Study of Thermal Properties of PP and ABS on Addition of Flame Retardant

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Abstract: The Study of thermal properties of polypropylene and acrylonitrile butadiene styrene (ABS) on addition of flames retardants was investigated. The thermal properties of polypropylene and ABS material were studied by the heat deflection temperature method and Vicat softening temperature method.

Keywords: *Polypropylene (PP), Acrylonitrile butadiene styrene (ABS), Flame Retardant (FR).*

Introduction

In the middle of the 20th century, the polymer industries saw incredible growth as numerous manufacturers created new types of plastic. To produce new polymers like thermosets, thermoplastics, and rubbers, significant research investments were needed to determine the chemical process[1]. The creation of novel chemical vessels, the synthesis of novel monomers made by intricate chemical processes, and the discovery of novel catalysts have all helped to drive the growth of the plastics industry. But this strategy was too costly for the plastics industries. For this reason, combining various polymer types has aided in the development of new plastic materials [2]. This new method makes use of compatibilizers that improve or reinforce additives between the products that make up the mixture. This method of creating novel plastic materials is less costly. These days, polymer blends account for around 30% of the world's plastic consumption. This tendency keeps rising steadily year after year. The thermoplastic polymer polypropylene (PP), commonly referred to as polypropene, finds extensive usage in diverse fields. It is made by chain-by-growth polymerization of the propylene monomer [3]. Polypropylene is a partially crystalline, non-polar member of the polyolefin family. It is a little bit harder and more heat-resistant than polyethylene, but otherwise its qualities are similar. Growth of a thermoplastic polymer chain polymerization partially crystalline polyolefinsnon-polar polyethylene It is a white, highly resistant to chemicals material that is also mechanically robust. The bio-based equivalent of polypropylene is called bio-PP. After polyethylene, polypropylene is the commodity plastic that is produced on a larger scale. The value of the polypropylene market worldwide was $126.03 billion in 2019. By 2019, revenues are predicted to surpass US$145 billion. Up until 2021, sales of this material are expected to increase at a 5.8% annual rate. Polypropylene thermoplastic is lightweight, affordable, and simple to machine, weld, and form. This thermoplastic material's good strength-to-weight ratio and balance of chemical, thermal, and electrical properties make it suitable for a wide range of applications [4]. Very low gas and water vapor permeability and outstanding chemical and solvent resistance characterize polypropylene. It is a commodity plastic that is biobased. It is therefore widely used in the semiconductor industry. It is an excellent option for the food processing sector as well. Its high-gloss, hard surface makes it appropriate for applications where direct food contact occurs and other environments where bacteria are a concern [5].

Polypropylene is an excellent choice for electrical applications due to its dielectric strength, excellent arc resistance, and good insulating qualities. It can be adjusted to be anti-static or conducive. Because of its superior electrical insulation, chemical resistance, and good mechanical qualities, polypropylene (PP) has seen extensive use in recent decades [6]. However, a number of drawbacks, including low thermal stabilities, flammability, and impact resistance, limit its applicability. Researchers are becoming more and more interested in enhancing its impact strength and thermal properties. Adding functional nanoparticles to polypropylene (PP) has shown to be a successful strategy for enhancing PP's thermal properties in recent years. Nevertheless, high nanoparticle content could result in a decrease in the mechanical qualities, particularly the tensile strength, creep deformation at high temperatures, and elastic modulus. Combining PP with stiff polymers to create a binary or ternary system is a conventional technique to simultaneously enhance mechanical and thermal properties [7]. Lately, there have been numerous reports of stiff nylon-6, polymethyl methacrylate, acrylonitrile–butadiene–styrene (ABS), and styrene acrylonitrile polymers. Since PP's high flammability restricts its applications, many studies are focused on increasing PP's free retardancy. The main methods for incorporating flame retardants (FRs) into polymer materials have become widely recognized in recent decades. Ammonium polyphosphate (APP), a polymeric flame-retardant additive, has drawn a lot of attention because of its ability to synergistically promote the formation of char by catalysing carbonization and acting as a synergistic between phosphorus (P) and nitrogen (N). Additionally, APP is a low-smoke, halogen-free intumescent flame retardant (IFR) with unparalleled. Unfortunately, because of the thermodynamic incompatibility between APP and the polymer matrix, high APP content in a polymer, like many other flame retardant additives, causes the polymer's mechanical properties to deteriorate[8].

Fig 1: Polypropylene

Thermal Properties Of Polypropylene

The gas propylene (C3H6) has no color. It is produced by heating ethylene to a fracture. High concentrations can result in burns to the skin and asphyxiation, while low quantities combine with air to generate an explosive and combustible combination. It is utilized in the chemical industries to produce propylene oxide, polypropylene, isopropyl alcohol, and other compounds, as well as in the petrochemical sector as an alkylate and fuel. Different crystalline modifications of polypropylene can be found, each with a unique molecular arrangement of the polymer chains [6 7]. The crystalline modifications are classified into mesomorphic forms and the α-, β-, and γ-modifications. In iPP, the α-modifications predominate. These crystals are composed of folded chains, or lamellae. The lame's arrangement in the so-called "cross-hatched" structure is a defining anomaly. Shear stress, the right temperature, and nucleating agents can all help to promote the formation of the β-modification. Under industrial conditions, the γ-modification is rarely formed and has limited understanding. However, because plastic is typically cooled quickly during industrial processing, mesomorphic modification happens frequent [4 7].

Introduction To Abs Plastic

Styrene and acrylonitrile are polymerized in the presence of polybutadiene to create ABS, a terpolymer. The percentages of acrylonitrile (15-35%) , butadiene (5%–30%), and styrene (40–60%) can vary. The result is a lengthy polybutadiene chain that is mixed in with shorter poly(styrene-co-acrylonitrile) chains. Because the nitrile bunches from adjacent chains are polar, they attract one another and bind the chains together, giving ABS greater stability than pure polystyrene. Acrylonitrile also increases the intensity deserting temperature and adds hardness, inflexibility, fatigue resistance, and compound blockage. The plastic's glossy, impermeable surface, hardness, unyielding character, and improved handling ease are all attributed to the styrene [7 9]. At low temperatures, the rubbery material polybutadiene provides resilience and pliability, however at the expense of rigidity, resistance, and intensity. Given its temperature-dependent mechanical properties, Acrylonitrile butadiene styrene is most useful between −20 and 80 °C (−4 and 176 °F) for most applications. Elastic hardening, in which tiny elastomer particles are scattered throughout the unbending grid, creates the properties. Ac ABS is an undefined thermoplastic polymer with effect safety design. Three monomers make up its composition: styrene, butadiene, and acrylonitrile. Because of its actual qualities, such as high inflexibility, protection from influence, scraped spot, and strain, it is a preferred choice for primary applications. Electronic housings, auto parts, consumer goods, pipe fittings, and Lego toys are among the products that use it. The opaque engineering thermoplastic Acrylonitrile Butadiene Styrene, or ABS for short, is used extensively in a variety of applications, including Lego toys, automotive parts, consumer goods, pipe fittings, and electronic housings. Learn all there is to know about the ABS polymer, including its main characteristics, limits, uses, processing requirements, and much more[2 7].

Fig 2: Abs Material

ABS Processing Conditions

A broad processing window allows Acrylonitrile-Butadiene Styrene (ABS) to be processed on most standard machinery.

Injection Melding

1. When using a vented cylinder for injection molding, pre-drying is not always required. If drying is required, four hours at 80°C should be plenty. If stripes, streaks, or bubbles appear in the molding, it indicates moisture and the material needs to be pre-dried.

1. Melt temperature: 210-270°C
2. Mold temperature: of 40-70°C
3. Material Injection Pressure: 50 - 100 MPa
4. Injection Speed: Moderate - High

Extrusion

1. Pre-drying in 3 hours at 70-80°C
2. Extrusion temperature at 210 to 240°C

3. Screw design at L\D ratio of 25-30 is recommended.

Thermal Properties Of ABS

The study was conducted to investigate the effect of fillers with different shapes on the properties like decomposition temperature, HDT of acrylonitrile butadiene styrene composites with talc and calcium carbonate at 10%, 20%, 30%, and 40% loading. The talc is long, platy in nature and has a higher aspect ratio of typically about 20:1, whereas the calcium carbonate particles are spherical and have an aspect ratio of 1. Titanate coupling agent was added to improve the interfacial adhesion between the filler and the acrylonitrile butadiene styrene matrix. Regarding the HDT, glass transition temperature determined by DSC, and decomposition temperature determined by TGA techniques, thermal properties did not exhibit any discernible changes.

Moulding

The process of shaping a liquid or pliable raw material with the use of a rigid frame known as a mold or matrix is known as molding or molding. It's possible that this was created using a model or pattern of the finished product. A hollowed out block filled with a liquid or solid is called a mold or mold. Pliable materials such as raw ceramic, glass, metal, or plastic. The fluid solidifies or sets taking on the shape of the mold inside. The opposite of a cast is a mold. The prevalent bi-Two molds are used in the valve molding process, one for each half of the object. In piece-molding, a several distinct molds, each of which created a portion of an intricate object. Typically, this is only utilized for more substantial and pricey. The mold maker is the manufacturer who creates the molds. Usually, a release agent is used to facilitate the hardened/set substance's removal from the mold. Molded furniture, molded household goods, molded cases, and structural materials are among the common applications for molded plastics.

Types Of Moulding:

Types of molding include:

- Extrusion molding
- Injection molding
- Blow molding
- Powder metallurgy plus sintering
- Compression molding
- Laminating
- Matrix molding.

Injection Moulding:

Injection molding is a manufacturing technique that involves injecting material into a mold to create parts. Metals, glass, elastomers, confections, and, most commonly, thermoplastic and thermosetting polymers can all be molded using injection molding. The material for the part is mixed and fed into a heated barrel before being pushed into a mold cavity, where it cools and solidifies to the specifications of the cavity. After a product is designed, usually by an engineer or industrial designer, a mold maker (also known as a toolmaker) creates molds from metal, usually aluminum or steel, which are then precisely machined to form the desired part's features. In order to make the molding process easier, injection-molded parts need to be meticulously designed. A number of factors need to be considered, including the material to be used, the desired shape and features of the part, the material of the mold, and the characteristics of the molding machine. This variety of design options and considerations contributes to injection molding adaptability.

Fig 3: Injection molding

The process of injection molding is used to create a wide range of products, such as wire spools, packaging, bottle caps, mechanical parts (such as gears), most plastic products available today, Game Boys, pocket combs, some musical instruments (and their parts), single-piece chairs and small tables, storage containers, and other items. Injection molding is the most widely used method of part manufacturing today, and it works well for mass producing identical parts.

Heat Deflection Temperature:

The heat deflection temperature (also called the heat distortion temperature, or HDT, HDTUL, or DTUL) is the temperature at which a polymer or plastic sample deforms under a specific load. Many engineering, design, and manufacturing processes that involve the creation of products with thermoplastic components make use of this property of a specific plastic material.

Fig 4: Heat Deflection Temperature

The following test protocol, which is described in ASTM D648, is used to determine the heat distortion temperature. Three-point bending is applied to the test specimen in an edgewise direction. The outer fiber stress used for testing is either 1.82 MPa or 0.455 MPa, and the specimen is heated at a rate of 2 °C per minute until it deflects 0.25 mm. This is similar to the test protocol described in the ISO 75 standard. Limitations pertaining to the computation of the 21 HDT include the sample's non-thermo isotropy and the fact that thick samples, in particular, will have a temperature gradient. Additionally, a given material's HDT may be extremely sensitive to the stress that the component is under. which is based on the dimensions of the component. The 0.2% additional strain, or 0.25 mm, of selected deflection is chosen at random and has no physical significance.

Vicat Softening Temperature:

The temperature in °C at which a circular indenter with a 1 sq. mm flat cross section area penetrates a sample with a minimum thickness of 3 mm, submerged in an oil bath heated at rate of 50 +/-5 °C per hour while bearing a 5 kg load, is known as the vacuum suction temperature (VST).

FIG 5: Vicat Softening Temperature

Muffle Furnace

High-temperature sintering, annealing, and heat treatment applications are the primary uses for the Muffle Furnace. While annealing and heat treatment procedures use the range 500°C to 800°C, sintering applications mainly use the 800°C to 1800°C range.

Industrial and lab environments frequently use muffle furnaces for heating. The heating methods used in contemporary electrical muffle furnaces are conduction, convection, or blackbody radiation. By using this method, the combustion by-products that were frequently produced in early 20th-century non-electric muffle furnaces are eliminated. Furthermore, improvements in element materials like molybdenum disilicial allow for the production of operating temperatures as high as 1,800 degrees Celsius. This high temperature muffle furnace feature makes it easier to carry out more complex metallurgical processes, such as metal injection molding end-to-end procedures and sintering and debinding.

FIG 6: Muffle furnace

Experiment Methods And Process

Materials Used:

ABS and Polypropylene materials was supplied by the company "Industrial traders" Fathenagar, Hyderabad. Acrylonitrile butadiene styrene and polypropylene addition of flame retardant was supplied by the online product materials.

Material	Supplied by
POLYPROPYLENE	Industrial traders, Fathenagar, Hyderabad
ABS	Industrial traders, Fathenagar, Hyderabad
PP AND ABS WITH FR GRADE	Online 1025 &AN 450M Natural

Table 1: The Materials and specifications

Experimental Procedure:

Preparation of blends:

Polypyrene (PP), Acrylonitrile butadiene styrene (ABS) and Flame retardant (FR) with PP ABS materials were prepared and taken four batches of weights and mixed thoroughly. Four batches of materials are kept in temperature 150 c at one hour. The materials are sent to be molded by injection. At this temperature, the materials melt and are injected into a mold that is fixed to produce the required size and shape of the specimen for testing.

Injection Moulding

Plastic materials are fed into the injection molding machine along with plastic. The plastic is heated by the molding machine until it becomes liquid. Next, the melted plastic is injected (under injection pressure) into the mold by the injection molding machine's nozzle. The plastic liquid is now inside the mold's cavity. After that, this will cool down and solidify. Ultimately, the cooled product is forced out of the machine as a finished part by ejectors. The process of injection molding is finished.

Heat Deflection Temperature

The test material specimen bars are positioned beneath the measuring apparatus. A load of either 1.80 MPa or 0.45 MPa is applied to each bar. After that, the temperature of the silicone oil bath is raised by 2° C per minute, lowering the specimen bars into it. For ASTM, the specimens are lowered until they deflect 0.25 mm.The test sample is immersed in oil that has been uniformly heated. The test bar's midpoint, which is supported close to both ends, receives the load. The HDT is defined as the temperature at which a material bar deforms by 0.25 mm.

Vicat Softening Temperature

A load of 10N or 50N is applied to the specimen. The specimen is then immersed in an oil bath at 23°C. Until the needle pierces 1 mm, the bath's temperature is raised by 50° or 120° C every hour. The Vicat softening temperature or Vicat hardness is used to calculate the softening point of materials, such as plastics, that lack a defined melting point. It is described as the temperature at which a specimen can be penetrated to a depth of 1 mm by a flat-ended needle having a 1 mm2 circular or square cross-section.

Results

MECHANICAL PROPERTIES OF PP(ABS) ON ADDITION OF FLAME RETARDANT

Table 2: Rectangular Shape

	Thickness	Width	Lower Support
Units	Mm	Mm	Mm
B1 – 1	6.3400	12.8500	100.0000
1 – 2	6.3600	12.9600	100.0000
1 – 3	6.2900	12.9000	100.0000
B2 – 1	6.3500	12.6900	100.0000
2 – 2	6.2100	12.6900	100.0000
2 – 3	6.2500	12.2400	100.0000
B3 – 1	6.1900	12.6400	100.0000
3 – 2	6.2000	12.7300	100.0000
3 – 3	6.1700	12.7800	100.0000
B4 – 1	6.1900	12.6600	100.0000
4 – 2	6.2200	12.6500	100.0000
4 – 3	6.1500	12.6600	100.0000

Name	LaForce	Maxis	Mistress	Mastrian
Units	N	Mm	MPa	%
B1 – 1	97.2500	5.99800	28.2422	2.28164
1 – 2	95.5000	5.99900	27.3260	2.28922
1 – 3	103.578	5.99900	30.4417	2.26402
Mean	98.7760	5.99867	28.6700	2.27829
B2 – 1	98.9844	5.99800	29.0168	2.28524
2 – 2	105.609	5.99300	32.3705	2.23299
2 – 3	106.453	5.98800	33.3971	2.24550
Mean	103.682	5.99300	31.5948	2.25458
B3 – 1	99.8906	5.98400	30.9377	2.22246
3 – 2	100.297	5.99200	30.7445	2.22902
3 – 3	101.641	5.99900	31.3370	2.22083

Mean	100.610	5.99167	31.0064	2.22410
B4 – 1	86.7500	5.99700	26.8254	2.22729
4 – 2	85.7813	6.00100	26.2913	2.23957
4 – 3	87.8906	5.99800	27.5328	2.21326
Mean	86.8073	5.99867	26.8832	2.22671
Total Mean	97.4687	5.99550	29.5386	2.24592

FILLER CONTENT

BATCH 1

Table 3: In this batch 1 polypropylene 1 kg and ABS 0.5kg with FR grade

W1	58.2012
W2	61.6320
W3	58.5249

Fc = 9.4351%

BATCH 2

Table: 4 in this batch 2 polypropylene 1 kg and ABS 1 kg with FR grade

W1	55.8117
W2	59.8156
W3	56.1424

Fc = 8.25%

BATCH 3

Table 5: In this Batch 3 polypropylene 1 kg and ABS 1 kg without FR

W1	63.2841
W2	65.4516
W3	63.2916

Fc = 0.344%

BATCH 4

Table 6: In this batch 4 (without FR) polypropylene 1 kg and (with FR) ABS 0.5kg

W1	62.8490
W2	66.5003
W3	62.8782

Fc = 0.799%

Table 7: VICAT SOFTENING TEMPERATURE

BATCHES	Initial temp	Final temp
1	30°C	150.9°C
2	30°C	104°C
3	30°C	143.9°C
4	30°C	106.4°C

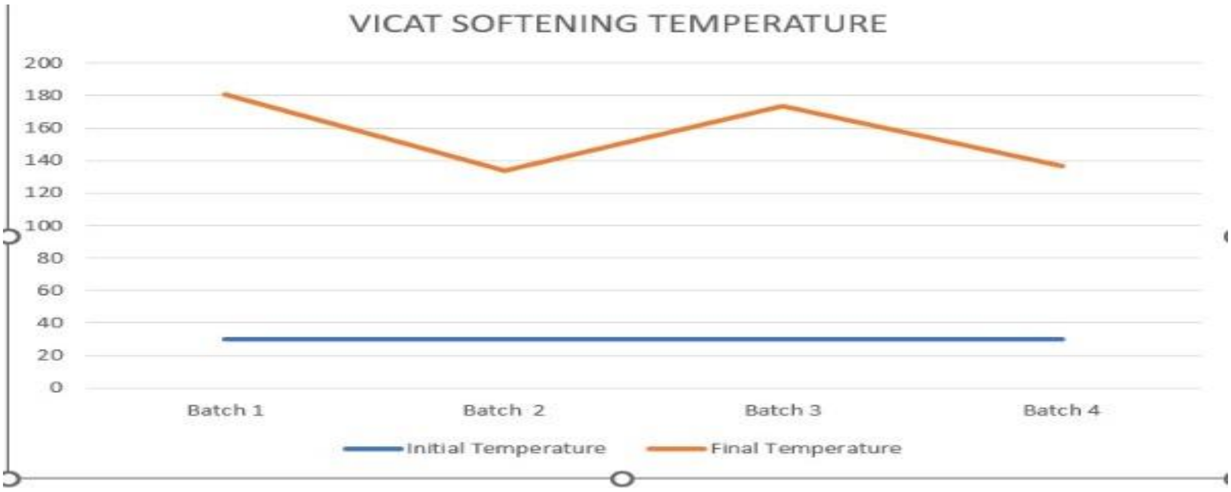

Fig 7: From the above graph it is observed that the temperatures are increase and decrease at the four different batches in this vicat softening temperature method.

Table: 8: HEAT DEFLECTION TEMPERATURE (2.54mm)

BATCHES	Initial temp	Final temp
1	30°C	119.3°C
2	30°C	71.3°C
3	30°C	119.8°C
4	30°C	72.9°C

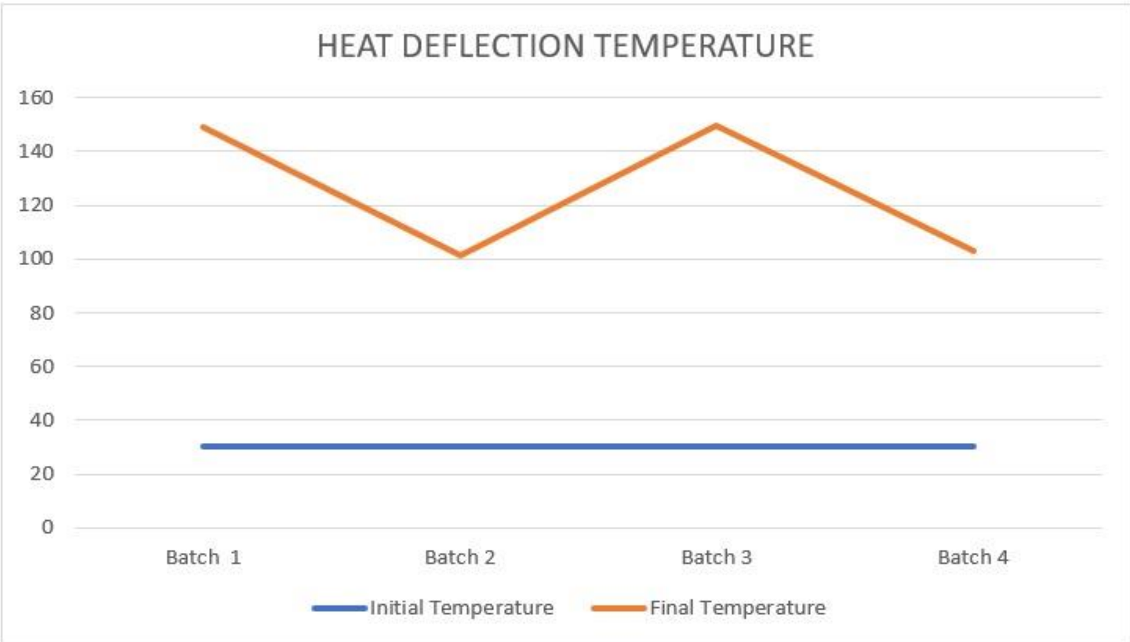

Fig 8: From the above graph it is observed that the temperatures are increase and decrease at the four different batches in this heat deflection temperature method.

Conclusions

From the analysis, the following conclusions have been:

The heat deflection temperature characteristics of polypropylene (PP) and ABS were observed to exhibit susceptibility to both normal load and mould temperature. The abrupt rise in its HDT when plotted as a function of mold temperature suggests that certain morphological changes of PP and ABS may have occurred at mold temperatures between 70°C and 120°C.

The temperature range of PP and ABS is between 100°C and 150°C, and its vicat softening test is above 100°C.

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