Comparative Weld-Able Plastics

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Abstract— This paper is relating the weld-able plastic materials among which is the most weld-able and economical by different means of welding techniques and methodologies. While considering material for the welding purpose it is also important to predict the chemical variation in there composition and the change of behaviour while heating i.e. the effect of temperature is also included during the welding. So, in this paper we will regard about the thermoplastics which are weld-able rather the method of welding technique or methodology used.

Key words: Plastics, Composites, PVC (Polyvinylchloride), PMMA, ABS (Acrylonitrile Butadiene Styrene)

I. INTRODUCTION

Plastics have various day to day applications like toys, pipes, building appliances, doors, panels, bumpers in automobiles and trucks etc. it has various medical applications also. So, it is very important to know the characterisation of the various plastic materials and effect upon it during the welding that make the plastic material weld-able by proper welding technique without the change of chemical composition. The various weld-able plastics are ABS, Acrylic, Hard PVC, Hypalon, Polycarbonate, Polyethylene (Hard), Polyisobutylene, Polypropylene, Polyvinylidene Fluoride etc.

There are various types of plastics and are the generalisation of the polymers and all types of polymers have its own chemical formula and is chemically chain of the centralised carbon. Generally polymers are a group of organic, inorganic substances containing large number of molecules forming the chain like structure. Polymers may be natural or synthetic (man-made). Today, the industries of synthetic polymers has grown to be larger than the aluminium, copper and steel industries combined. Humans have progressed from the Stone Age, through the Bronze, Iron and Steel Ages into its current age. Now, the age of Polymers – an age in which synthetic polymers are and will be the material of choice.

II. CLASSIFICATIONS OF THE POLYMERS

The polymeric materials are classified as below.

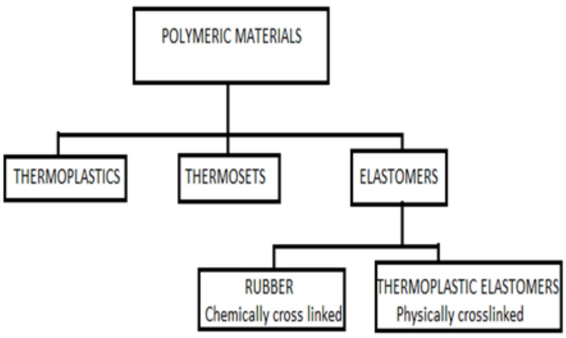

Fig. 1: Polymeric material

Polymeric materials have various new applications in the future and are being developed I such areas like molecular based information storage and processing, molecular composites, conduction and storage of light, revolutionary new forms of food packaging and processing, health, housing and transportation. Polymeric materials can be separated into three different groups depending on their behaviour when heated.

A. *Thermoplastics:*

Thermoplastics are polymeric materials with linear macromolecules synthesized by addition or condensation polymerization. Thermoplastics can be soften by heating upto required temperature as thermoplastics have weaker secondary bond between the chain and strong primary covalent bond within the chain and as such they can be moulded and recycled on heating. Thermoplastics will retain their newly reformed shape after cooling and restricting the motion long molecules. When heated again they regain the ability to flow.

B. *Thermosets:*

Thermoset plastics cannot be soften under heat and pressure and they cannot be moulded and recycled as they have also strong chemical linkage between the chains besides strong covalent bonds chemically hold different chains together in a thermoset materials. Because of this "cross-linking" between the chains they resist softening upon heating.

C. *Elastomers:*

An elastomer is a polymer with the property of "elasticity" generally having notable low Young's Modulus and high yield strain compared with other material. Elastomers are slightly cross-linked polymers, which permits almost full molecular extension. The links across the molecules hinder them from sliding past each other, making even large deformations reversible and they have less glass transition temperature than room temperature.

III. WELD-ABLE PLASTICS

Plastics are common name for thermoplastics and thermosets. The name "plastics" refers easy processability and shaping. But only thermoplastics are the materials which could be moulded recycled and can be welded also. So, the various weld-able thermoplastic material are as follows.

1) Polypropylene 300ºC
2) ABS 350ºC
3) Acrylic 350ºC
4) Polystyrol 250ºC
5) Polycarbonates 2500C-350ºC
6) Polyvinylidene Fluoride 350ºC
7) Hard PVC 220 - 300ºC
8) Polyethylene 250 - 280ºC
9) Polyisobutylene 600ºC

A. Polypropylene:

The three main types of PP are generally available:

1) Homopolymers are made in a single reactor with propylene and catalyst. It is the stiffest of the three propylene types and has the highest tensile strength at yield. In the natural state (no colorant added), it is translucent and has excellent see-through or contact clarity with liquids. In comparison to the other two types, it has less impact resistance, especially below 0°C.
2) Random copolymers (homophasic copolymer) are made in a single reactor with a small amount of ethylene (5%) added which disrupts the crystallinity of the polymer allowing this type to be the clearest. It is also the most flexible with the lowest tensile strength of the three. It has better room temperature impact than homopolymer but shares the same relatively poor impact resistance at low temperatures.
3) Impact copolymers (heterophasic copolymer) also known as block copolymers, are made in a two reactor system where the homopolymer matrix is made in the first reactor and then transferred to the second reactor where ethylene and propylene are polymerized to create ethylene propylene rubber (EPR) in the form of microscopic nodules dispersed in the homopolymer matrix phase. These nodules impart impact resistance both at ambient and cold temperatures to the compound. This type has intermediate stiffness and tensile strength and is quite cloudy. In general, the more ethylene monomer added, the greater the impact resistance with correspondingly lower stiffness and tensile strength.

B. Abs:

ABS (Acrylonitrile Butadiene Styrene) is a thermoplastic resin commonly used for injection moulding applications. ABS Plastic is a copolymer of Acrylonitrile, Butadiene, and Styrene, and generally possess medium strength and performance at medium cost. ABS is a common thermoplastic resin and can often meet the property requirements at a reasonable price, falling between standard resins (PVC, polyethylene, polystyrene, etc.) and engineering resins (acrylic, nylon, acetal, etc.). ABS is considered the best of the styrenic family. It is tough, hard and rigid and has good chemical resistance and dimensional stability. Its glass transition temperature is approximately 105 °C (221 °F). ABS is amorphous and therefore has no true melting point. ABS is stable to decomposition under normal use and polymer processing conditions with exposure to carcinogens well below workplace exposure limits. However, at higher temperatures (400 °C) ABS can decompose into its constituents: butadiene (carcinogenic to humans), acrylonitrile (possibly carcinogenic to humans), and styrene. Acrylonitrile is a synthetic monomer produced from propylene and ammonia; butadiene is a petroleum hydrocarbon obtained from butane; and styrene monomers, derived from coal, are commercially obtained from benzene and ethylene from coal. The advantage of ABS is that this material combines the strength and rigidity of the acrylonitrile and styrene polymers with the toughness of the polybutadiene rubber. The most amazing mechanical properties of ABS are resistance and toughness. A variety of modifications can be made to improve impact resistance, toughness, and heat resistance. The impact resistance can be amplified by increasing the proportions of polybutadiene in relation to styrene and acrylonitrile although this causes changes in other properties. Impact resistance does not fall off rapidly at lower temperatures. Stability under load is excellent with limited loads.

Even though ABS plastics are used largely for mechanical purposes, they also have good electrical properties that are fairly constant over a wide range of frequencies. These properties are little affected by temperature and atmospheric humidity in the acceptable operating range of temperatures. The final properties will be influenced to some extent by the conditions under which the material is processed to the final product; for example, molding at a high temperature improves the gloss and heat resistance of the product whereas the highest impact resistance and strength are obtained by molding at low temperature.

C. Acrylic (Pmma):

Large number of acrylic polymers are manufactured, PMMA is by far the most common. Nearly everyone has heard of Plexiglas. PMMA has two very distinct properties that set the products apart from others. First, it is optically clear and colourless. It has a light transmission of 92%. The 4% reflection loss at each surface is unavoidable. Secondly, its surface is extremely hard. They are also highly weather resistant. PMMA shows very good abrasion resistance, weather resistant (with a UV absorbers), and are absolutely colourless.

D. POLYSTYRENE (POLYSTROL):

Polystyrene is the simplest plastic based on styrene. Its structure is shown in Figure1. Pure solid polystyrene is a colourless, hard plastic with limited flexibility. Polystyrene can be transparent or can be made in various colours. It is economical and is used for producing plastic model assembly kits, plastic cutlery, CD "jewel" cases, and many other common objects where a fairly rigid, economical plastic is desired. There are numerous medical applications.

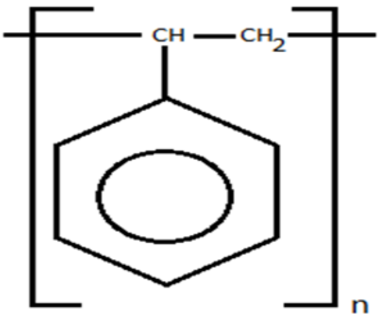

Fig. 2: Polystyrene

Three general polystyrene types are:

1) General purpose or crystal (PS or GPPS)
2) High impact (HIPS)
3) Syndiotactic (SPS).

Sterilization:

Polystyrene is not recommended for steam and autoclave sterilization. Its low heat distortion temperature will cause the parts to warp and disfigure. Polystyrene can be sterilized with ETO.

ETO resistance: Polystyrene resins retain their properties after exposure to one normal ETO sterilization cycle. Excessive or multiple exposures to ETO sterilization are not recommended because ETO can cause embrittlement and stress cracking of the polymer.

Gamma and electron beam resistance: Polystyrene is very stable to gamma radiation and electron beam due to its high aromatic content. Colour changes are seen after e-beam sterilization.

UV light sterilization resistance: Styron is resistant to sterilization by UV light. This technology is based on a short wavelength of 254 nm during which the part-to-lamp distance is controlled.

Applications and uses:

- General purpose: Diagnostic instruments and disposable laboratory ware, Petri dishes, tissue culture components, flasks, and pipettes.
- Oriented: Oriented polystyrene films can be printed and laminated to foams for food service plates and trays offering improved aesthetics. The films can also be used as a laminate to polystyrene sheet for a high-gloss shine.
- High impact: Laboratory ware and other medical devices.

E. Polycarbonates:

Polycarbonates are polyesters of phenol and carbonic acid. They can be prepared by condensing diphenoxymethylene derivatives with diphenyl carbonate. Biphenol-A with diphenyl carbonate gives a polycarbonate

Polycarbonate melts at 2650C and has a very hard impact strength. It is resistant to water and many other components but alkalies with slowly hydrolyse it. It is a transparent plastics. Many useful articles such as safety goggles, safety shields, telephone parts, and machinery housings can from this plastic.

PC performance properties include:

- Very impact resistance, is virtually unbreakable and remains tough at low temperature.
- “Clear as glass” clarity.
- High heat resistance.
- Dimensional stability.
- Resistance to UV light, allow exterior use.
- Flame retardant properties.

F. Polyvinyl floride and polyvinylidene floride

Polyvinyl floride has following structure and is obtained from acetylene.

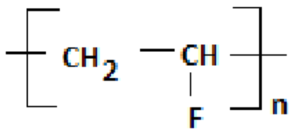

Fig. 3: Polyvinyl floride

Polyvinyl fluoride is a crystalline polymer with a melting point 2000C. It has excellent outdoor life. And, in that respect, resembles other fluorocarbons polymers such as Teflon. It maintains good structure integrity even above 1500C has a good thermal stability. Gas permeability is also sufficiently low. It has already proved its merit as a protective as well as a glancing material over cement mortars in the building industry. For, durability, even in extremely small thickness, It is far better than conventionally used materials such as paints and other surface coatings.

Polyvinylidene floride is a crystalline polymer with a melting point of around 1700C.

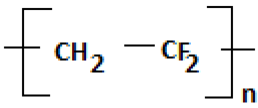

Fig. 4: Polyvinylidene floride

It does not undergo creep or distortion over a vide temperature range. Like polyvinyl fluoride, it is resistant to many solvents and finds use in coating compositions.

G. Polyvinyl Chloride (Pvc):

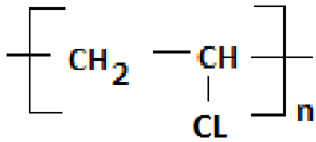

Fig. 5: Polyvinyl Chloride

PVC is a flexible or rigid material that is chemically nonreactive. Rigid PVC is easily machined, heat formed, welded, and even solvent cemented. PVC can also be machined using standard metal working tools and finished to close tolerances and finishes without great difficulty. PVC resins are normally mixed with other additives such as impact modifiers and stabilizers, providing hundreds of PVC-based materials with a variety of engineering properties. PVC can be used in a wide range of temperatures, and it retains its flexibility, strength, and durability at low temperatures. PVC can be easily welded to various other plastics by a wide range of method having welding temperature of about 2200-3000. PVC is one of the cheapest and most widely used plastic globally. It is used for the large scale production of cable insulation, equipment parts, pipes, laminated material and in fibre manufacture. PVC is thermally not very stable and, beyond 2000C, it degrades with the evolution of HCL. The total chlorine content in PVC is around 56.8%.

H. Polyethylene:

There are two varieties of polyethylene, viz., low density and high density. Low density polyethylene consists of molecules with branches, where as the high density varieties is essentially linear. Low density polyethylene is produced by the high pressure polymerisation of ethylene, using oxygen as an indicator. The reaction occurs at high pressure i.e. 1500 atmosphere and in the temperature range of 180-2500C.

Low density polyethylene melts at 110-1250Cand is only around 40% crystalline. The density is around 0.91-0.92g/cc. while practically no solvent dissolves it at room temperature, several solvents can do so at high temperature. Some of the useful solvents for polyethylene at high temperature are carbon tetrachloride, toluene, xylene, decaline and trichloroethylene. High density polyethylene is 90% crystalline and possesses densities as high as 0.965 g/cc. it has a melting point in the range of 144-1500C. It is much stiffer than LDPE and has a higher tensile strength and hardness. Chemically it is more resistant than the low density variety and has a significantly lower gas permeability.

HDPE is a common plastic that can be heat welded in the field using specialized equipment. Fish farmers may find this material useful when used for building hauling tanks, fish tanks, or other farming related uses. As a plastic, HDPE material is lighter than metal, non-corrosive, long lasting, and is a poor conductor of electrical current. High density polyethylene (HDPE) is a hard plastic that is used in many applications due to its resistance to degradation and fatigue. Some of the commercial products made from this material include drainage culverts, pipes, and white water kayaks. There are specialty companies that can custom make just about any product needed, however the average person can quickly learn how to properly prepare and weld this material.

I. Polyisobutylene:

Polyisobutylene has the following structure:

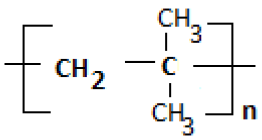

Fig. 5: Polyisobutylene

It is produced by a cationic polymerisation of isobutylene using BF3 and ALCL3 catalysts in a suitable solvent such as hexane or methylene dichloride at 800C. This polymer dissolves in many hydrocarbons and halogenated hydrocarbons. Polyisobutylene is chemically one of the most inert polymers known so far. Moisture, acids and alkalis have practically no effect on this polymer.

Polyisobutylene is widely used as an insulation material in the electrical industry. It is also added to motor oils to suppress the sharp fall in viscosity with increasing temperature.

A copolymer of isobutylene with 2-5% of isoprene is made under the commercial name of “butyl rubber”. Due to the presence of the double bonds in the molecule butyl rubber can be vulcanised to form cross linked structure with improved mechanical properties.

IV. Methods of Welding Thermoplastics

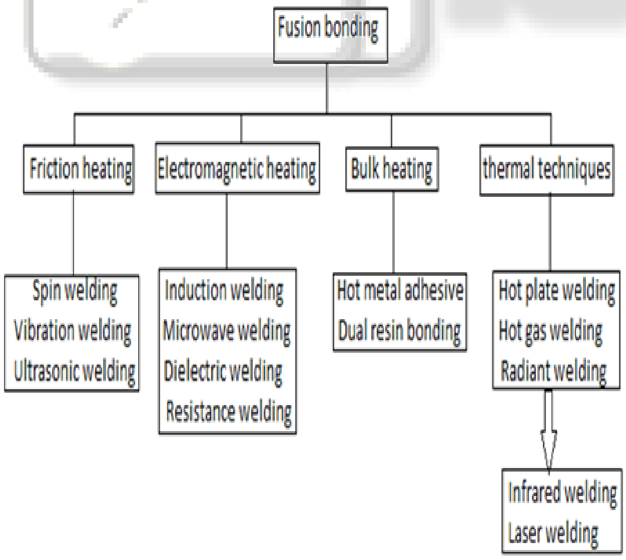

Fig. 7: Methods of welding thermoplastics

V. Conclusion

Among all the weld able thermoplastics the PVC (Polyvinyl chloride) is the most useful and practically being used cheapest material. It can be easily recycled, machined, weld-able, and mouldable than other thermoplastic materials as most of the materials made of plastic is PVC plastic.

There are various methods of joining thermoplastics in which laser welding produces the best quality of welded material strength with good finish and appearance than the other techniques used. But, this process is expensive and is not easily available. This one has good medical applications also.

So, the better method of joining the thermoplastics is hot gas welding, which is easily available and could perform by anybody where it is needed as it is the cheapest one among all the methods of joining thermoplastics but, this method has also some disadvantages because the surface finish is not good and the strength of weld bead attained is not high than laser method i.e. comparative lower.

VI. Applications

There are number of applications among which few are given below.

- Generally pipe section and containers are made of PVC, ABS, PE and PP which are easily weld-able.
- Weld-able thermoplastic materials are also used in automotive industries and repairing of their parts can be done by any one of the method mentioned above.
- Repairing of exhaust fans and cooling fans in engines and engine cooling systems.
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- Repairing of thermoplastic doors, windows etc.

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