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Automatic Resistance Spot Welding Using Arm Controller

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***Abstract* - Resistance Spot welding system which is used for performing a welding process. The paper is divided into 3 sections. First, brief introduction of welding, methods of welding control such as resistance and spot welding is given. Secondly, the critical factor in the design of a welding process is dealt along with the principle of the welding process. Following this, the introduction to the design of the control scheme employed by us with the basic block diagram of the welding system and the functioning is presented. Finally, the conclusions is drawn along with its working and future improvements. The traditional approach in relation to spot welding machines is to use 50 Hz welding transformers. The drawback associated with these transformers is that they are both heavy and bulky. With the development of high power semiconductor switches and DC-DC converter topologies, it is now possible to develop inverter drive resistance spot welding equipment which can be operated at frequencies higher than the 50Hz frequency. The advantage of using high frequencies is the reduction in the size of the transformer. Automated resistance welding machines use micro-controller based control systems to regulate and ensure consistent welds. The design hopes to achieve complete automation of the resistance welding process. This is done by accepting various process inputs from the user and after due process, controlling various parameters like the current, conduction angle, weld count, etc.,. This is achieved by using a micro-controller, which will acquire data from the user and process it to generate suitable control signals as and when required during the welding process. The use of arm microcontroller makes the operation extremely fast, reliable and flexible. In the design, the most important parameter to be monitored and controlled is the primary welding current. For this constant current control method, an adaptive algorithm takes care of the past and present values, to predict the firing angles of thyristors in the next cycle, to ensure the present value of the current is maintained. The design and development of the control software algorithm is dealt with. Finally, the conclusions are drawn along with its working.**

I.INTRODUCTION

An inexpensive and efficient way of joining metals can be achieved by *resistance spot welding.* This system uses microcontroller and complex programmable logic Device (CPLD) to replace the original discrete components of electronic control system. The energy accumulation to control the amount of melting instead of control by the time, namely excessive or inadequate of the melting can also be achieved.

Welding in the simplest terms is the process of fusing or joining two or more metal pieces with the application of heat and pressure. Resistance welding uses the concept of heat generated due to the current flowing through a resistance. The heat energy generated is large enough to weld two work-pieces together. Automated resistance welding machines use micro-controller based control systems to regulate and ensure consistent welds. The design hopes to achieve complete automation of the resistance welding process. This is done by accepting various process inputs from the user and after due process, controlling various parameters like the current, conduction angle, weld count, etc.This is achieved by using a ARM-controller, which will acquire data from the user and process it to generate suitable control signals as and when required during the welding process. The use of a μC makes the operation extremely fast, reliable and flexible. In the design, the most important parameter to be monitored and controlled is the primary welding current. For this constant current control method, an adaptive algorithm takes care of the past and present values, to predict the firing angles of thyristors in the next cycle, to ensure the present value of the current is maintained. Also, various other parameters like the weld count, job count, conduction angle, etc., need to be monitored. This is done by using a ARM-controller which will take care of all the processes parameters with minimum of supervision. Different energy sources including laser, electric arc, electron beam, electric current, etc, are used for this welding. Arc welding and oxy-fuel welding were the first processes to be developed followed by resistance welding. Different welding methods used commercially are described as follows.

A. Forge welding: In this process, the metals to be welded are heated to a high temperature and then pressure is applied to make the welding joint. Forge welding is one of the simplest methods by which, similar and dissimilar metals can be joined together.

B. Thermite welding: In this process, two metals become bonded after being heated by a superheated metal that has experienced a chemical reaction. It is a chemical welding process involving the joining of two electrical conductors.

C. Gas welding: In this process an oxy-fuel welding torch is used for heating the metal to form a welding joint. This welding is commonly called oxy acetylene welding.

D. Arc welding: In this process heat is applied by means of an electric arc which is inserted between the parts to be joined together. During the welding process the electrode melts and fills the gap at the joint.AC and DC power units can be used to create an electric arc between the electrode and the base material.

E. Resistance welding: In this process the parts to be welded are joined together by passing an electric current. Work-pieces are held together, under pressure, which is exerted by electrodes. The amount of heat delivered during spot welding is determined by the resistance between the electrodes and the amplitude and duration of the current.

II.RESISTANCE WELDING PROCESS

The resistance welding process can be classified into

A. Projection welding:-It is a type of resistance welding process in which specially designed projections. The simultaneous welding of several projections is possible during one weld. This projection, act as a current concentrator for the welding process and these projections are the high points during the welding cycle, that make the first contact. The main advantage of the resistance projection welding is the speed and versatility to be automated. With projection welding, several welds can be conducted simultaneously.

B. Spot Welding:-Spot welding process is a widely used process in both the automotive and other industries. The process utilizes a large amount of current within the range 1kA to 200kA. In RSW, a high welding current is passed from the welding electrodes. The metal sheets to be joined together are placed in between the welding electrodes. Due to the resistance, offered at the junction of the work pieces, heat is generated, which melts the metal at the interface thus forming a welding nugget. Sufficient heat must be generated a the welding joint to raise the metal to the desired temperature. If the heat produced is less than this temperature then the result will be a low strength weld.

C. Seam Welding:-In seam welding the electrodes which are used for the welding, are in the form of rollers as shown in Figure 3. The electrical current is passed through the roller shaped electrodes, which produce heat at the interface of the sheets to be joined. A seam welding process produces a series of nuggets at the interface of the work pieces.

D. Flash Welding:-In flash / butt welding process, one work piece remains fixed at one end by mean of the stationary clamps and the other is movable. The arms are connected to the power supply unit. The movable component is brought closer to the fixed work piece and as these work pieces come closer to each other, a short circuit takes place, which leads to arcing or flashing as shown 5 in Figure 4. This flashing produces heat at the interface and brings the temperature to the forging temperature. At this point both the work pieces are forged together to form a welding joint.

III. SURFACE CONDITIONS OF SPOT WELDS

TYPE	CAUSE	EFFECT
Deep electrode indentation	Improperly dressed electrode face; lack of control of electrode force; high contact resistance.	Loss of weld strength due to reduction of metal thickness at periphery of weld area bad appearance
Surface fusion	Scaly or dirty metal; low electrode force; misalignment of work, high welding current, electrodes improperly dressed.	Under size welds due to heavy expulsion of molten metal; large cavity in weld zone extending through to the surface increased cost of removing burrs from surface of work.

Irregularly shaped weld	Misalignment of work in electrodes; bad electrode or improper electrode bearing on radius of flange.	Bad appearance; reduced corrosion resistance; reduced weld strength if molten metal is expelled.
Cracks, deep cavities or pin holes	Removing electrode force before thoroughly quenching weld to a temp well below visible red heat; excessive heat generation resulting in expulsion of metal	Reduction of fatigue strength if weld is in a tension member or if crack of imperfection extends into periphery of weld area corrosive in recess of cavity

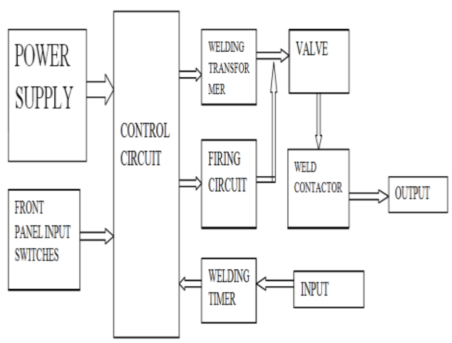

Fig1. Block diagram of automatic resistance spot welding machine

IV. MICRO CONTROLLER

A microcontroller or Microcontroller Unit (MCU) is a small computer on a single integrated circuit. In modern terminology, it is a System on a chip or (SoC). Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems.

Types of Microcontrollers

A. 8051:-8051 manufactured in 1985. This is an 8-bit microcontroller. The width of the register represents the bit number of microcontroller. For example 89C51 has 8-bit register, so 89C51 is 8-bit microcontroller. In this you can store numbers from 0 to 255, in hexadecimal it is represented as 0x00 to 0xFF. Coming to the instruction set 8051 has 250 instructions which take 1 to 4 machine cycles to execute. The speed of the 8051 microcontroller is 1 million instructions per second. 8051 has powerful instruction set; it has commands which perform more complex calculations. The ALU of the 8051 makes computations simple. In 8051 family there is no inbuilt memory bus and A/D converters. 8051 microcontroller has 32 I/O pins, timers/counters, interrupts and UART's.

B. AVR:-AVR is an 8-bit RISC architecture microcontroller. This is available from 1996 onwards only. There are 16-bit and 32-bit microcontrollers also available in the same family. RISC means Reduced Instruction Set Computer. AVR has 140 instructions which are all 1 cycle based instructions. By default AVR microcontrollers operate with the 1 MHz clock cycle. The speed of AVR microcontroller is 12 million instructions per second. AVR family microcontroller has on-chip boot-loader. By this we can program our microcontroller easily without any external programmer. AVR controllers has number of I/O ports, timers/counters, interrupts, A/D converters, USART, I2C interfaces, PWM channels, on-chip analog comparators.

C.PIC:-PIC (Programmable interface controller) microcontrollers are available in 3 different architectures. Those are 8-bit, 16-bit and 32-bit microcontrollers. PIC has nearly 40 instructions which all are take 4 clock cycles to execute. The speed of the PIC controller is 3 million instructions per second. The programming part of the PIC microcontroller is very hard. So those who entering into embedded world freshly this is not preferable for them. It has on-chip peripherals like SPI, ADC, I2C, UART, analog comparator, internal RC oscillator, in-system programmability, etc.

D. ARM:-At the time of manufacturing ARM was named as Acorn RISC Machine. Later ARM limited was established in1990. From then onwards ARM renamed as Advanced RISC machine. This is the advanced RISC controller. Most of the industries get license from ARM limited. ARM has the features like load-store architecture, fixed-length instruction set and 3-address instruction format. It has 32-bit ARM instruction set and 16-bit Thumb compressed instruction set. So many on-chip peripheral are there and on-chip debugger, on-chip boot loaders, on-chip RTC, DAC also available.

V. METHODOLOGY

Resistance welding is a thermo-electric process. The amount of heat produced is determined using below laws:

A. Ohm's Law:-Ohm's law states that the current through a conductor between two points is directly proportional to the voltage across the two points. More specifically, **Ohm's law** states that the R in this relation is constant, independent of the current.

V=IR

Where V is the voltage in V, I is the current in KA and R is the resistance in ohm.

B. Joule's Law:-The heat produced by an electric current, and second about how the energy of a gas relates to pressure, volume and temperature.
Joule's first law shows the relation between heat generated by an electric current flowing through a conductor. It is named after James Prescott Joule and shown as:

H=I^2 RT

Where *Q* is the amount of heat, *I* is the electric current flowing through a conductor, *R* is the amount of electric resistance present in the conductor, and *t* is the amount of time.

Two methods of welding control

A. Phase angle control

B. The integral cycle control –on / off control.

A. Phase angle control:-The principle of phase shifting is used for varying the welding current. This is done where, for instance, slow cooling of the welds is required for the metallurgical reasons. A complete sequence of currents may be automatically controlled to affect the welding and heat treatment of welds. In special alloys, where control of thermal cycles is essential to produce satisfactory welds.

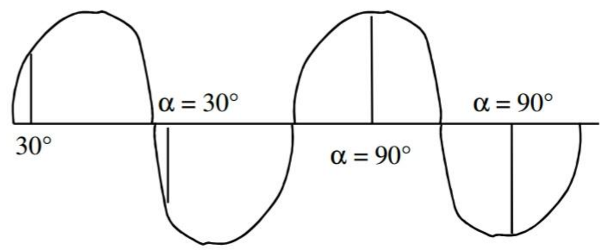

Fig2. Firing angle instant

B. Integral cycle control:-It works on the principle of on / off control. When the controller is in the ON mode, a number of current cycles are sent which are controlled. The number of current cycles passed determines the amount of current that flows through the electrodes. This is the time when the welding takes place. When the controller is OFF, no current passes through the electrodes.
This is of course more to the operation of resistance welding machines than the control of the electric current. Mechanical handling, positioning, and clamping of the work piece and the application of the electrical pressure are usually accomplished by the pneumatic circuits supplied with the compressed air. It is also common for the air pressure to actuate the timer once it is exceeded a value which ensures adequate contact pressure between the electrodes.

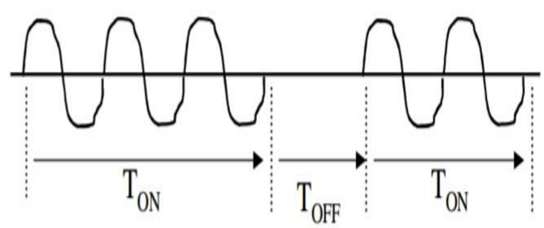

Fig3. On-Off duty cycle

VI. ARM MICROCONTROLLER

The ARM processors have a less number of transistors because they have a reduced instruction set, which allows a smaller size for the IC. Thereby being space efficient also. Most of the electronic devices such as

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tablets, mobiles, smart phones and other mobile devices consist of these processors. By combining the ARM microprocessor with RAM, ROM and other peripherals in one single chip, we get an ARM microcontroller, for example, LPC2148.

Fig4. ARM Microcontroller

A. Key criteria for ARMv7-M implementations
Enable implementations with industry leading power, performance and area constraints — Opportunities for simple pipeline designs offering leading edge system performance levels in a broad range of markets and applications

Highly deterministic operation — Single/low cycle execution — Minimal interrupt latency (short pipelines) — Cache less operation

Excellent C/C++ target – aligns with ARM's programming standards in this area — Exception handlers are standard C/C++ functions, entered using standard calling conventions

Designed for deeply embedded systems — Low pin count devices — Enable new entry level opportunities for the ARM architecture

Debug and software profiling support for event driven systems.

B. ARM core registers

There are thirteen general-purpose 32-bit registers (R0-R12), and an additional three 32-bit registers which have special names and usage models.

SP stack pointer (R13), used as a pointer to the active stack. For usage restrictions see Use of 0b1101 as a register specifier on page A5-4. This is preset to the top of the Main stack on reset. See The SP registers on page B1-8 for additional information.

LR link register (R14), used to store a value (the Return Link) relating to the return address from a subroutine which is entered using a Branch with Link instruction. This register is set to an illegal value (all 1's) on reset. The reset value will cause a fault condition to occur if a subroutine return call is attempted from it. The LR register is also updated on exception entry, see Exception entry behaviour on page B1-21. Note R14 can be used for other purposes when the register is not required to support a return from a subroutine.

PC program counter. For details on the usage model of the PC see Use of 0b1111 as a register specifier on page A5-3. The PC is loaded with the Reset handler start address on reset.

Applications often interact with external events. A summary of the types of events recognized in the architecture, along with the mechanisms provided in the architecture to interact with events, is included in Exceptions, faults and interrupts.

VII. SOFTWARE REQUIRED

A. C Language:-C was originally developed by Dennis Ritchie between 1969 and 1973 at Bell Labs,[5] and used to re-implement the Unix operating system.[6] It has since become one of the most widely used programming languages of all time,[7][8] with C compilers from various vendors available for the majority of existing computer architectures and operating systems. C has been standardized by the American National Standards Institute (ANSI) since 1989 (see ANSI C) and subsequently by the International Organization for Standardization (ISO).

C is an imperative procedural language. It was designed to be compiled using a relatively

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straightforward compiler, to provide low-level access to memory, to provide language constructs that map efficiently to machine instructions, and to require minimal run-time support. Therefore, C was useful for many applications that had formerly been coded in assembly language, for example in system programming.

Despite its low-level capabilities, the language was designed to encourage cross-platform programming. A standards-compliant and portably written C program can be compiled for a very wide variety of computer platforms and operating systems with few changes to its source code. The language has become available on a very wide range of platforms, from embedded microcontrollers to supercomputers.

B. **Keil MDK version:-**Keil Software, world's leading developer of Embedded Systems Software, makes ANSI C compilers, macro assemblers, real-time kernels, debuggers, linkers, library managers, simulators, integrated environments, and evaluation boards for the 8051, 251, ARM7, and C16x/ST10 microcontroller families. Keil Software implemented the first C compiler.

VIII. CONCLUSION

Automated resistance welding control system is designed and implemented for a welding process in the industry as Commercially available controllers have analog inputs and outputs, whereas our design incorporates digital inputs and outputs. The controller is fully automatic and compact and easily upgradeable. Due to the presence of digital inputs and outputs, human error can be drastically cut down making the process more accurate. Due to presence of non-volatile RAM, presetting of the schedules and storage of various process parameters will b e possible, which is not available in most of the controllers. Also, it will be possible to detect and correct a wide range of errors than that is possible in commercially available controllers. Micro-controller can be programmed to store many schedules that can be recalled in seconds to minutes by front panel switch access. Although the control may be reprogrammed in minutes, it often takes hours to re-setup a machine.

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