MAJOR PROJECT

"DEVELOPMENT OF PAINTABLE PP COMPOSITIONS"

SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

MASTER OF ENGINEERING IN
Polymer Technology

Submitted By:

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CERTIFICATE

This is to certify that **Ms. Anju Bajaj** has carried out her major research project entitled **“Development of Paintable PP Compositions”** under our joint supervision and guidance during the session 2004-2005. To the best of our knowledge and belief, this work has not been submitted to any other university or institution for the award of any degree or diploma.

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(ANJU BAJAJ)

EXECUTIVE SUMMARY

Polypropylene among thermoplastics has gained wide recognition as engineering plastic to find varied applications in automobiles and appliance sector. However being nonpolar in nature PP has got poor paintability / printability which restricts its applications area and aesthetic appeal especially in exterior applications. Current painted PP based exterior automotive parts are pretreated before a topcoat is applied. These treatments can be flame treatment or plasma treatment, pretreatments add cost to the final product and pretreatment equipments take valuable space in the factory. Hence there is a need to develop alternate system to make PP paintable.

One of the approach's to improve the paintability of PP, is to incorporate different additives in impact modified grade of PP. In the present work paintable PP compositions have been developed which retained better physico mechanical properties than PP and study the effect of primer on these compositions. The developed product will have significant advantages in automobile sector e.g. bumpers, dashboards, helmets etc.

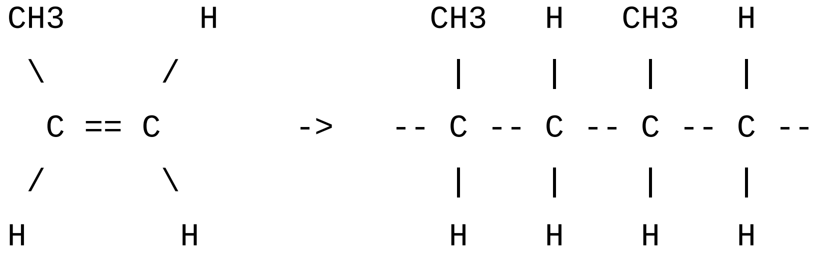
CONTENTS

CHAPTER-1

INTRODUCTION

Polypropylene (PP) is the fastest growing general-purpose thermoplastic in existence today. Copolymer and modified PP are responsible for the growth of PP as engineering thermoplastic as well as a general purpose plastic. PP is the only high volume thermoplastic that is processable by all four major fabrication methods: molding, extrusion, film & fibers. Because of polypropylene's excellent processability & unusually good properties, its market has grown rapidly & steadily.

PP was first produced by G. Natta, following the work of K. Ziegler, by polymerization of propylene monomer in 1954. The macromolecule of PP contains 10,000 to 20,000 monomer units. The steric arrangement of the methyl groups attached to every second carbon chain may vary. If all the methyl groups are on the same side of the winding spiral chain molecule, the product is referred to as Isotactic PP. A PP structure where pendant methylene groups are attached to the polymer backbone chain in an alternating manner is known as Syndiotactic PP. The structure where pendant groups are located in a random manner on the polymer backbone is the Atactic form.



propylene monomer

polypropylene polymer

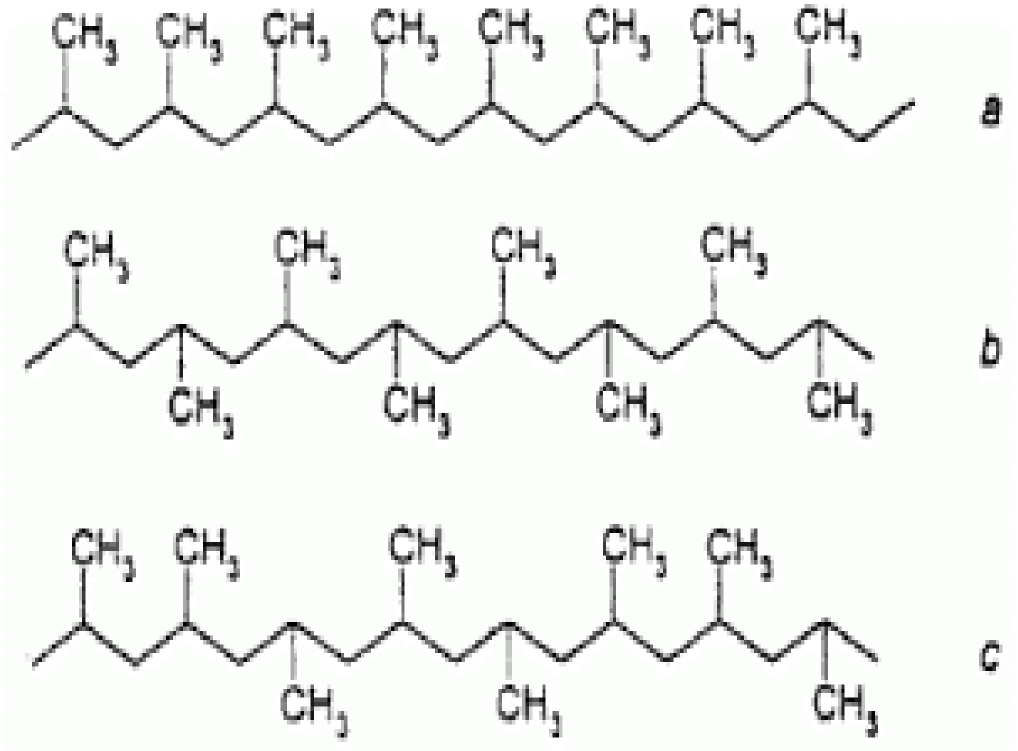


Fig.-1

a:- Isotactic PP, b:- Syndiotactic PP, c:- Atactic PP

The pendant group significantly affects the properties of the polymer & consequently properties of PP are very different from other commodity plastics such as PE, PVC & PS. Only Isotactic PP has requisitic properties required for a useful material. Stereospecific or Ziegler-Natta catalysts are used to polymerize PP in this form.

A major reason of polypropylene's success is its higher stiffness at lower density & resistance to higher temperature when not subjected to mechanical stress. In addition to this, PP offers good fatigue resistance, good chemical resistance, good environmental stress cracking resistance, good detergent resistance & ease of machining. The properties of unmodified PP are compared with other competitive thermoplastics in Table-1.

Table-1

Properties of Unmodified Polypropylene and other materials

Property	PP	LDPE	HDPE	HIPS	PVC	ABS
Flexural modulus (GPa)	1.5	0.3	1.3	2.1	3.0	2.7
Tensile strength (MPa)	33	10	32	42	51	47
Specific density	0.905	0.92	0.96	1.08	1.4	1.05
Specific modulus (GPa)	1.66	0.33	1.35	1.94	2.14	2.57
HDT (ºC)	105	50	75	85	70	98
Maximum continuous use temperature (ºC)	100	50	75	85	70	98

It can be seen from Table-1 that PP offers advantages over most of its competitive materials on the basis of specific modulus, heat deflection temperature (HDT), maximum continuous use temperature or modulus to cost ratio. Environmental and food legislation may further tip the balance in favour of PP. Being a general-purpose thermoplastic, PP has found applications in almost every field where plastics are used. The main application of PP in different market sector are given in Table 2.

Table-2

Typical Applications of PP	
Sector	Typical applications
Automotive industry	Radiator expansion tank, brake fluid reservoir fittings, steering wheel covers, wheel arch liner, bumpers, bumper covers, side strips, spoilers, mudguards, battery cases, tool boxes
Domestic appliances	Dishwasher parts such as top frame, basement, tubs, extruded gaskets, water duct, water softener compartment, etc.,washing machine parts such as detergent dispenser, door frames, inlet and outlet pipes, bellows, etc. Microwave oven cabinet, irons and coffee maker body parts.
Household goods	Buckets, toys, bottle caps, bottles, food processor housing, video cassettes, luggage
Pipes & fittings	Tower packings for distillation columns, domestic waste water pipes, pressure pipes, heat exchangers, corrugated pipes, small diameter tubing, e.g., drinking straws.
Furniture	Stackable chairs
Fibers	Artificial sport surfaces, monofilaments for rope and cordage, stretched tapes, woven carpet backing, packaging sacks and tarpaulins, staple fibers, coarse fibers, filament yarns, fine fibers
Packaging	Ice-cream tubs, films, thin walled packaging etc

1.1Market share & consumption trend:

Over the last four decades, PP has established itself as one of the major commodity plastics. PP is now the third largest consumed plastic material after PE and PVC. Demand for PP has grown consistently, managing an impressive growth even during recessions. Approximately 55% of PP is used in extrusion and rest in injection molding. Sixty percent of the PP consumed in homopolymer, 20% block copolymer, with the rest either compounded or random copolymer grades. It is estimated that the growth of PP in the coming decade will be around 6%, the strongest growth pattern for the bulk polymers.

1.1.1 Consumption trend of PP in Automotive Sector:

Polpropylene is the major polymeric material used in the automotive sector. Consumption pattern of various polymers in automotive sector is given in Fig-2. Current legislative and environmental needs are forcing manufacturers to reduce vehicle emissions significantly. This is presently being achieved by a number of strategies, one being to replace or re-design traditional metallic components with new lightweight versions in polymeric materials for instance. Polypropylene (PP) is a good example of a polymer, which is increasingly finding its way into new vehicles. Not only is PP low density but it can be conveniently recycled at the **End of the Vehicles Life (ELV).** Concept of **ELV** is becoming very important for environmental concern.

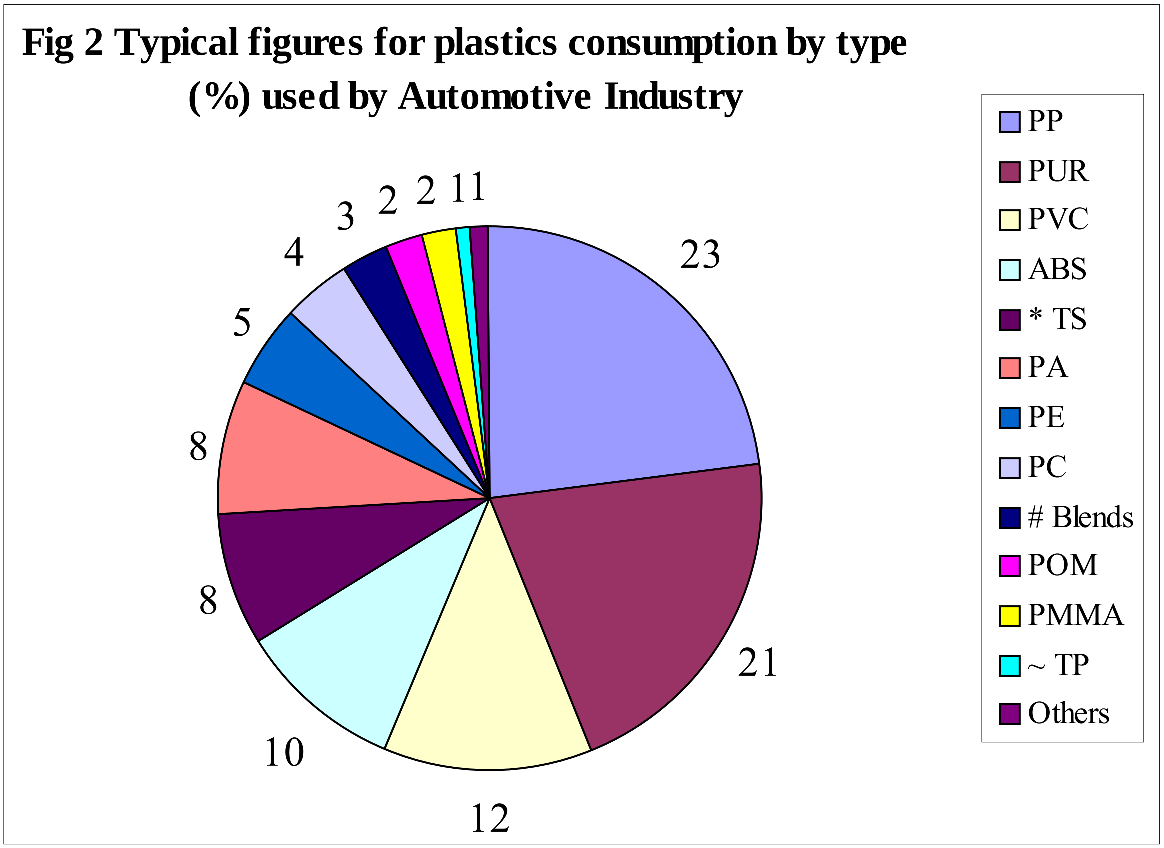


Fig 2 Typical figures for plastics consumption by type (%) used by Automotive Industry

*TS-	Thermosetting Polymers
#Blends-	PPE / PPO Bends
~ TP-	Thermoplastic Polyester

1.2Precursor for Paintability:

All materials, whether liquid or solid, have surface forces. These are referred to as surface tension in liquids and surface energy in solids. Visualize a drop of liquid on a flat surface. Tension in the liquid is trying to pull itself up into a bead. The solid is pulling out on the drop. If the surface energy of the solid is greater than the liquid, the drop will expand.

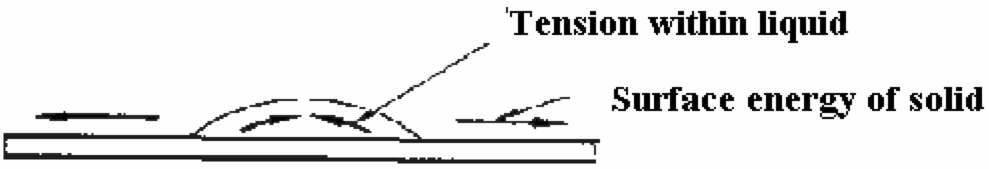


Fig. 3 Surface Tension

Wetting out a liquid on to a solid is treated first by considering the Young's equation.

$\gamma_{SL} = \gamma_S - \cos\theta\ \gamma_L$

γ_{SL} — The interfacial energy between the solid and the liquid (the energy required to spread the liquid out or create an interface)

γ_S — The surface energy of the solid (the energy necessary to increase the surface of the solid)

γ_L – The surface energy of the liquid (the energy necessary to increase the surface of the liquid)

Which is valid at equilibrium. Fig 2 shows a representation of the physical situation.

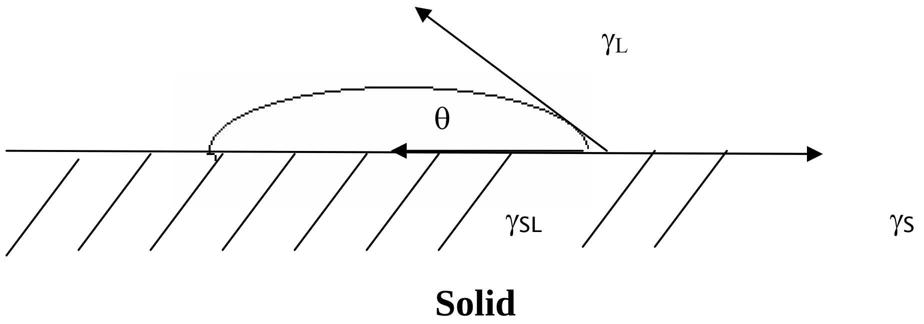
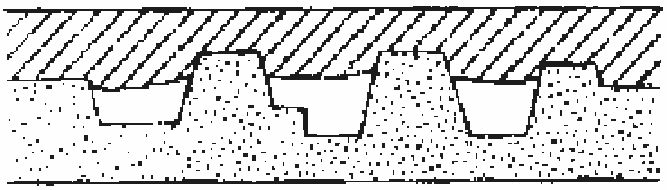


Fig.4 Spreading of Liquid onto Solid and Contact Angle.

When θ is zero, cos θ is 1, and wetting occurs with the surface energy of the solid being equal to or greater than the liquid, depending on the interfacial energy. The surface energies of the solid, the liquid, and the interface are material properties; the contact angle is measured. One can see that liquids with low vector force is to "pull the liquid down." This means that oil (low surface energy) spreads out on water (high surface energy), but water (paint in this case), doesn't spread out on oil ("solid oil" like polyolefins).

Surface tension controls the intimacy of contact an adhesive or paint can achieve on a solid surface. All surfaces have some degree of microscopic texture which must be coated for best adhesion, as in Fig. 5.



(A) Unwetted

(B) Wetted

Fig. 5 Wetting of a Solid Substrate by a Fluid Adhesive

It is apparent from this discussion that wetting can be achieved by either increasing the surface energy of the solid or by decreasing the surface tension of the liquid.

1.3 Limitations in PP

PP is one of the most commonly used plastics in automotive, furniture, packaging and domestic appliances etc, due to its low cost, environmental friendliness, recyclability and excellent strength per weight ratio.

Despite these useful properties, PP has the inherent problem of paintability, and dye uptake etc, due to very low surface energy and unreactive surface chemistry, which impedes wettability. The low polarity of the molecules in PP is the cause of low surface energy. In general, a surface with a higher surface energy is more readily wetted by paint and hence is more paintable and coating adhesion will be better. Metals typically have substantially higher surface energies than plastics. The low polarity of molecules in PP is the cause of the low surface energy.

1.4 Why Painting is Needed:

Painting in plastics is needed for: -

- Aesthetics
- Color matching of metal and plastic surface in automotives and appliances.
- Protection against outdoors weathering.
- To hide the irregularities of surfaces (parting line, weld line and flow marks etc.)

CHAPTER-2

LITERATURE REVIEW

Polyolefins (such as PE and PP etc) are difficult to wet and bond, because of low surface energy, incompatibility, chemical inertness, or the presence of contaminants and weak boundary layers. Surface treatments are used to change the chemical compositions, increase the surface energy modify the crystalline morphology and surface topography, or remove the contaminants and weak boundary layers. Literature is replete with various techniques to enhance paintability in PP, which are reviewed as under.

2.1 Chemical Treatments (Chromic Acid Etching of Polyolefins):

Chromic acid is used commercially in 1968 to etch the PP and ABS prior to metal plating. A typical chromic acid bath contains potassium dichromate, water, and concentrated sulfuric acid at weight ratio of 4.4:7.1:88.5. Chromic acid etching preferentially removes amorphous or rubbery regions. Depending on surface crystalline morphology, highly complex rootlike cavities may be formed on the etched surface. Some surface oxidation also occurs. Improvements of wettability and bondability arise however, mainly from the complex topography rather than from polar groups introduced by surface oxidation. The dissolution of hydrocarbon polymer by hexavalent chromium in acid medium proceeds through the formation of a tetravalent chromium intermediate, which hydrolyzes to an alcohol. Further oxidation causes chain scission to give an olefin, and aldehyde, a ketone or a carboxylic acid.

2.2Flame Treatment:

In flame treatment the Polymer surface (often polyolefins) is treated with a burner flame (1000-2000 ºC, 0.2-0.3 S) to promote adhesion and wetting. Oxidizing flames having oxygen in slight excess of oxygen / fuel stoichiometry usually give the optimum results. Polymer surfaces are oxidized to a depth of about 40-90 Å. Flames contain excited species of O, NO, OH, and NH. These free radicals can abstract hydrogen from polymer surfaces. Subsequent surface oxidation propagates by a free radical mechanism. Chain scission occurs during the free radical propagation, giving polymer and mobile scission products. The improved wettability results from the introduction of surface polar groups are reported [1].

2.3Corona Discharge Treatment:

Corona discharge is the electrical method most widely used for polyolefins film. The work piece (usually thin polymer film) is placed between an electrode and grounded metal roll. Electrons are ejected from the electrode by a strong electric field. These electrons are ejected from the electrode by strong electric field. These electrons collide with air molecules and the polymer surface to generate free radicals, ions, photons, excited and reactive intermediates. Reactions at the polymer surface can lead to chain scission, cross-linking and introduction of functional groups and thus promote adhesion and wettability [2].

2.4Plasma Treatments:

Plasma treatments are widely used to improve the wettability and bondability of polyolefins, polyesters, and many other polymers. The treatments cause chain scission, ablation, cross-linking, and oxidation to a depth of typically 50-500 Å. The polymer radicals formed during plasma treatments are long-lived, and can react with oxygen and nitrogen upon exposure to the air after treatments. Therefore, even when carried out in inert gasses (helium, argon, nitrogen and the like), plasma treatments always introduce polar oxygen and nitrogen groups onto polymer surfaces. The wettability is always improved to various degrees.

Two types of plasma are used mainly: cold plasma (glow discharge in reduced pressure) and hybrid plasma (corona discharge at atmospheric pressure) in various gasses (helium, argon, hydrogen, oxygen, air,nitrogen,nitrous oxide,ammonia, carbon dioxideand others). Both types of plasma modify the surface composition, wettability, and bondability, similarly differing only in details.

2.5Surface Grafting:

Grafted surfaces show dramatically increased wettability and bondability, whereas surface similarly abraded in air show marginal improvements. Various colloidal metal oxides, silica, and carbon black can be deposited on polymer surfaces to increase their wettability. Grafting sites on polymers are produced by exposure to plasma, UV radiations, or chemical agents. Polymer radicals (formed in the absence of O_2) or polymer peroxide (formed in the presence of O_2) by plasma and UV exposure serve as the initiation and grafting sites. Grafting can be done by preirradiation of the polymer surface followed by exposure to monomer, or by simultaneous irradiation of the polymer and the monomer. Alternatively, grafting sites may be generated by chemical means. Abrasion of the polymer surface breaks chemical bonds and produces polymer radicals. When abraded in air, the radicals formed react instantly with O_2, N_2, or H_2O to form polar groups. On the other hand, when abraded in a liquid, radicals formed will instantly react with liquid [3].

Anamelia S. Vasconcellos and coworkers reported a method to obtain adherent PP, treated with nitric acid and sulfuric acid and measure the adhesive strength of the samples joined with leather using commercial polychloroprene [4].

Inagaki N. and coworkers have reported the modification of hydrophobic PP surface by carbon di-oxide plasma [5] and carbon tetrachloride plasma [6] treatment to convert them into hydrophilic surface. This technique has potential applications in coating and adhesion to other materials such as polymers, metals, and ceramics.

Akovali Guneri and coworkers have studied the plasmo-mechanical modification of a PE film surface by several selected silicon and tin containing monomers such as vinyltriethoxysilane (VTES), hexamethyldisiloxane(HMDS), aminopropyltrietoxysilane (APTS) and hexabutyldistannoxane(HBDS). The plasma of organosilicon and organotin compounds were used to produce thin hydrophobic, biologically active and inactive PE film surfaces [7].

Mitov Z. and Velichkova R. have reported the mechanism and site of addition of maleic anhydride to styrene-isoperene block copolymers which promotes oxygen stability, adhesion, dyeability, crosslinking and wettability [8].

Fu Qiang and Wang Guihenz have studied a new route to polymer toughening in which PE was successfully toughened with rigid calcium carbonate particles rather than rubber particles. This not only increases toughness but modulus, and is very cheap [9].

Edge Stephen and coworkers have studied the photochemical grafting of 2-hydroxyethylmethacrylate onto low density PE film. The grafting technique employed involved irradiating a solution of 2- hydroxyethylmethacrylate and benzophenone in acetone spread between films of poly(ethyleneterephathalate) or glass and low density PE. After irradiating for 2 min., the contact angle of PE films with water falls from 97º to about 50º. The resulting surface-modified polymer films exhibit improved wettability and printability [10].

Yang and Garton reported when PP and LDPE are coated with about 100 nm of triphenyphosphine (TPP) or cobalt acetylactonate primers, and adhesive bonds can be made using ethylcyanoacrylate [11].

Bhowmick and coworkers reported a method of grafting of PE with dibutylmaleate (DBM) and vinyltrimethoxysilane (VTMO) and characterize the modified surface by contact angle and ESCA studies. It is found that the higher the oxygen-carbon ratio, the lower the contact angle value for PE. The total surface energy is increased with grafting. The surface energy of silane grafted PE is found to be lower than that of modified-grafted PE [12].

Aleckner and coworkers reported a method of forming articles having a high receptivity toward automotive paints by molding blends of (A), (B), and (C) components. Where A is a copolymer of an ethylenically unsaturated carboxylic acid and ethylene, B is an elastomer compatible with components (A) and (C) and C is a crystalline polymer or copolymer of propylene. Such formed parts have excellent paintability, a broad range of stiffness values and high impact and tensile strengths suitable for modern motor vehicle applications such as bumpers and fascias and wheel covers [13].

Ouhadi and coworkers reported the compatibilized blends comprising a non-polar thermoplastic elastomer, a polar thermoplastic polymer selected from thermoplastic polyurethane (TPU), chloro containing polymers, fluoro containing polymers, polyesters, acrylonitrile-butadiene-styrene copolymers, styrene-acrylonitrile copolymers, styrene-maleic anhydride copolymer, polyacetal, polycarbonate, polyphenylene oxide, and a suitable compatibilizer [14].

Evans and coworkers reported a compound comprising a blend of polypropylene with the reaction of a functionalized polypropylene and polyether amine in which the polyether amine is grafted into the functionalized polypropylene in a customary mixing apparatus. The blend may include an elastomer such as EP rubber and/or a filler such as glass. Blends of the present invention are advantageously useful to prepare paintable automotive body parts.

Beholtz and coworkers have studied a method for improving surface adhesion characteristics of a polymeric substrate in which the portion of the surface of the polymeric substrate to be treated is contacted with a composition containing at least one oxidizing agent. Contact between the composition containing the oxidizing agent and the polymeric substrate is maintained for an interval sufficient to produce or modify functional groups in the polymeric substrate . The oxidizing agent of choice is a halogenated bivalent oxygen compound. The oxidizing agent is activated by an activator agent containing at least one carboxylic acid group or derivative thereof. The activator agent may be present in the composition upon initial contact with the polymeric substrate, or may be added to the composition subsequent to initial contact with the polymeric substrate[16].

Ryntz and coworkers reported a method of improving paint adhesion to thermoplastic olefins. The method comprises providing a thermoplastic olefin prepared from a TPO blend comprising maleated polypropylene and amine-terminated polyester. A paint is provided comprising a base paint and a paint adhesion promoter selected from the group consisting of a chlorinated polyolefin, a hydrogenated poly(butadiene)diol, and mixtures thereof [17].

Ryntz have reported a electrical conductivity modified thermoplastic olefin (TPO) polymer blend with improved electrostatic painting efficiency, the blend comprising a substantially uniform mixture of: I. polymeric material being the reaction product of: (a) polypropylene, (b) maleated polypropylene, (c) elastomer, and (d) amine-terminated polyether being a linear or branched polymer of oxypropyleneamine or oxyethyleneamine repeating units having 40-100 such units, and II. alkali metal salt, the alkali metal salt being included in the thermoplastic polymer blend in an amount which provides the blend with a conductivity of at least 10-12 S/cm at 25 DEG C [18].

The invention provides a package of solid material of carboxylic anhydride-modified chlorinated polyolefin to be used for a binder resin for paint or primer that aims at the protection of polyolefinic resins, capable of suppressing the changes in physical properties after storing for a long term, and a method of preserving said solid material. A package of solid material of carboxylic anhydride-modified chlorinated polyolefin, comprising said solid material of carboxylic anhydride-modified chlorinated polyolefin wrapped with a film with the value of water vapor transmission rate measured according to ASTM D895 ("Standard Test Method Water Vapor Permeability of Packages") (measuring conditions: temperature 37.8+-1.1 DEG C., relative humidity 90+-2%) of 1.5 g/m2.24 hr or lower [19].

Kunz Martin and Bauer Michael reported a new and versatile technology to improve the adhesion of UV-cured inks, coatings and adhesives and, in some cases, thin metal films on polymer substrates. The superior adhesion is achieved by the formation of covalent bonds between the polymer surface and the coating. Formation of the covalent bonds is accomplished by a combination of plasma treatment and subsequent application of acrylated photoinitiator. This permanent and homogeneous surface modification introduces a latent functionality, which can be activated by UV light and used for lithographic surface modifications [20].

Wong and Mai studied the effect of rubber functionality on microstructures and fracture toughness of impact modified nylon 66/ PP blends [22].

Dharmarangan N. and coworkers have studied the compatibilized polymer blends of isotactic PP and styrene-maleic anhydride (SMA) copolymer. In this system amino functionalized polyolefins acts as a compatibilizer. The blends have bulk properties such as impact strength and solvent resistance similar to PP; however, their surface reactivity (eg. Adhesion of paint and polar substrates) is similar to that of SMA [22].

Dechent and coworkers have reported a method to develop water based polyester coatings for chlorinated polyolefin primed PP. They have studied the need of CPO, different cloth peel tests between Paint/CPO/Plastic, CPO/Plastic, Paint/Paint and CPO/CPO, effects of heat cycle etc. [23].

3. OBJECTIVES OF THE PROJECT:

1. **To study the phenomenon of paintability in Polypropylene by selection of appropriate grade and modification through incorporation of additives .**

2. **To study the surface modification of paintability including use of primer.**

3. **Evaluation of prepared paintable compositions for mechanical properties, surface characteristics and paintability.**

CHAPTER-4

EXPERIMENTAL DETAILS

4.1 Materials Used:

4.1.1 PP Repol D120MA from Reliance Industries Ltd., Hazaria (Gujrat)

- MFI (230 ºC / 2.16 kg) ─ 12.0 g / 10 min

4.1.2 PP Repol H110MA from Reliance Industries Ltd., Hazaria (Gujrat)

- MFI (230 ºC / 2.16 kg) ─ 11.0 g / 10 min

4.1.3 Additives:

- Calcium Carbonate from local market
- Styrene Grafted Maleic Anhydride (SMA) from Pluss Polymers Ltd.

4.1.4 Primer:

- Chlorinated Polyolefins (CPO) based primer from Berger Paints Ltd

4.1.5 Paints:

- Alkyd based Paint from Berger Paints Ltd.
- PU Paint from Berger Paints Ltd.

4.2 Details of Formulations Prepared:

- Batch size used: 3 Kg in each formulation
- All the concentrations are expressed in terms of phr (parts per hundred parts of resin)
- PP Repol H110MA: Repol H110MA is a homopolymer of PP.The main features of this grade are low static charge buildup and reduce dust pickup, consistent processability and excellent color and processing stability. It is an ideal material for rigid containers, thermowares and housewares.
- PP Repol D120MA: Repol D120MA is a copolymer of PP with 22 % EPDM rubber. The main features of this grade are high flow behaviour, good stiffness-impact balance, good surface gloss, low stat static charge buildup and reduce dust pickup. It is an ideal material for compounding, automotive components, luggage etc.

Table-3

Formulations of PP with Additives

S.NO.	COMPOSITIONS NO.	PP REPOL H110MA	PP REPOL D120MA	$CaCO_3$	SMA
1.	B1	100	-	-	-
2.	B2	-	100	-	-
3.	B3	-	90	10	-
4.	B4	-	80	20	-
5.	B5	-	100	-	3

All the above-mentioned compositions were tumbler mixed with their respective additives in a tumbler mixer for a period of 15 minutes and then fed to the injection-molding machine for molding of specimens.

4.3 Injection Molding:

All the five compositions were injection molded (L / D = 18: 1) to produce ASTM specimens (dumbell, rectangular and disc shape) in a family mold for characterization.

Processing parameters of injection molding machine:

- Make: Klockner Windsor India Limited
- Shot size: 350 gm.
- Screw speed: 56 rpm
- Injection pressure: 395
- Hold down pressure: 395
- Clamping force: 180 tons
- Temperatures from nozzle: 180,175,175,170,170 ºC
  To feed zone respectively
- Mold temperature: 40-50 ºC
- Oil temperature: 35 ºC
- Injection speed: 20 mm / min
- Cycle delay: 0.5 sec.
- Injection delay: 0.3 sec.
- Cooling time: 20 sec.
- Injection period: 5 sec.
- Hold on period: 15 sec.

4.4 METHODS OF TESTING:

4.4.1 Tensile Propertie:

Principle:

Tensile test, in a broad sense, is a measurement of the ability of a material to withstand forces that tend to pull it apart and to determine to what extent material stretches before breaking. The tensile property data are more useful in preferential selection of a particular type of plastic from large from a large group of plastic materials and such data are of limited use in actual design of the product.

Apparatus:

- Universal testing machine
    - Make: LLOYD
    - Capacity: 10 KN tension or compression
    - Crosshead Speed: 0.5-500 mm / min
- Grips for mounting the specimens
- Extensometer
- Micrometer (Accuracy = 0.01mm)

Sample:

Test minimum five samples of each above-mentioned compositions in the form of dumbbell shaped specimen (Type-I) with grip separation rate = 50.8 mm /min and distance between the grips = 114 ± 1 mm.

Procedure:

- Switch on the UTM and select programme for tensile properties.
- Test samples are conditioned for minimum 24 hrs at 23 ± 2ºC before testing.
- Make two marks 1± 0.1 in. apart, on all the test specimens at the center of narrow portion of the sample.
- Measure the width and thickness to the nearest 0.001 mm.
- Enter the width and thickness.
- Place the specimen in the grip of the testing machine and tighten the grips.
- Attach the extensiometer on the marks made on the sample.
- Tare the initial load.
- Set the speed of the testing machine and start the machine.
- Record the load vs. extension curve of the specimen.
- Record the load and extension at the yield point and at the point of rupture.

Note:

Tensile Strength at yield (TYS), Ultimate Tensile strength (UTS), % Elongation at break and % Elongation at yield are directly displayed on the screen.

4.4.2 Flexural Properties:

Principle:

The flexural test measures the force required to bend a beam under three point loading conditions. The data is often used to select materials for parts that will support load without flexing. Flexural modulus is used as an indication of a material's stiffness when flexed.

Apparatus:

- Universal testing machine.
- Loading noses and supports.
- Micrometer (accurate to 0.001 mm)

Sample:

Test minimum five samples of each above-mentioned compositions in the form of rectangular beam. Support span = 50 ± 2 mm and speed of testing = 1.3 mm / min.

Procedure:

- Mount the appropriate load cell on the machine depending on the type of the material. Attach the loading nose to the load cell and supports to the stationary crosshead. Assure parallel alignment of the loading nose and supports.
- Switch on the machine and set the instrument parameters.
    - Speed of testing for PP: 1.3mm/ min
    - Select appropriate programme for flexural properties.

- Test specimens are conditioned at 23 ± 2 ºC for minimum 24 hrs before testing.
- Enter the width and thickness of the sample.
- Set the support span 50 ± 2 mm for PP.
- Center the specimen on supports.
- Start the experiment.
- Load deflection curve is displayed. Flexural yield strength, modulus of elasticity and 1 % secant modulus are directly displayed on the screen.

4.4.3 Notched Izod Impact Resistance:

Principle:

Notched Izod Impact is a single point test that measures a material resistance to impact from a swinging pendulum. Izod Impact is defined as the kinetic energy needed to initiate fracture and continue the fracture until the specimen is broken. This test can be used as a quick and easy quality control check to determine if a material meets specific properties or to compare material for general toughness.

Apparatus:

- Izod impact tester (Make- Ceast)
- Notch cutter with micrometer screw gauge
- Vernier callipers (Accuracy-0.01 mm)

Sample:

Test minimum five samples of each above-mentioned compositions. Molded specimen shall have the width and thickness 13 mm and 3.2 mm respectively. The depth of the plastic material remaining in the bar under the notch shall be 10.16 ± 0.05 mm and distance of the notch from the end should be somewhere between 31.5 to 32 mm.

Procedure:

- Select the 2.75 J energy “hammer”.
- Select the relevant range, according to the hammer installed, by means of the range selector and the range switch.
- Check manually that the hammer can swing freely between the anvil.
- Release the hammer without specimen. Value on the display indicates the amount of energy lost due to friction, windage etc. This value must be subtracted from each sample reading.
- Position the hammer on the anvil.
- Test samples are conditioned for at least 24 hrs. at 23 ± 2 ºC before testing.
- Position the specimen and tighten it with torque wrench.
- Release the hammer.
- If the display exceeds 70% of the 2.75 J, then change to the next higher energy hammer and repeat the above steps.
- Note the breaking energy value on the digital display

Impact Strength:

$$\text{Izod Impact Energy} = \frac{(\text{Energy required breaking the specimen} - \text{Air resistance energy})}{\text{Thickness of the specimen}}$$

4.4.4 Contact Angle measurement:

Principle:

The surface tension of the polymer surface has been determined from contact angle measurements. Measuring the contact angle, which a drop of liquid makes with the surface, is a highly convenient way of assessing the wettability of a polymer surface. This is key to the success of the adhesion process. To be effective, adhesives need to spread and hence the lower the contact angle, the greater the likelihood of strong bonding taking place.

Apparatus:

- Contact angle measuring instrument
- Testing Liquid (water)
- Manual dosing system

Sample:

Disc shape molded specimen with thickness 3 mm is used for each above-mentioned compositions. Take the reading at five places on a disc.

Procedure:

- Take the disc shape molded specimen.
- On the solid surface, a drop of water is formed with the manual dosing system.

- With the CCD camera, a digital picture of the drop on the surface is recorded and saved.
- The SCA 20 software now automatically determines the contact angle between liquid and solid.
- Repeat all the steps after applying primer (CPO) on all the above-mentioned compositions.

4.4.5 Paintability Test:

On many industrial sectors, plastics play an important role for the production of high-quality consumer goods. In this connection, the coating and painting of these materials is of particular importance. This applies for instance to the painting of plastic bumpers and the coating of other injection-moulded items. In these processes problems sometimes occur because the plastic surfaces have relatively poor wetting and adhesion properties. Proper adhesion between a substrate and paint is an important criterion for selecting the plastic materials.

Apparatus:

- Spray gun
- Cross cut tester
- Adhesion tape (cellotape with 24 mm width)

Chemicals Used:

- Isopropanol
- Chlorinated Polyolefin based Primer (CPO)
- Alkyd paint
- PU paint

Sample:

Minimum five samples of each above-mentioned compositions in the form of molded disc (thickness = 3 mm) are used for paintability test.

Procedure:

- Molded disc was cleansed by whipping the surface with isopropanol and the surface was then air dried.
- Apply the primer on the surface and air dried.
- Apply the base coat (Alkyd paint) with the help of spray gun and bake it at the temperature of 100-110 ºC for 50-55 min.
- Apply the final coat and bake it at the temperature of 100-110 ºC for 50-55 min.
- After 24 hrs. a checker board pattern containing 100 squares (10* 10) was made on the above coated surfaces with a cross cut tester.
- A pressure adhesive tape was applied thereon under pressure with the finger.
- The tape was peeled by pulling its one end rapidly.
- The coating adhesion was evaluated on the basis of the remaining ratio of squares (%) based on the number of remaining squares on the coating.
- Repeat the above-mentioned steps without using primer.
- Repeat the above-mentioned steps using PU paint at temperature of 60-70ºC for 50-55 min.
- Repeat the above-mentioned steps without primer for PU paint.

4.4.5.1 Humidity Test:

Humidity test is done to check the durability of a product in humid environment. The above-mentioned painted components are exposed at 49 ºC and 90% humidity for 196 hrs. in humidity chamber. The paintability test is carried out as mentioned above.

4.4.5.2 UV Test:

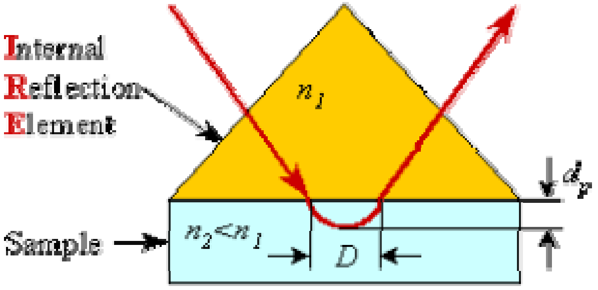
Humidity test is done to check the durability of a product in outdoor applications. The above-mentioned painted components are exposed to UV for 500 hrs. in UV chamber. The paintability test is carried out as mentioned above.

4.4.6 FTIR-ATR (ATTENUATED TOTAL REFLECTANCE)

Internal reflection spectrometry or attenuated total reflectance (ATR/ IR) spectrometry can provide valuable information related to establish the identity of two compounds or to determine the structure of a new compound. In revealing the structure of a new compound, it is quite useful to predict the presence of certain functional groups absorbs at definite frequencies. The shift in the absorption position helps in predicting the factors, which cause this shift. This method works well with samples that are too opaque or too thick for standard transmission methods. The technique is rapid, simple and required very little sample preparation. Also, one of the major advantages of the ATR technique is that the spectrum obtained is independent of the sample thickness. Typically, the reflected radiation penetrates the sample to a depth of only a few microns. In consequence, the method is particularly useful for surface analysis. ATR spectra of compounds are plotted as % transmittance (%T) against wave number (υ).

Principle:

Fig shows the schematic representation of path of a ray of light for total internal reflection. The ray penetrates a fraction of a wavelength (*dp*) beyond the reflecting surface into the rarer medium of refractive index *n2* and there is a certain displacement (*D*) upon reflection.



Instrumentation:

- ATR spectrum one (Make-Perkin Elmer)
- Source: SiC
- Detector: DTG (deuterated triglycrine sulphate)
- Inbuilt reference: NaBr

Sample:

Disc shape samples were used for taking the ATR of above-mentioned compositions.

Procedure:

- ATR of above- mentioned compositions were taken when primer is not used.
- ATR of above-mentioned compositions were taken when primer is used.
- ATR of above-mentioned compositions were taken after the application of alkyd paint (without primer).
- ATR of above-mentioned compositions were taken after the application of alkyd paint (with primer).

CHAPTER-5

RESULTS AND DISCUSSION

5.1 Grade Selection:

PP homopolymer has least polarity, however incorporation of rubber in PP to make it more wettable has been achieved in impact modified PP. Repol D120MA is a typical example of rubber modified PP suitable for paintability. Two grades Repol D120MA and Repol H110MA (as described in chapter-2) were evaluated for mechanical properties and surface characterization. The data on mechanical properties, contact angle and % paintability are presented in Table- 4,5 and 6 respectively. As can be seen from Table-4 tensile strength and flexural modulus of H110MA is higher than D120MA, while impact strength is higher in D120MA. Table-5 shows the value of contact angle of H110MA and D120MA, presence of rubber in D120MA decreases the contact angle. Table-6 shows the % paintability of D120MA is higher than that of H110MA.

TABLE- 4

MECHANICAL PROPERTIES

S.NO.	SAMPLE IDENTIFICATION	TENSILE STRENGTH (MPa)	FLEXURAL MODULUS (MPa)	IMPACT STRENGTH (J / m)
1.	PP REPOL H110MA	34.75	1645	624
2.	PP REPOL D120MA	19.2979	838.54	27

TABLE- 5

CONTACT ANGLE

S.NO.	SAMPLE IDENTIFICATION	BEFORE PRIMER (º)	AFTER PRIMER (º)
1.	PP REPOL H110MA	51	42
2.	PP REPOL D120MA	45	37

TABLE- 6

DATA ON % PAINTABILITY

S.NO.	SAMPLE IDENTIFICATION	% PAINTABILITY (ALKYD PAINT)	
		WITH PRIMER	WITHOUT PRIMER
1.	PP REPOL H110MA	40	60
2.	PP REPOL D120MA	65	88

So from the above discussion it can be concluded that D120MA has higher impact strength, lower contact angle and also higher paintability than H110MA. Keeping this in view only D120MA was selected for further study of mechanical properties and surface characterization such as contact angle, and ATR, which are important to study the phenomenon of paintability in PP.

5.2 Mechanical Properties:

The data on mechanical properties are presented in Table-7 and Fig-6, 7 and 8 respectively.

As can be seen from Table-7 the initial tensile strength of D120MA is 19 MPa, flexural modulus 838 MPa, impact strength 624 J / m. Incorporation of 10 % $CaCO_3$ substantially increases the flexural modulus, even though there is decrease in impact strength. This may be attributed to the fact that $CaCO_3$ increases the stiffness. By further addition of $CaCO_3$ increase in flexural modulus is observed while impact strength decreases further.

However the use of styrene grafted maleic anhydride (SMA) has a significant effect on mechanical properties, which included an increase in the stiffness through enhancement of values of flexural modulus. More important was a slight increases in impact strength. Hence SMA can be safely incorporated as an additive in D120MA with both enhancement of properties and obtaining paintability.

TABLE- 7

MECHANICAL PROPERTIES OF VARIOUS COMPOSITIONS

S.NO.	SAMPLE IDENTIFICATION	TENSILE STRENGTH (MPa)	FLEXURAL MODULUS (MPa)	IMPACT STRENGTH (J /m)
1	PP REPOL D120MA	19	838	624
2	PP REPOL D120MA + 10 % $CaCO_3$	20	1153	211
3	PP REPOL D120MA + 20 % $CaCO_3$	21	1160	176
4	PP REPOL D120MA + 3 % SMA	22	1043	625

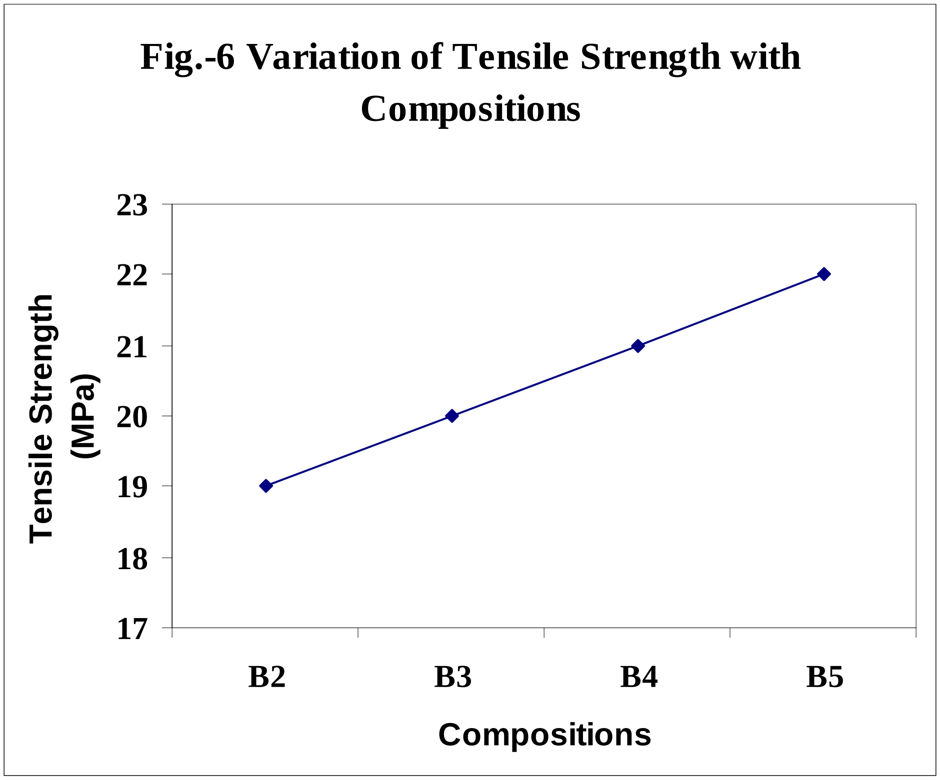
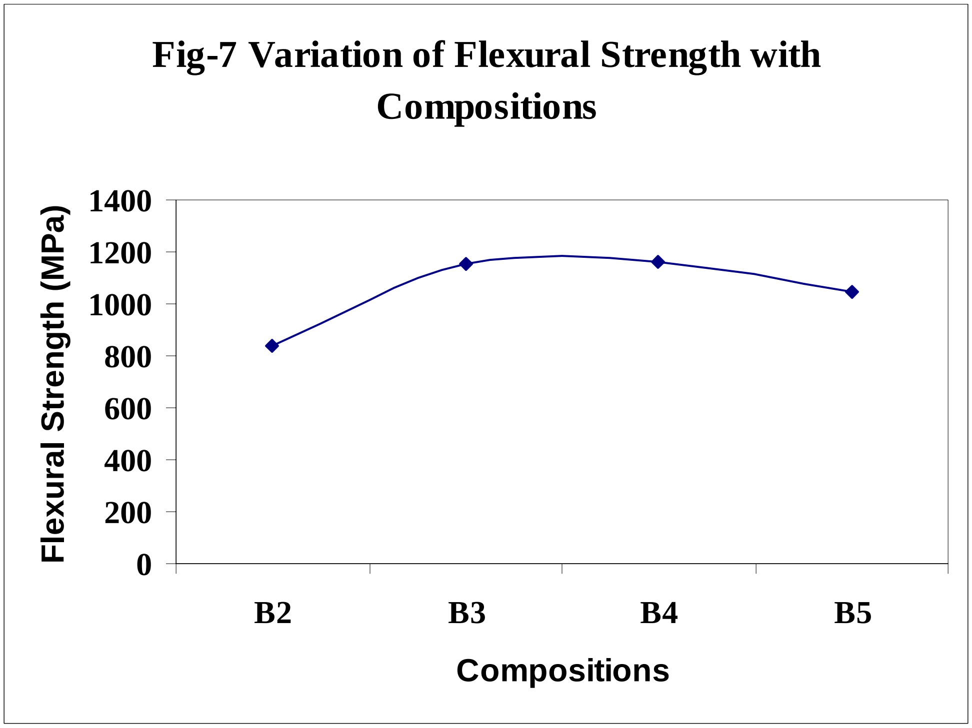


Fig.-6 shows the variation of tensile strength with compositions. Tensile strength increases linearly with compositions. Tensile strength of Repol D120MA (B2) is 19 MPa. In 90:10 Repol D120MA / Repol D120MA + 10 % $CaCO_3$ (B3) tensile strength increases from 19 MPa to 20 MPa. In 80:20 Repol D120MA / Repol D120MA + 20 % $CaCO_3$ (B4) tensile strength increases from 19 MPa to 21 MPa. In 100:3 Repol D120MA / Repol D120MA + 3% SMA (B5) tensile strength increases from 19 MPa to 22 MPa.



As can be seen from the Fig-7 there is an initial increase in flexural modulus from 838 MPa to 1160 MPa and it is further increases to 1160 MPa.This is due to the fact that $CaCO_3$ increases the stiffness. Flexural modulus decreases from 1160 MPa to 1043 MPa. But flexural modulus of Repol D120MA / Repol D120MA + 3 % SMA (B5) is higher than that of Repol D120MA (B2) because the function of SMA is similar to rubber and as the rubber content increases stiffness decreases.

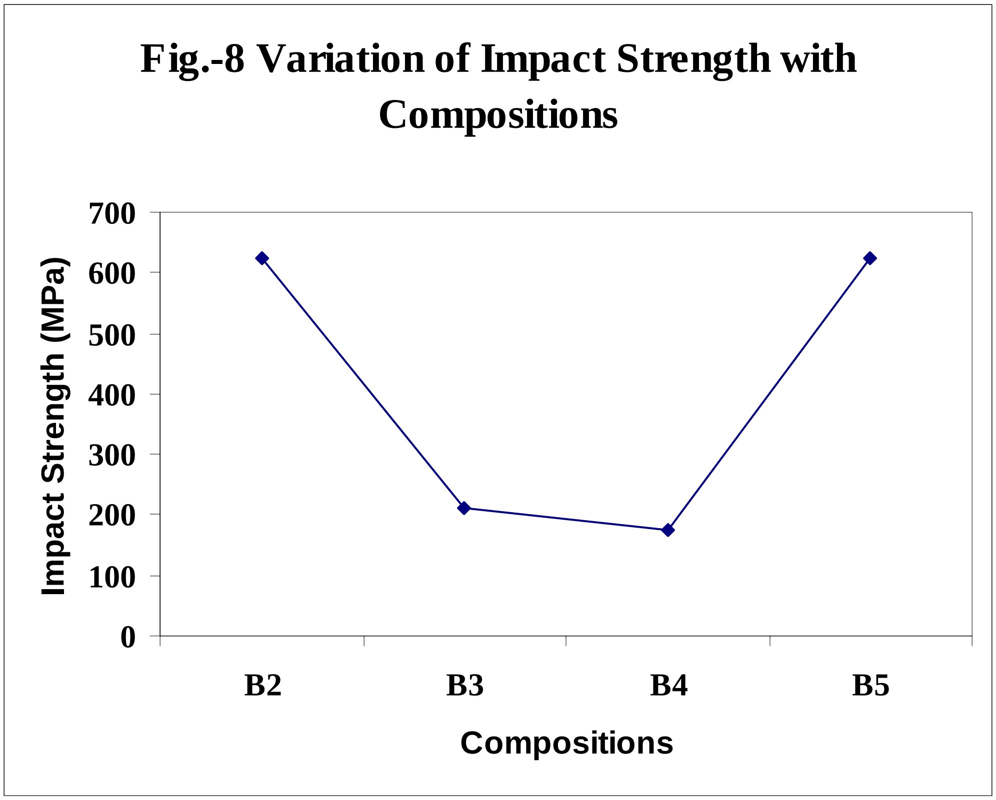


Fig.-8 Variation of Impact Strength with Compositions

Fig-8 shows the variation of impact strength with compositions. Impact strength decreases by the incorporation of $CaCO_3$ while it increases with SMA. This may be attributed to the fact that $CaCO_3$ increases stiffness while SMA increases toughness.

5.3 Surface Characterization of PP:

5.3.1 Contact Angle

The data on contact angle are presented in Table-8 and Fig-9 when primer is not used before the application of paint.

Initial contact angle for Repol D120MA is 45º. Incorporation of 10 % $CaCO_3$ decreases the contact angle. This is due to the fact that $CaCO_3$ imparts polarity to the surface. As the content of $CaCO_3$ increases contact angle decreases. However the use of SMA decreases the contact angle significantly. This is due to the fact that surface reactivity of Repol D120MA + 3% SMA is almost similar to SMA.

TABLE- 8

CONTACT ANGLE OF VARIOUS COMPOSITIONS (WITHOUT PRIMER)

S.NO.	COMPOSITIONS NO.	SAMPLE IDENTIFICATION	BEFORE PRIMER (º)
1.	B2	PP REPOL D120MA	45
2.	B3	PP REPOL D120MA + 10 % $CaCO_3$	41
3.	B4	PP REPOL D120MA + 20 % $CaCO_3$	40
4.	B5	PP REPOL D120MA + 3 % SMA	36

Fig.-9 Variation of Contact Angle with Compositions
(Without Primer)

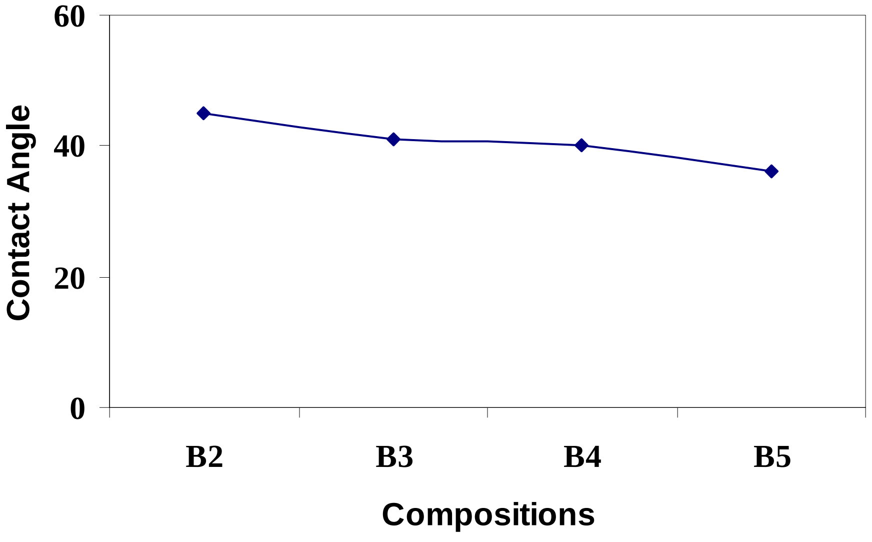


Fig-9 shows the variation of contact angle with compositions when primer is not used before the application of paint. Contact angle decreases with compositions. Contact angle of Repol D120MA is 45º while it is 36º after the addition of 3% SMA in Repol D120MA. This may be attributed to the fact that surface energy of Repol D120MA + 3 % SMA is higher then Repol D120MA.

The data on contact angle are presented in Table-9 and Fig-10 when primer is used before the application of paint.

Contact angle for Repol D120MA after the application of primer is 37º. By the incorporation of 10 % $CaCO_3$ contact angle decreases. This is due to the synergistic effect of primer and $CaCO_3$. In 100:3 Repol D120MA / Repol D120MA + 3 % SMA contact angle decreases from 37º to 27º. This is due to the synergistic effect of primer and SMA.

TABLE- 9

CONTACT ANGLE OF VARIOUS COMPOSITIONS (WITH PRIMER)

S.NO.	COMPOSITIONS NO.	SAMPLE IDENTIFICATION	AFTER PRIMER (º)
1.	B2	PP REPOL D120MA	37
2.	B3	PP REPOL D120MA + 10 % $CaCO_3$	36
3.	B4	PP REPOL D120MA + 20 % $CaCO_3$	29
4.	B5	PP REPOL D120MA + 3 % SMA	27

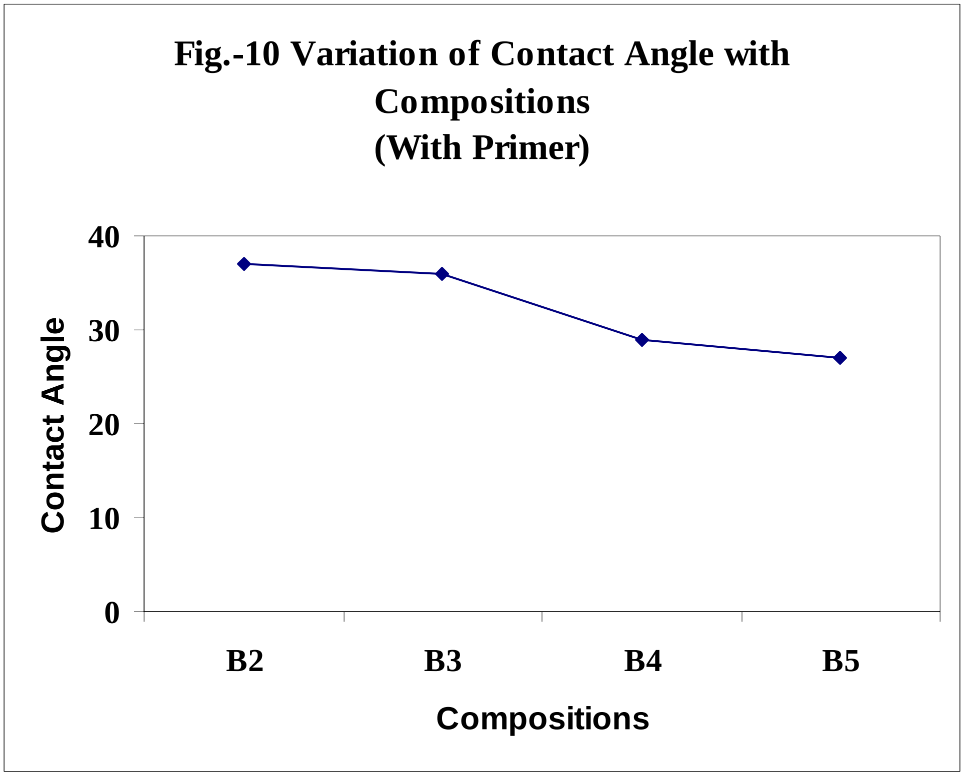
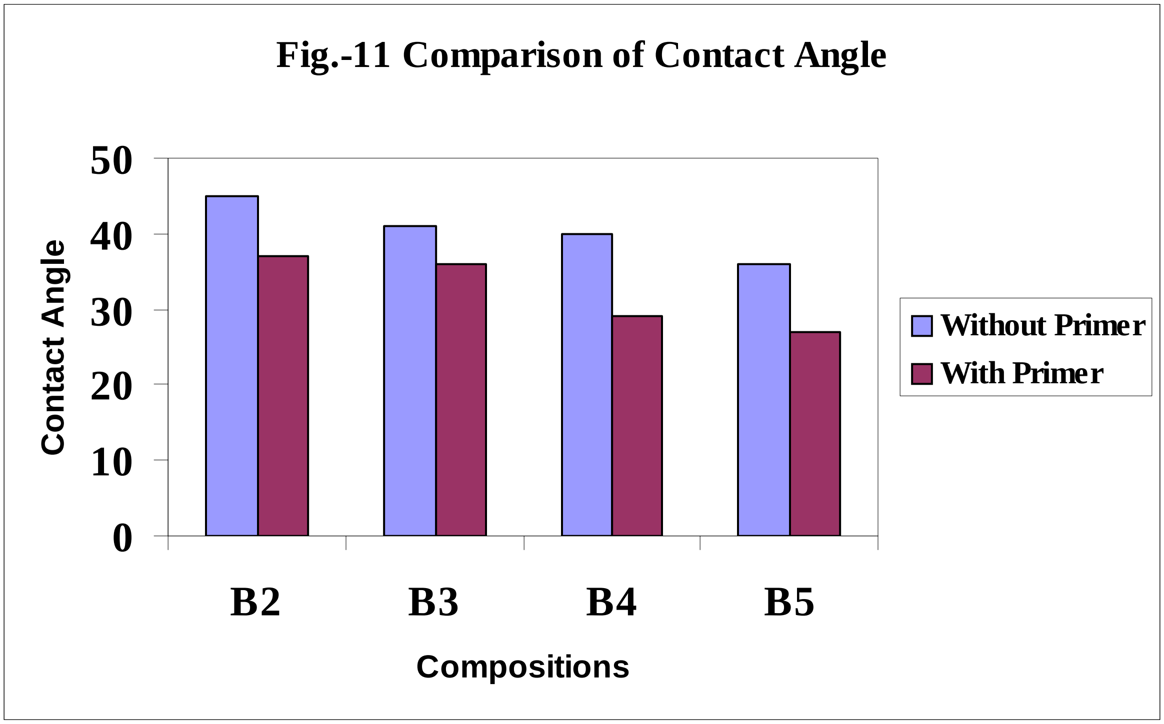


Fig.-10 Variation of Contact Angle with Compositions (With Primer)

Fig-10 shows the variation of contact angle with compositions when primer is used before the application of paint. Contact angle decreases with compositions. Contact angle of Repol D120MA is 37° while it is 27° after the addition of 3% SMA in Repol D120MA.

Comparison of contact angle between with and without primer is shown in Fig.-11.



It can be seen from the Fig that contact angle of different formulations was decreases by the application of primer. This is due to the fact that surface tension of primer is less then the surface energy of solid.

5.3.2 Adhesion Test:

The data on paintability using alkyd paint is presented in Table-10 and Fig-12 and Fig-13 respectively, when primer is not used before the application of paint.

Paintability of Repol D120MA is 65 % when primer is not used before the application of paint. In 90:10 PP D120MA / PP D120MA + 10 % $CaCO_3$ paintability increases from 65 % to 70 %. In 80:20 PP D120MA / PP D120MA + 20 % $CaCO_3$ paintability increases from 65 % to 72 %. This is due to the fact that paintability increases as the surface of PP changes from non-polar to polar. In 100:3 PP D120MA / PP D120MA + 3% SMA paintability increases from 65 to 76 %.

TABLE- 10

DATA ON PAINTABILIT OF VARIOUS COMPOSITIONS USING ALKYD PAINT (WITHOUT PRIMER)

S.NO.	COMPOSITIONS NO.	SAMPLE IDENTIFICATION	% PAINTABILITY
1.	B2	PP REPOL D120MA	65
2.	B3	PP REPOL D120MA + 10 % $CaCO_3$	70
3.	B4	PP REPOL D120MA + 20 % $CaCO_3$	72
4.	B5	PP REPOL D120MA + 3 % SMA	76

Fig.-12 Variation of % Paintability with Compositions using Alkyd Paint (without Primer)

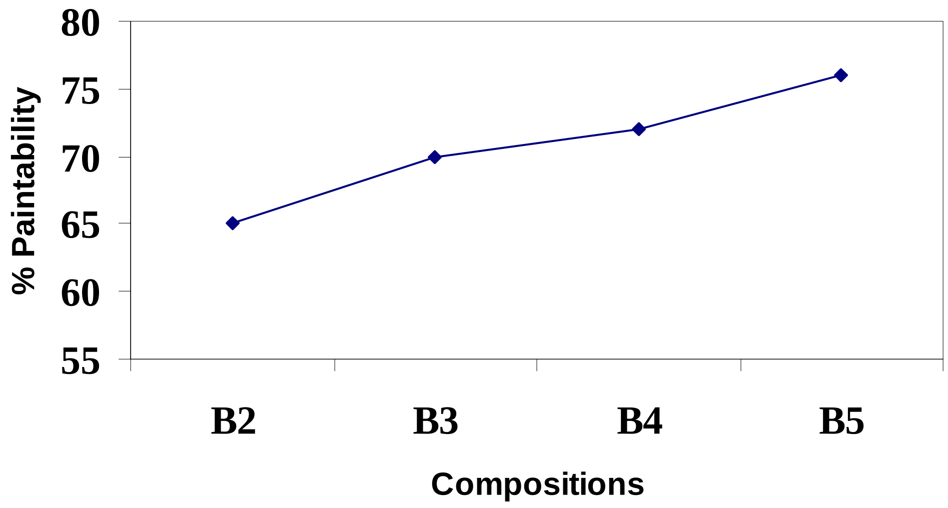


Fig-12 shows the variation of % paintability with compositions using alkyd paint when primer is not used before the application of paint. Percent paintability increases linearly with compositions. This may be attributed to the fact that $CaCO_3$ and SMA imparts polarity to the surface of Repol D120 respectively.

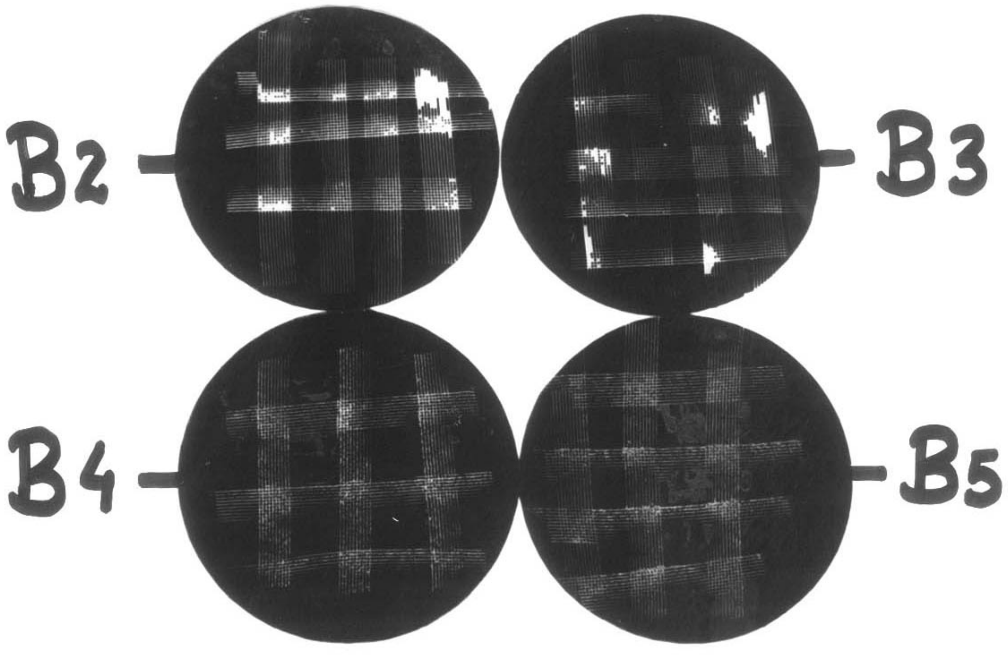


Fig.-13 Alkyd Painted photographs of different Compositions of PP (Without Primer)

B2: - PP Repol D120MA (Control Sample), B3: - PP Repol D120MA + 10 % $CaCO_3$

B3: - PP Repol D120MA + 20 % $CaCO_3$, B4: - - PP Repol D120MA + 3 % SMA

The data on paintability using alkyd paint is presented in Table-11 and Fig-14 and 15 respectively when primer is used before the application of paint.

Paintability of Repol D120MA is 88 % when primer is used before the application of paint. In 90:10 Repol D120MA / Repol D120MA + 10 % $CaCO_3$ paintability increases from 88 % to 90 %. In 80:20 Repol D120MA / Repol D120MA + 20 % $CaCO_3$ paintability increases from 88 % to 95 %. This is due to the combined effect of primer and $CaCO_3$. In 100:3 Repol D120MA / Repol D120MA + 3 % SMA paintability increases from 88 to 100%. This is due to the synergistic effect of primer and SMA.

TABLE- 11

DATA ON PAINTABILIT OF VARIOUS COMPOSITIONS USING ALKYD PAINT (WITH PRIMER)

S.NO.	COMPOSITIONS NO.	SAMPLE IDENTIFICATION	% PAINTABILITY
1.	B2	PP REPOL D120MA	88
2.	B3	PP REPOL D120MA + 10 % $CaCO_3$	90
3.	B4	PP REPOL D120MA + 20 % $CaCO_3$	95
4.	B5	PP REPOL D120 MA+ 3 % SMA	100

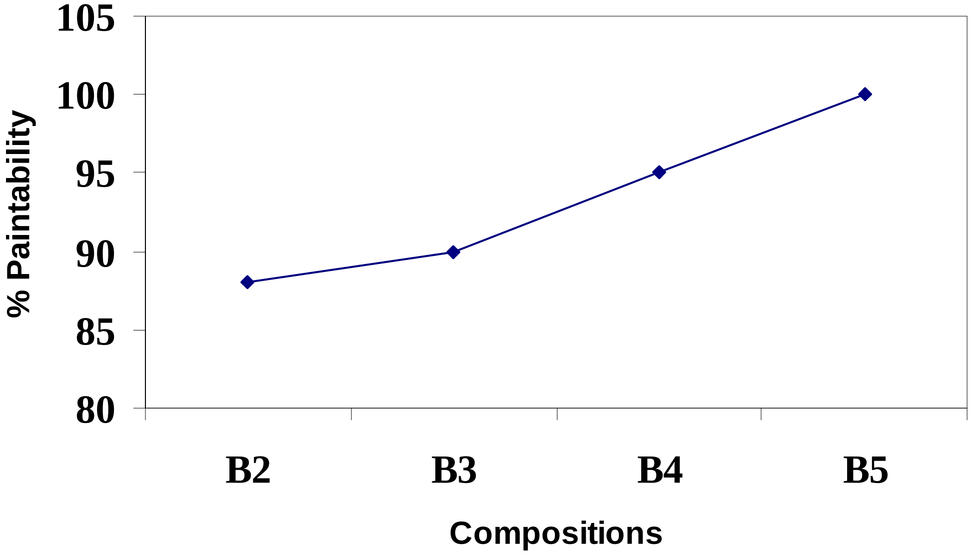


Fig.-14 Variation of % paintability with Compositions using Alkyd Paint (With Primer)

Fig-14 shows the variation of % paintability with compositions using alkyd paint when primer is used before the application of paint. Percent paintability increases linearly with compositions.

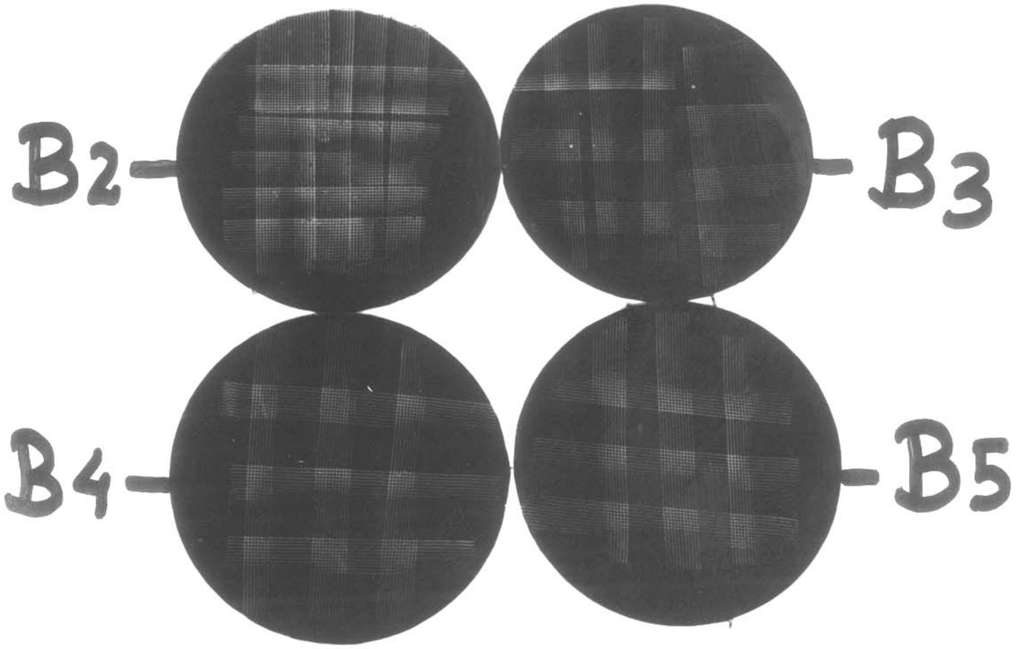


Fig. 15Alkyd Painted photographs of different Compositions of PP (Without Primer)

B2: - PP Repol D120MA (Control Sample), B3: - PP Repol D120MA + 10 % $CaCO_3$
B3: - PP Repol D120MA + 20 % $CaCO_3$, B4: - - PP Repol D120MA + 3 % SMA

Comparison of % paintability between with and without primer is shown in Fig.-16.

Fig.-16 Comparison of % Paintability (Alkyd Paint)

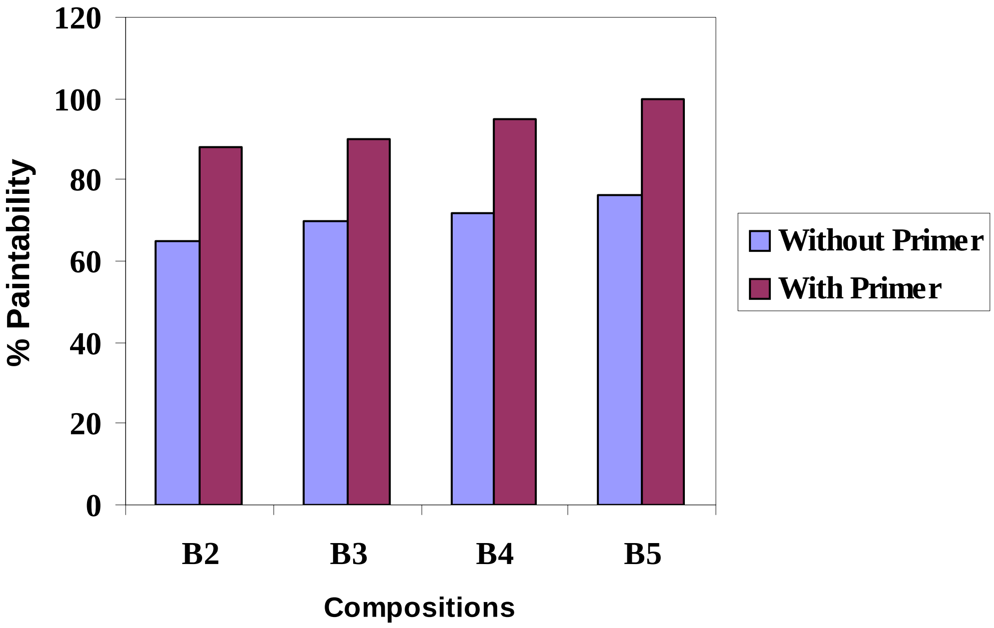


Fig shows that % paintability increases when primer is used before the application of paint. This is due to the fact that surface tension of primer is less than the surface energy of solid.

The data on paintability using PU paint is presented in Table-12 and Fig-17 when primer is not used before the application of paint.

Paintability of Repol D120MA is 66% when primer is not used before the application of paint. In 90:10 Repol D120MA / Repol D120MA + 10 % $CaCO_3$ paintability increases from 66 % to 72 %. In 80:20 Repol D120MA / Repol D120MA + 20 % $CaCO_3$ paintability increases from 66 - 75 %. In 100:3 Repol D120MA / Repol D120MA + 3 % SMA paintability increases from 66 to 82 %.

TABLE- 12

DATA ON PAINTABILIT OF VARIOUS COMPOSITIONS USING PU PAINT (WITHOUT PRIMER)

S.NO.	COMPOSITIONS NO.	SAMPLE IDENTIFICATION	% PAINTABILITY
1.	B2	PP REPOL D120MA	66
2.	B3	PP REPOL D120MA + 10 % $CaCO_3$	72
3.	B4	PP REPOL D120MA + 20 % $CaCO_3$	75
4.	B5	PP REPOL D120MA + 3 % SMA	82

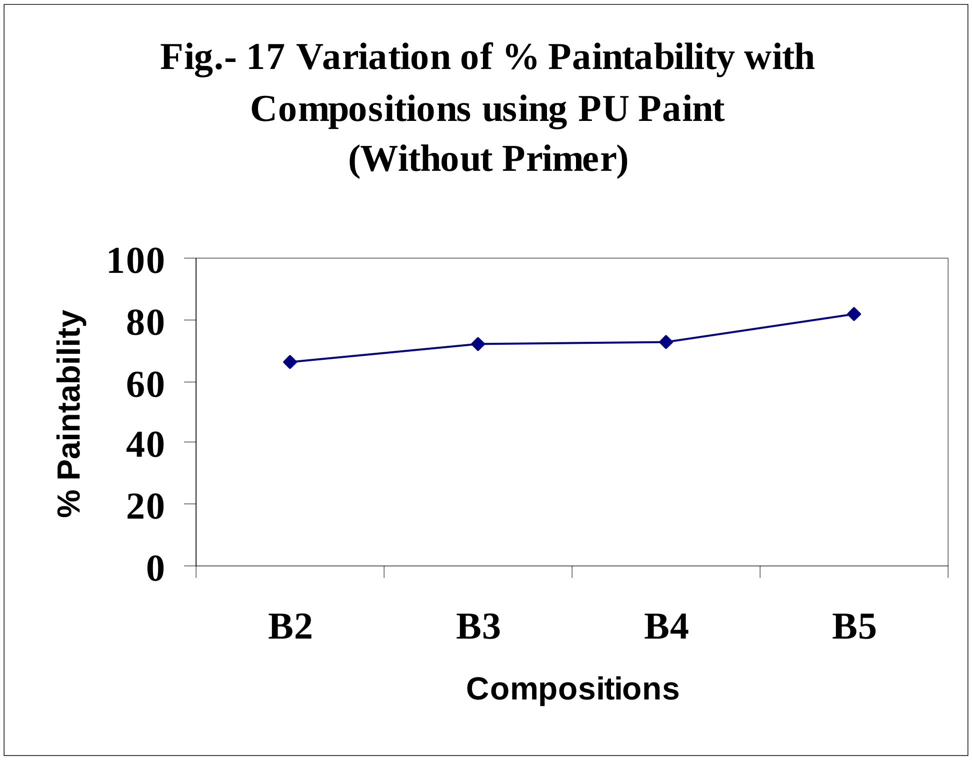


Fig-17 shows the variation of % paintability with compositions using PU paint when primer is not used before the application of paint. Percent paintability increases linearly with compositions.

The data on paintability using PU paint is presented in Table-13 and fig-18 when primer is used before the application of paint.

Paintability of Repol D120MA is 90% when primer is used before the application of paint. In 90:10 Repol D120MA / Repol D120MA + 10 % $CaCO_3$ paintability increases from 90 % to 95 %. In 80:20 Repol D120MA / Repol D120MA + 20 % $CaCO_3$ paintability increases from 90 - 98 %. In 100:3 Repol D120MA / Repol D120MA + 3% SMA paintability increases from 90 -100 %.

TABLE- 13

DATA ON PAINTABILIT OF VARIOUS COMPOSITIONS USING PU PAINT (WITH PRIMER)

S.NO.	COMPOSITIONS NO.	SAMPLE IDENTIFICATION	% PAINTABILITY
1.	B2	PP REPOL D120MA	90
2.	B3	PP REPOL D120MA + 10 % $CaCO_3$	95
3.	B4	PP REPOL D120MA + 20 % $CaCO_3$	98
4.	B5	PP REPOL D120MA + 3 % SMA	100

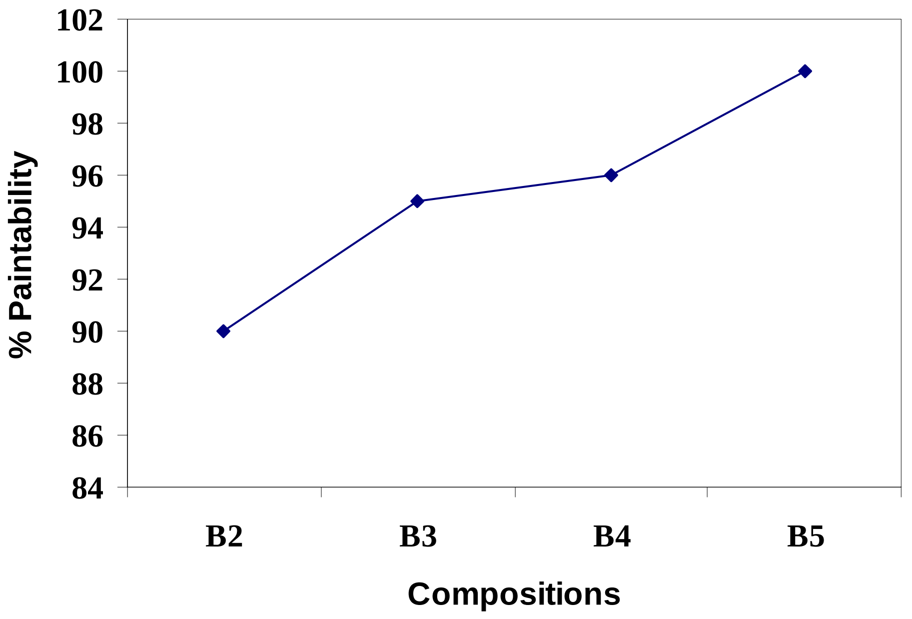


Fig.-18 Variation of % Paintability with Compositions using PU Paint (With Primer)

Fig-18 shows the variation of % paintability with compositions using PU paint when primer is used before the application of paint. Percent paintability increases linearly with compositions.

Comparison of % paintability between with and without primer is shown in fig.-19.

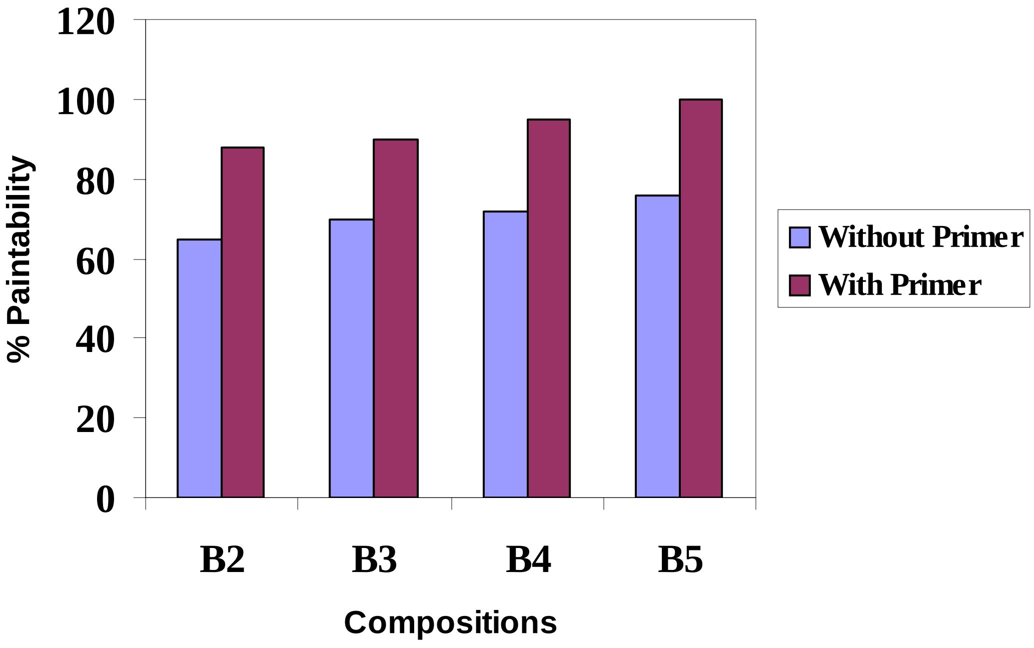


Fig.-19 Comparison of %Paintability (PU Paint)

Fig shows that % paintability increases when primer is used before the application of paint. This is due to the fact that surface tension of primer is less than the surface energy of solid.

5.3.3 FTIR -ATR:

Evidence of chemical reaction between the components was obtained through FTIR-ATR. Surface properties of the different compositions were determined from injection-molded test specimen.

Fig.-20 & 21 shows the spectra of PP and PP + 3% SMA respectively when primer is not applied on the surface of PP.

In Fig.-20, the C-H stretching bands are near 2950 $cm^{-1}$and 2918 cm^{-1}. A peak present near 2838 cm^{-1} indicates C-H stretching in CH_2 and CH3. The spectrum shows the band of C- H deformation in CH_3 near 1376 cm^{-1}. Peaks present near 997.88 cm^{-1} and 973.42 cm^{-1} are the characteristics peaks of PP.

In Fig.-21, the band around 1736 cm^{-1} shows the presence of $C = O$ group of anhydride. Peaks present near 720 cm^{-1} and 841 cm^{-1} indicate the presence of benzene group. The anticipated free carboxylic acid formed from the reaction between PP and SMA is not observed.

Fig.-22 shows the spectra of primer.

A sharp peak of C-Cl stretching occurs in the region of 732 cm^{-1}. Peaks present near 1705 cm^{-1} and 1605 cm^{-1} indicates $C = O$ group of anhydride. Peaks near 1119.76 and 1052 cm^{-1} indicate presence of C-O structure of anhydride group. In halogen compounds C-H stretching shifts to higher wave no. due to –I effect of halogen atom, so peak near 3017.70 cm^{-1} is due to asymmetric C-H stretching vibrations of CH_3 group in CH_3-Cl.

Fig. 23, 24, 25 and 26 show the spectra of different compositions of PP (B2, B3, B4, B5) after the application of primer.

As described earlier the absorption peaks of C-H stretching occur near 2950, 2918 and 2858 cm^{-1}in PP when primer is not used. In the present case when primer is used on the surface of PP one more peak present near 3030.68 cm^{-1} due to asymmetric C-H stretching present in primer. A sharp absorption band around 740 cm^{-1} indicates the presence of –Cl group of primer. Absorption peak near 1605 cm^{-1} indicates $C = O$ group of anhydride in primer. Similar peaks are coming for other compositions of PP.

Fig.-27 shows the spectra of PP after the application of alkyd paint.

Absorption peak around 3460 cm^{-1}shows the presence of –OH group and broadband indicate the presence of intermolecular hydrogen bonding. Absorption band near 1721.94 cm^{-1} indicates the presence of $C = O$ group of ester and peak near 1066.37 cm^{-1} indicate C-O stretching of ester. Peaks near 1548.41, 1447.67 and 1374.81 cm^{-1}, indicates $C = C$ stretching of aromatic group and it may indicate the presence of phthalic group. Absorption band around 741.11 cm^{-1} indicates C-C deformation of O-disubstituted benzene groups.

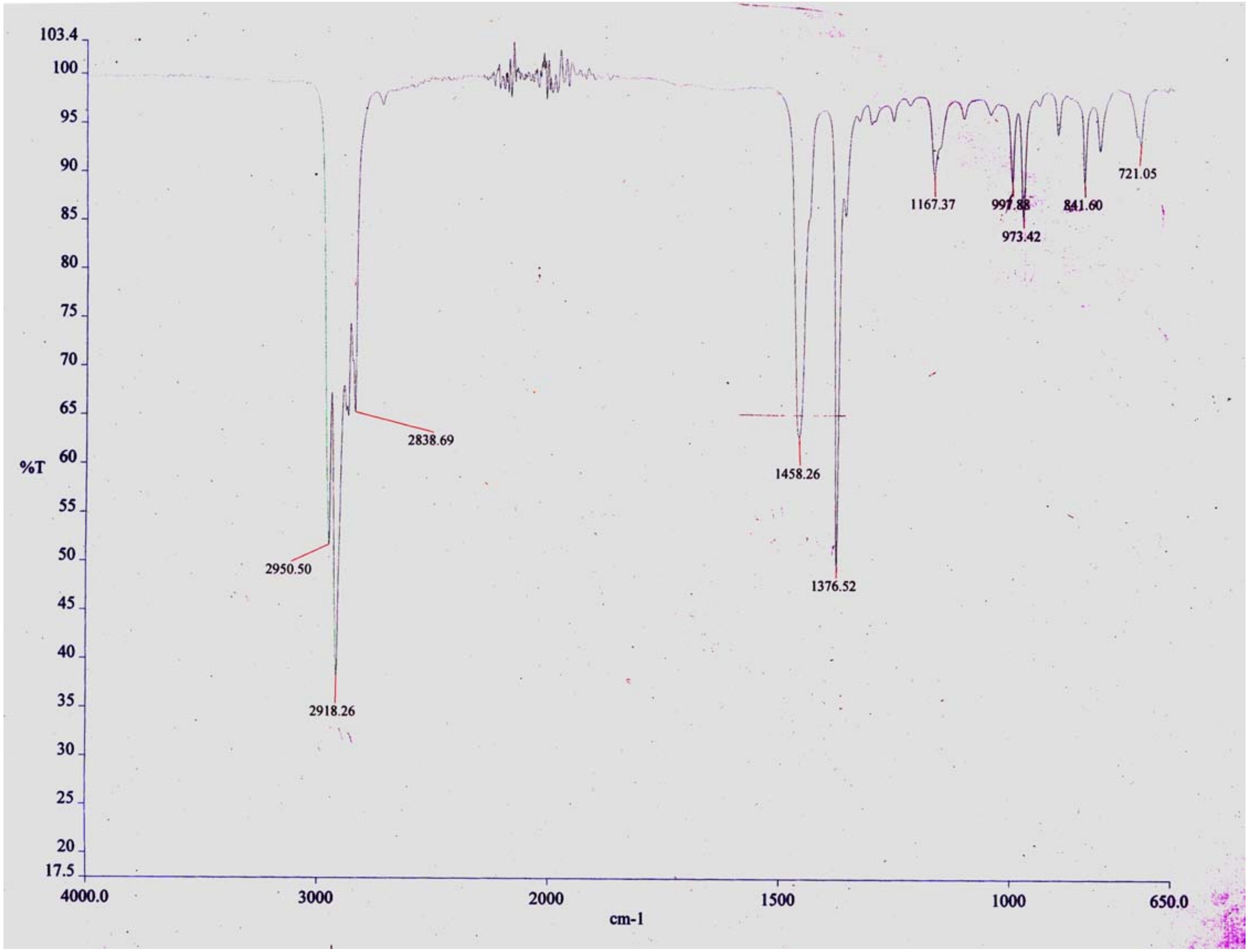
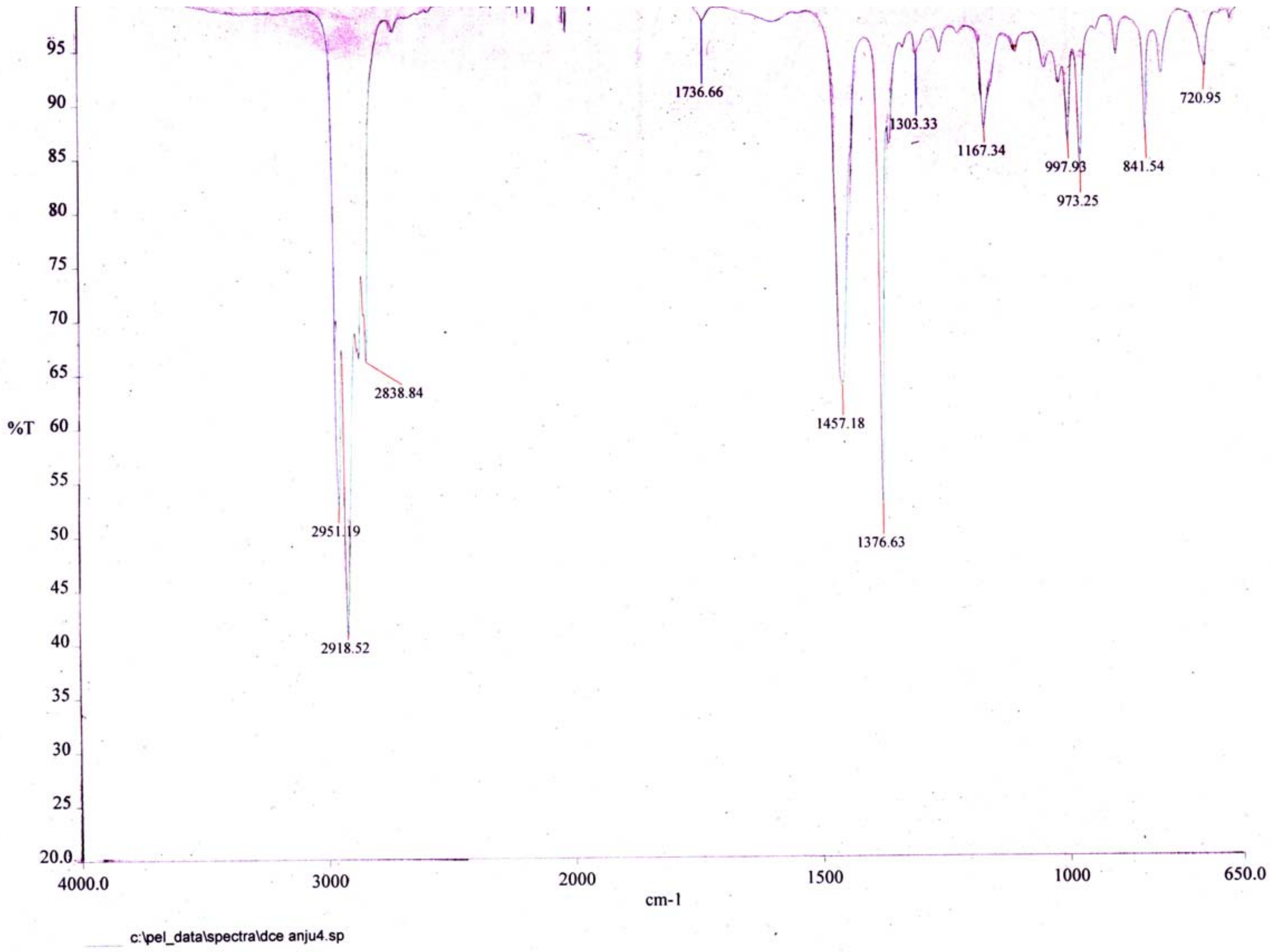
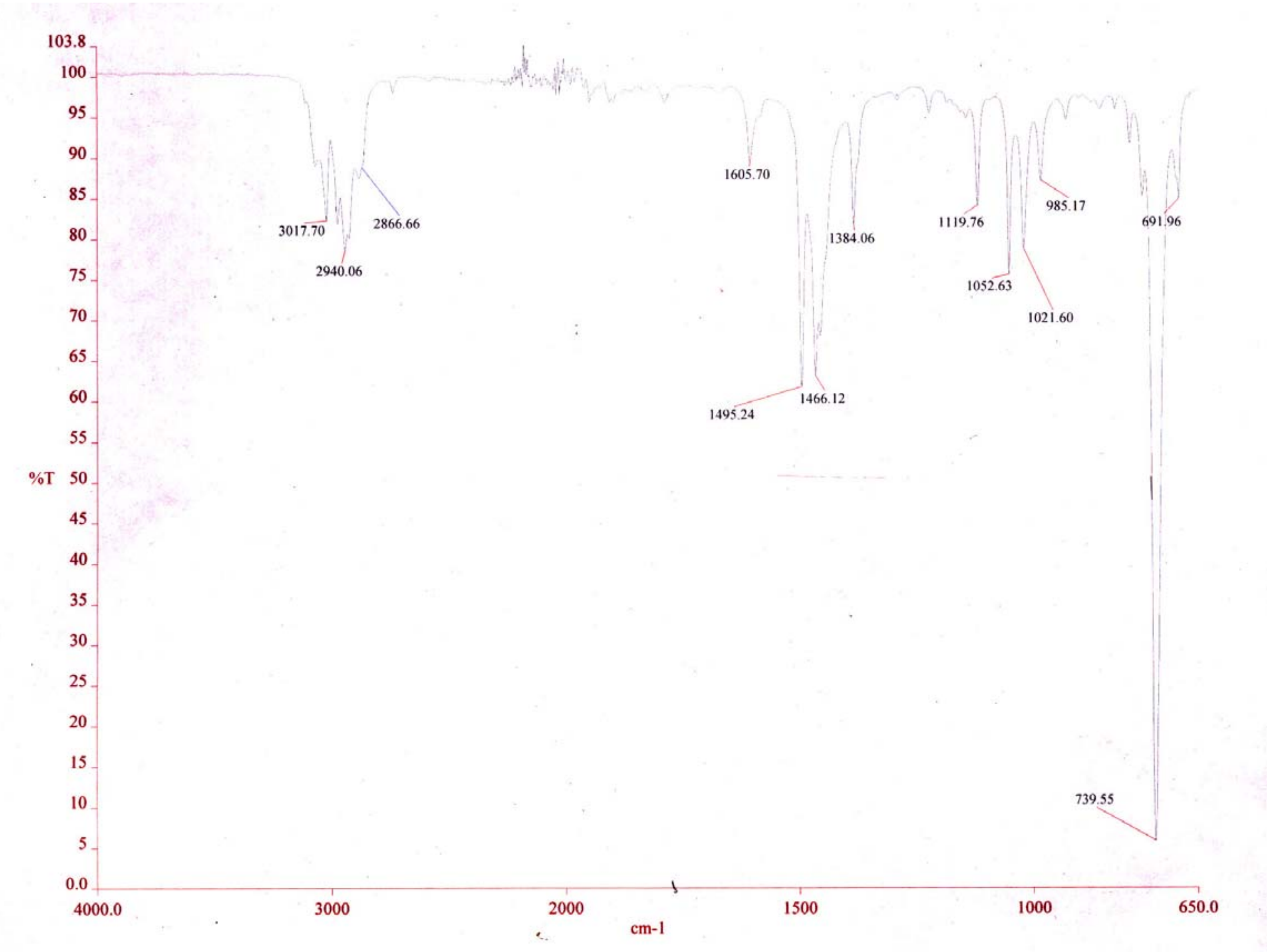

103.4
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
17.5
%T
4000.0
3000
2000
1500
1000
650.0
cm-1
2950.50
2918.26
2838.69
1458.26
1376.52
1167.37
997.88
973.42
841.60
721.05

Fig. -20



95
90
85
80
75
70
65
%T 60
55
50
45
40
35
30
25
20.0
4000.0
3000
2000
1500
1000
650.0
cm-1
1736.66
1303.33
1167.34
997.93
973.25
841.54
720.95
2838.84
2951.19
2918.52
1457.18
1376.63
c:\pel_data\spectra\dce anju4.sp

Fig. -21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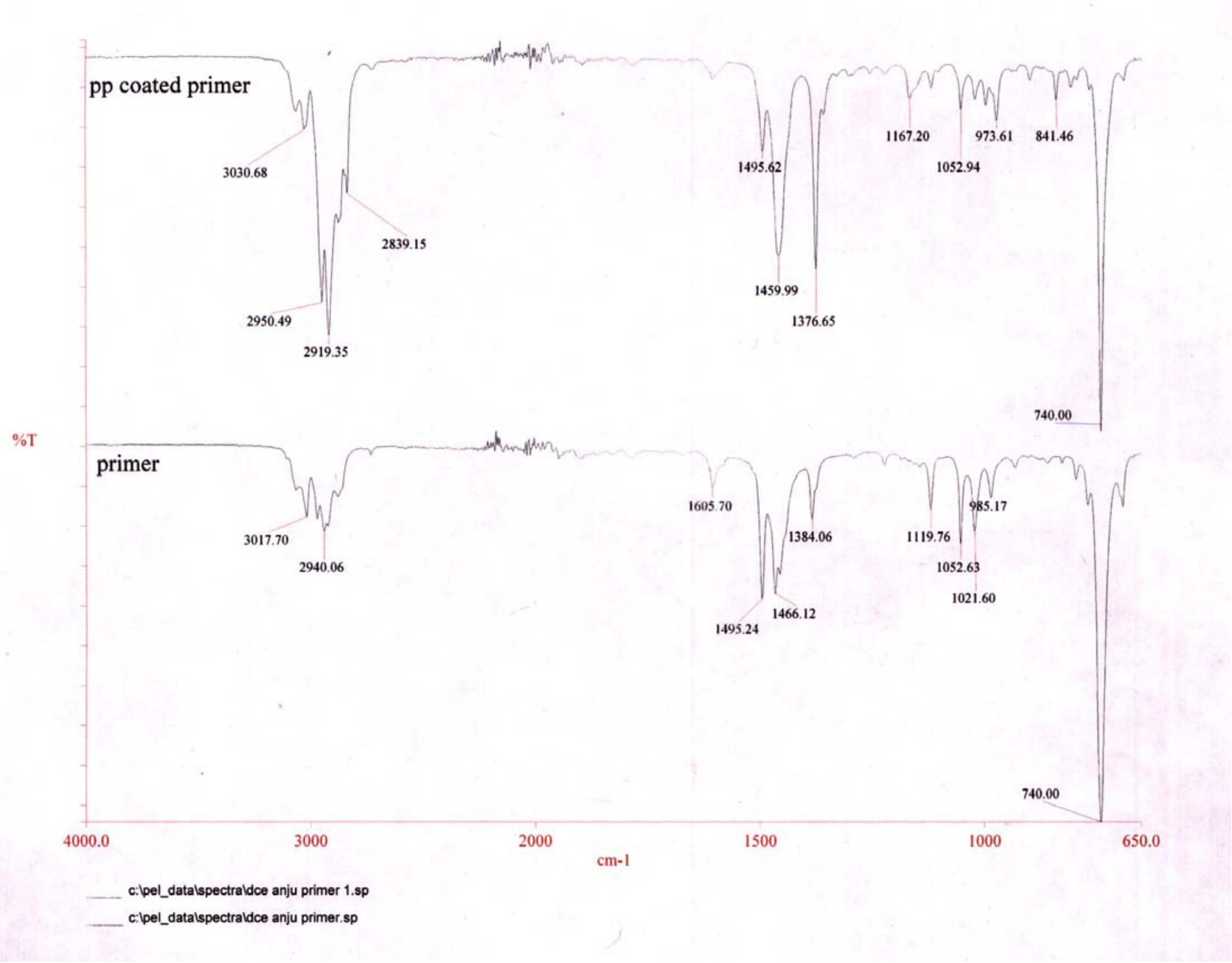
100
95
90
85
80
75
70
65
60
55
%T 50
45
40
35
30
25
20
15
10
5
0.0
4000.0
3000
2000
1500
1000
650.0
cm-1
3017.70
2940.06
2866.66
1605.70
1495.24
1466.12
1384.06
1119.76
1052.63
1021.60
985.17
691.96
739.55

Fig. -22


pp coated primer
3030.68
2950.49
2919.35
2839.15
1495.62
1459.99
1376.65
1167.20
1052.94
973.61
841.46
740.00
%T
primer
3017.70
2940.06
1605.70
1384.06
1495.24
1466.12
1119.76
1052.63
1021.60
985.17
740.00
4000.0
3000
2000
1500
1000
650.0
cm-1
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c:\pel_data\spectra\dce anju primer.sp

Fig. -23

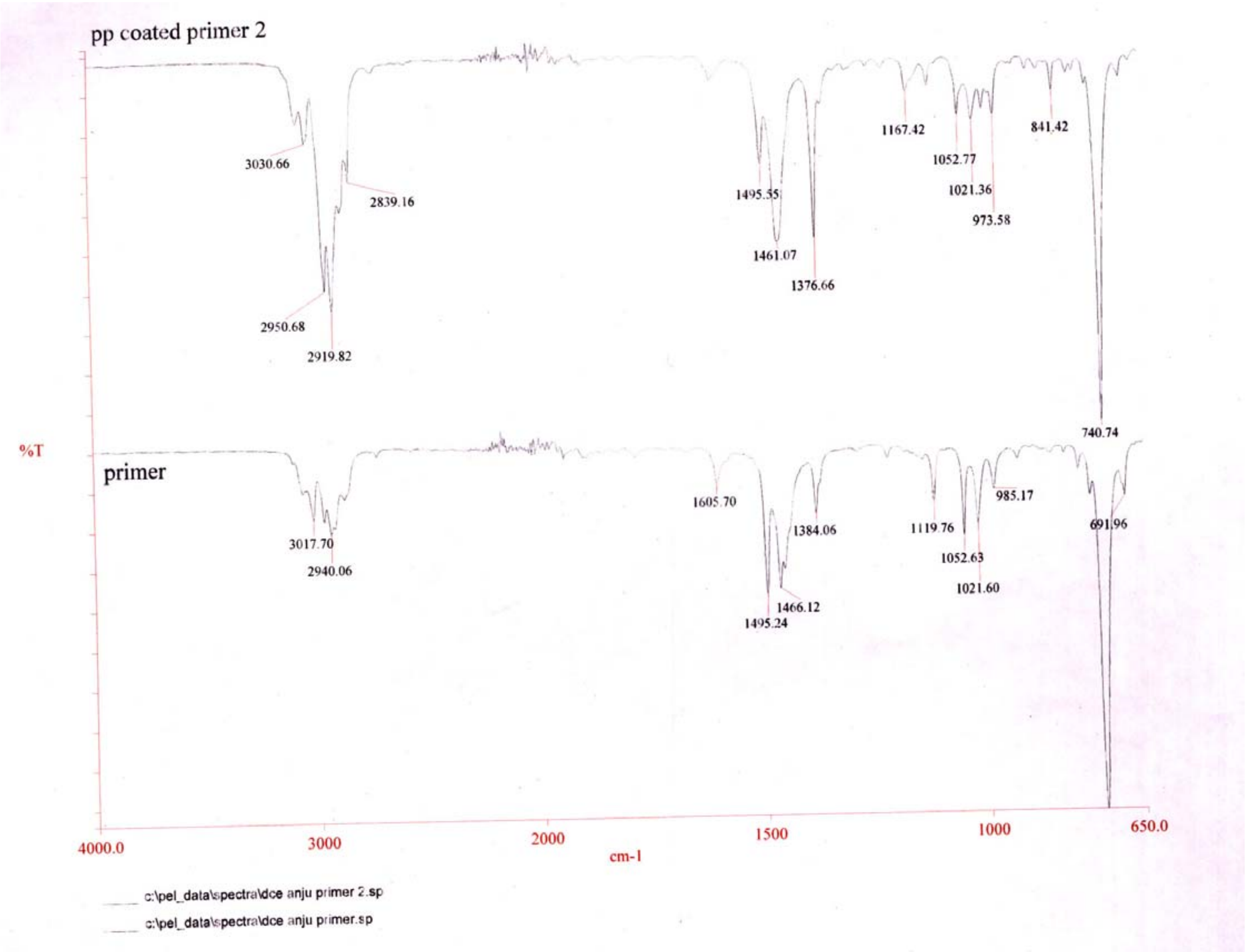
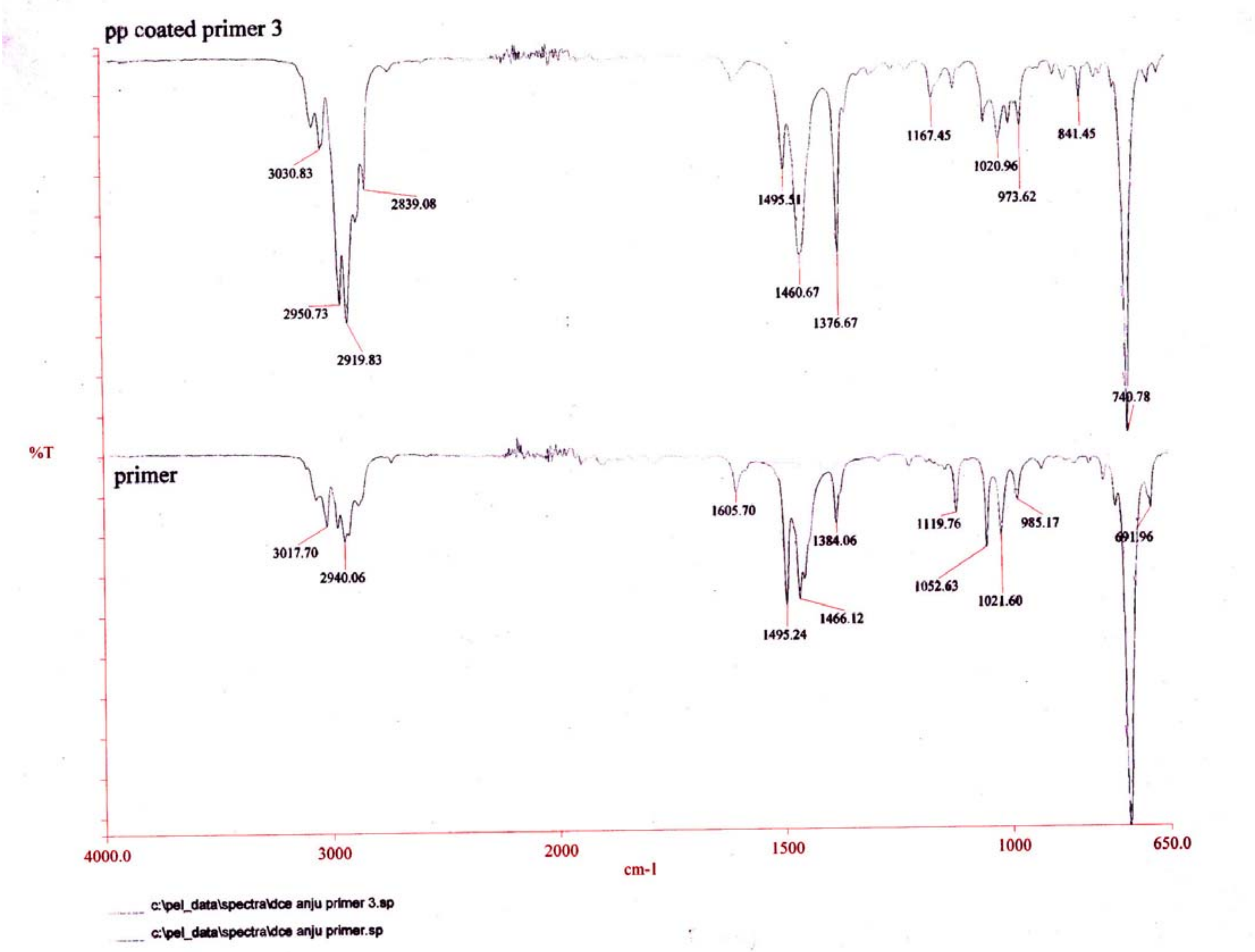

pp coated primer 2
3030.66
2839.16
2950.68
2919.82
1495.55
1461.07
1376.66
1167.42
1052.77
1021.36
973.58
841.42
740.74
%T
primer
3017.70
2940.06
1605.70
1384.06
1466.12
1495.24
1119.76
1052.63
1021.60
985.17
691.96
4000.0
3000
2000
1500
1000
650.0
cm-1
c:\pel_data\spectra\dce anju primer 2.sp
c:\pel_data\spectra\dce anju primer.sp

Fig. -24


pp coated primer 3
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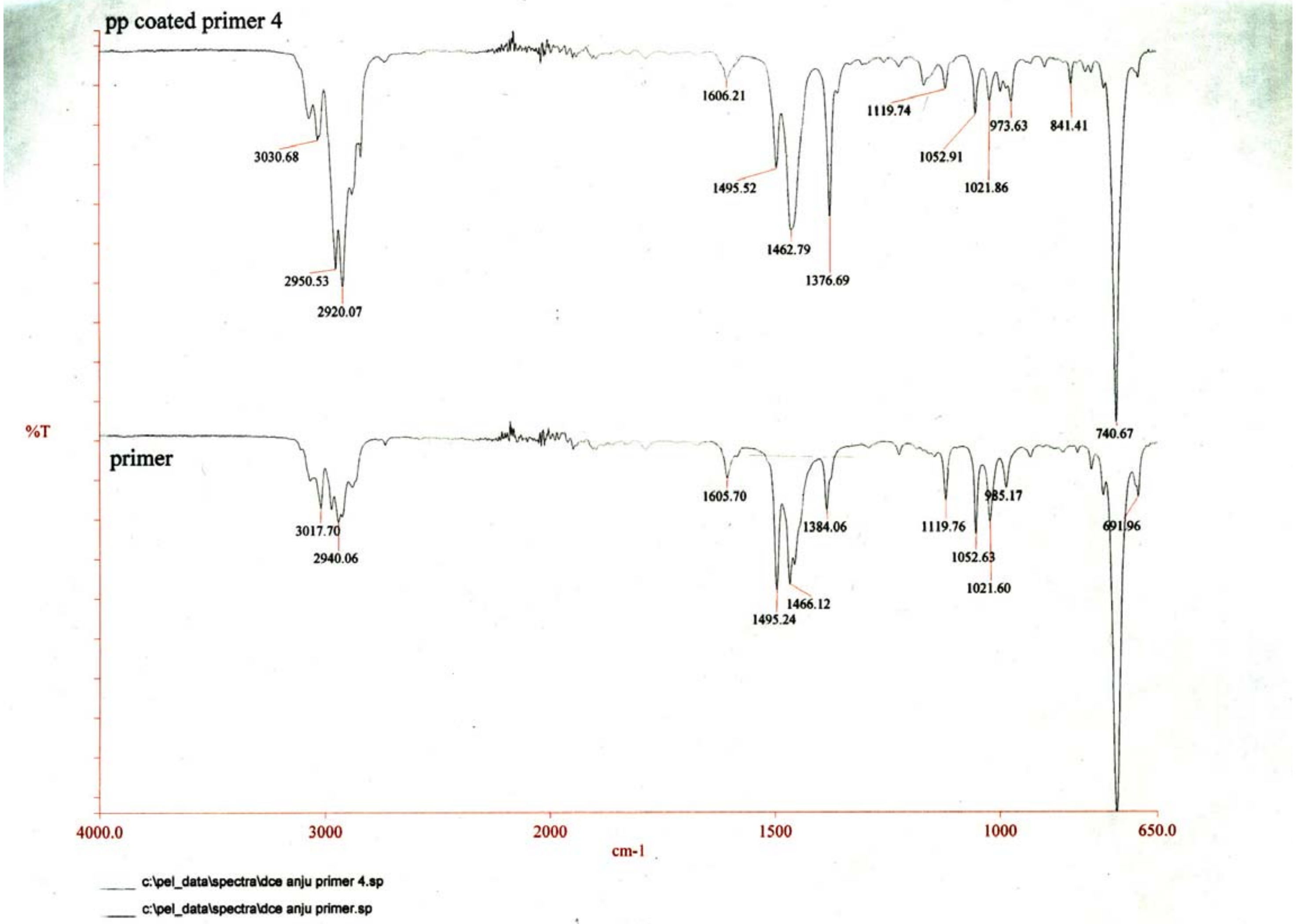
2839.08
2950.73
2919.83
1495.51
1460.67
1376.67
1167.45
1020.96
973.62
841.45
740.78
%T
primer
3017.70
2940.06
1605.70
1384.06
1495.24
1466.12
1119.76
1052.63
1021.60
985.17
691.96
4000.0
3000
2000
1500
1000
650.0
cm-1
c:\pel_data\spectra\dce anju primer 3.sp
c:\pel_data\spectra\dce anju primer.sp

Fig. -25


pp coated primer 4
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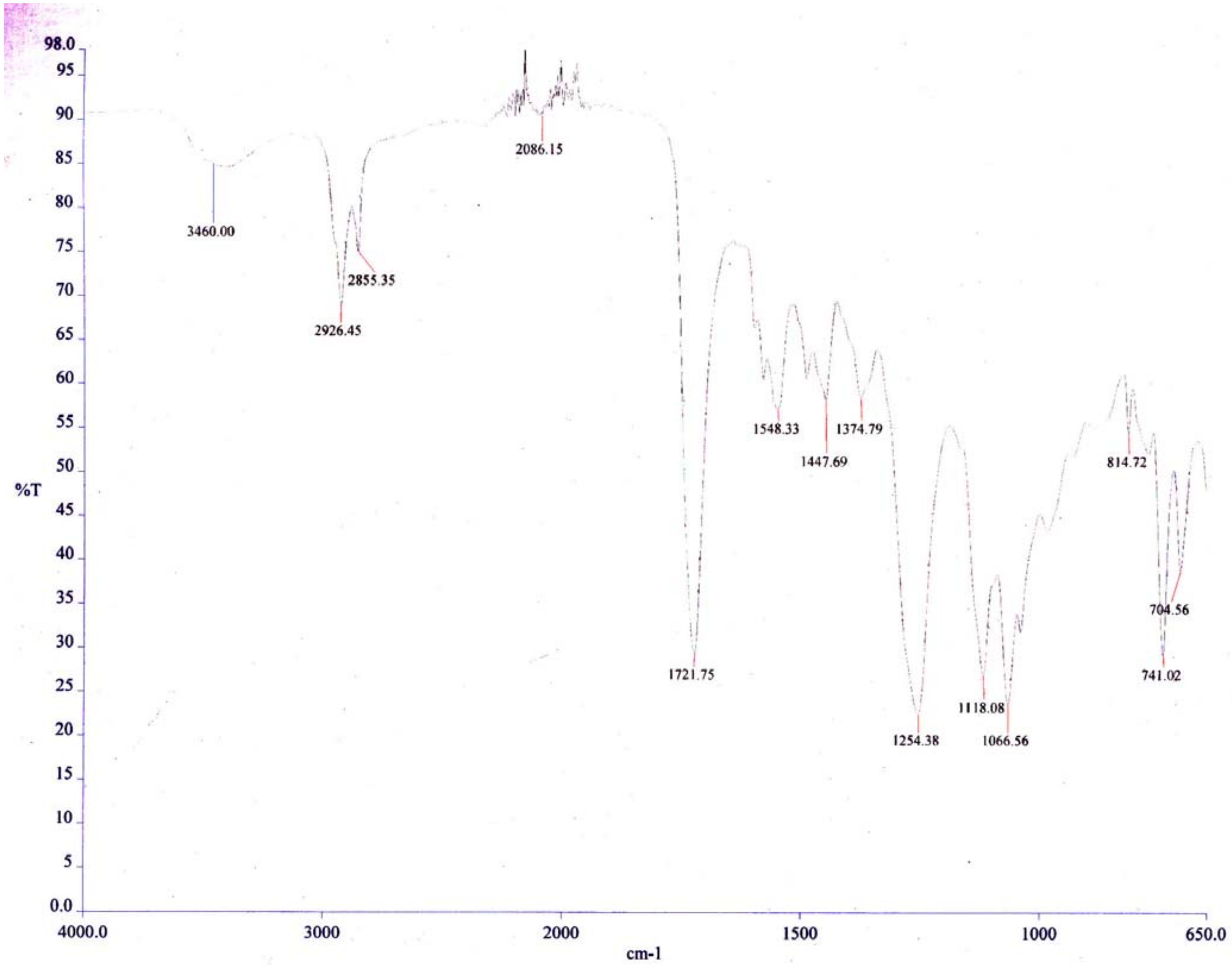
1606.21
1495.52
1462.79
1376.69
1119.74
1052.91
1021.86
973.63
841.41
740.67
%T
primer
3017.70
2940.06
1605.70
1384.06
1495.24
1466.12
1119.76
1052.63
1021.60
985.17
691.96
4000.0
3000
2000
1500
1000
650.0
cm-1
c:\pel_data\spectra\dce anju primer 4.sp
c:\pel_data\spectra\dce anju primer.sp

Fig. -26



98.0
95
90
85
80
75
70
65
60
55
50
%T
45
40
35
30
25
20
15
10
5
0.0
4000.0
3000
2000
1500
1000
650.0
cm-1
3460.00
2926.45
2855.35
2086.15
1721.75
1548.33
1447.69
1374.79
1254.38
1118.08
1066.56
814.72
741.02
704.56

Fig. -27

CONCLUSIONS

This study was to analyze paintability in PP by selection of appropriate grades, incorporation of additives and effect of primer. From the results obtained, following conclusions can be drawn.

- PP Repol D120MA (impact modified grade) shows better adhesion than PP Repol H110MA (homopolymer grade).
- Among various compositions used, combination Repol D120 + 3 % SMA in the ratio of 100:3 was found to be best.
- With the use of primer paintability results were found to be excellent.
- When primer is not used before the application of paint, PU paint gives better result than alkyd paint.
- Mechanical properties such as tensile strength, flexural modulus and impact strength of Repol D120MA + 3 % SMA is higher than Repol D120MA.
- Even without the use of primer, paintability results were found to be good for the combination Repol D120 + 3 % SMA.

SCOPE FOR FUTURE WORK

- In future this study can be carried out by taking different primer such as non-chlorinated polyolefin or the mixture of two different primer.
- This study can be carried out by using different fillers such as talc or we can take mixture of $CaCO_3$ and talc.
- Study can be carried out by using $CaCO_3$ with SMA.
- Study can be carried out by using $CaCO_3$, talc and SMA.
- Study can be carried out by increasing the percentage of SMA in Repol D120MA so that excellent paintability may be achieved even without using the primer.
- Blends of Repol D120MA and SMA can be made with a suitable compatabilizer, which may have excellent paintability without using the primer.

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LIST OF TABLES

LIST OF FIGURES