

# DEVELOPMENT OF HOT AIR PLASTIC WELDING MACHINE FOR WELDING OF POLYPROPYLENE MATERIAL

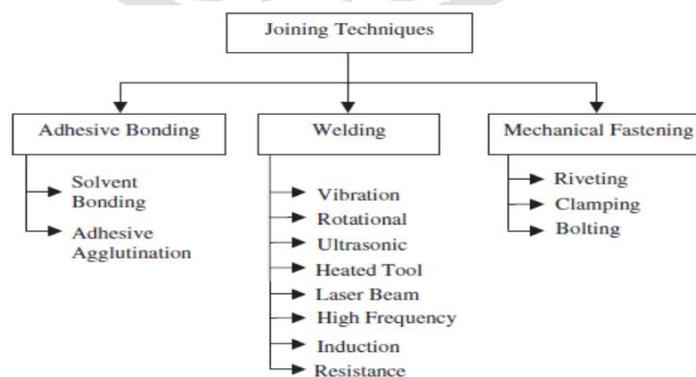
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**Abstract**—plastic is a material comprising of a wide range of semi-synthetic or synthetic organics that are malleable and can be molded into solid objects of different shapes. Today, joining of thermoplastic composite structures is becoming more significant since thermoplastic composite materials are being used to replace metallic or thermoset composite material to better withstand various loads in automotive, aerospace, agricultural machineries and marine industries. Plastic welding is reported in ISO 472 as a process of joining softened surfaces of materials, with the help of heat. Welding of thermoplastics is accomplished in three successive stages, as follows surface preparation, application of heat and or pressure, and cooling. Numerous welding methods have been evolved for the joining of plastic materials. This paper presents development one of the hot air plastic welding where the hot air is used to fuse or melt a filler thermoplastic rod and simultaneously heat the surfaces to be joined. In case of hot-gas welding the parameters of welding such as welding temperature, flow rate, feed rate, welding force, gas, angle, filler rod, Pressure of hot air/gas, Gap distance and shoe influence the strength of the welded joint. In this sequence A welding machine was designed and built to make the feed rate of manual hot-gas welding controllable and independent of human factors. The performance of the above developed machine was carried out by preparing seven samples of varying welding, feed rate keeping other parameters constant throughout the experiments. The strength of welded Polypropylene material joint was tested by using ASTM D 638 standard tensile test digital Universal Testing Machine. Also it was observed from the experimental study that feed rate influence the strength of the welded joint significantly.

**Keywords:** Plastics, Hot gas welding, Process Parameters, Polypropylene; Filler feed rate, Tensile Test.

## I. INTRODUCTION

The word plastic is derived from the word (plastikos) meaning capable of being shaped or molded. Plastic is a material comprising of a wide range of semi-synthetic or synthetic organics that are able to change the shape and can be molded into solid objects of different shapes. Plastics are mostly organic polymers of high molecular mass, but they many a times contain other substances. They are generally synthetic, most commonly derived from petrochemicals, but many are partly natural. Plasticity is the common property of all materials that are able to deform without breaking, but this occurs to a degree with this class of moldable plastics that their name is an stress on this ability. Today, joining of thermoplastic composite structures is becoming more significant since thermoplastic composite materials are being used to replace metallic or thermoset composite material to better withstand various loads in automotive, aerospace, and marine industries. Many joining techniques have been developed to weld thermoplastic polymers typically organic polymers with greater high molecular mass, but they often consist of other substances. They are mostly synthetic, mostly derived from petrochemicals, but many of them are partially natural too. Many joining techniques have been developed to weld thermoplastic polymers in figure 1<sup>(4)</sup>



**Fig1** Plastic Joining Techniques

Joining methods for plastics are classified as mechanical fastening, adhesive bonding, and welding. Mechanical fastening methods have drawbacks arising from stress concentrations, corrosion, difference of thermal expansion coefficients, etc. Adhesive bonding, which involving a chemical process where a substance is used to create a bond between two materials, is problematic because of hectic surface preparation, extended curing time, the difficulty of bonding adhesive materials to plastics, etc. Welding can eliminate these limitations, but its applications are restricted to thermoplastics.

### Plastic welding:

Plastic welding is reported in ISO 472 as a process of joining softened surfaces of materials, generally with the help of heat (except solvent welding). Welding of thermoplastics is accomplished in three sequential stages, preparation of surface, heat and pressure application,

cooling<sup>(5)</sup>. Numerous welding methods are developed for the joining of plastic materials. Classification of plastic welding is depicted in figure 2<sup>[3,4]</sup>:

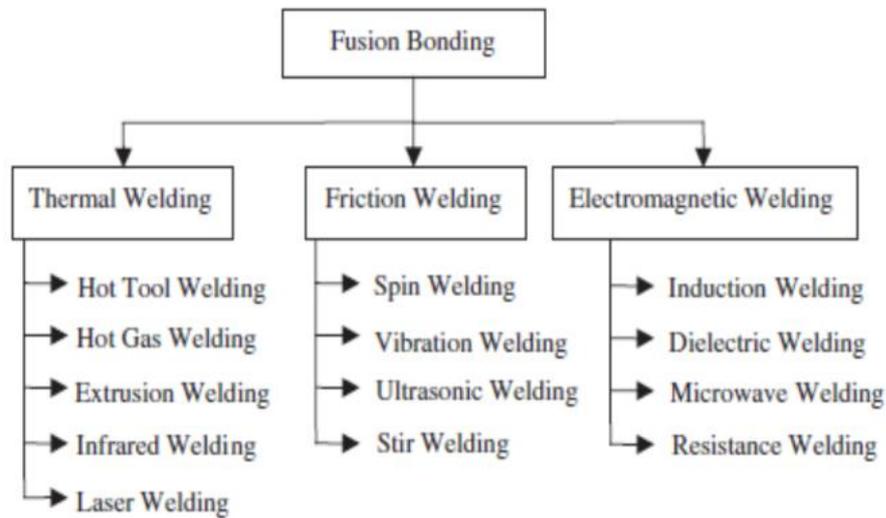


Fig 2 Classification of plastic welding

### Working principle of hot gas welding:

Hot gas welding is one of the external heating methods, and it was patented by Reinhardt in 1940<sup>(2)</sup>. In this method, weld groove and filler rods were heated with stream of hot gas until they become soft sufficiently to be fused; after that the welding rod is pressed into the weld groove. It is very simple, portable, economical, and the most suitable process in the more complex and intermittent fabrications, and hence it is employed widely to fit plastic constructions. It is used in the fabrication of storage containers, the sealing of roof or floor membranes for coverage, and the repair of injection molded components. But, this method has some disadvantages. The main disadvantage is that the weld quality depends on the skill of operator, which is standardized by EN 13067. Thermal degradation and oxidation are possible as the temperature of hot gas is higher than the melting point of the polymer being welded. Mostly used gas is air, but the use of carbon dioxide, nitrogen, and other inert gases are mentioned. Hot gas welding process is portrayed in figure 3.

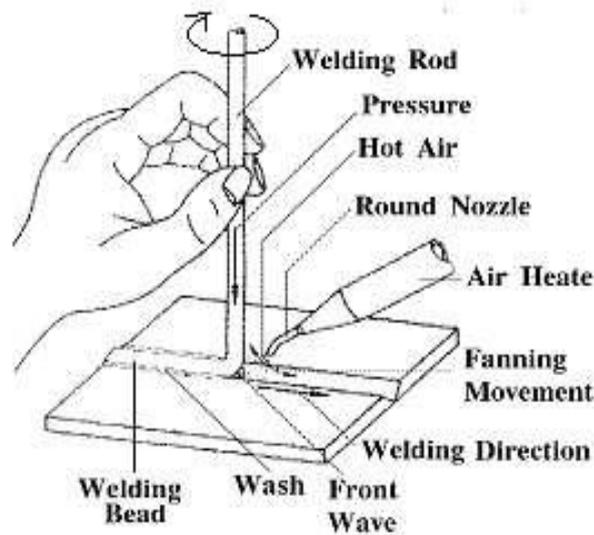


Fig 3 Hot gas welding process

Hausdorfer et al. investigated whether multilayer hot gas welding of thick polyethylene (PE) sheets (30 mm) with plasticized welding rod can become an alternate solution to single layer extrusion welding. The best results were obtained in the strength testings while extrusion welding and hot gas welding were combined. The root layer of V-groove was welded by hot gas welding using partly plasticized welding rod, and the central and upper layers were welded by extrusion welding method using completely plasticized welding materials. They attained long-term weld factors of up to 0.90 for each welding process. Diedrich and Kempe studied hot gas welding of pipes and fittings made from different grades of high-density PE (HDPE). Abram et al. performed hot gas welding using nitrogen gas at a temperature of 280°C on double V-grooves of unplasticized polyvinyl chloride (uPVC) and uPVC/calcium carbonate (15 wt%) sheets of 10-mm thickness. Reported weld factors were 0.29, 0.85, and 0.94 for hot gas welded uPVC material, uPVC/calcium carbonate material, and hot plate welded uPVC material sheets, respectively. Investigations of Scanning electron microscopy (SEM) showed that fracture started from the regions which were unfused in weld root for both materials. Obviously, the main cause for the low tensile strengths of welds was higher notch sensitivity of material. In addition to that, high degree of orientation present in the welding rod may contribute to residual stress levels significantly in the welds. It was concluded that the poor thermal stability and high pseudomelt viscosity of PVC all make perfect fusion very difficult. John et al. compared creep strengths of hot gas, extrusion, and hot plate welded thick Polyethylene sheets. They reported weld factors as, 0.84, 0.57, 0.85, and 0.98 for hot plate welding, hot gas double V-welding, extrusion single V-welding, and extrusion double V-welding, respectively. Hessel and Mauer also studied hot gas butt welds for HDPE, polypropylene (PP), and PVC pipes. Atkinson and

Turner designed a new work holding device to minimize weld pores through the escape of hot gas easily from the beneath of the weld. They investigated the effects of hot gas temperature and pressure applied during welding on mechanical properties of hot gas welded polycarbonate or polyester, poly (butylene terephthalate), and EPDM sheets of 3-mm thickness. The weld factors reported of single V-welds with heated roller, single V-welds and double V-welds (X-welds) were 0.70, 0.59 and 0.63 for the polycarbonate/polyester material, 0.76, 0.89, and 0.97 for poly (butylene terephthalate) and 0.78, 1.00, and 0.67 for EPDM, respectively. Marczis and Czigany designed and developed a hot gas welding portal to reduce human interference on the welding parameters such as speed of welding, welding force applied, temperature of hot gas, and flow rate of hot gas. They observed that the tensile strength of hot gas welded PP sheets 19 MPa when the welding force applied in the range of 12–16 N. The heat affected zone (HAZ) of welds is divided into three parts, namely the cool, plastic, and flow zone of the weld center. Cramer explained and classified weld defects for hot gas, extrusion, and hot plate welding as undercuts in the base material and on the root of the weld, excessive and incomplete fusion, pores, reinforcement on welds, etc. Sims et al. studied on pollutants from laser cutting and hot gas welding of PP, PVC, PC, PMMA, and PA6 sheets. They performed hot gas welding for four hours in a cabinet and obtained a simple mixture of substances in small fractions with zero detectable particulate content. The aim of this work is to design and develop a welding machine with adjustable filler feed rate to investigate the effect of process parameter; filler feed rate on the weld strength of hot gas welded Polypropylene sheets. Hot gas welding is widely employed in various streams of engineering such as automotive, aerospace, agricultural and marine industries. One of the applications of plastic welding is discussed in research paper, The harvesting of coconut marked as a major problem due to less availability of suitable harvesting tools, machines and trained coconut climbing labours in India. Dr. K. P. Kolhe designed and developed tractor mounted hydraulic lifter for pruning, harvesting, and spraying of horticultural crops upto 12 m. In this setup bucket made of Plastic material which carries person subjects to heavy loading which could lead to failure of bucket. Hence plastic welding machine is suitable to join the failed material. <sup>(16-19)</sup>



Fig. 4 Tractor mounted hydraulic coconut harvesting machine

**Process parameters of Hot gas plastic welding:**

In case of welding there are numerous parameters which affects the quality of welded component. <sup>(10-15)</sup> There are numerous parameters which significantly affects the characteristics of Welded joint of hot gas plastic welding enlisted in Table 1 <sup>(1,5,7)</sup> ,.

Table 1 Process parameters

Process parameters	Description
Temperature	Temperature of hot gas
Angle	Angle between weldment and rod.
Gas	Air
Travel Speed	The rate at which weld is being deposited
Weld Force	Amount of force applied to filler rod
Filler rod	Composition of filler rod
Gap distance	Distance between specimen and air gun
Weld joint	Butt joint and double strap fillet joint
Pressure of hot air/ gas	Pressure of gas at which it coming out
Shoe	Design and size of welding

**II. DEVELOPMENT OF HOT GAS WELDING MACHINE**

Design consists of application of scientific principles, technical information and imagination for development of new advanced machine to perform a specific function with maximum economy & efficiency .Hence a careful design method has to be adopted. The total design work has been split up into two parts; System design and Mechanical Design. System design mainly concerns with the various physical constraints and ergonomics, space requirements, arrangement of components on frame of the system, man + machine interactions, controls, position of controls, ambient condition of machine, failure chances, safety precautions to be provided, servicing aids, maintenance easiness, scope of

improvement in future, total weight of machine and a lot more. In mechanical design the components are designed considering various forces such as Dead weight forces, Friction forces, Inertia forces, Centrifugal forces, Forces arised during power transmission etc. Components are listed down and stored on the basis of their procurement, design in two categories namely, Designed Parts and Parts to be purchased. For designed parts detailed design is done & distinctions thus obtained are compared to next dimensions which are readily available in market. The various tolerances on the works are specified for design. The process charts are prepared and passed on to the manufacturing stage. The parts which are to be purchased are selected from various catalogues and purchased the same from the shop with specifications given.

Table 2 Material Details

Sr No.	Description	Qty	Material
1.	Motor	01	Std
2.	Motor Mounting Bracket	01	Mild Steel
3.	Pinion Gear	02	Case Hardened Steel
4.	Worm and Worm Gear	01	Nylon-66
5.	Hot Air Gun	01	Std
6.	Lh Bearing Hsg	01	Plain Carbon Steel
7.	Rh Bearing Housing	01	Plain Carbon Steel
8.	Motor Mounting Plate	01	Plain Carbon Steel
9.	Support Rib Plate	01	Plain Carbon Steel
10.	Rh Pillar	01	Plain Carbon Steel
11.	Air Gun Holder	01	Cast Iron
12.	Job Fixture	01	Mild Steel
13.	Base Frame	01	Mild Steel
14.	Base Plate	01	Mild Steel
15.	M6 Bolts	08	Std

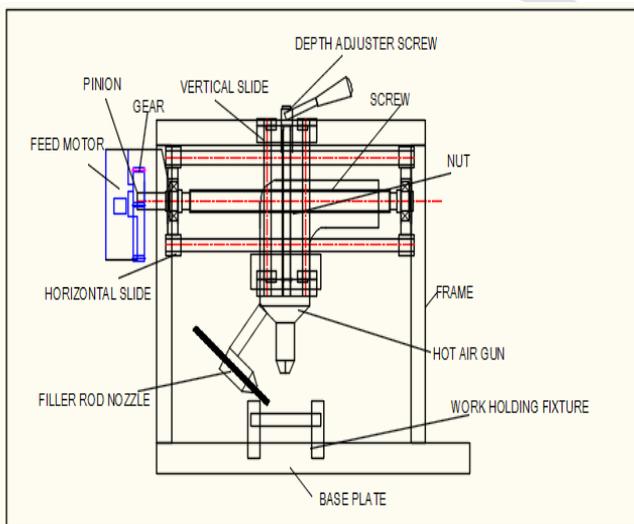
**Specification of standard Purchased Parts :**

**1. Hot air gun**

- Model No.Rt-881
- Rated Voltage: 230 Volt
- Rated Frequency: 50- Hz
- Output Watt: 750-500
- Temperature : 350-250
- Support Material Of Heater: High Temperature Ceramic
- Air Quantity : 200/300 Cfm

**2. Specifications Of Feed Motor**

- voltage: 12V DC
- No-load speed: 45 rpm
- No-load current: 1.30A
- Stall torque: 2 Nm
- Stall current: 2.4A



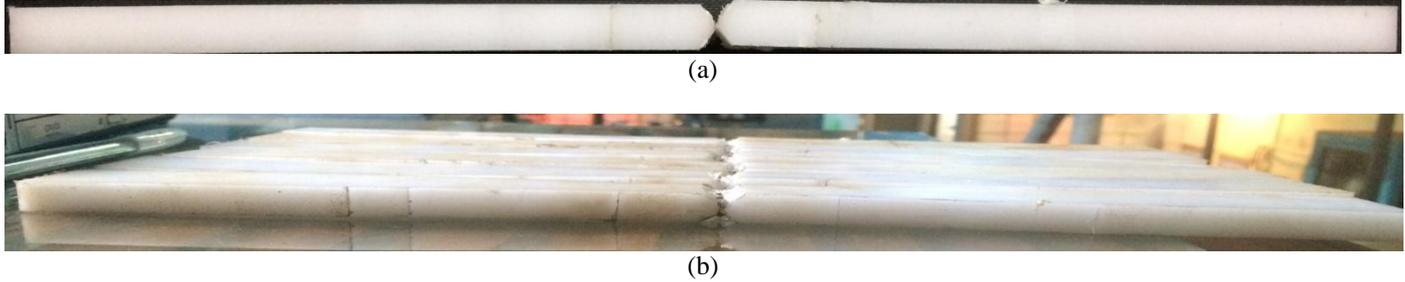
(a) Designed hot gas plastic welding machine

(b) Experimental setup of developed plastic welding machine

**Fig. 5 (a,b) Designed and Developed Plastic Welding Machine**

**Hot gas welding Specimen Preparation**

To see the performance of above developed hot gas welding, Polypropylene material was selected for testing the actual strength of welded joint. Welding experiments were performed on seven identical 10-mm-thick, extruded polypropylene block polymer sheets. Differential Scanning Calorimetry examinations revealed that the melting point of the crystalline phase of the aforementioned PP block copolymer is between 180 and 260°C. The welding rod was made of the same raw material. The 10-mm-thick sheets were available in the form of 1500 x 2000 mm<sup>2</sup> blocks (length/width), from which 150x 30 mm<sup>2</sup> sheets were cut and the profile with 45° slope necessary for welding was prepared along the width of the specimen. After preparing the sheet and prior to welding, the welding specimens as well as the filler material were cleaned with acetone to clean the surface. After that the seam was prepared by the designed welding machine after the opposing two specimens were kept next to each other. No root gap was applied while welding the specimen.



**Fig. 6(a,b) Specimen before Welding**

**Experimental Procedure**

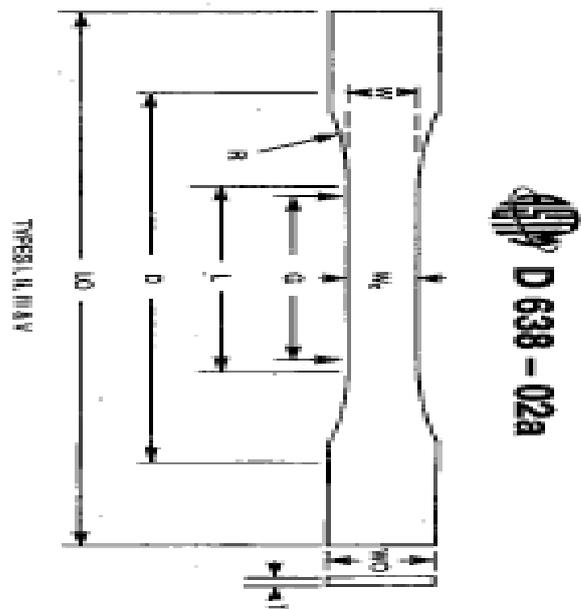
The range of welding parameters was determined in pre-experiments. The appropriate welding temperature was chosen during manual hot gas welding. As a consequence, welding temperature was chosen to be 250°C. The experiments are carried out on designed welding machine model in a single Run which is shown in figure. Air with flow rate 200 CFM used as a hot gas to soften the material to be welded and filler rod. 10mm diameter Polypropylene Filler rod used to weld the test specimens. The material chosen for the present study was Polypropylene. Sample of 75mmx30mmx10mm size has been used as a work piece material. The Polypropylene sheet is converted in to seven samples as per desired work piece size by using cutting operation. Double V groove with 60° V edge preparation was made on these specimens as shown in figure. Set up was made by hot gas welding. No Root gap was applied. Welding process parameters taken as per Table 2. Filler feed rate is varied and Temperature, Gun Nozzle tip to plate distance, and gas flow rate are kept constant. Numbers were assigned to each specimen. Total seven experiments were carried out within filler feed rate ranging from 22.5 mm/min to 45 mm/min, by varying voltage of DC motor from 6 V to 12V Fig. 5 shows welded Samples-1 to 7 before welding. After welding, Tensile Samples were prepared as per ASTM-D-638 Standard. Tensile test were made using Universal Testing Machine (UTM).

**Universal Testing Machine Specimen Preparation**

The basis of the tensile test was standard ASTM D638. Seven identical Test specimens of the type 3 were prepared from the each welded joint. First, the specimens were cut out of the welded sheets roughly, and then the exact size 246x30mm<sup>2</sup>, was finished with milling operation. The tensile test was performed on a universal test machine at standard test conditions.



(a) Specimen for testing



(b) ASTM D638 standard for tensile test

**Fig.7 (a,b) Welded Specimen for Testing**

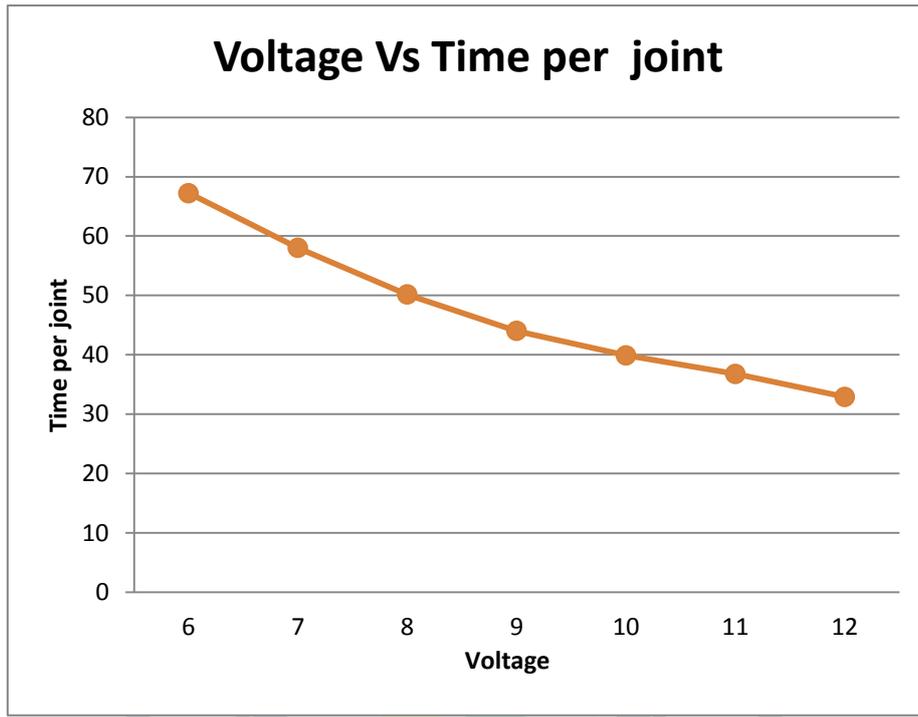
**III. RESULTS AND DISCUSSION**

Seven identical Polypropylene components were welded with above developed Hot gas welding Machine and tested for Tensile strength with Universal Testing Machine according to ASTM D638 standard. Results obtained in this test are shown in Table 3.

Table 3 Test results

Expt. No.	VOLTAGE (V)	SCREW SPEED (rpm)	FEED RATE (mm/min)	Fail load (kg)	Time/ joint (sec)
1	6	3.75	22.5	31.02	67.21
2	7	4.375	26.25	33.78	58
3	8	5	30	34.9	50.15
4	9	5.625	33.75	33.6	44
5	10	6.25	37.5	32.8	39.90
6	11	6.875	41.25	31.7	36.76
7	12	7.53	45	25.84	32.89

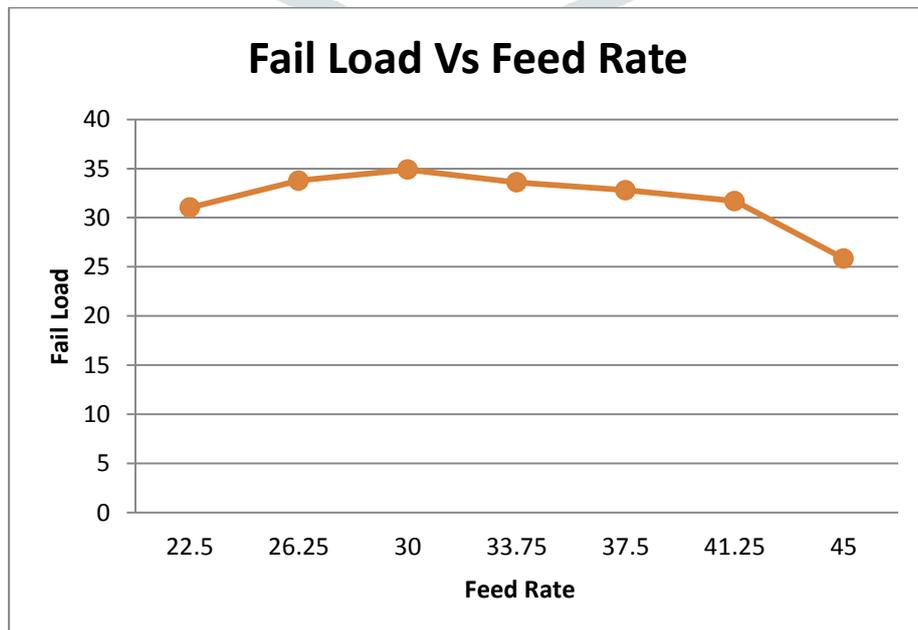
**Effect of motor Voltage on time required per joint**



**Fig.8** Voltage Vs Time required per joint

Figure 8 depicts that the time required per joint drops with increase in voltage of feed motor, which in turn increases productivity.

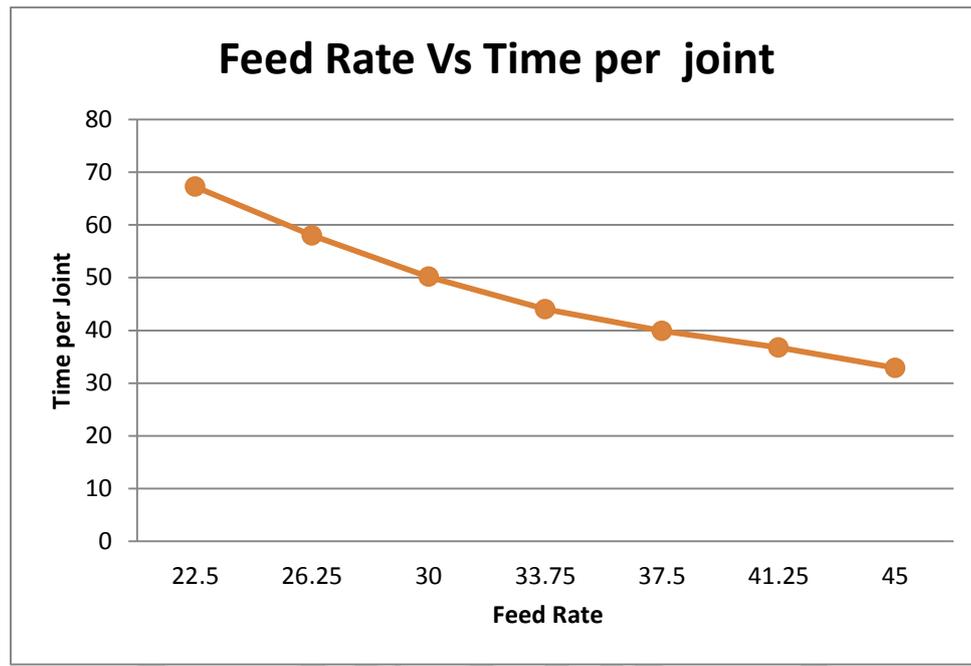
**Effect of Filler feed rate on joint Fail Load**



**Fig.9** Fail Load Vs Feed Rate

Figure 9 depicts that the Fail load increases with decrease in feed rate upto a certain limit and again drops indicating a optimal filler feed rate.

#### Effect of Filler feed rate on time required per joint



**Fig.10** Feed Rate Vs Time per joint

Figure 10 depicts that The time required per joint drops with increase in Filler feed rate.

#### IV. CONCLUSIONS

- Hot air welding machine is developed with adjustable filler feed rate.
- The Feed rate of motor and there by the filler feed rate can be varied by controlling feed motor voltage.
- The time required per joint reduces with increase in filler feed rate, indicating improvement in productivity of machine.
- The Fail load increases with decrease in feed rate upto 30mm/min and then further decrease in feed rate shows a drop in fail load Indicating the optimal fed rate for given temperature and air flow setting for Polypropylene material.

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