting input voltage 220V power converters need dc voltage. This paper adopts not controlled rectifying circuit by electric capacitance filtering provide dc power to the back power amplifier circuit. Circuit diagram, as shown in figure 2 shows.

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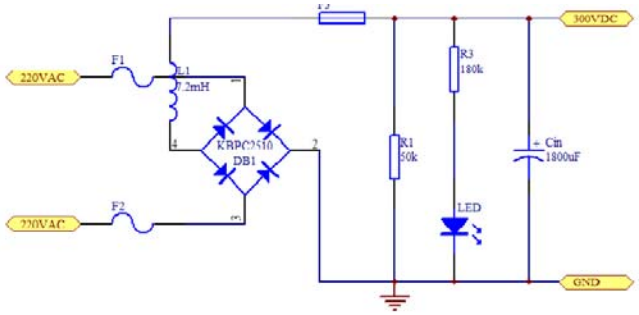

Fig.2: Rectifier Filter Circuits

3.1. 3.1. The Production of 300V DC

Input Filter Capacitance C_{in} design

Phase voltage RMS U:

$$220^{+10\%}_{-10\%} = 198 \sim 242(AC) \quad (3\text{-}1)$$

Phase voltage peak $\sqrt{2}U : 280 \sim 342V$

After rectifying the biggest pulsation of dc voltage values $U_{PP} : 20V$

After rectifying dc voltage

$$U_{in} : (\sqrt{2}U_{\min} - U_{PP}) \sim \sqrt{2}U_{\max} (260 \sim 342V) \quad (3\text{-}2)$$

Each cycle C_{in} can provide the energy W_{in} is about

$$W_{in} = \frac{P_{in}}{f} = \frac{P_{out}}{\eta f} \quad (3\text{-}3)$$

P_{in} is the power input power, P_{out} is the power output power, f is ac voltage frequency, η is communication point of efficiency, in the equation.

This paper rated output power (transducer outputs) for 1000 W, consider matching circuits matching inductance and loss of transformer and matching performance, with certain power allowance, power efficiency estimation for 0.8, then

$$Win = \frac{1700}{0.8 \times 50} = 42.5J \quad (3\text{-}4)$$

Every half cycle filter capacitance provided energy

$$\frac{W_{in}}{2} = \frac{1}{2} C_{in} \left[\left(\sqrt{2}U_{\max} \right)^2 - (\sqrt{2}U_{\min} - U_{PP})^2 \right] \quad (3\text{-}5)$$

By the upon equation

$$Cin = \frac{Win}{[(\sqrt{2}U\max)^2 - (\sqrt{2}U\min - U_{PP})^2]} = 0.861 \times 10^{-3} F = 861uF \quad (3\text{-}6)$$

According to the equation (3-6) calculated the electric capacity and after rectifying the dc voltage maximum and the manufacturers to provide manual, we can choose corresponding electrolytic capacitors. We choose the 900uF/450V electrolytic capacitors in this power.

$$U_{in(\min)} = \sqrt{(\sqrt{2}U_{\max})^2 - \frac{W_{in}}{C_{in}}} = 305.5 \quad (3\text{-}7)$$

3.2. Selection of Filtering Inductances Parameter [5]

Filtering inductances L1 role is to restrict current volatility. Inductance value choice principle is the most current volatility value ΔI_{pm} is no more than 10%-20% of the peak current. Power output is 1700W, input voltage (effective Value) minimum of 198V, peak current is

$$I_{PK} = \frac{P_O}{\sqrt{2}U_{\min}} = \frac{1700}{280} = 6.07A \quad (3\text{-}8)$$

According to the circuit principle, available the peak current duty cycle D is

$$D = \frac{U_O - \sqrt{2}U_{\min}}{U_O} = \frac{300 - \sqrt{2} \times 198}{300} = 0.07 \quad (3\text{-}9)$$

Set the switch cycle is Ts, the current volatility is

$$\Delta I_P = \frac{\sqrt{2}U_{\min} \times D \times T_S}{L_1} \le \Delta I_{pm} \quad (3\text{-}10)$$

Then, $L_1 \ge \frac{\sqrt{2}U_{\min} \times D \times T_S}{\Delta I_{pm}} = 0.40mH \; I_D > 1.2\frac{P_{OUT}}{V_{in(\min)}} = \frac{1.2 \times 1700}{280} = 7.29A$ (3-11)

Actual take L_1=7.2Mh

3.3. Choice of Rectifier Diode

The standard rectifier devices' current capacity on Rectifier bridges BD1 must to meet the maximum average current value when produced in low input voltage.

$$I_P = \frac{1700}{0.8 \times \sqrt{2} \times 198} = 7.59A \quad (3\text{-}12)$$

So, conducting electricity flow of rectifying device most more than 7.59A, minimum blocking voltage is twice the highest input voltage, in other words 684V. So, we can choose Rectifier bridges BD1 of 900V/15A.

The actual rectifier filter circuit diagram, as shown in figure 1 shows.

3.4. The Designed of 12V DC

Because this ultrasonic system use 12V DC for 555 time-based circuit and middle relays control terminals supply power, so make a brief explanation generating of 12 V DC

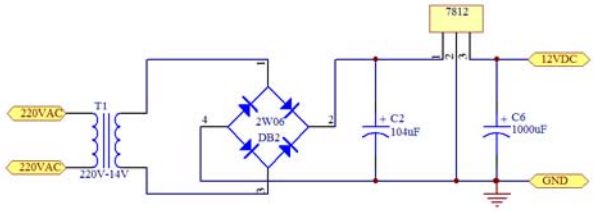

Fig.3: 12V DC Circuits

4. Calculation of Ultrasonic Power Amplifier Circuit Parameters[4]

Because the output power of the circuit is larger, input is single-phase rectifier voltage, therefore power amplifier main circuit choose the push-pull type circuit. We obtained 300V dc by rectified from Single-phase 220V ac filter circuits, 300V dc as the input of voltage power amplifier dc voltage.

4.1. The Choice of Power Switch Tube

The main purpose of the power switch part is to change the input dc voltage into pulse width modulation of ac voltage. The stage followed the power switch can use transformer raise or lower the ac wave form, finally add the ac voltage to transducer by the output stage.

In the push-pull type circuit, each switch tube withstand voltage is no greater than the power voltage E, considering the network voltage fluctuation and the peak voltage which caused leakage of inductance by high-frequency transformer, power switching pipe actual can endure highest voltage.

$$U_m = 1.1 \times 1.2 \times E = 1.32E = 396V \quad (4\text{-}1)$$

In addition, consider working temperature, the transient process of circuit etc. factors, rated voltage of actual selected devices is:

$$U_{CER} > (1.25 \sim 2) \times U_m = (1.65 \sim 2.64)E = 6.732V \tag{4-2}$$

Set the power amplifier is η, the conduction ratio is α, the power of output is Po, the power of input is Pi, then the equivalent peak value of load current is:

$$I_m = \frac{2P_i}{E\alpha_1} = \frac{2P_o}{E\eta\alpha_1} \tag{4-3}$$

The current peak is sum of load current peak of devices and excitation current of the transformer's original edge. Usually, excitation current take $K_m \times I_m, K_m = 0.1 \sim 0.3$, Km is excitation current coefficient, Therefore peak current which flows through devices should be

$$I_{pm} = I_m + I_m K_m = (1.1 \sim 1.3) I_m = \frac{(2.2 \sim 2.6)P_o}{E\eta\alpha_1} \tag{4-4}$$

$$I_{CE} > 1.5 I_{pm} \tag{4-5}$$

Through calculation,

$$U_{DSS} > 2U_{in} > 2 \times 342 = 684V \text{ take1500V} \tag{4-6}$$

$$I_D > 1.2 \frac{P_{out}}{V_{in(\min)}} = \frac{1.2 \times 1000}{280} = 4.29A \tag{4-7}$$

Choose a bipolar power transistor C4237, which is high speed switches, and the parameters are 1500V, 10A, 120W.

4.2. The Structure of Lord Amplifier Circuit

In practical applications, considering the output power of power transformer is large, in order to enhance the system reliability, using 5 transistors in parallel, forming the push-pull amplifier, as it is shown in figure4. So, if a pipe is damaged other power amplifier tubes still work when it works, so that the system reliability enhanced. But, 5 power amplifier tube of parallel brought equal flow problem, so we adopt method forced equal flow in here, between the base and shot extreme of amplifier tubes parallel place the same value resistors, make its working condition is always reliable.

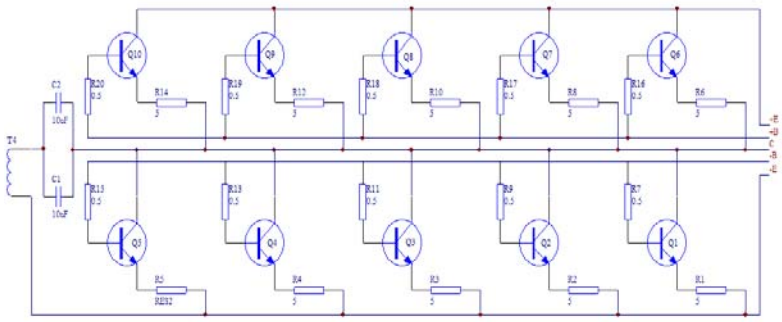

Fig.4: The Structure of Lord Amplifier Circuit

5. Ultrasonic Power Feedback Circuit Principle[3]

5.1. Design of Power Feedback Circuit

In ultrasonic power, we need the power feedback circuit. Because when load change or electronic grid voltage change, ultrasonic power output power will change too, reflected in energy converter is the mechanical vibration transducer suddenly large or small, in order to make the transducer work stably, we design a power feedback circuit when the design of ultrasonic power supply, make the ultrasonic power system operation stably.

In the ultrasonic power, the parameter which we need to control is always current of the transducer, and the transducer current constant need by control the both ends of the voltage transducer to realize. This paper is

done by changing moving phase Angle of the push-pull driving circuit to change the output voltage amplitude transducer, then change on the both ends voltage of transducer in order to achieve the purpose of that power output constantly. The circuit is shown in the figure 5.1.

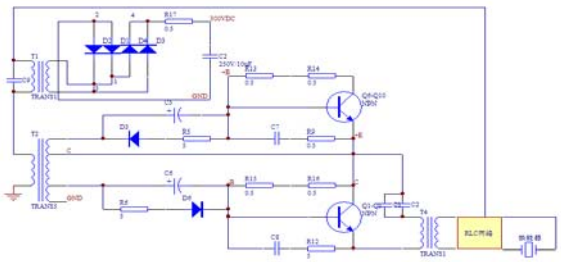

Fig.5.1: Power Feedback Circuit.

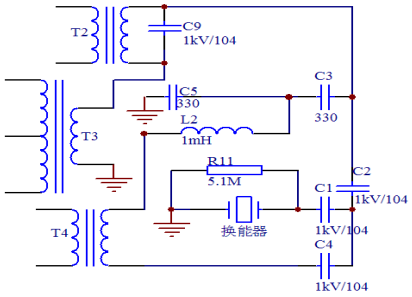

Fig.5.2: Power Feedback Circuit.

When ultrasonic power frequency is constant, the power output to transducer increase , then the feedback voltage increase, constant dc voltage of phase shifting control circuit increase ,the conduction angles of transistor Q6 ~ Q10 reduce, thus the output voltage decrease, When the voltage transducer reduce, feedback voltage at both ends of U_{R13} decrease, and the constant dc voltage of the phase shifting control circuit reduce, the conduction angles of transistor Q6 ~ Q10 increase, output voltage increase, the output power is effectively controlled, finally realizes the power feedback circuit control output power, make transducer work process stability.

5.2. The Type of Load Divide Voltage Feedback System

This paper adopts the type of load divide voltage feedback system. Because the frequency of the ultrasonic welding transistor is 20kHz, frequency deviation is small while working, using the type of load divide voltage feedback system advantage is: good stability, system structure is simple and cost-effective

This network is mentioned RLC network, and C2,C3,C5 is not a capacitor, it is the combination of several capacitors , in the figure5.2, T4 connect amplifier unit, T3 connect drive unit, T2 connect feedback unit.

The electric circuit generate an instantaneous electrical pulses through amplifier added to both end of the transducer, and then induced vibration of the transducer. Its vibration frequency is the natural frequency of the transducer itself, oscillating signal at the ends of the transducer, via divide voltage sent to adjustable phase shifter, and then sent to the power amplifier. When adjustable phase shifter transferred to phase satisfy self-excited conditions, the system self-excited by the inherent frequency. A slight change of transducer resonant frequency, circuit system are timely tracking makes work always in the best state.

6. Ultrasonic Power Feedback Circuit Principle[3]

6.1. Principle of Time Base Electric Circuit [1]

This design uses chip of NE555 produce the needed certain frequencies of time pulses, working principle is shown as the figure6.1.

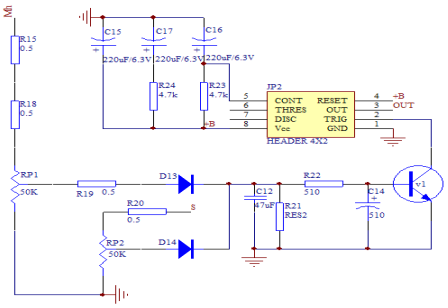

Fig.6.1: Time Base Electric Circuit.

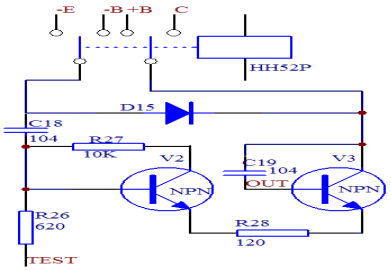

Fig.6.2: Control Signal Circuit.

6.2. Production of Control Signal

HH52P is middle relays in figure6-2, it through TEST button and time-based signal TOU together control working time of ultrasonic, generate several time base cycle of ultrasonic when the press TEST button, when again press TEST button to stop the ultrasonic's work. And thus realizes the super living wave control.

6.3. Drive Circuit

In double ends converter (e.g. push-pull, bridge type, half bridge type converter circuit), may produce transistors at the same time conduction phenomenon. The conducting transistor under the action of the base positive driving pulse, another is shut off the transistor, though it has lost positive driving signal, but, owing to effect of the storage time still continue to conduct, thus the two tubes at the same time conduct, this is commonly known as "connected" phenomenon.

In push-pull type converter, its two base driven signals are square signals which phase difference of 180 degrees, the conversion between its height and low electrical level, on time is in complete agreement. However, due to existence storage time in shut off the transistors, make the collector still conduct, the collector voltage continues to stay in Uces = 1 V state, lasted for several us because of the open time much shorter than storage time, until the storage time end, did it stop two tube conduct at the same time. This phenomenon can cause catastrophic failure, because shutting off the transistor in storage period, has been always made supply voltage add in the half a primary winding, due to transformer role, another transistor's collector is still in 2 Ui voltage conduction, and could not enter the saturated zone, but at the moment ,the base of transistors has been driven by positive pulse, so the conducting transistors under the action of 2 Ui collector voltage flow (about βIi) collector current which is great value of number, cause bigger high-frequency loss.

Even the average power loss of tube was not enough to damage to the transistor, however, the two breakdown role will also likely damage it. To be on the safe side, should try to avoid converter transistor simultaneously conduction phenomenon. Because of this design is used power push-pull type converter, it is a two active switch converter, so this problem should be taken into consideration.

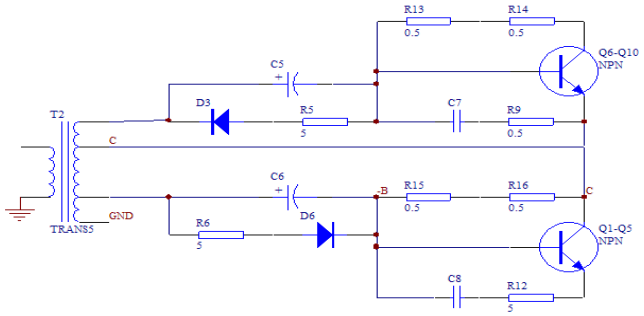

Fig.6.3: Drive Circuit

The synchronous transformer's second coils obtain the sine wave synchronous voltage which in R5, R6. Capacitor used to eliminate high frequency interference signals when press TEST button. The terminals voltage of R5 ends and the terminals voltage of R13, R14 stacked， and then added to transistor Q6 ~ Q10 launch knot. The terminals voltage R6 and the terminals voltage of R15, R16stacked, and then added to transistor Q5~ Q1 launch knot .Only when u2, u3 respectively than the ends voltage of R13, R14, R15, R16, the transistor Q6 ~ Q10, Q1 ~ Q5 to begin to work.

7. conclusion

Presently, the ultrasonic system is widely used in the people's livelihood .such as ultrasonic pulverization in the pharmacy, ultrasonic welding and ultrasonic washing in the spinning and weaving, ultrasonic test and ultrasonic crack detection in the projection. At the same time, it has testified that ultrasonic has improved efficiency and brought convenience. For different applications, we should based on the different function step by step complete the theory analysis and the design then take the specific applications for it.

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