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Research Paper

DESIGN AND DEVELOPMENT OF MICRO UPSET WELDING SETUP

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Designing and constructing resistance welding machines involves a combination of electrical design, machine structures, mechanisms and controls. The machines vary from simple mechanisms to exceptionally complicated units. Monitoring the condition of large upset welding machines in operating industries has attracted increasing interest in recent years owing to the need for decreasing the energy consumption on production machinery and for reducing the extent of secondary damage caused by failures. Upset Welding (UW) is a resistance welding process utilizing both heat and deformation to form a weld. A micro-setup would certainly reduce heat consumption and offer greater efficiency. In this paper an electro-mechanical micro upset welding setup is constructed following the fundamental principles of resistance welding. The chief electrical and mechanical components used are single phase ac transformer, welding arms or copper alloy electrodes, externally threaded steel shaft, frame, multimeter and control switches. After the construction of the micro welder, two thin sheets of mild steel are welded.

Keywords: Upset welding, Electro-mechanical, Micro setup, Threaded shaft

INTRODUCTION

Resistance welding is a group of welding processes in which coalescence is produced by the heat obtained from resistance of the work to electric current in a circuit of which the work is a part and by the application of pressure (Althouse *et al.*, 1980). There are at least seven important resistance-welding processes. These are flash welding, high frequency resistance welding, percussion welding, projection welding, resistance seam welding, resistance spot welding, and upset welding. Three factors involved in making a resistance weld are:

- The amount of current that passes through the work,
- The pressure that the electrodes transfer to the work, and
- The time the current flows through the work.

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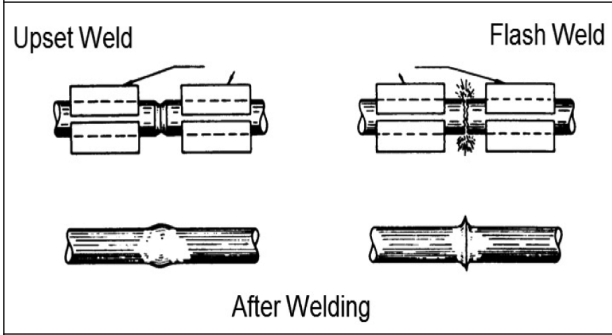
Heat is generated by the passage of electrical current through a resistance circuit. The force applied before, during, and after the current flow forces the heated parts together so that coalescence will occur. Pressure is required throughout the entire welding cycle to assure a continuous electrical circuit through the work.

I is the current in amperes, E is the voltage in volts, and R is the resistance of the material in ohms. The total energy is expressed by the formula: Energy equals $I \times E \times T$ in which T is the time in seconds during which current flows in the circuit: H (heat energy) = $I^2 \times R \times T$. For practical reasons a factor which relates to heat losses should be included; therefore, the actual resistance welding formula is: H (heat energy) = $I^2 \times R \times T \times K$.

Upset welding is often called butt welding. However, butt welding merely means that the pieces are welded together in a butted position. Therefore a butt weld may be made by any of the usual welding techniques. Figure 1 explains the types of butt welds before and after welding (Khanna, 2011). Upset welding consists of clamping two pieces of metal to be welded together in separate electrode jaws. The two metals are then touched together; heavy current is passed from one piece to the other, and the resistance to the electrical flow heats the faces to fusion temperature. The two pieces are pressed together (upset) under pressure while the current is flowing and after the current is turned off. The metals fuse together and upon cooling become one piece. This process, by its upsetting action mixes the two metals intimately, tends to push the impurities, if any, out of the weld and reduces the heated zone to a minimum.

Figure 1: Types of Butt Welds



Source: Welding Handbook

Upset welding can be used on most metals. No special preparation is required except that heavy scale, rust, and grease must be removed. The joints must be cut square to provide an even upset across the entire surface. The material to be welded is clamped in the jaws of the upset welding machine with a high clamping pressure. The upset pressure for steel exceeds 10,000 psi (68, 950 kPa). For high-strength materials, these pressures may be doubled. For tubing or hollow members, the pressures are reduced. As the weld area is more compact, upset pressures are increased. If insufficient upset pressure is used, a porous low strength weld will result. Excess upset pressure will result in expelling too much weld metal and upsetting cold metal. The weld may not be uniform across the entire cross section, and fatigue and impact strength will be reduced. The speed of upset, or the time between the end of flashing period and the end of the upset period should be extremely short to minimize oxidation of the molten surfaces.

WORKING PRINCIPLE

The steps involved in making a resistance upset butt weld are given below (Khanna, 2011):

- The two pieces to be butt welded are gripped firmly, one in each clamp and are correctly aligned so that when brought into contact one with the other by sliding the movable clamp to the fixed one, they fit together exactly.
- Force is applied so that the faces of two pieces touch together and remain under pressure.
- A heavy current is then passed from one piece to another. The resistance to the electrical current flow heats the faces to fusion temperature.
- Both pressure and current are applied throughout the weld cycle and when the faces (or ends) of the pieces become plastic, they are pressed together more firmly, upsetting the metal pieces to form a dense joint. Upsetting takes place while the current is flowing and continues until after the current is switched off.
- The welding current is switched off.
- Upsetting force is released as the welded joint has cooled to the desired temperature.
- Work pieces are unclamped. Figures 2 and 3 explains the working principle clearly.

Figure 2: Principles of Upset Butt Welding Courtesy of TWI Ltd.

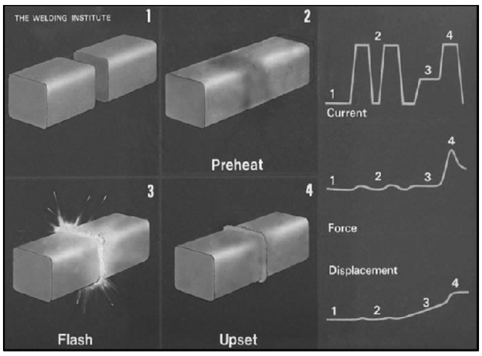
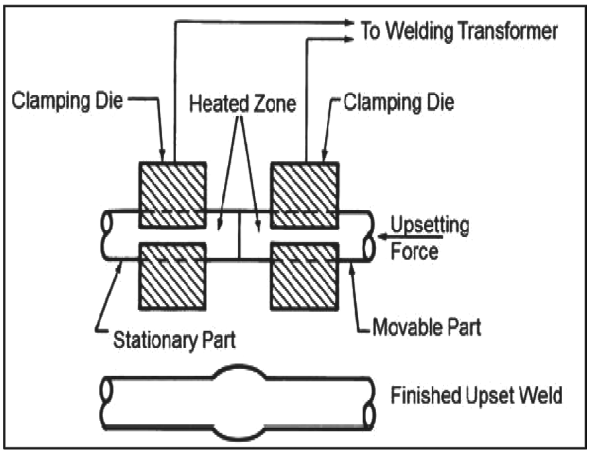


Figure 3: Upset Welding: Basic Mechanism



Source: Materials & Design and Welding Handbook

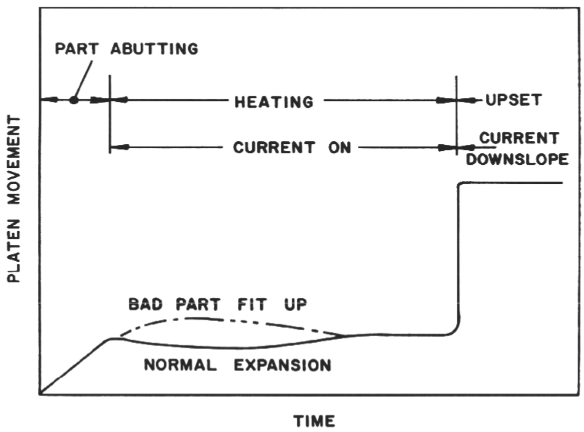
WELD CYCLE

The complete sequence of events involved in making a resistance weld is shown in Figures 4 and 5.

The weld cycle has three stages: squeeze time, weld time, hold time.

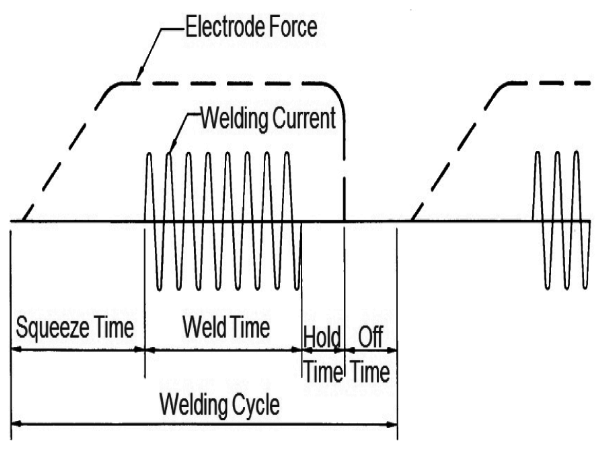
1. The electrodes come together, bring the components together and apply a force. This force builds up and requires a certain length

Figure 4: Schematic of Typical Butt Weld Cycle



Source: Welding Journal

Figure 5: Basic Single Impulse Welding Cycle



Source: Assembly and Automation In Focus

of time, called the "squeeze time", to build up to a value where welding can take place.

2. The welding current is applied for the "weld time" which typically lasts for a few cycles of the mains frequency.
3. The electrode force is maintained during the "hold time" whilst the weld nugget is allowed to solidify and cool.

CONSTRUCTION DETAILS OF UPSET BUTT WELDING SETUP

The components required for the micro upset welding setup can be divided into two categories:

1. Mechanical Components.
2. Electrical/Electronic Components.

Mechanical Components

Electrode Clamps (Khanna, 2011)

An upset welder consists of clamps suitably mounted on a horizontal slide, one being fixed rigidly and the other movable. Both clamps are made of conducting material (Cu-alloy like brass) and are connected to the secondary of the transformer. There are certain requirements which these electrodes must possess. They must:

- Be a good conductor of electricity.
- Be a good conductor of heat.
- Have good mechanical strength and hardness.
- Have a minimum tendency to alloy (combine) with the metals being welded.

For the welding of steel copper alloys are generally used for the manufacture of the electrode clamps. For aluminium, however, steel, sometimes copper plated, has been found to give better results, conducting less heat away from the weld, providing a longer life and more positive clamping.

Weldable Metals/Workpiece (Althouse et al., 1980)

Metals that are weldable, the thicknesses that can be welded and joint design are related to specific resistance welding processes.

Difficulties may be encountered when welding certain metals in thicker sections. Some metals require heat treatment after welding for satisfactory mechanical properties. Weld ability is controlled by three factors: resistivity, thermal conductivity, and melting temperature. Metals with a high resistance to current flow and with a low thermal conductivity and a relatively low melting temperature would be easily weldable. Ferrous metals all fall into this category. Metals that have a lower resistivity but a higher thermal conductivity will be slightly more difficult to weld. This includes the light metals, aluminium and magnesium. Table 1 shows the list of weldable metals.

Table 1: List of Weldable Metals

Base Metal	Weldability
Aluminums	Weldable
Magnesium	Weldable
Inconel	Weldable
Nickel	Weldable
Nickel Silver	Weldable
Monel	Weldable
Precious Metals	Weldable
Low Carbon Steel	Weldable
Low Alloy Steel	Weldable
High and Medium Carbon	Possible But Not Popular
Alloy Steel	Possible But Not Popular
Stainless Steel	Weldable

For micro upset welding the workpiece selected are thin sheets of mild steel (about 3 mm in thickness) because of its high weld ability, low thermal conductivity and high electrical resistivity.

Specific Heat of mild steel S = 0.49 KJ/kgK

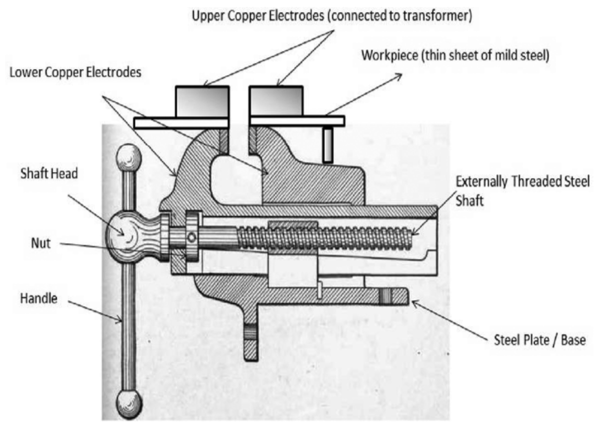
Resistivity/Specific Resistance of mild steel $\rho = 1.18 \times 10^{-7}\ \Omega$m

Melting Temperature of mild steel T = (1225 – 1440 °C)

Externally Threaded Steel Shaft, Steel Handle and Collar Head

An externally threaded steel shaft is rotated manually to move one of the copper electrodes horizontally along the steel plate until the two workpieces touch each other. The handle is attached to the shaft using cotter joint. The whole setup is placed on a wooden base. The mechanism followed is similar to the bench vice clamping mechanism. Figure 6 shows the final design setup.

Figure 6: Final Design Setup of Micro-Upset Welder



ELECTRICAL/ELECTRONIC COMPONENTS

Step-Down Transformer/Welding Transformer (Althouse *et al.*, 1980)

It provides the electrical current for heating. Control of secondary current is achieved by transformer tap switches or electronic phase-shift devices. In a step-down transformer number of turns in primary winding is greater than number of turns in secondary winding, i.e., $N1 > N2$ since [$V1/V2 = N1/N2$] where $V1$ is the primary voltage and $V2$ is the secondary voltage. The basis of the upset welding machine is an AC transformer, the majority of production equipment being single phase machines. The capacity of the machine is limited by the current requirements of the joint and the upset pressure available. The power demanded of the transformer is based on the cross-sectional area of the faces. The varying electrical conductivity of the different alloys also has an effect on power requirements.

The current requirements for upset butt welding ranges from around 2500 to 5500 A. Voltages vary from 2 volts at a low cross-sectional area to 20 volts for the thicker sections.

The welding transformer is rated on a specified input and not on the output like other transformers. It is usually rated at 50% duty cycle, which means that it should be used in actually creating welds 30 seconds out of each 60 seconds, 10 seconds out of 20 seconds, or any segment of time where the idle time at least equals the weld time. The KVA is the input or primary circuit rating. For example, with a 230 volt input and 43.48 amperes flowing, the machine would be rated at 10 KVA (230 × 43.48 = 10,000.40 VA).

Controls

Controls for resistance welding machines vary from simple hand adjustments and switches to precise electronic controls. The variables of resistance welding can all be controlled manually or automatically (Althouse *et al.*, 1980). These variables are:

- Current
- Pressure
- Time

The current may be manually adjusted by the primary steps on the transformer.

The pressure of the electrodes on the metal being welded can be controlled by the operator's pressure on the lever, semiautomatically controlled by the use of adjustable springs, or automatically controlled by hydraulic or pneumatic pressure and the size of the cylinders.

The time that the current flows and the time the pressure is imposed can be manually controlled on simple machines. The more automatic machines use electronic timers that function on the basis of the number of AC cycles that pass through the circuit such as:

- Pressure applied for 20 cycles (Squeeze Time).
- Current flows for 6 cycles (Weld Time).
- Current off-pressure maintained for 15 cycles (Hold Time).

Multimeter

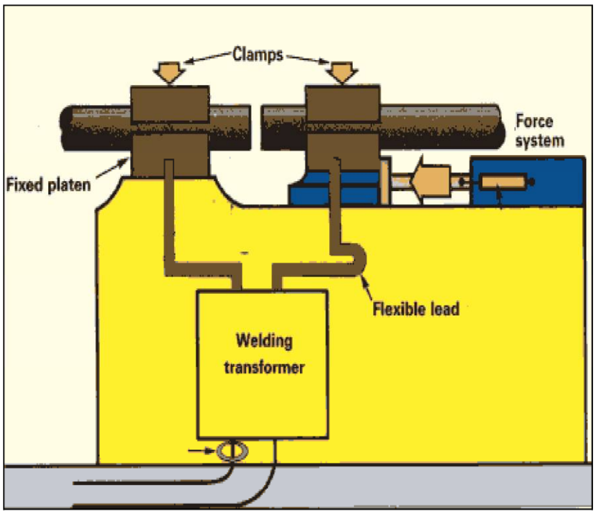
It is used to measure the electric current and voltage across the metal to be welded. Multimeter is very essential instrument in order to pass the current in the circuit in a desired range.

Connecting wires, tap switches and wire nuts are a few secondary electrical components used in constructing the micro-upset welding setup. Figure 7 shows the electrical circuit diagram of micro welder.

GOOD UPSET BUTT WELD IS OBTAINED IF (KHANNA, 2011)

- Faces to be butt welded are clean, parallel and reasonably smooth.
- The two workpieces are equal in cross-sectional area and of equal specific resistance. If the two pieces are of unequal specific resistance, the part having the lesser resistance should project farther from the clamping die than the other. Similarly, if the two pieces have equal specific resistance, but unequal area of cross-section, one with the larger cross-sectional area should project from the clamping die farther than the other part.
- To facilitate heating at the abutting surfaces, the areas are sometimes restricted by bevelling the ends.

Figure 7: Electrical Circuit Diagram of Micro Upset Welder



RESULTS

The current design setup is referred to as a micro setup since it offers upset welding of very thin sheets of steel with minimum requirement of energy contrary to the conventional upset welders that are less energy efficient and are restricted to larger size of workpieces. Upset welding typically results in solid-state welds with no melting at the joint. The effect of process parameters including heating and post-weld heating power and their corresponding duration along with interference, on the tensile strength of the welded joint are being experimentally investigated.

Table 2: Upset Butt Welding Energy and Time

Power Required (KW)	Time Needed (sec)	Distance Between Two Workpieces (inches)
19	3	0.79
14	6	1.6
12	9	2.4
10	11	3.2
8	14	3.9
7.5	17	4.5
7	20	5.5

After the welding of ½ inch rectangular steel bars the results obtained are shown in Table 2.

CONCLUSION

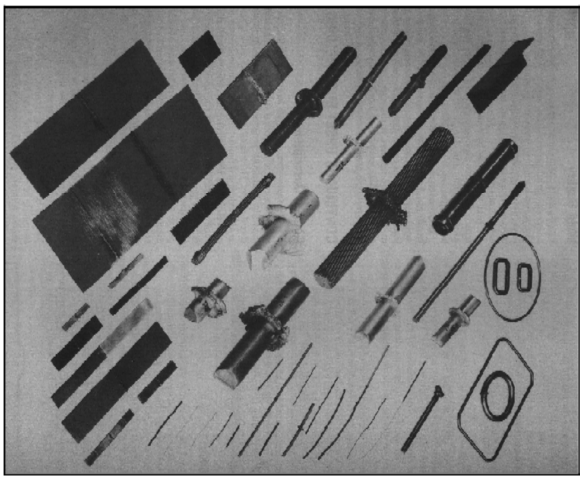
Recent developments in upset welding include the use of pulsing of the current in order to reduce metal expulsion and to improved performance when welding coated material. Tong size varies in length and may be air or water cooled. This process is commonly married to robotics and lends itself to the joining of thin coated material utilized in the automotive industry. It produces high quality joining at a very rapid pace and is typically utilized to join base materials that are less than ¼” (6 mm) in thickness. In resistance upset welding, the heat is generated by resistance of the interface of abutting surfaces to the flow of electrical current in heating and post-weld heating stages.

The applications of Upset Welding (Khanna, 2011) are tremendous and some of which include welding of:

- Chains,
- Rails,
- Pipelines,
- Wheel rims,
- Rings made of steel strip and
- Bar welding.

Upset welding is used in wire mills and in the manufacture of products made from wire. In wire mill applications, the process is used

Figure 8: Typical Mill Forms and Products of Upset Welding



Source: Welding Handbook

to join wire coil to each other to facilitate continuous processing. The process also is used to fabricate a wide variety of products from bar, strip, and tubing. Wire and rod from 0.05 to 1.25-in. (1.27 to 31.75 mm) diameter can be upset welded. Figure 8 shows all the typical mill forms and products of upset welding.

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