Design and Modeling of Advanced Welding System for Thermoplastics

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Abstract— In this paper we have Design a simple model of plastic welding system that joins the thermoplastics parts. This project is used to join the plastic parts by the application of heat with the help of electric supply and spring force. A separate plastic rod is loaded in the gun and that rod is melted by the positive and negative power supply to join the two plastic parts. The melted plastic is poured over the required plastic parts that to be joined. The plastic rod is loaded manually over the spring. And the AC power supply is given to the copper nozzle so which the heat is produced and the plastic rod is melted. As the plastic rod is being melted, the length of the rod is gradually reduced. The rod is pushed out to the power supply zone by the spring action for continuous process of welding. This plastic welding gun is compact in design and portable.

Key words: plasticrod, plastic welding system, thermoplastics, copper nozzle, spring, Gun, AC power supply.Introduction

I. INTRODUCTION

Plastic welding is also called as heat sealing, which is the process for welding or joining plastic work pieces. Thermoplastics like Polyethylene, Polypropylene, Polyvinyl Chloride, Polyurethane and Acrylonitrile Butadiene Styrene (ABS) are frequently used in plastic welding. Plastics that can be welded are called "*thermoplastics*" and when they are heated to a sufficiently high temperature they will soften and welded.

Mr. Robert A Grimm, et al. have investigated the standard heater plate is replaced with two banks of short wave infrared emitters clamped and spring-loaded on either side of a movable platen. Powers can be very much greater compared with conventional hot plate welding but weld times are significantly shorter. This technique is also capable of handling large surface area products, as it is a simple operation to add more emitters to the heating bank. The newly developed, high power short wave infrared emitter is also proving more efficient and effective than infrared emitters previously considered for welding applications. [1].

Mr.M.Devrient,M.Kern,etalthe investigation on laser transmission welding, the parts to be joined are brought into contact prior to welding, and heating and joining phases take place simultaneously. The laser beam of the Nd: YAG laser transparent the part being joined and is converted into heat by the absorbing part. The transparent part is similarly heated and plasticized by means of heat conduction thereby ensuring the parts are welded together [2]. Mr. Giuseppe, et al. Hot gas welding is mainly used for joining thin (< 6mm) sheets of PP, PVC, PE and PVDF to themselves and also to pipes. The welding equipment is a hand-held welding gun consisting of an integral blower, a heating element with thermostat and a set of interchangeable nozzles for directing hot gas at the work piece. A filler rod is used and this is made from the same polymer as the parts to be welded have observed that [3]. Mr.Giuseppe ,Casalino,et al The welding equipment is a hand-held welding gun consisting of an integral blower, a heating element with thermostat and a set of interchangeable nozzles for directing hot gas at the work piece [4].

C.Ageorges, et al, The equipment is based on an electric drill with a mini extrusion barrel attached to the front. The extrusion barrel is heated along its length, either by cartridge heaters or hot air. A thermoplastic rod or granule feedstock is fed into the rear of the extrusion barrel and the material is heated as it is drawn through the barrel by the rotating extruder screw. Molten thermoplastic is continuously ejected through a PTFE shoe attached to the front of the extrusion barrel. The PTFE shoe is shaped to match the profile being welded, and defines the shape and size of the final weld [5] A.s. Wood, et al The butt fusion welding technique (also known as hot plate welding, butt welding, mirror welding or platen welding) is primarily used for joining PE pipes for the water and gas industries, and PP and PVDF pipes for the chemical industry. It can be carried out on a wide range of pipe sizes, typically between 63 and 1600mm outside diameter (OD).The welding sequence begins when the hot plate, at a preset temperature, is positioned between the two pipe ends. The pipes are pushed towards each other until the pipe ends come into contact with the hot plate and the pressure is increased to give good thermal contact. The pipe ends melt and the interface pressure forces the molten material outwards to form 'weld beads' at the outside and inside pipe surfaces [6] N.s. Taylor,et al The socket fusion technique is mainly used for welding pipes made from PE, PP and PVDF for chemical pipe work. The process operation is generally manual and can either be carried out by hand (for pipe sizes up to 50mm OD) or on a manual machine for pipe sizes typically between 63mm and 150mm OD.A socket mounted on a hot plate is used to heat the outside surface of the pipe being welded. On the opposite side of the hot plate, a spigot is used to heat the inside surface of an injection moulded fitting. Both the fitting and the pipe are heated for a set period, known as the heating time. When the heating time is complete, the heated pipe and fitting are removed from the socket and spigot, and the pipe is pushed inside the fitting, producing the weld. [7]

II. PLASTIC WELDING ROD

Thermoplastics like Polyethylene, Polypropylene, Polyvinyl Chloride, Polyurethane and Acrylonitrile Butadiene Styrene (ABS) are frequently used in plastic welding. Plastics that can be welded are called "*thermoplastics*". The thermosetting plastics are straight opposite to the thermoplastics in nature. It means that the defected part that to be welded and the welding rod must be similar in material. Also they must be similar in all aspects like properties and characteristics. Only then it is quite possible to execute the operation.

A. Thermoplastics:

Only plastics that are thermoplastics can be welded and only like thermoplastics can be welded.Each thermoplastic has a particular melting temperature and viscosity, therefore, it should be noted that only the same thermoplastics could be welded to each other.Some thermoplastics, on account of their very high molecular mass, do not achieve a sufficient ability to flow and cannot be welded.

The ideal welding temperature varies between the various types of plastics. The Leister tools allow you to dial in the correct temperatures of the various plastics that you may encounter.

The codes of thermoplastics are derived in detail as follows. The codes are nothing but the abbreviations.

ABS	:	Acrylonitrile Butadiene Styrene
ABS/PC	:	Polymer alloy of above
PA	:	Polyamide (Nylon)
PBT (POCAN)	:	Polybutylen Terephtalate
PC	:	Polycarbonate
PE	:	Polyethylene
PP	:	Polypropylene
PP/EPDM	:	Polypropylene/Ethylenediene Rubber
PUR	:	Polyurethane (Not all PUR is weldable)
PVC	:	Polyvinyl Chloride
GRP/SMC	:	Glass Fibre Reinforced Plastics (Not weldable)

B. Thermosetting Plastics:

A thermosetting plastic, also known as a thermo set, is polymer material that irreversibly cures. The cure may be done through heat (generally above 200 °C (392 °F)), through a chemical reaction (two-part epoxy, for example), or irradiation such as electron beam processing.Thermo set materials are usually liquid or malleable prior to curing and designed to be molded into their final form, or used as adhesives. Others are solids like that of the molding compound used in semiconductors and integrated circuits (IC). Once hardened a thermo set resin cannot be reheated and melted back to a liquid form.

III. DIFFERENCES BETWEEN THERMOPLASTICS AND TERMOSETPLASTICS

The essential difference is that thermoplastics remain permanently fusible so that they will soften and eventually melt when heat is applied, whereas cured thermoset polymers do not soften, and will only char and break down at high temperatures. This allows thermoplastic materials to be reclaimed and recycled.

Effectively the thermoset is one large molecule, with no crystalline structure. Compared with thermoplastics, thermosets are generally harder, more rigid and more brittle, and their mechanical properties are not heat sensitive. They are also less soluble in organic solvents.

IV. PROCEDURE OF SELECTING THE PLASTIC ROD

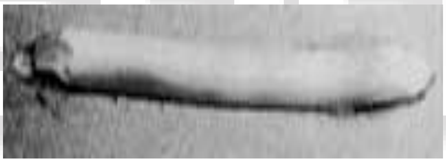
The common procedure of selectioning the plastic rod is given bellow in detail. This procedure is normally followed in all the industries where the plastic welding is proceeded. As it is impossible to find out the material of parent part, this testing is carried out.

- Fit the appropriate welding nozzle for the selected welding rod to the Leister TRIAC S hot-air tool.
- Set the welding temperature on the rotary control according to the welding rod material to be employed in the test. Allow the tool to attain the operating temperature.
- Scrape the surface in the area of the test to remove any contamination.
- Feed the welding rod through the nozzle and into the contact with the surface of the component.
- Following the technique described in Main Welding operations, weld 2 cm of the test rod to the surface of the component.
- Remove the welding tool from the rod and then cut the rod approximately 2 cm from the component surface.
- Allow the weld to cool and then try to pull the rod from the surface of the component.

If it stays firmly in place the component plastic has been positively identified.

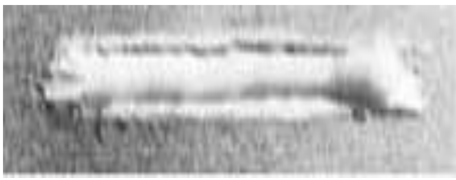
V. WELDING DEFECTS

A. Poor Weld Penetration:



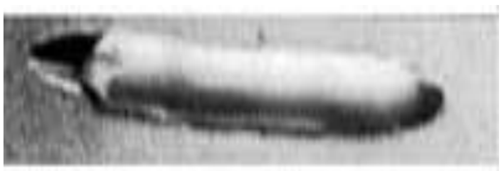
- The weld was started correctly but completed too quickly.
- Incorrect weld site preparation
- Weld speed too fast / temperature too low
- Weld attempted with dissimilar materials
- Poor technique

B. Uneven Weld Bead Width:



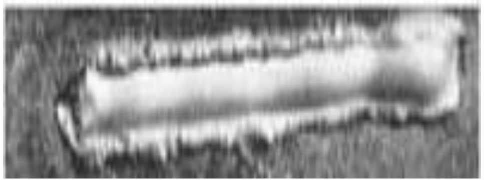
- Welding rod stretched
- Uneven pressure applied to welding rod

C. Charred Weld:



- Welding speed too slow
- Temperature too high

D. Warping:



- Repair area overheated
- Parts fixed under tension
- Poor site preparation

VI. WELDING TEMPERATURE OF PLASTICS

THERMOPLASTICS CODE	WELDING TEMPERATURE ^{O}C
ABS	350
ABS/PC	350
PA	400
PBT	350
PC	350
PE hard	300
PE soft	270
PP	300
PP/EPDM	300
PUR	300/350
PVC hard	300
PVC soft	350

VII. CAUSES OF WELDING DEFECTS

DEFECTS	CAUSES
Poor weld penetration (or) poor bonding	Incorrect weld sitepreparation Weld speed too fast / temperature too low Weld attempted with dissimilar materials Poor technique
Uneven weld bead width	Welding rod stretched Uneven pressure applied to welding rod
Charred weld	Welding speed too slow Temperature too high
Warping	Repair area overheated Parts fixed under tension Poor site preparation

VIII. COMPONENTS AND DESCRIPTIONS OF PLASTIC WELDING SYSTEM

- Gun holder.
- Nozzle.
  - Copper rod.
  - Soldering filament.
- Nozzle holder.
- Spring.
- Spring holder.
- AC Power supply

A. Gun Holder:

Gun holder is an important part of this advanced plastic welding gun. It has a handle to hold the gun while welding. The solid handle is placed under the hollow steel tube. The handle has a deep hole for the passage to AC power supply line.

On both sides of the hollow tube external threads are cut to tighten the nozzle holder and spring holder which have internal threads. The travel of plastic rod takes place only in the gun holder.

B. Nozzle:

The main purpose of nozzle in the advanced plastic welding gun is to melt the plastic rod and to guide the plastic rod over where the plastic welding to be carried out. In the nozzle two sub parts are used which are copper rod and the soldering filament. At the edge of the nozzle the power supply is given through the soldering filament and copper rod.

The power supply is alternative current supply (AC Supply). So no additional controlling devices are needed to control (or) convert the current supply.

C. Copper Rod:

A copper steel plate is bended as a hollow rod exactly to the same dimension of nozzle tip where the heat is to be produced. One end of copper rod is in round shape which is kept inside of the nozzle. The round shape side is not visible where three copper plates are attached in 120^{o} of angle to each other.

Another end of the rod is bent into cone shape. The middle part of the copper rod is in round shape. Copper is a good heat conducting material. It needs less time to absorb the heat. Also copper does not melt soon. It can withstand the heat for long time period. That's why copper is implemented in this project at the heat produced zone.

1) Some General Details Of Copper Are As Follows:

Copper is a chemical element with the symbol **Cu** (from Latin: *cuprum*) and atomic number 29. It is a ductile metal with very high thermal and electrical conductivity. Pure copper is soft and malleable; an exposed surface has a reddish-orange tarnish.

It is used as a conductor of heat and electricity, a building material, and a constituent of various metal alloys. The metal and its alloys have been used for thousands of years. In the Roman era, copper was principally mined on Cyprus, hence the origin of the name of the metal as *cyprium* (metal of Cyprus), later shortened to *cuprum*.

Its compounds are commonly encountered as copper (II) salts, which often impart blue or green colors to minerals such as turquoise and have been widely used historically as pigments. Architectural structures built with copper corrode to give green verdigris (or patina). Decorative art prominently features copper, both by itself and as part of pigments.

Copper (II) ions are water-soluble, where they function at low concentration as bacteriostatic substances, fungicides, and wood preservatives. In sufficient amounts, they are poisonous to higher organisms; at lower concentrations it is an essential trace nutrient to all higher plant and animal life. The main areas where copper is found in animals are tissues, liver, muscle and bone.

2) The Characteristics Of Copper Are As Follows:

Copper just above its melting point keeps its pink luster color when enough light outshines the orange incandescence color. Copper, silver and gold are in group 11 of the periodic table, and they share certain attributes: they have one s-orbital electron on top of a filled d-electron shell and are characterized by high ductility and electrical conductivity. The filled d-shells in these elements do not contribute much to the interatomic interactions, which are dominated by the s-electrons through metallic bonds.

Contrary to metals with incomplete d-shells, metallic bonds in copper are lacking a covalent character and are relatively weak. This explains the low hardness and high ductility of single crystals of copper. At the macroscopic scale, introduction of extended defects to the crystal lattice, such as grain boundaries, hinders flow of the material under applied stress thereby increasing its hardness.

For this reason, copper is usually supplied in a fine-grained polycrystalline form, which has greater strength than monocrystalline forms. The low hardness of copper partly explains its high electrical (59.6×10^6 S/m) and thus also high thermal conductivity, which are the second highest among pure metals at room temperature. This is because the resistivity to electron transport in metals at room temperature mostly originates from scattering of electrons on thermal vibrations of the lattice, which are relatively weak for a soft metal. The maximum permissible current density of copper in open air is approximately 3.1×10^6 A/m^2 of cross-sectional area, above which it begins to heat excessively.

As with other metals, if copper is placed against another metal, galvanic corrosion will occur. Together with osmium (bluish), and gold (yellow), copper is one of only three elemental metals with a natural color other than gray or silver. Pure copper is orange-red and acquires a reddish tarnish when exposed to air. The characteristic color of copper results from the electronic transitions between the filled 3d and half-empty 4s atomic shells – the energy difference between these shells is such that it corresponds to orange light. The same mechanism accounts for the yellow color of gold.

D. Soldering Filament:

Soldering filament is the heat producing part. This filament is directly attached with the copper rod plates to which the AC supply is given with no additional controlling (or) converting devices. In market this filament is available with the specification of watts like 25W, 35W, 65W, 125W, etc. in advanced plastic welding gun three 35W soldering filament is used. As per then increment of watts range, the heat production rate is also increased. A propane soldering iron that has a hot air attachment works great and puts heat in a small area without effecting surrounding components.

E. Nozzle Holder:

To hold the nozzle rigidly the nozzle holder is provided. It has internal threads to tighten it on the front side of gun holder which has external threads. Also another side of the nozzle holder the internal threads in front to tighten it on the back side of nozzle which has the external threads.

F. Spring:

Spring is used for producing the retraction force. The plastic rod is compressed on the spring. As the plastic rod is being melted by AC supply, the length of the rod is gradually reduced. The rod is pushed out to the power supply zone by the spring action for continuous process of welding.

G. Spring Holder:

To hold the spring rigidly the spring holder is provided. It has internal threads to tighten it on the back side of gun holder which has external threads. A cup is provided on the spring which can easily travel throughout the hollow pipe which is attached with the spring holder to guide the spring. The cup provided for transforming motion to the plastic rod from spring.

H. AC Power Supply:

To melt the plastic rod, the nozzle plate has to be heated so which the rod melts. The AC power supply is given to heat the nozzle. The handle has a deep hole for the passage to AC power supply line.

IX. SPECIFICATION OF PARTS

A. Gunholder:

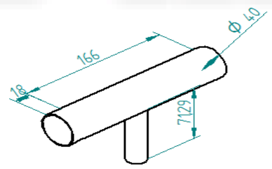


Fig.4.1: Gun holder

All dimensions are in “mm”

Gun holder is an important part of this advanced plastic welding gun. It has a handle to hold the gun while welding. The solid handle is placed under the hollow steel tube.

B. Nozzle:

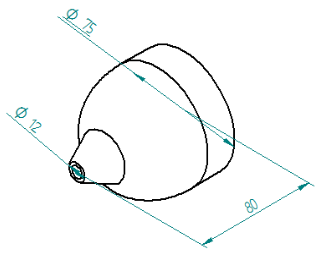


Fig.4.2: Nozzle
All dimensions are in “mm”

The main purpose of nozzle in the advanced plastic welding gun is to melt the plastic rod and to guide the plastic rod over where the plastic welding to be carried out.

C. Nozzle Holder:

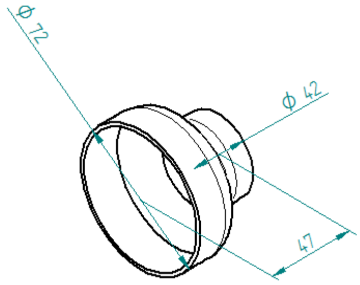


Fig.4.3: Nozzle holder

All dimensions are in “mm”

To hold the nozzle rigidly the nozzle holder is provided. It has internal threads to tighten it on the front side of gun holder which has external threads.

D. Spring:

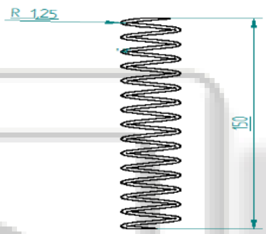


Fig.4.4: Spring

All dimensions are in “mm”

Spring is used for producing the retraction force. The plastic rod is compressed on the spring.

E. Spring Holder:

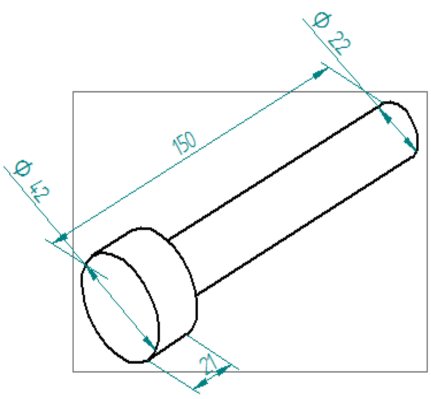


Fig.4.5: Spring holder

All dimensions are in “mm”

To hold the spring rigidly the spring holder is provided. It has internal threads to tighten it on the back side of gun holder which has external threads.

F. Full View:

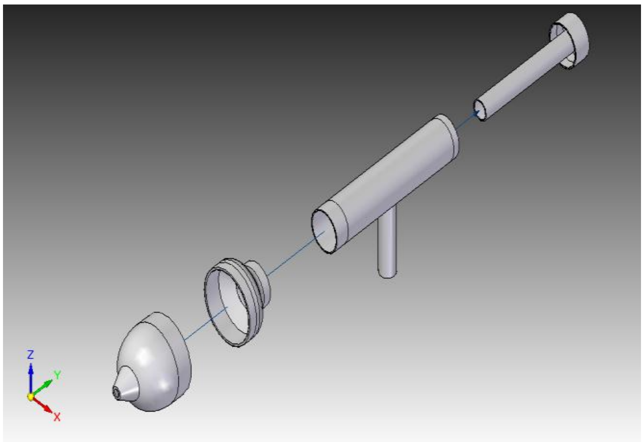


Fig.: Full view

X. WORKING PRINCIPLE

To weld the two plastic parts, a separate plastic rod is loaded on the spring in the gun and that rod is melted by the positive and negative power supply. The melted plastic is poured over the required plastic parts that to be joined.

The main part is spring holder, in which the plastic rod is loaded manually over the spring. At the outer most end of the gun tube the nozzle holder which has nozzle is placed where the AC power supply is given to the rod by nozzle so which the heat is produced and the plastic rod is melted.

As the plastic rod is being melted, the length of the rod is gradually reduced. The rod is pushed out to the nozzle by the spring action for continuous process of welding. After the rod is fully melted, a new rod can be replaced by opening the spring supporter and the welding can be continued.

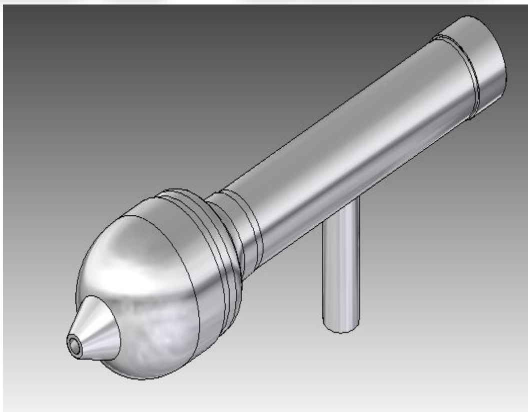


Fig.: Plastic Welding System

XI. ADVANTAGES

These are will be basic advantages offered by the welding system for thermoplastics as follows.

- Design of the plastic welding system will be very easy.
- The welding system will be very reliable.
- Cost wise it’s very cheaper to fabricate.
- It is very safer to use.
- It can be carried out to any places.
- It is portable.

- It will work for long time period.
- Way of maintenance is easy.
- Weather condition does not affect the operation.
- No extra devices are needed to be installed.
- It requires least maintenance cost.

XII. Applications

- Home applications.
- Industrial applications like,
  - Tank fabrications.
  - Metallic pipe lining.
  - Fabrication of Pipe leakages and other type of maintenance.
  - Bumpers.
  - Grilles.
  - Spoilers.
- Automobiles
  - Air intake manifolds
  - Body panels
  - Electrical and electronic control systems

XIII. Conslusion

This project provides more examples of plastic applications, types of welding technologies involved in the plastic materials .And the characteristics of thermoplastic and thermosetting plastics have given clearly. Thus we have developed a "DESIGN AND MODELING OF ADVANCED PLASTIC WELDING SYSTEM FOR THERMOPLASTICS" which helps to know how to achieve the arriving at a proper and effective design of electrically driven plastic gun for much efficient employment, fabrication of the electric plastic gun based on the design developed, testing and proving the efficiency of the developed plastic gun than the existing hot air gun. Moreover an effective comparison is made with the conventional welding model to enlist the advantages of this electric welding gun. The cost effectiveness of this new welding gun will also be assessed in the light of the present market value.

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