EFFECTS OF WEATHERING ON SOME MECHANICAL PROPERTIES OF BLENDS OF RECYCLED POLYPROPYLENE WITH POLYSTYRENE, POLYVINYL CHLORIDE AND VIRGIN POLYPROPYLENE

BY

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A THESIS SUBMITTED TO THE DEPARTMENT OF TEXTILE SCIENCE AND TECHNOLOGY , AHMADU BELLO UNIVERSITY, ZARIA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN TEXTILE SCIENCE AND TECHNOLOGY.

OCTOBER 2012

DECLARATION

I hereby declare that this research has been conducted solely by me under the supervision of Prof. E. G. Kolawole, and Dr. A. Danladi. I have neither copied someone's work nor has someone else done it for me. Credit has been given to writers whose works have been referred to in this thesis.

_____ _____

Fadipe, E. Olufemi Date.

CERTIFICATION

This thesis entitled "Effects of Weathering on some Mechanical Properties of Blends of Recycled Polypropylene with Polystyrene, Polyvinylchloride and Virgin Polypropylene" by FADIPE, Emmanuel Olufemi meets the regulations governing the award of the degree of Master of Science in Textile Science and Technology of Ahmadu Bello University, Samaru – Zaria, Nigeria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research work is dedicated to the glory of God, who has never disappointed me.

ACKNOWLEDGEMENTS

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Fadipe, Emmanuel.O.

ABSTRACTS

Natural weathering degradation of the blends of recycled polypropylene (PPr) with Polystyrene (PS), Polyvinyl chloride (PVC) and Virgin Polypropylene (PPv) was studied. Film samples of 25 by 1.5 by 0.02Cm^3.PS, PVC and PPv were blended with PPr for the purpose of improving its mechanical properties, which was generally considered as inferior. While no particular blends had over all good result of all the mechanical Properties tested, however, PS/PPr produced the best result of tensile strength, followed by the blends of PPv/PPr and PVC/PPr. The blend of PPv/PPr had the highest elongation followed by the blends of PVC and PS. The young modulus results show that at 20%, the PS blends has the highest young modulus. Also PS blend resist embrittlement more than PPv and PVC blends. In summary the blends of PS and PPr at ratio 20:80 is considered good enough to improve the mechanical properties of recycled polypropylene better than the other blends.

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CHAPTER I

1.1 INTRODUCTION

Plastics; materials made up of large organic (carbon - containing) molecules that can be formed into a variety of products. The molecules that compose of plastics are long carbon chain that gives plastics many of their useful properties. In general, material that is made up of long chain like molecules are called polymer.

Plastics are indispensable to our modern way of life. Plastics are used in low performance products like toys, wrapping product, storage of beverages and also high performance products like automobile, aerospace, constructions, packaging and electrical industries. Plastics are also used in specialized fluids, such as the health industries to make medical instruments, dental fillers, optical lenses and bio compatible joints.

Plastic materials have substituted ferrous, wood and ceramic materials in many applications, for this reason, plastic consumptions have increased exponentially in the past decade. Infact, the demand for plastic products and goods is on the increase due to rapid population growth and changes in consumption pattern, particularly for packaging; shopping, carrier bags, containers, agricultural tools, water satchet and house hold items.

There are environmental problems and challenges associated with the management of plastic wastes in Nigeria as well as in many developing countries. Due to their non – biodegradability and diverse applications, plastic wastes from petrochemical source are prevalent in the environmental and causes health hazards.

Chocking of fertile soils, flooding due to blockage of drainage, breeding grounds for mosquitoes, death of livestock due to ingestions, food hazards, pollution (dioxin and furan) from burning of plastics. According to the study carried out by the federal ministry of environment, Nigeria generated more than 2.260 million tonnes of plastic wastes annually. Anonymous. (2008)

The Government through the Federal Ministry of Land, Housing and Urban Development has embarked on a number of measures to address these problems being encountered in the management of plastic wastes in Nigeria. These measures include the introduction of an integrated waste management scheme for Nigerian cities under a public – Private partnership (PPP) arrangement in which the recovery, recycling and re-use of plastic waste is a major component. Anonymous (2008)

The efforts of the Government are also being complemented by private sector operators who engage in collection and recovery of plastic wastes which are then sorted, shredded, blended and reprocessed to make new products or sent to secondary processing plants to make " lower" quality products.

Although scientifically, it has been proved that recycled process affects the properties of plastics, these changes have not been qualified. This study will be directed towards quantifying the property changes in recycled polypropylene and to improve on these properties when it is blended with virgin polypropylene, polystyrene and polyvinyl chloride

1.2 AIM OF THE RESEARCH

This research is concerned with the effect of weathering on mechanical reliability of plastic products. Under outdoor conditions, polymer degrades, mainly due to action of UV- light, while heat and humidity have secondary effects. Degradation tends to reduce the mechanical reliability, and in some cases this reduction may be very drastic.

The ultimate aim of this research is to;

1. Investigate the mechanical properties of recycled polypropylene.
2. Established the level of degradation on the mechanical properties of recycled polypropylene.
3 Deduce how the properties can be improved upon when blended with another polymer.
4 Encourage the use of recycled polypropylene for new product, hence reduce environmental pollution.
5 Formulate new materials with peculiar properties than the existing ones.

CHAPTER TWO

2.1 LITERATURE REVIEW

2.1.1 POLYPROPYLENE – BRIEF HISTORY

Polypropylene (PP) was first synthesized in the Mid 1950s by Guillio Natta's group in Italy, through the polymerisation of propylene (C_3H_6) in the presence of Titanium Aluminum (Alt_3) (Catalyst concoctions development by Karl Ziegler).

The starting materials used in this polymerization are simple organic molecules

Propylene $CH_2 = CH\text{-}CH_3$

Ethylene $CH_2 = CH_2$

Hydrogen H_2

Scheme.2.1 Simple organic molecules

The propylene reacts with the active catalyst to form a long chain of propylene units. The length of the chain is dependent on temperature and the concentration of hydrogen. Production of block co-polymers is achieved by feeding the active catalyst and the polypropylene chain into another reactor and then reacting it with various amounts of ethylene and additional propylene. Production of random co-polymer is achieved by reacting the propylene and the ethylene with the catalysts in one reactor. The product (polymer powder), on either stream, is then ready for dechlorination.

The powder that is ejected out of the reactor consists of polypropylene, $AlCl_3$, $TiCl_3$ and other catalyst residues. The aim of dechlorination is to rid the

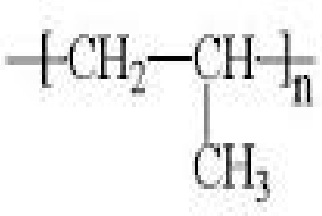
polymer of these residues which otherwise would degrade the powder during processing and ultimately, the final product.

In the dechlorination process, the powder is fed into a fluid bed and reacted with mixture of N_2 (99%). Propylene oxide (0.5%) and moisture (0.5%). The moisture converts the catalyst residue to the hydroxides and hydrochloric acid. The hydroxides are converted to the oxides and water and the oxides remain dispersed in the polymer. The propylene oxide reacts with the HCL to form propylene chlorohydrins. This is then passed through a caustic scrubber which converts the chlorohydrins back to propylene oxide and sodium chloride. The propylene oxide is re-fed into the system. The powder is now devoid of most of the catalyst residues.

The powder, after this process, is ready to be mixed with the master batch. All master batches used to make the final products contain an antioxidant. The purpose of antioxidant is to prevent degradation of the polymer resulting from exposure to air (oxygen) and /or heat

At this stage of the process, the powder (Dechlorinate) and the master batch are mixed at a specific rate to yield the desired products. The final homogeneous mix is melted and the molten product is extruded through a set of dies to form laces. The laces are cooled and quenched by flowing water. The solidified laces are now passed through cutters which cut the laces to form the final granules.

The granules are held in hopper or bins ready for final quality control analysis. Once classified according to specification, they are ready to either bulk Shipment in 20 tonnes road tankers or 25kg packaged bag delivery.



Scheme 2.2 structure of Polypropylene

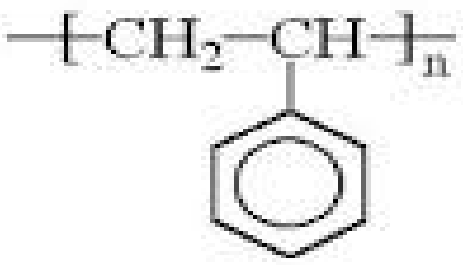
2.2 POLYSTYRENE - BRIEF HISTORY

Polystyrene was discovered by Eduard Simon in Berlin, from storax, which he named styrol. By 1845 English Chemists John Blyth and German chemists August Wilhelm Von Hoffmann showed that the same transformation of styrol took place in the absence of oxygen. They called their substance metastyrol. In 1866, Marcelin Berthelot correctly identified formation of metastyrol from styrol as a polymerization process. Following the thesis of German organic chemists Hermann Staudinger (1881-1965), it was realized that heating of styrol starts a chain reaction which produces macromolecules. This eventually lead to the substance receiving its present name, polystyrene. (The history of plastics)

After the discovery, many companies have developed methods of extruding polystyrene like I. G Farben, Ludivishafen, Germany in 1931, and Koppens Company in 1945.

2.2.1 STRUCTURE OF POLYSTYRENE.

Polystyrene has a very simple repeating structure. It is an atactic polymer thus regarded as amorphous. The specific location of the benzene ring is sufficiently random to inhibit crystallization. Brydson, (1996).



Scheme 2.3 Structure of Polystyrene

Polystyrene is a hard, crystal clear, amorphous solid at room temperature that exhibits high stiffness, good dimensional stability, moderately high heat deflection temperature and excellent electrical insulation properties. Myer Kutz, (2002). It retains its stiffness to about 20-25^{0}C below glass transition temperature (Tg).however, polystyrene will become softer as it closer to Tg which is around 100^{o}C.above Tg polystyrene behaves under stress as a viscous fluid When the temperature is further raised ,it will become rubbery and highly extensible. Polystyrene is easily processed by all normal thermoplastic processes to produce common applications such as wall tiles, electrical parts, lenses, bottle caps, transparent display boxes, e.t.c. However, it is brittle under impact and the resistance towards surfactants and solvents is very poor.

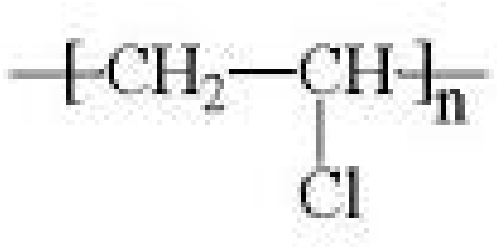
2.2.2 POLYMERISATION

Polymerization results when styrene monomers interconnect. In the polymerization one carbon-carbon double bond (in the vinyl group) is replaced by a much stronger carbon –carbon single bond, hence it is very difficult to depolymerise polystyrene.

2.3 POLYVINYL CHLORIDE-BRIEF HISTORY

Polyvinyl chloride was accidentally discovered on at least two different occasions in the 19th century first in 1835 by Henri Regnault and in 1872 by Eugen Baumann. On both occasions, the polymer produced could not be processed, because it was brittle and rigid. In 1926, Waldo sermon and B.F. Goodrich Company developed a method to plasticize PVC by blending it with various additives. This resulted to a more flexible and more easily –processed materials that soon achieved widespread commercial use. (The history of plastics)

The effects of plasticization are primarily those to be expected from the shift of the glass transition temperature (Tg). Dibenedtio.*et al* (1970) However in addition to the shift in the glass transition temperature, plasticizer produces other effects like flexibility and morphology of the films depending on their compatibility with the polymer. Malac *et al* (1969).Aiken *et al* reported that if a sufficient amount of plasticizer was used to shift the Tg below room temperature, the plasticizer did not exhibit the excessive flow or creep after being under load for a long time. Loss of plasticizer is a potential cause of the property deterioration in the weathering of flexible PVC compounds.



Scheme 2.4 Structure of Polyvinyl Chloride

2.3.1 POLYMERIZATION OF POLYVINYL CHLORIDE.

Polyvinyl chloride is produced by polymerization of vinyl chloride. Since a significant proportion of the mass is chlorine, a given mass of P.V.C require less petroleum than other polymer. Many of the vinyl products contain additives to change the chemical constituent of the products. Plasticizers must be added to make PVC flexible.

2.4.0 POLYMER WEATHERING.

Weathering refers to a variety of chemical reactions and physical processes which occur when macromolecules, either natural or synthetic, are exposed to outdoor conditions for an extended period of time. Guillet (1970) Extensive research over the past thirty or forty years has shown that for the great majority of synthetic macromolecules used as plastics and synthetic fibres, the most important degradative mechanism are associated with the absorption of ultraviolet light. Natural polymers on the other hand, although they also degrade by photochemical mechanism usually are more degraded biologically, that is by attack of micro-organism. Apart from ultra violet light, other environmental factors such as moisture, oxygen or pollutants such as sulphur dioxide, hydrochloric acid, ozone etc also have effects on degradation of polymer.

Natural weathering of polymers provides the most accurate information of the behavior of plastic, but it usually takes a long time to generate the information needed. In addition the results are highly dependent upon the geographical

location of exposure as a result of the climatic differences. One also has to consider how the orientation of the samples usually is exposed to the weather e.g. the direction and the angle of exposure. Natural weathering data usually is generated at various tests sites around the world with different climates.

2.4.1 MECHANICAL PROPERTIES OF POLYMER.

Mechanical properties of polymer involve its behavior under stress.

i. TENSILE STRENGTH: The tensile strength of a material quantifies how much stress the material will endure before permanent deformation, Ashby (1996). This is very important in applications that rely upon a polymer physical strength or durability. In general, tensile strength increases with polymer chain length and cross linking.

ii. PERCENTAGE ELONGATION: Elongation of a polymeric material is the percentage increase in length that occurs before it breaks under tension. Elongation is important in manufacturing – it measures how much bending and shaping can a polymer withstand without breaking.

iii. YOUNG'S MODULUS: It is the slope of stress-strain curve. Stress-strain curve often are not straight line plots, indicating that the modulus is changing with the amount of strain. In this case the initial slope usually is used as modulus. It can be used to predict how much a material sample extends under tensions or shortens under compression.

iv. TOUGHNESS: The toughness of a material is the area under a stress-strain curve. The stress is proportional to the tensile force on the material and the strain is proportional to its length. The area under the curve is then proportional to the integral of the force over the distance the polymer stretches before breaking. The integral is the work (energy)

required to break the sample. The toughness is a measure of energy a sample can absorbed before it breaks.

2.4.2 POLYMER BLENDING

Blending of polymers is the mixing of two or more homopolymer polymers together to produce a blend. This provides an efficient way of developing new materials with tailored properties. By blending different polymers, several properties can be improved, while retaining some original properties. Polymer blends are popular forms of producing new thermoplastic engineering materials and constitute rapidly changing field. The continuous pressure to reduce costs, improve productivity, quality and variety, and the uses of plastics in downstream processes has generated the research in polymer blends. Ching. (2001).This technique can be used to improve several properties desired while retaining some of the properties. For both the processor and the end user application, the use of blends and alloy technology allows the "customizing" of a polymer product to specific requirements, usually at a significantly low cost than synthesizing new materials. Xhanthos. (1988)

Polymer blends falls into three categories; miscible immiscible and partially miscible. Trantina and Nimmer (1994)

a) Miscible blends consist of a single polymer phase-two or more polymers that are completely soluble in each other. The mechanical properties are usually weighted averages of the properties of the two components.
b) Immiscible blends results from mixing two materials with little affinity for each other. The polymer with the smallest volume is usually a poorly disperse sections with little adhesion between the phases.

c) Partially miscible blends; some blends are neither completely miscible nor immiscible. These partially miscible blends show limited mutual affinity, but small amounts of one polymer are soluble in the other. The best properties of each blend may be combined, often without the challenge of developing a compatiblization mechanism.

2.4.3 PROCESS OF U.V DEGRADATION OF POLYMERS

All organic polymers are to a greater or lesser extent degraded upon exposure to sunlight. The process of degradation by light, either natural or artificial, is called photo degradation. Degradation under outdoor conditions including temperature and humidity effects is usually termed weathering.

UV-light is considered the most important component of the weather causing chemical changes. A photochemical reaction is possible when two conditions are met.

- The wavelengths of the incident light i.e. the energy of light quanta or photons) is such that, it can be absorbed by polymer molecules.
- The energy of the absorbed photons is sufficient to dissociate bonds in the polymer molecules. The first condition is met only if the difference between two energy levels which the molecules can occupy is equal to the energy of the photon. Secondly, dissociation of the molecular link occurs when the amount of the vibration energy reaches the energy of dissociation

Bond dissociation by the absorption of light, preceding the photodegradation processes, is called photoinitiation. Schoolenberg (1988)

The photo initiation of polyolefin's poses a problem because pure saturated hydrocarbon do not absorb light in this UV range, their photo initiation was attributed to UV absorbing impurities (chromophore). The photo initiation reactions are of primary interest because they are considered to be the key to a successful development of photo stabilizer

2.4.4. CHAIN SCISSION AND CROSS LINKING

Photo degradation alters the polymer's molecular structure and thereby changes its mechanical properties, the effect on the molecular structure are:

- Chain scission (breaking of polymer molecule)
- Cross linking (connection of two polymer molecule)

Chain scission results in a lower molecular weight causing a loss of ductility, and this is observed by a reduction of elongation and stress at rupture. The effects of extensive cross linking are a higher yield stress and Young's modulus. In most polymers, both chain scission and cross linking occur, but the chain scission reaction usually prevails after some time, and the main effect of photodegration in solid polymer is embrittlement. In polypropylene degraded by U.V- light, chain scission is dominant. Cross linking is highly observed, embrittlement occurs most rapidly and severe in crystalline polymers.

2.4.5. MOLECULAR MASS REDUCTION

The reduction of the molecular mass due to degradation was observed for many polymers, Ranby and Rabek (1976.) observed that the reduction of the molecular

mass is a phenomenon that is more directly related to mechanical deterioration than carbonyl formation. Carbonyl formation can also occur in reactions that do not cause main chain scission and thus do not cause embrittlement

2.4.6. PHOTOOXIDATION; A FREE RADICAL CHAIN MECHANISM.

There is general agreement that the oxidation process in polyolefin occurs through a free radical chain mechanism. Bolland proposed the reactions in Scheme 2.4, for thermal oxidation, and they are believed to be closely parallel to those in photooxidation. Scoolenberge (1988)

This reaction process is autocatalytic; the reaction accelerates itself. After the formation of a free radical by photoinitiation, propagation reactions follow. These are chain reactions which can involve many molecules in the process after only one initiation event.

Intiatiion	:P $\xrightarrow[\Delta]{H/hv}$ R' - - -	1.1
Propagation:	R'+ O_2 ⟶ RO'$_2$ - - -	1.2
	RO_2 + RH ⟶ ROOH + R- -	1.3
Branching	ROOH ⟶ RO' + OH'- -	1.4
	2ROOH ⟶ RO_2 + RO' + H_2O-	1.5
	RO' + RH ⟶ ROH + R'- -	1.6
	HO' + RH ⟶ R' + H_2O- -	1.7
Termination	:R' + R'- - - - -	1.8
	RO_2 + R - - - - -	1.9
	RO_2 + RO_2 - - - -	- 1.10

Scheme 2.5 Photooxidation of polyolefin.

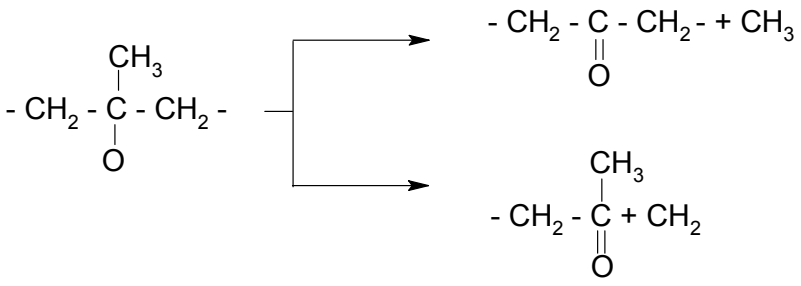
With the accumulation of hydroperoxide, the rate of branching (1.4-1.7) increases. Free radicals formed in (1.6) and (1.7) are new sources of hydroperoxide formation. (1.2 and 1.3). Termination reactions end the chain reactions, because inert products are formed. At some point the rate of destruction of the hydroperoxides exceeds the rate of formation, because termination reactions start dominating. Then the amount of hydroperoxide decreases. This is schematically shown in Fig. III.

2.4.7 PHOTODEGRADATION; CHEMICAL REACTION PROCESS IN POLYPROPYLENE.

The findings of Carlson and Wiles (1976) are referred for more detail information. First of all, the importance of hydroperoxides both as photoinitiators and in radical propagation are stressed. Hydroperoxide and peroxide group are always present in polypropylene due to thermal degradation during processing or storage.

Because the tertiary hydrogen is easily dissociated, tertiary peroxide will be formed in reaction 1.1

Alkoxy radicals are formed by 1.4 or by photo cleavage of the product formed by tertiary radical termination [1.10]The reaction taking place after the formation of the alkoxy radical give rise to the formation of the compound containing hydroxyl [-OH] and carbonyl [> C-O].The β-scission process [reaction 1.11 and 1.12 in structure 5] are example. Reaction 1.12 is the most important because it leads to scission of the main chain



….(1.12)

Scheme 2.6: Photodegradation of Polyoleifin

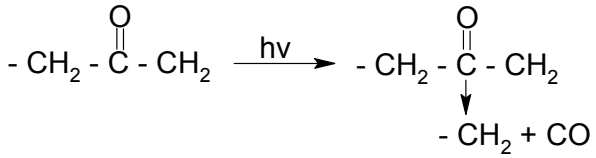
Carbonyl compound undergo photolysis by the so called Norrish reaction Scoolenberg. (1988). affirms that carbonyl compounds absorb U.V- light more efficiently than hydroperoxides. This causes a continuing controversy about whether hydroperoxides or carbonyl groups are the main photointiators. Some carbonyl groups will usually be present in polyolefins as well as hydroperoxides.

The Norrish type I process (1.13), for the type a ketone formed by (1.11) yields free radicals and causes chain scission, but has low quantum efficiency. It was that most ketonic species will be in the polymer backbone in polypropylene. In that case the two adjacent macro radicals formed in [1.13] will probably recombine before the initiation of oxidative chain can occur by O_2 interception, so the process cannot be important in photoinitiation.

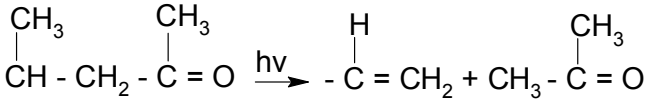
The Norrish type II process has higher quantum efficiency but does not yield free radicals. According to Ranby and Rabek (1976) (who at that time still accepted carbonyl groups to be important photoinitiation in polypropylene) it occurs manly in the type of ketone formed in reaction (1.12), in which case it does not lead to additional chain scission.

Because no free radicals are formed, this reaction cannot initiate chain reaction. Carbonyl compounds are therefore rather unimportant as

photoinitators in polypropylene and contribute to the degradation process only after prolonged exposure when large quantity of them has been formed.



……(1.13)



…… (1.14)

Scheme 2.7 Norrish reaction of carbonyl photolysis

CHAPTER 3

MATERIALS AND METHODS

3.2.1 MATERIALS AND EQUIPMENT.

MATERIALS.

I. Polypropylene (virgin)

II. Polypropylene (Recycled)

III. Polyvinyl Chloride chips and

IV. Polystyrene chips.

EQUIPMENT

I. Triple beam balance (700 series).

II. Agglomerator,(Model no 4600)

III. Palletizers.

IV. Two roll-mill.(Model no 5185)

V. Mechanical heat press.(Model no D288)

VI. Particle board.

VII. Hundsfield Tensometer.

3.2.2 PREPARATION OF THE SAMPLES

The virgin polypropylene was obtained from Orlon manufacturing, U.S.A

The wastes that was recycled comes mostly from the extrusion film making machine (Prandi) and other film cutting and trimming machines at Domino development Limited, along Zango Road, Dakata, Kano. The waste collected was fed into agglomerator machine to melt the films into crumbs with the help of heat and stirrer, the temperature of the machine was set at 165^0C. The polymer crumbs were then taken to crusher which is made up of a motor, hopper

and crushing blades. The motor drives the crushing blades inside the hopper to produce a fine particle of reasonable size good enough for the palletizer machine. The palletizer then converts the polymer fine particle to chips form. The machine was made up of extruder, cooling water bath and knife edge.

The virgin and the recycle polymers were now in chip form.

3.3 FORMULATIONS OF SAMPLES.

Twenty three samples were prepared in the following percentages, using three different polymers; Polystyrene (PS), Polyvinyl Chloride (PVC) and Polypropylene virgin (PPv) to the recycled polypropylene (PPr)

FORMULATION 1

TABLE 3.1 Percentage composition of blends of recycle Polypropylene (PPr) and Virgin Polypropylene (PPv)

PPr	PPv
0	100
10	90
20	80
30	70
40	60
50	50
60	40
70	30
80	20
90	10
100	0

TABLE 3.2 Percentage compositions of blends of recycle Polypropylene with Polyvinyl chloride (PVC} and polystyrène (PS)

PPr	PVC,PS
0	100
20	80
40	60
50	50
80	20
100	0

The samples were processed on two a roll-mill machine at the Federal Institute of Chemical and Leather Technology, (CHELTECH). Zaria (M/C No 5185).The machine produced homogenous mixture of virgin and recycle material as formulated above. The machine is made up of two rollers and a collection tray. The temperature of the machine was set at 160-165^0 C



Plate 3.1. Two-roll-mill machine

3.4 PRODUCTION OF FILMS

The films were produced using the heat press machine (Moore Birmingham S/No D 288) at the Polymer laboratory in the Department of chemistry, Ahmadu Bello University, Zaria. For each formulated samples, ten samples of 1 gramme each were heat pressed to produce a thin film of 7cm & 7cm of about 20 microns. The process of film formation involves placing the sample (1 gm) at the centre of the prepared flat mould; this will prevent the polymer from flowing outside the mould. The pressure arm was lowered with force to allow both the upper and lower mould housing the sample to get contact with the heater. This was carried out at temperature of 165 + 2^0C. The polymer was preheated for 1 minute to allow softening and flowing at zero pressure and then moulded under a pressure of 10 tonnes for 2 minutes.



Plate 3.2. Hydraulic heat press machine

3.4.1 ENVIRONMENTAL EXPOSURE

The prepared film was cut into equal dimension of 5cm x5cm and mounted on a neatly prepared particle board. The outdoor weathering of the films was carried out by exposing the films in an open air at the Fire Service Training School field from May-August, 2010. The field station is situated at Dakata, 10km north of Kano, on latitude $9^0$21 N and longitude 8^0 3 E. The positions of the film were rotated so that they face the direction of the sun always. The daily temperature between this period varied between 23^0 C – 40^0C in May – August. The average relative humidity was 60% R.H during the period of exposure.



Plate 3.3. Film exposure particle board

3.4.2 METHOD OF MONITORING DEGRADATION

(i) Embrittlement Time

(ii) Evaluation of Mechanical properties of the polymer films. (Tensile tests, Elongation and Young's modulus.)

3.4.3 EMBRITTLEMENT TIME

The polymer films were tested at 24- hour interval for embrittlement, the test samples were bent through an angle of 180^0, the time taken for respective polymer to show signs of crumbling and flaking was recorded as the embrittlement time for the respective samples. Kolawole and Olugbemi (1985)

3.4.4 TENSILE TESTS

The tensile tests were carried out by using a Hundsfield Tensometer (S/No 3179). in the Strength of Materials and Heat Treatment Laboratory, Department of Mechanical Engineering, Ahmadu Bello University, Zaria.

The film sample for the test was 6cm long and 1.5cm wide, neatly cut with scissors from the film. The sample was placed between two claws of the machine with the guage length of 2.5cm long & 1.5cm width and force was applied gently in both directions with the aid of tension winder until the sample breaks. The force and extension were read from the machine and also on the graph paper provided.

CHAPTER 4

4.0 RESULTS AND DISCUSSION

Mechanical properties and other tests were carried out with films of the following blends

Recycled polypropylene /polypropylene virgin. (PPr/PPv)

Recycled polypropylene / polystyrene. (PPr/PS) and

Recycled polypropylene/ polyvinyl chloride. (PPr/ PVC)

The weight ratio ranging from 10:0 to 0:10. The following mechanical properties and tests were examined.

1. Ultimate tensile strength
2. Elongation
3. Young^{s} modulus
4. Embrittlement time

4.1 .0 TENSILE STRENGTH

The tensile strength measures the steady force required to break a specimen. The tensile test is used to produce a load – elongation curve, which was used to determine the ultimate tensile strength, breaking elongation, Young's Modulus and toughness.

Figs. 1-6, show that as the exposure time increases, the tensile strength decreases. This is due to degradation by chain scission undergone during continuous exposure, which leads to decrease in molecular weight and the quantity of entanglements that gives strength to the polymer. Also as the percentages of the virgin polymers increases in the blends, the tensile strength

increases this is due to the incorporations of virgin polymers in the recycled which improve some of the properties due to long chain of the virgin polymer. However, out of the three polymers blend studied, PS/PPr has the highest tensile strength irrespective of the percentage composition, followed by the blends of PPv and PVC.

Though the PS/PPr blends systems were considered partially miscible, because PS contains aromatic rings, while PP contains straight carbon chains of aliphatic kinds. Past studies by Wantinee. *et al* (2007), shows that at 20% or more of the PS in the PP blends shows a distinct and fine disperse morphology, which will produce high tensile strength as good disperse morphology increase the molecular weight and high crosslinking. The low tensile strength of PPr/PVC may be due to Immiscibility of the polymers which may require comptabilizers. However, Jianzhi. *et al.* (2006) in one of their works compared the mechanical properties of PP/PVC blends and PP/PVC/HBP (compatibilizer) the results shows that the tensile strength of the later is a little better than the former. This means that the blends of PP/PVC without comptabilizer can produce a reasonable good tensile strength.

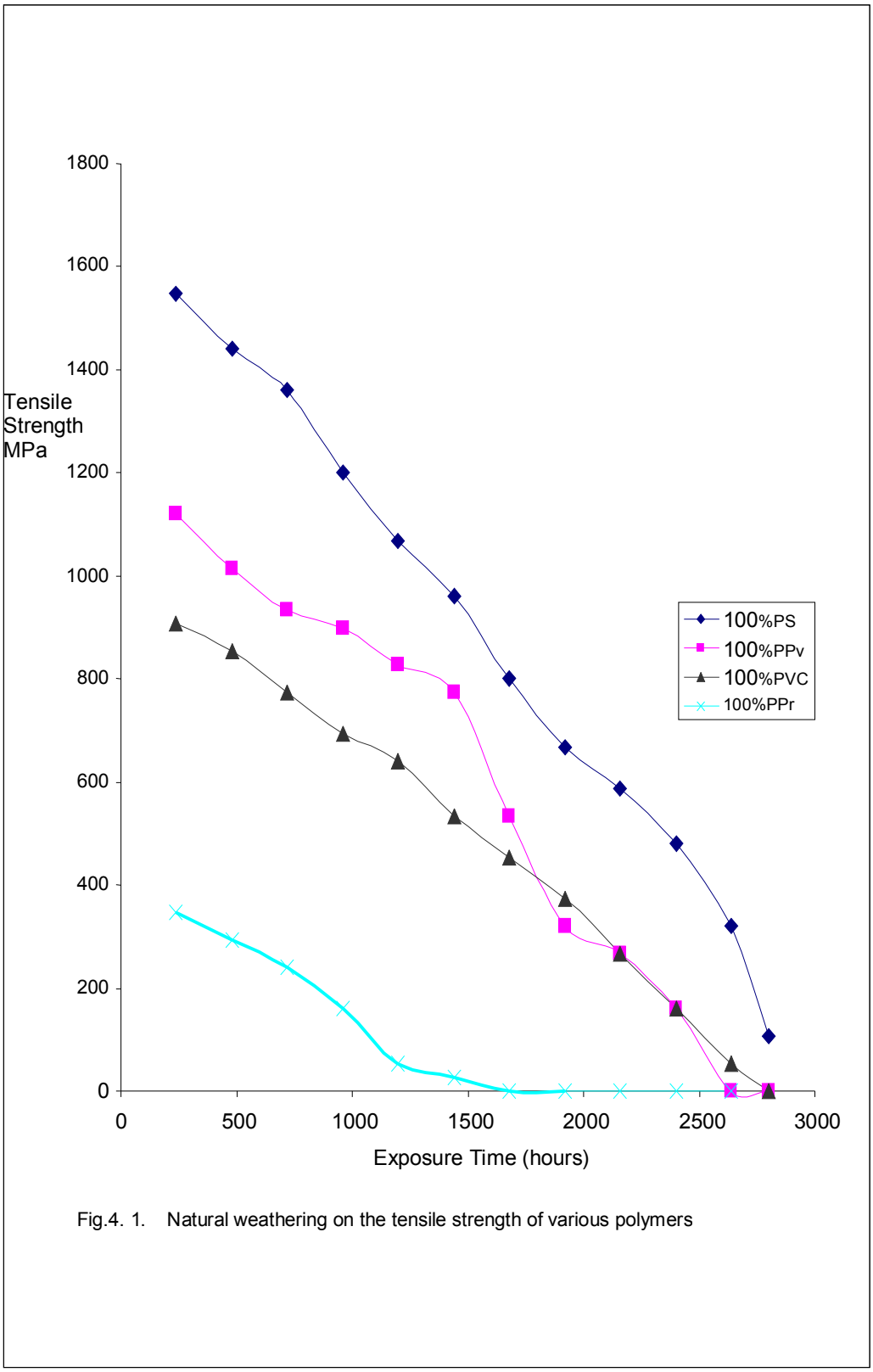


Fig.4. 1. Natural weathering on the tensile strength of various polymers

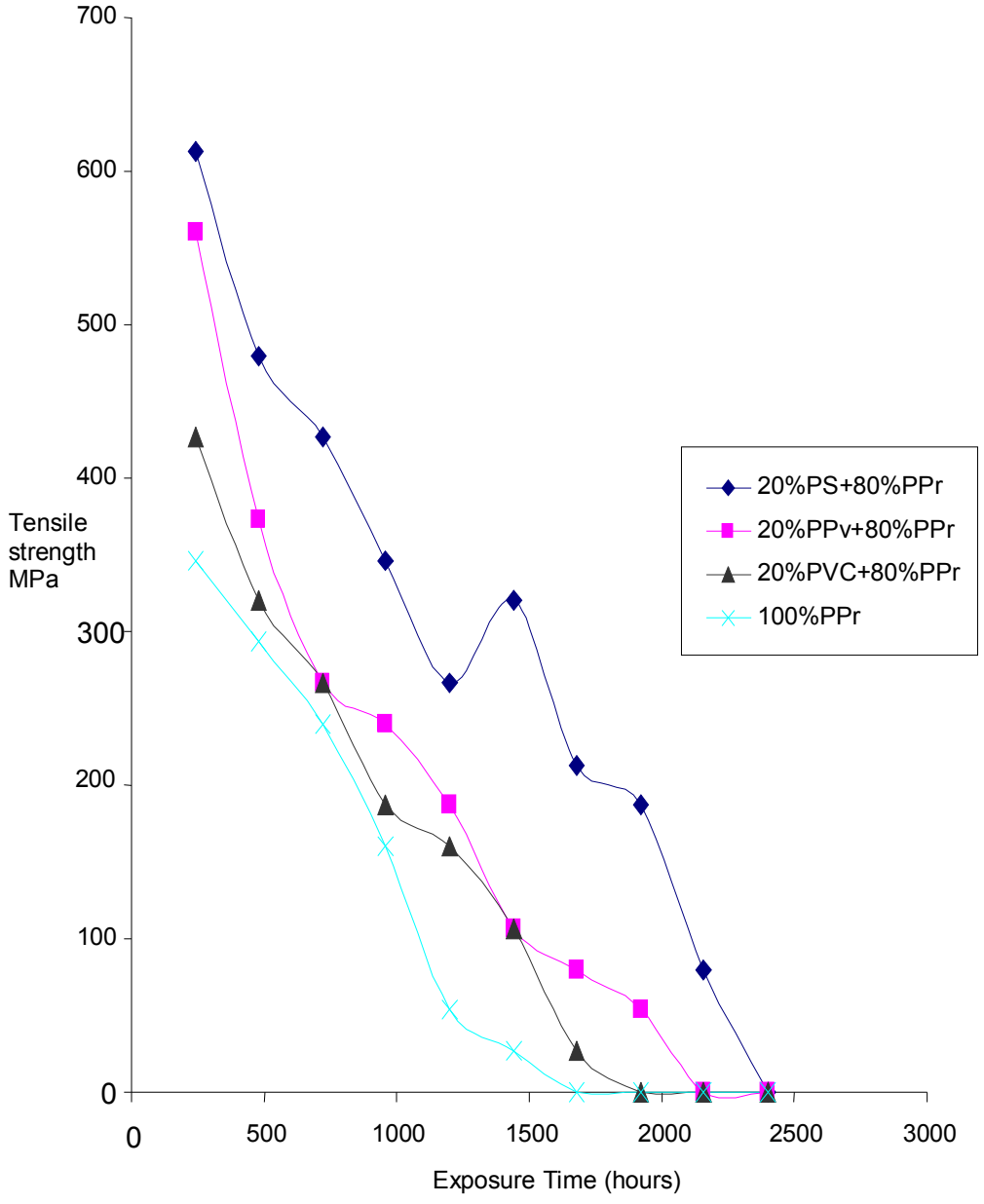


Fig.4. 2. Natural weathering on the tensile strength of various polymers.

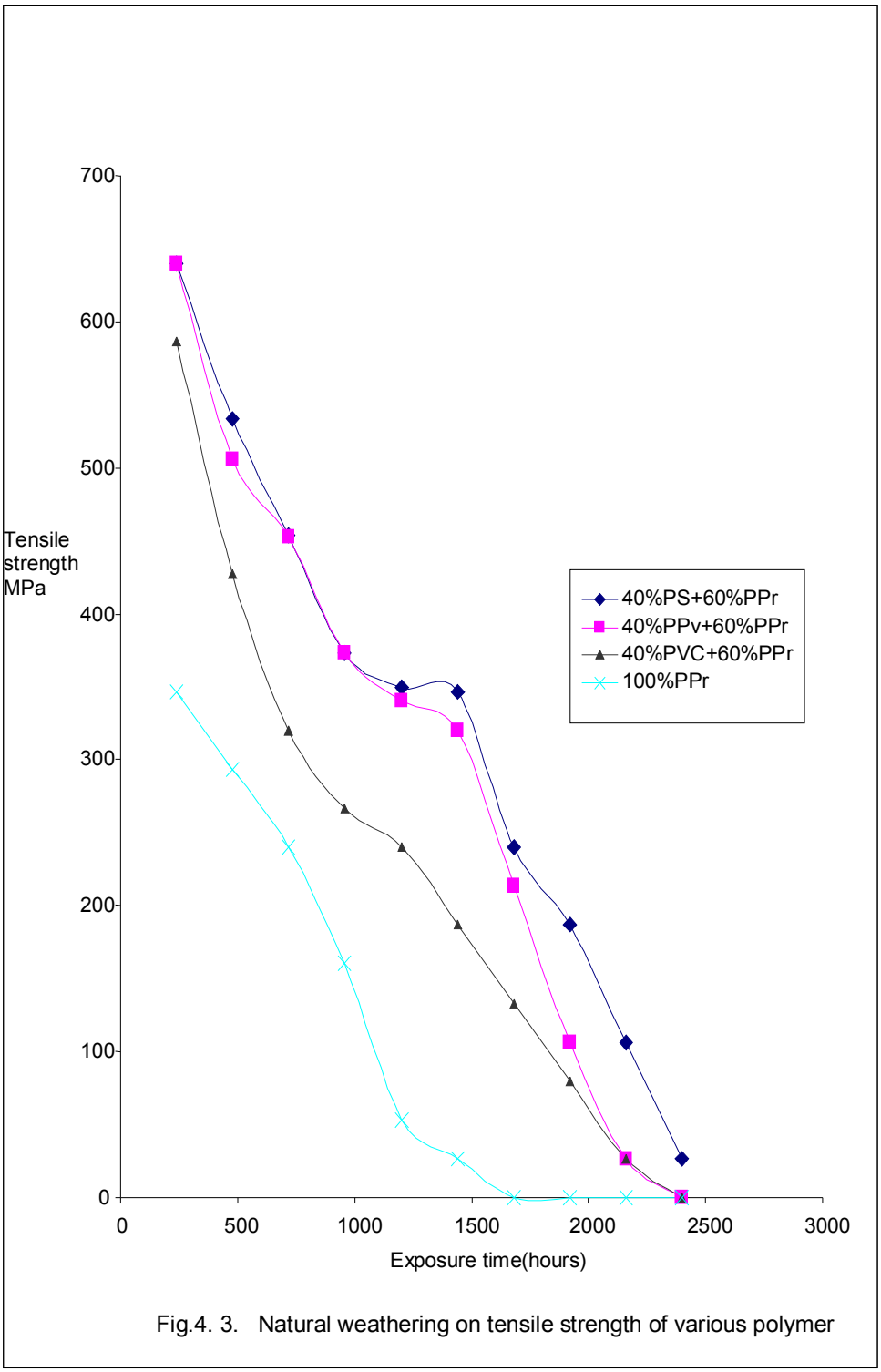


Fig.4. 3. Natural weathering on tensile strength of various polymer

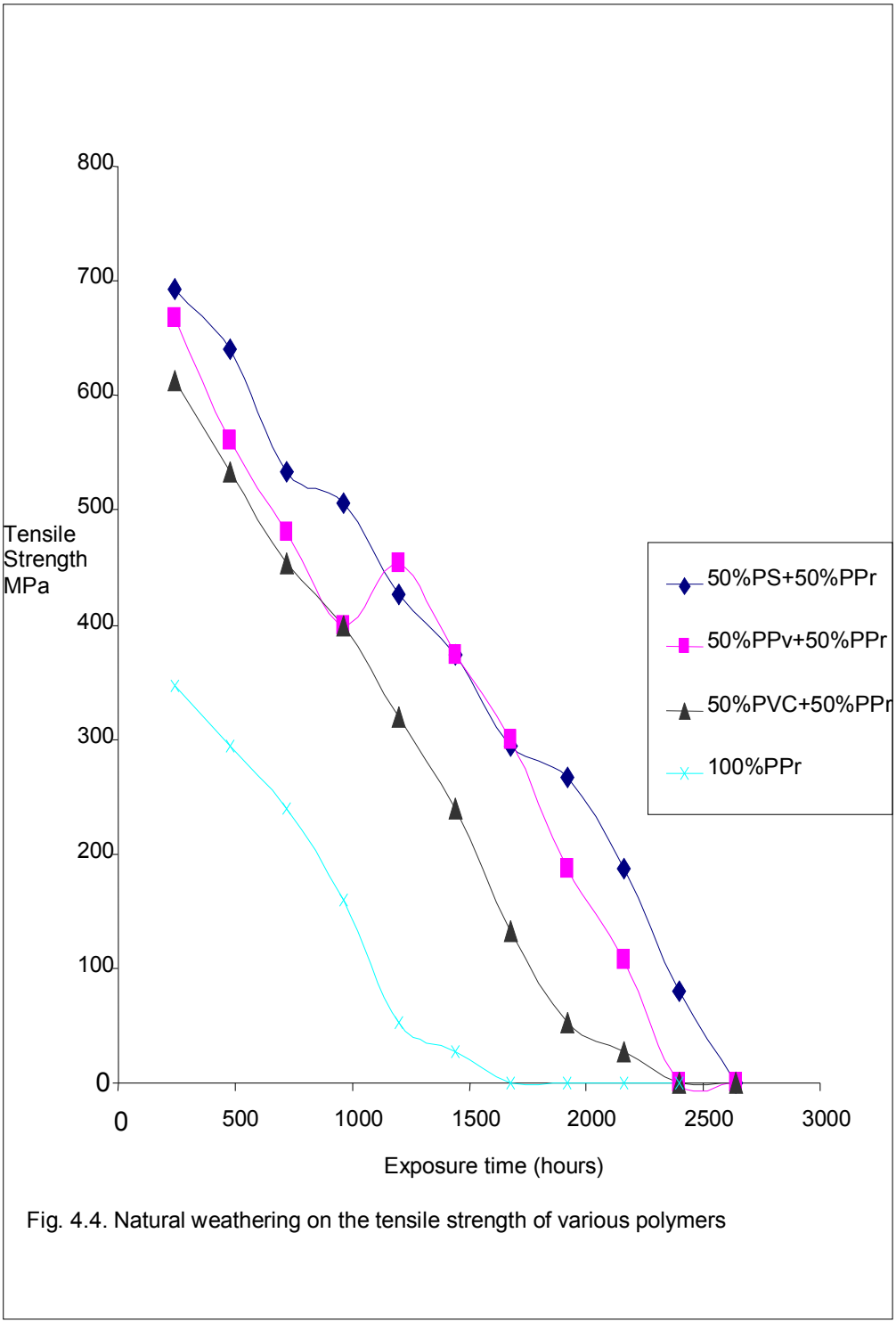


Fig. 4.4. Natural weathering on the tensile strength of various polymers

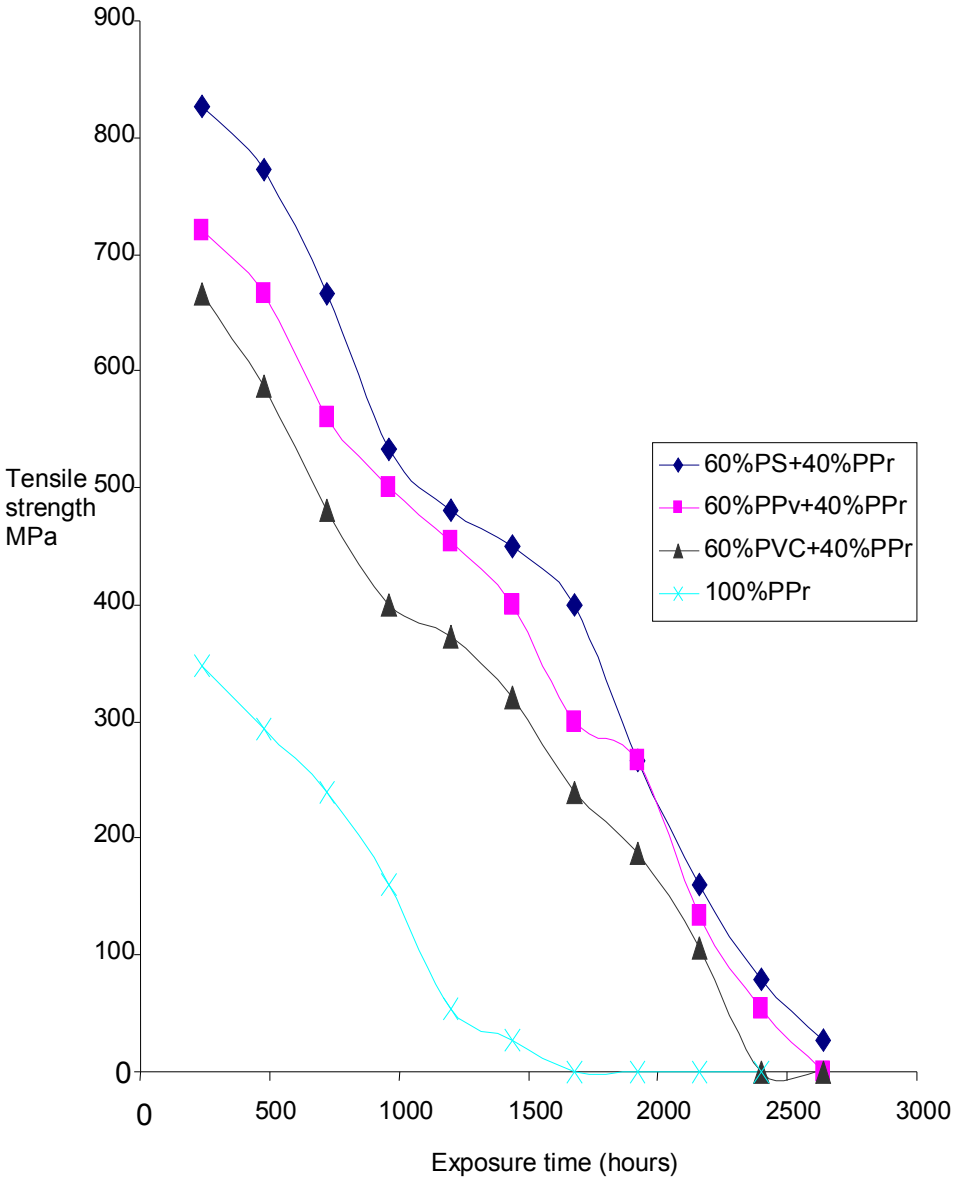


Fig. 4.5. Natural weathering on tensile strength of various polymers

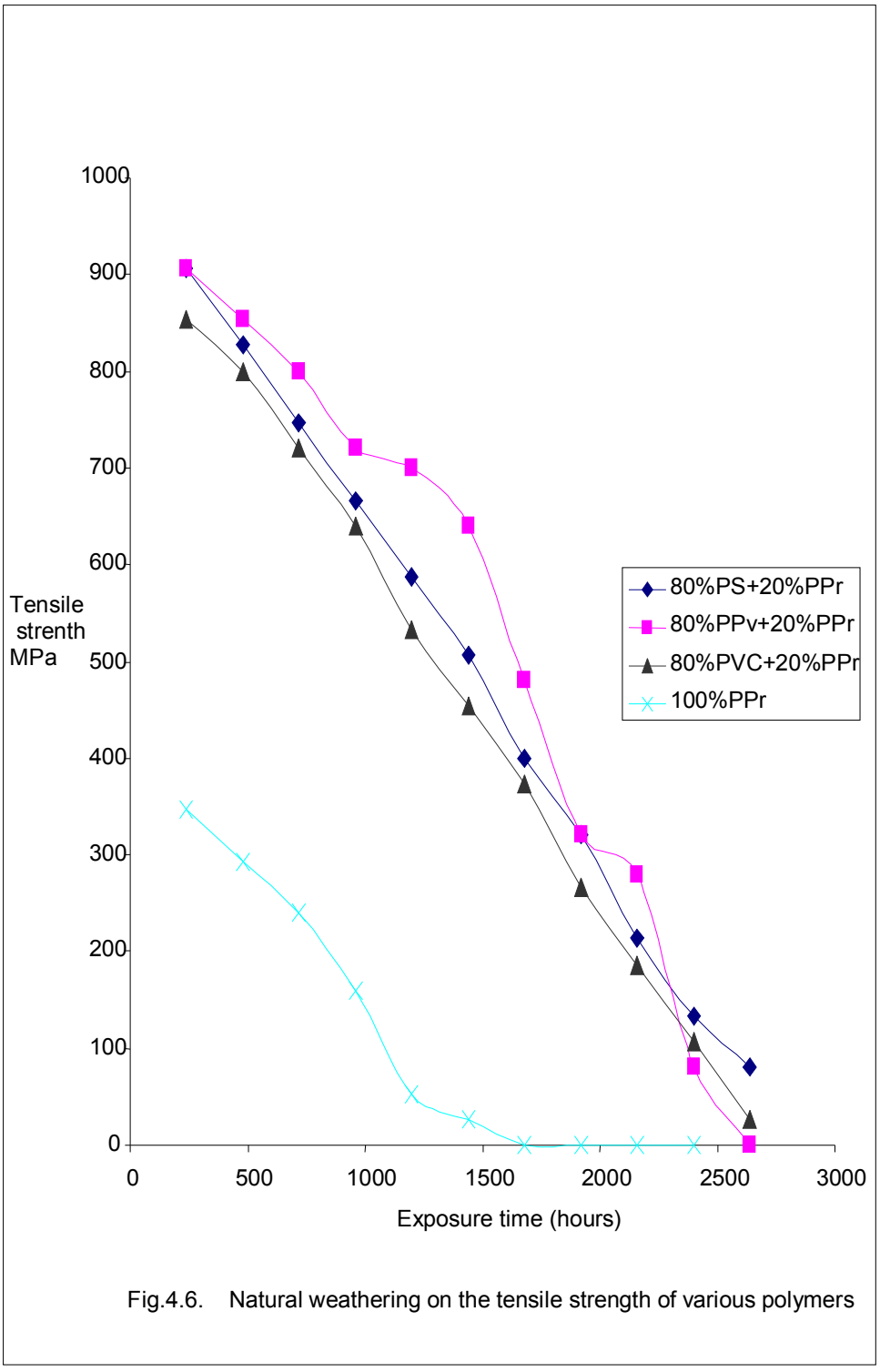


Fig.4.6. Natural weathering on the tensile strength of various polymers

4. 1.1 BREAKING ELONGATION

The breaking elongation of a polymeric material is the percentage increase in length that occurs before it breaks under tension. It may be expressed by actual elongation, Fractual elongation (strain) or the percentage increase in length. Elongation portrays the ease of change in the sample dimension on the application of load.

Figs.7-12 shows the graph of elongation vs the exposure time of homo-polymer and different percentage compositions. In all cases, as the exposure time increases the elongation decreases. This is due to cross linking which imposes restraints on the slippage and the extension of the molecular chains; hence large deformations are not possible unless the chain breaks.

From the Figs. 7-12, the followings were observed.

- As the percentage of PPr increases in the blends, the elongation decreases.
- As the exposure time increases, the elongation decreases for all blends.
- The blend of PPv/PPr produces the highest elongation.

The low elongation of PVC/PPr blends may be attributed to loss of the plasticizing effects, because of the plasticizer evaporation which leads to fusion in the polymer matrix or reduction in the interaction between the polymer matrix, this in turn causes rigidity or stiffness to the polymeric materials. The two other blends PPv/PPr and PS/PPr were considered to be miscible and partially miscible; hence better adhesion between phases is expected to produce a good elongation.

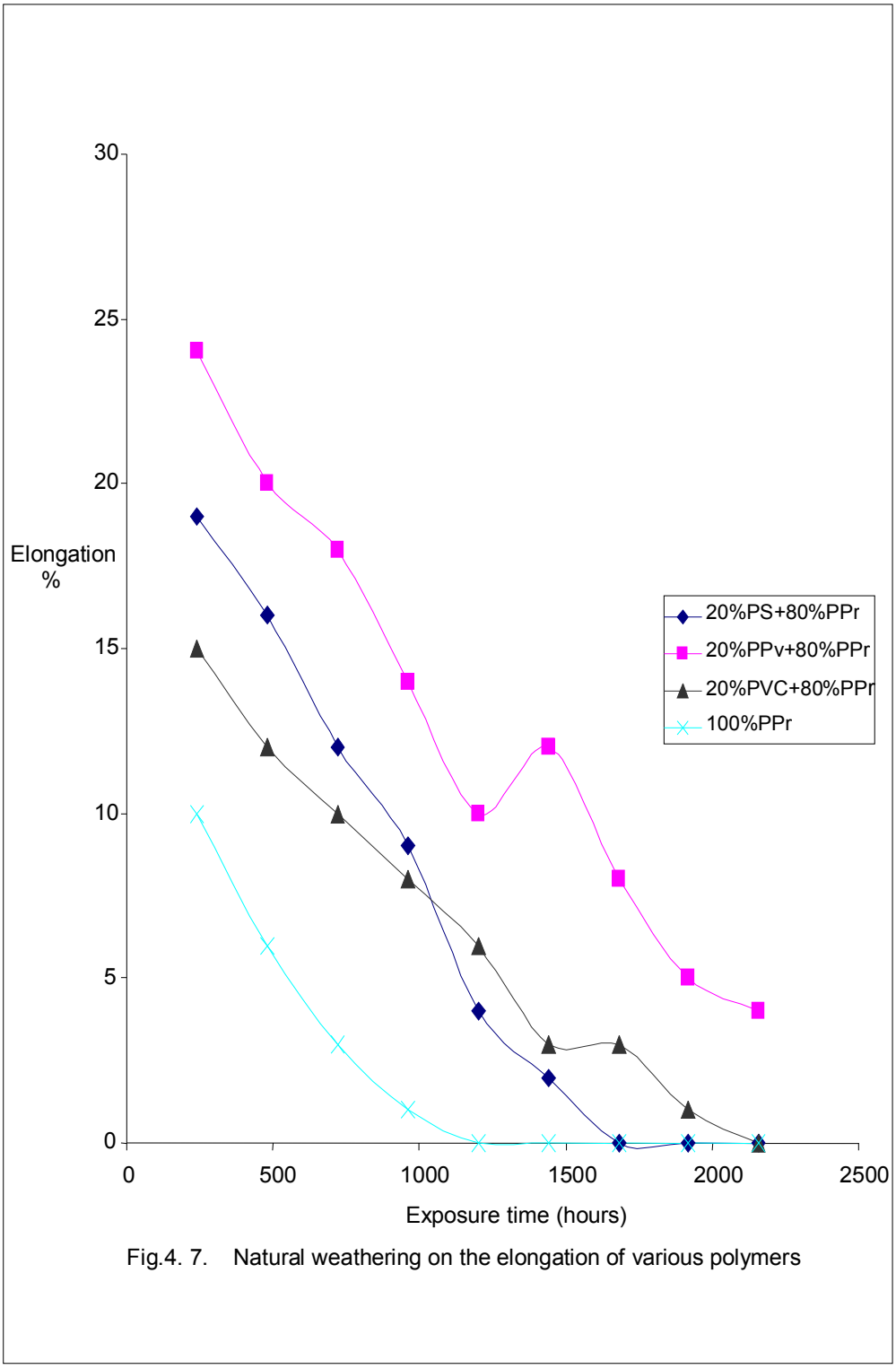


Fig.4. 7. Natural weathering on the elongation of various polymers

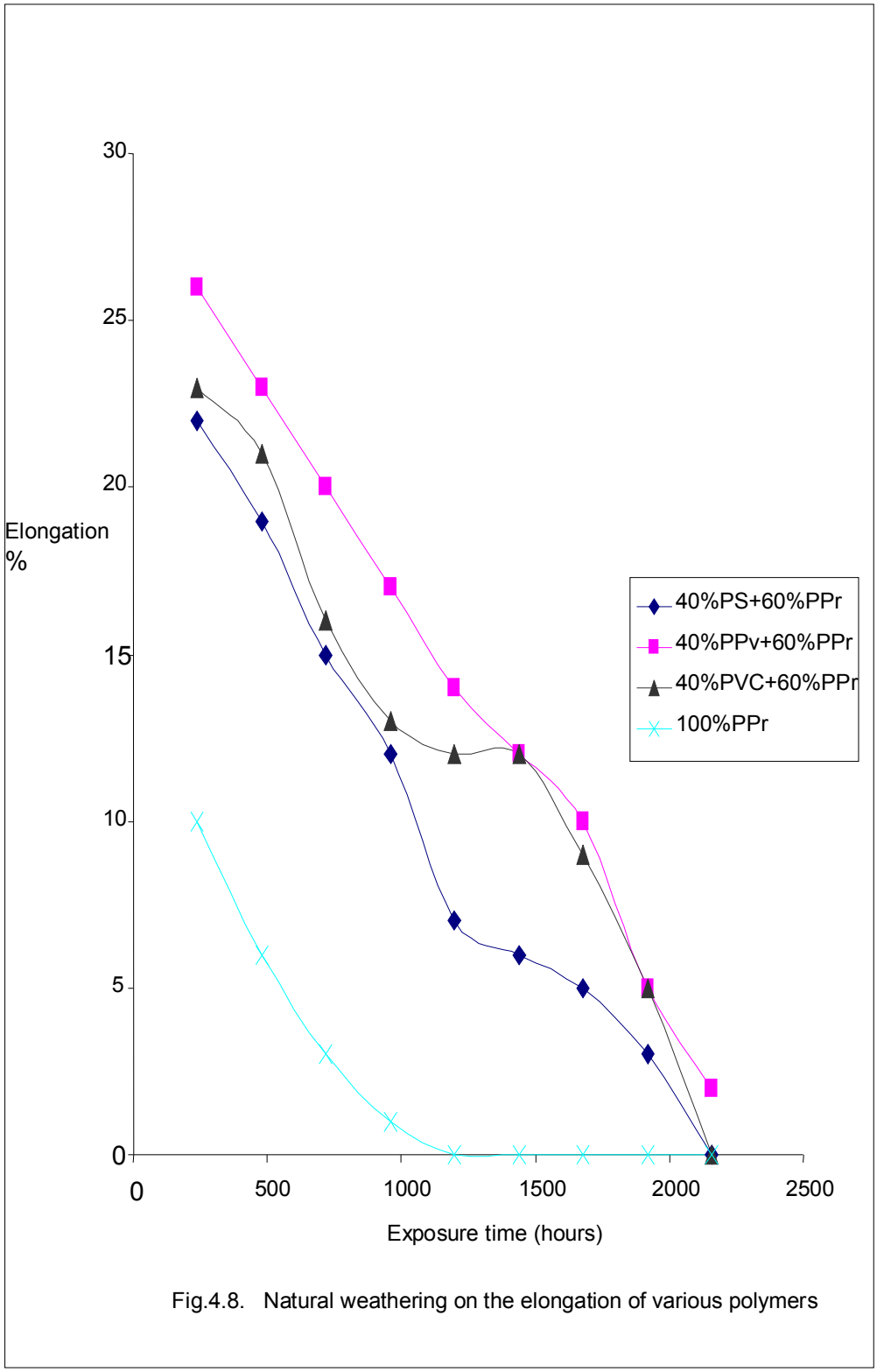


Fig.4.8. Natural weathering on the elongation of various polymers

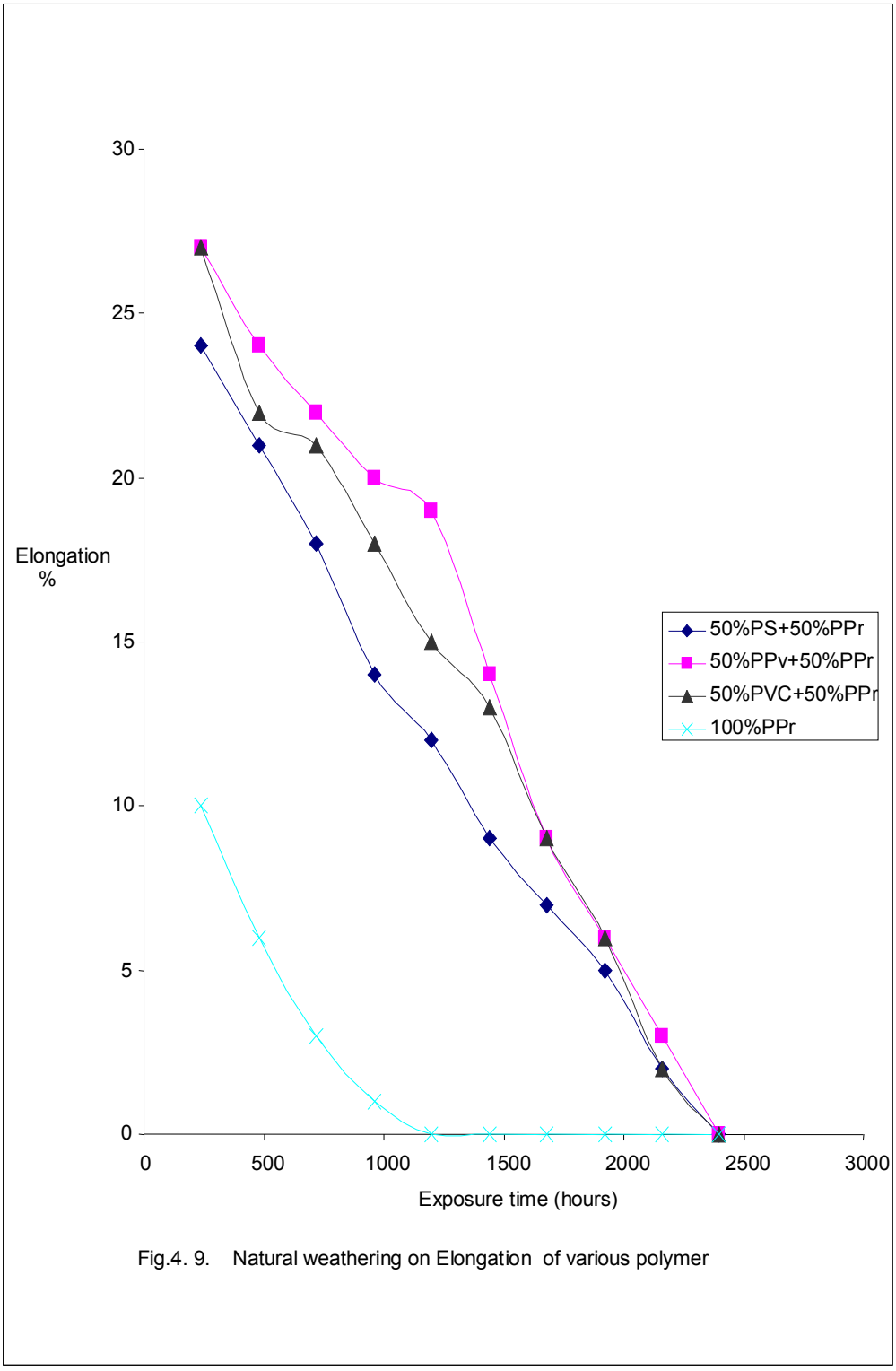


Fig.4. 9. Natural weathering on Elongation of various polymer

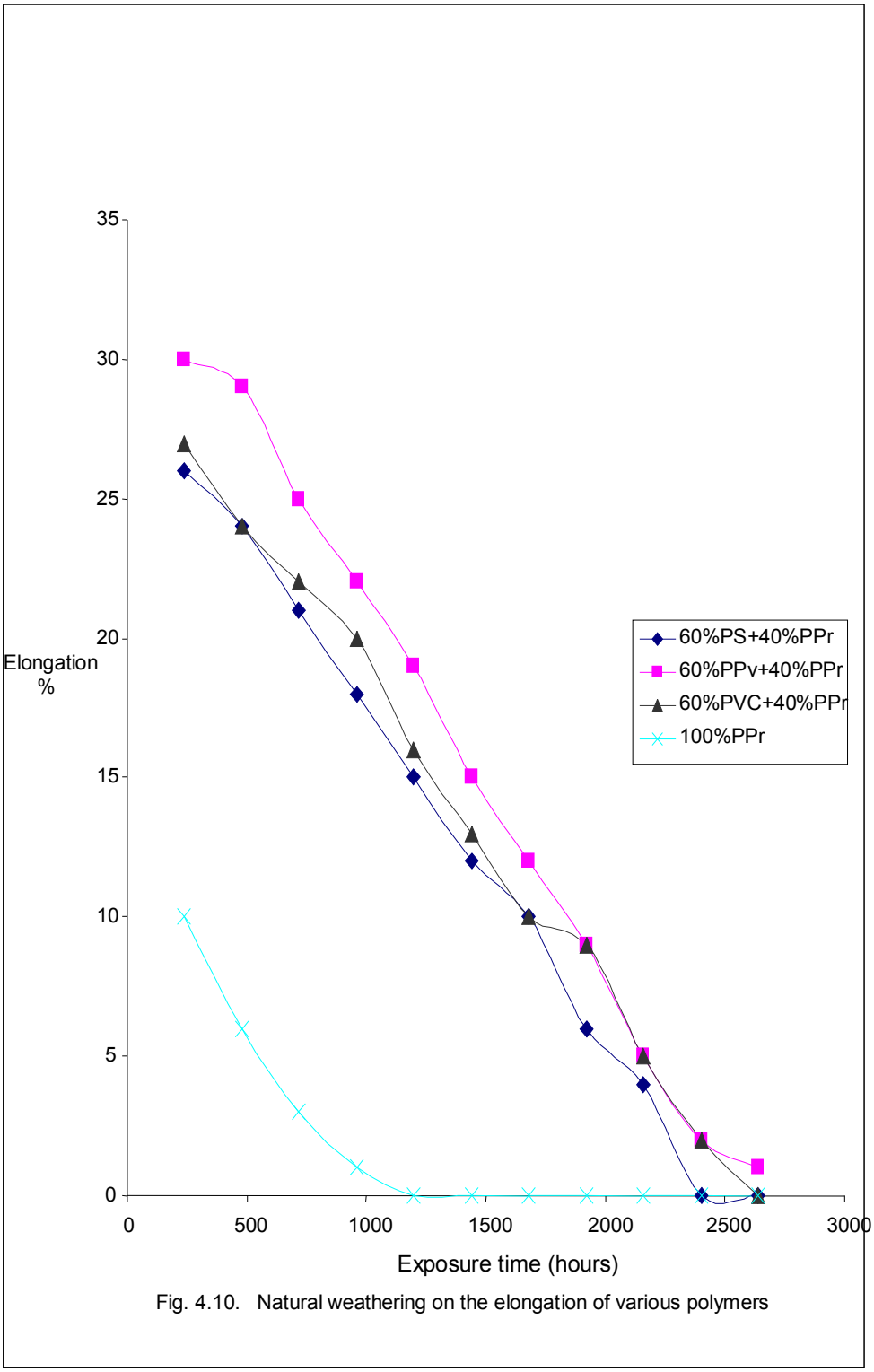


Fig. 4.10. Natural weathering on the elongation of various polymers

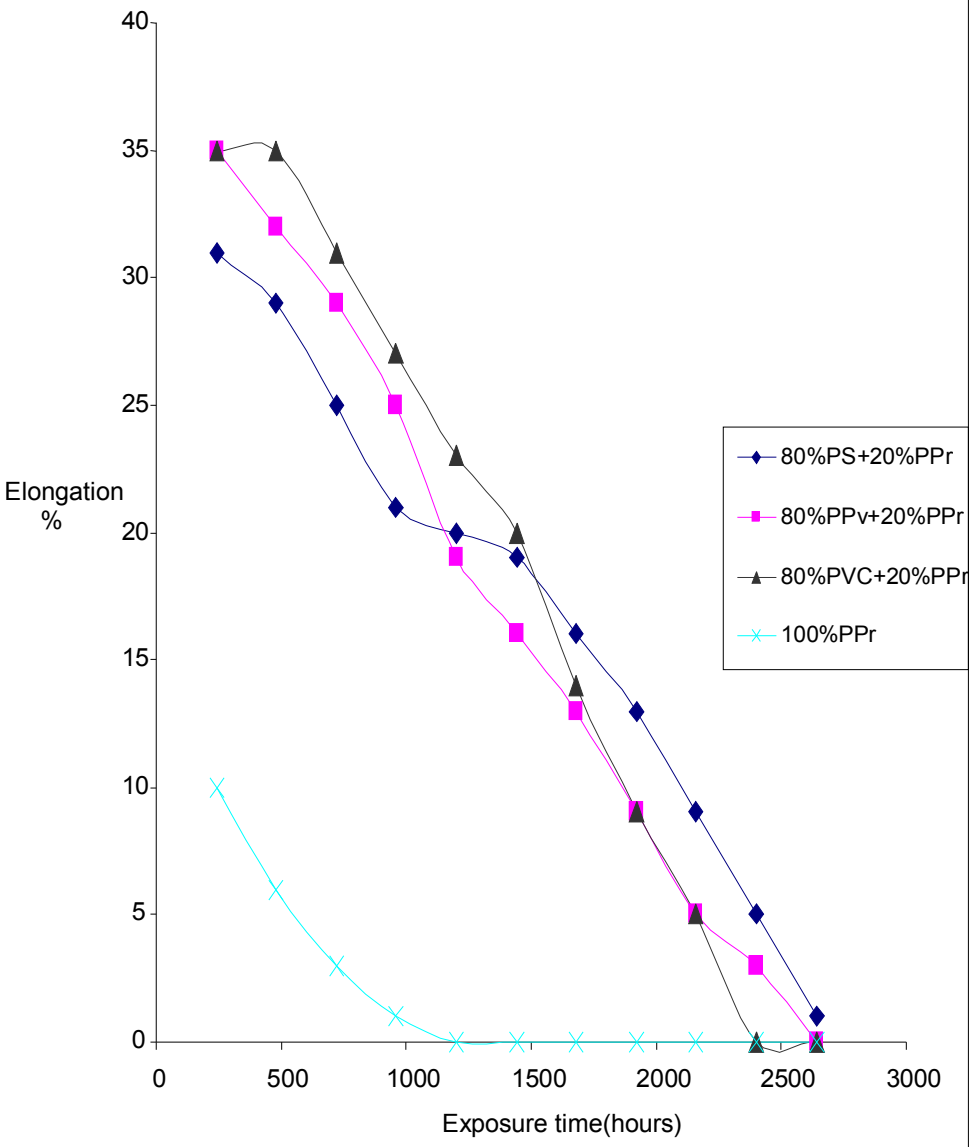


Fig. 4.11. Natural weathering on the elongation of various polymers

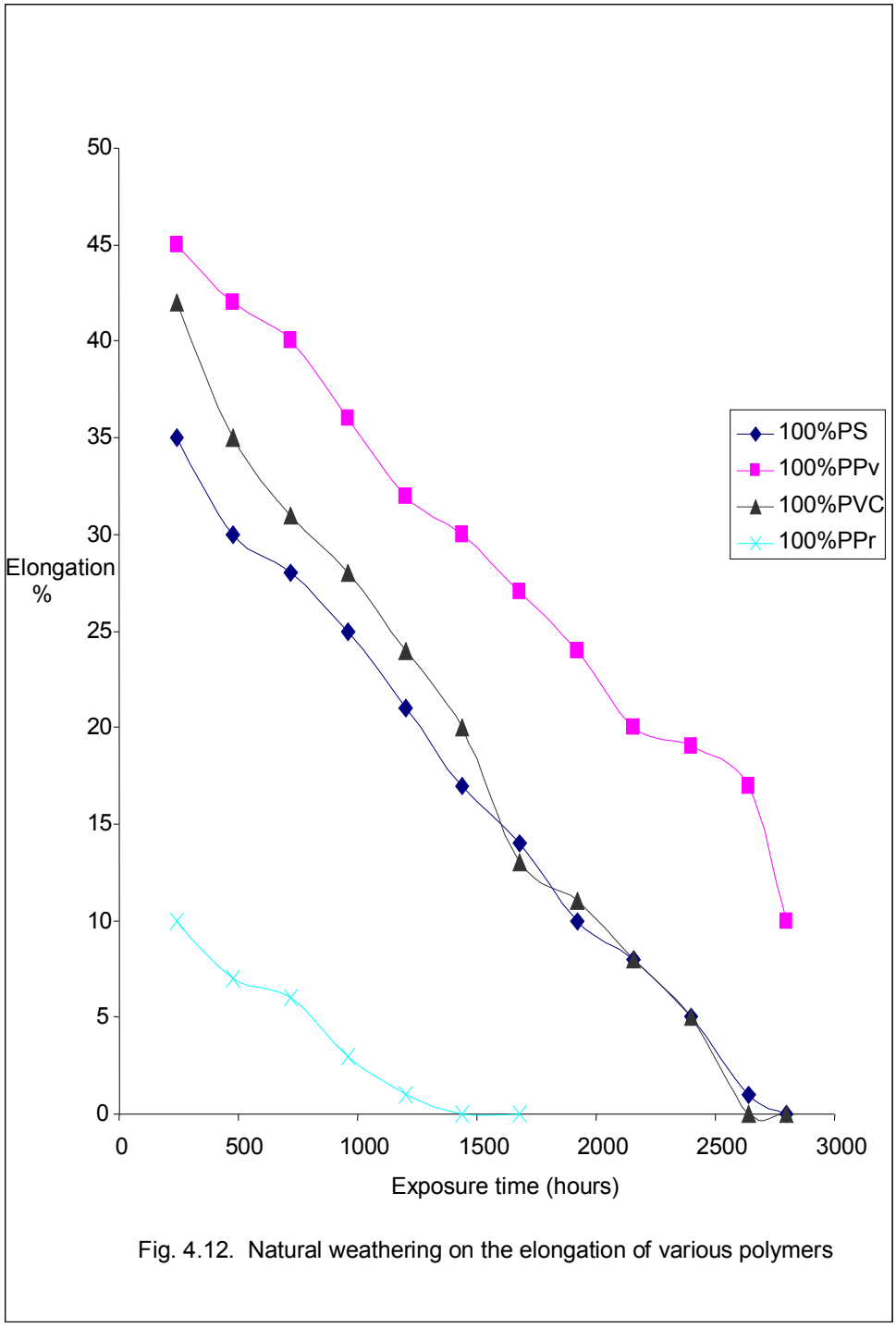


Fig. 4.12. Natural weathering on the elongation of various polymers

4.1.2 YOUNG'S MODULUS

This is an important dynamic property; it indicates inherent stiffness of a material under dynamic loading conditions. There are shear modulus, tensile modulus, or flexural modulus-depending upon the investigative technique. Modulus is a measure of interactive binding forces.

Figs. 13-18 show the relationship between Young's Modulus and the exposure time. The graphs did not follow a particular pattern, but what can be established is that between 0hrs and 1000 hours of exposure, there is progressive decrease in Modulus for all the blends. This is an indication of chain scission. Siman and Bopp. (1951) in one of their works reported that the most important chemical reactions leading to changes in mechanical properties of polymers during degradation are those involving chain scission and cross linking. Polymers under go Simultaneous scission and cross linking, but in most cases one or the other clearly predominates. In the case of the polymer blend samples, both scission and cross linking must have taken place at different stages of exposure. In general, the modulus of a flexible polymer undergoing predominantly cross linking increases whereas the elongation at breaks decreases. The material becomes stiffer, harder and eventually (at prolong irradiation) brittle. For flexible materials that that are initially not highly cross linked, the tensile elongation may in some cases increase with low irradiation, but drop sharply at higher doses of irradiation due to predominance of chain scission. Allen and Edge (1992) for flexible polymer materials undergoing predominantly scission, the Modulus, elongation and tensile strength typically decrease. Siman and Bopp (1951). Fig. 14 at 20:80 of any of the polymer samples in the blends produce the best result.

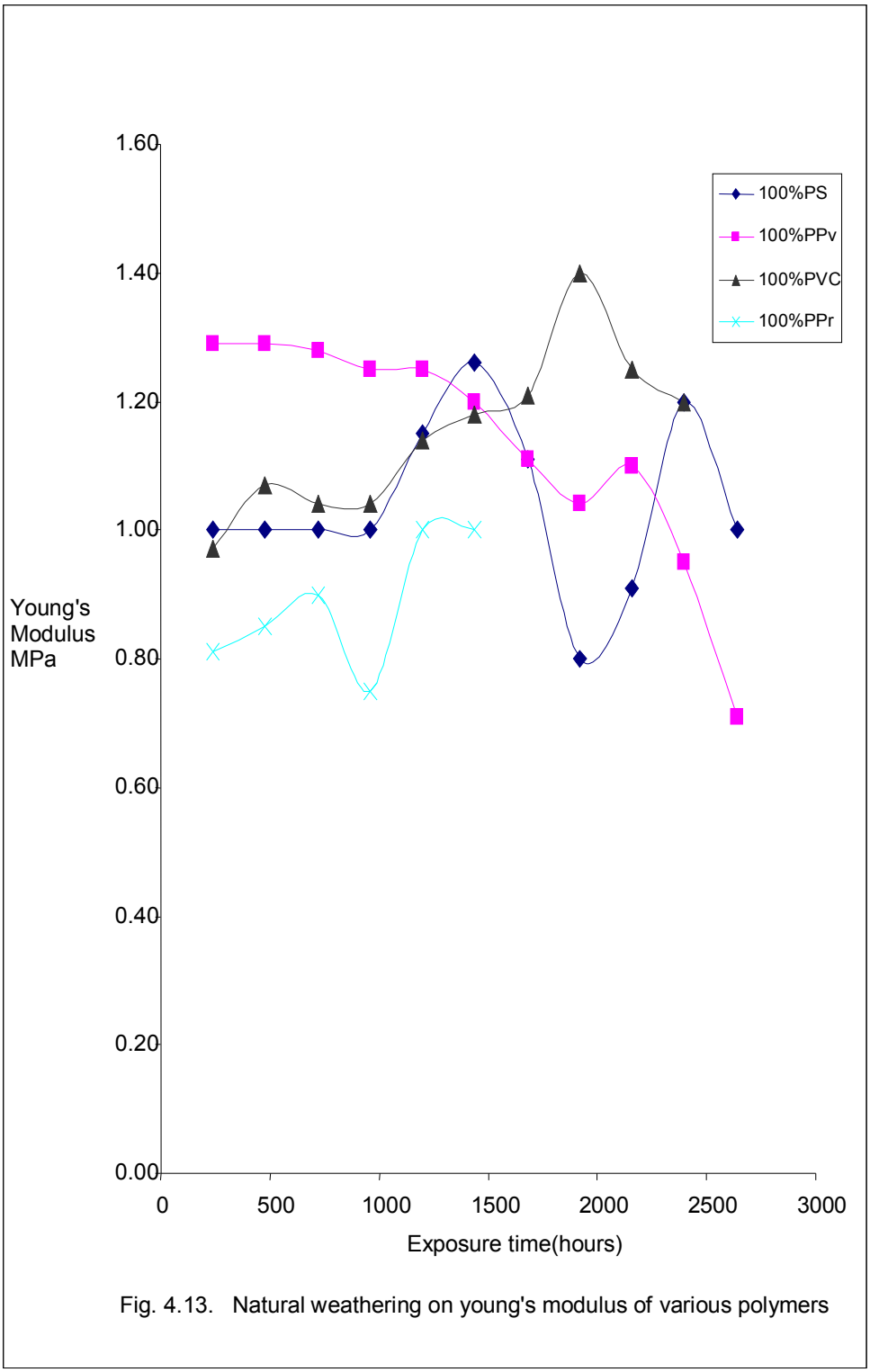


Fig. 4.13. Natural weathering on young's modulus of various polymers

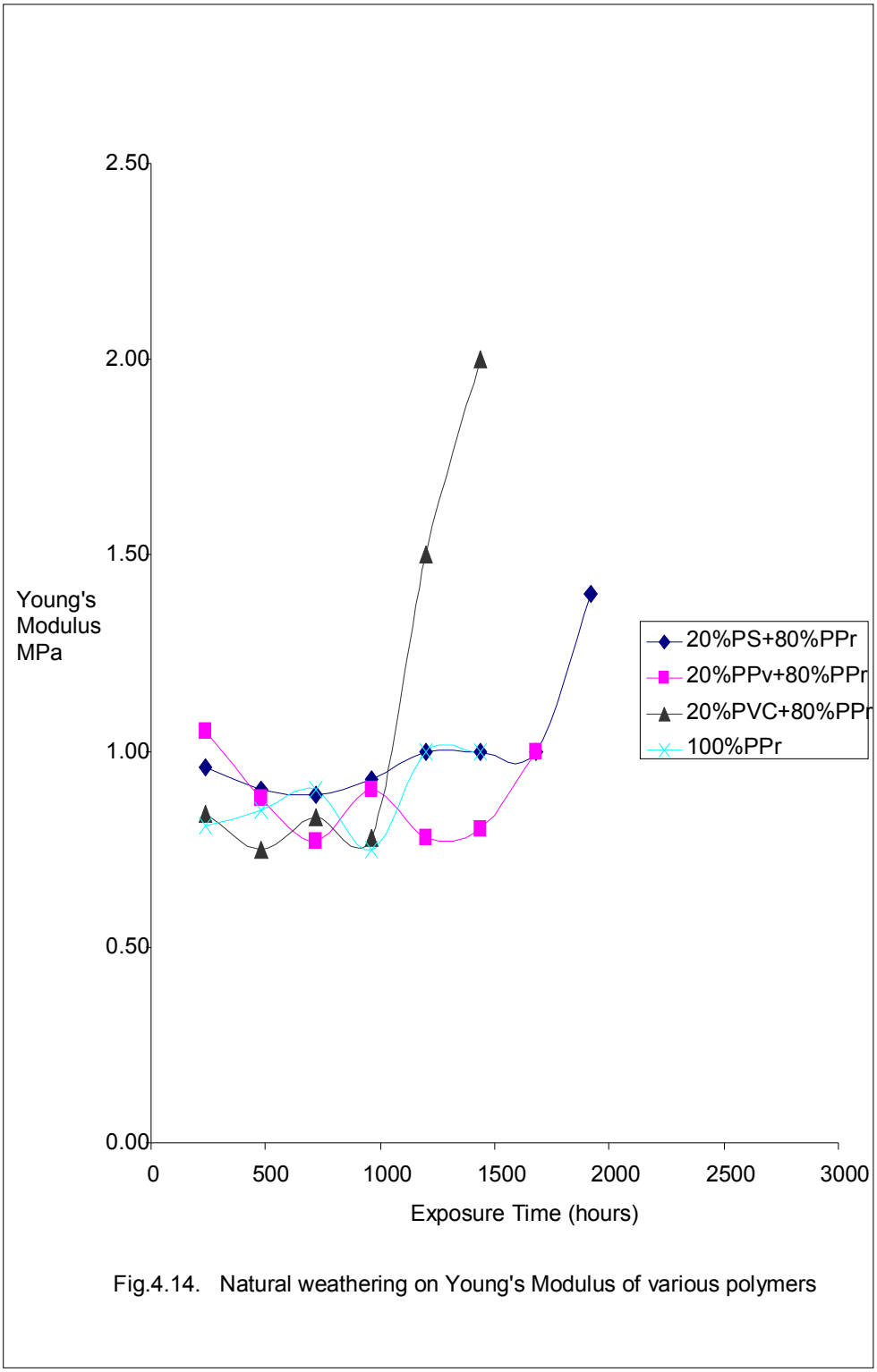


Fig.4.14. Natural weathering on Young's Modulus of various polymers

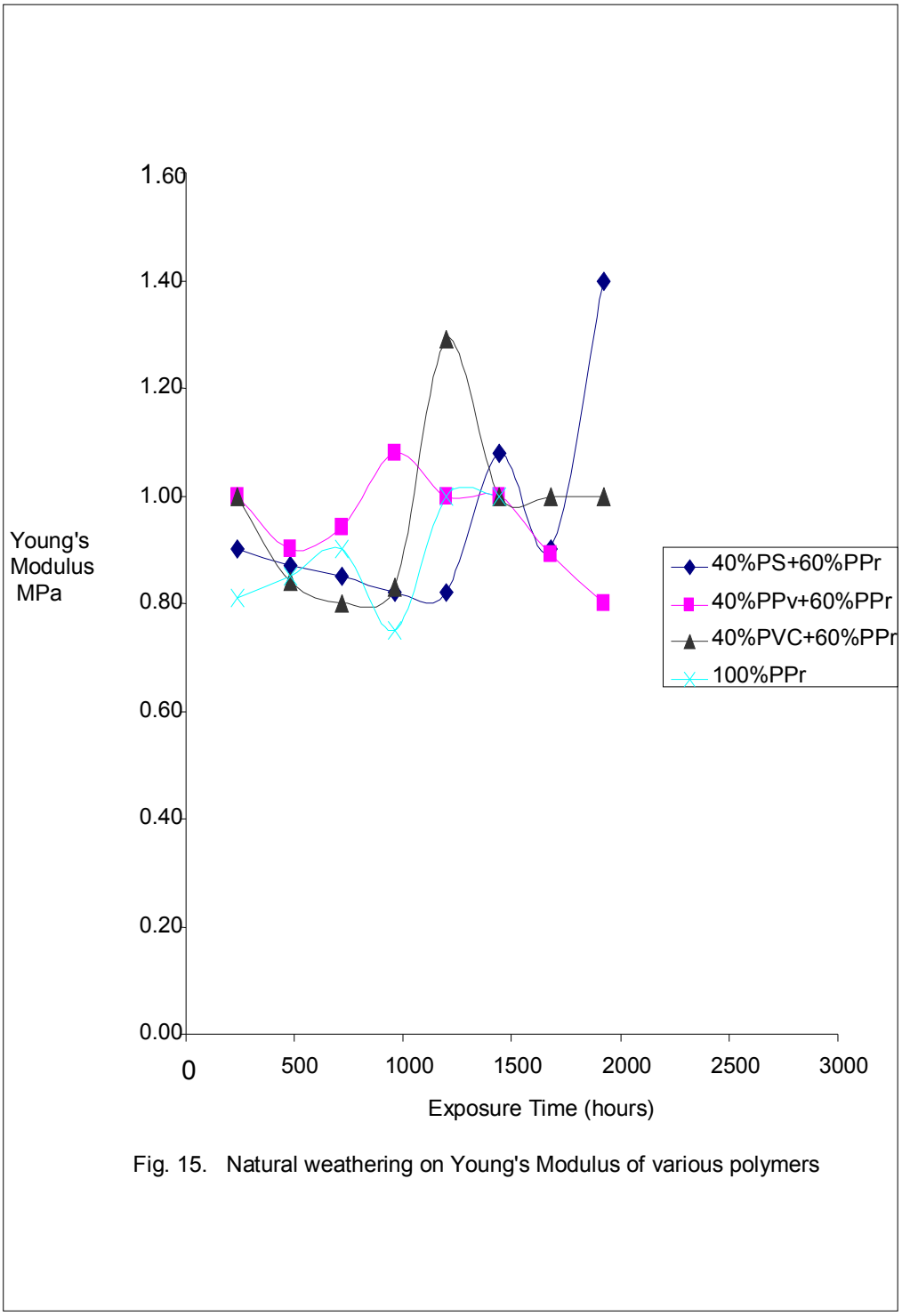


Fig. 15. Natural weathering on Young's Modulus of various polymers

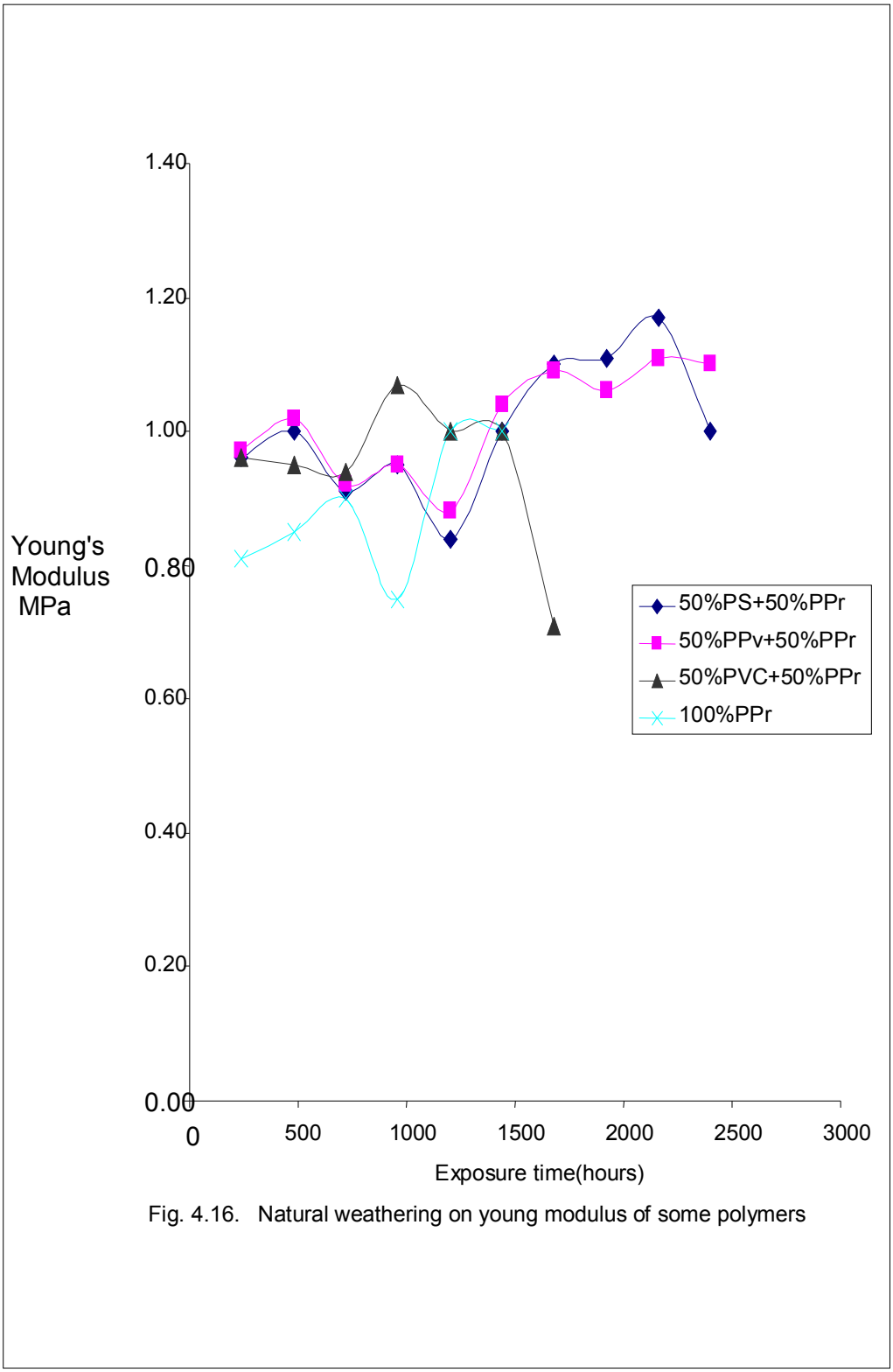


Fig. 4.16. Natural weathering on young modulus of some polymers

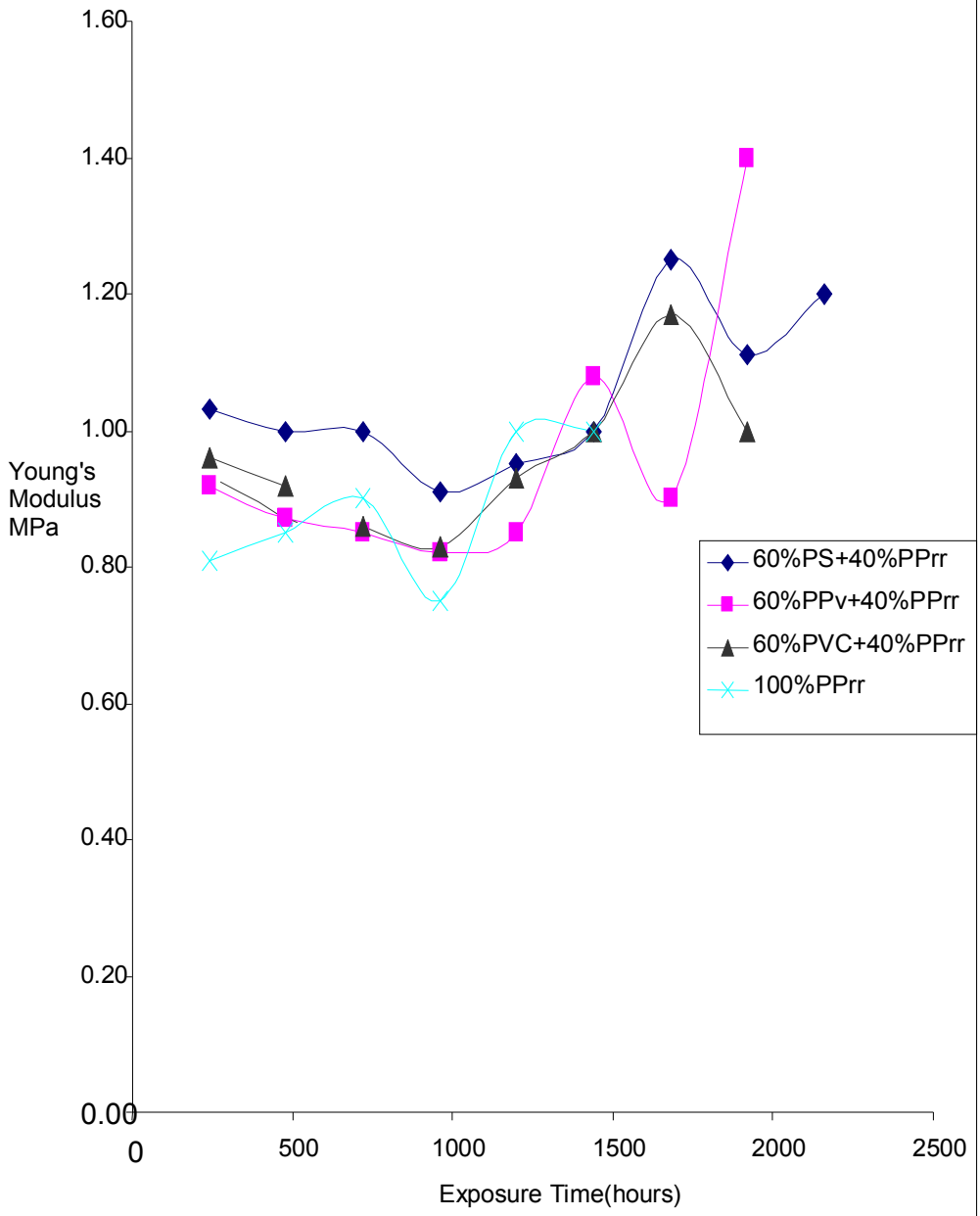


Fig. 4.17. Natural weathering on Young's Modulus of some polymers

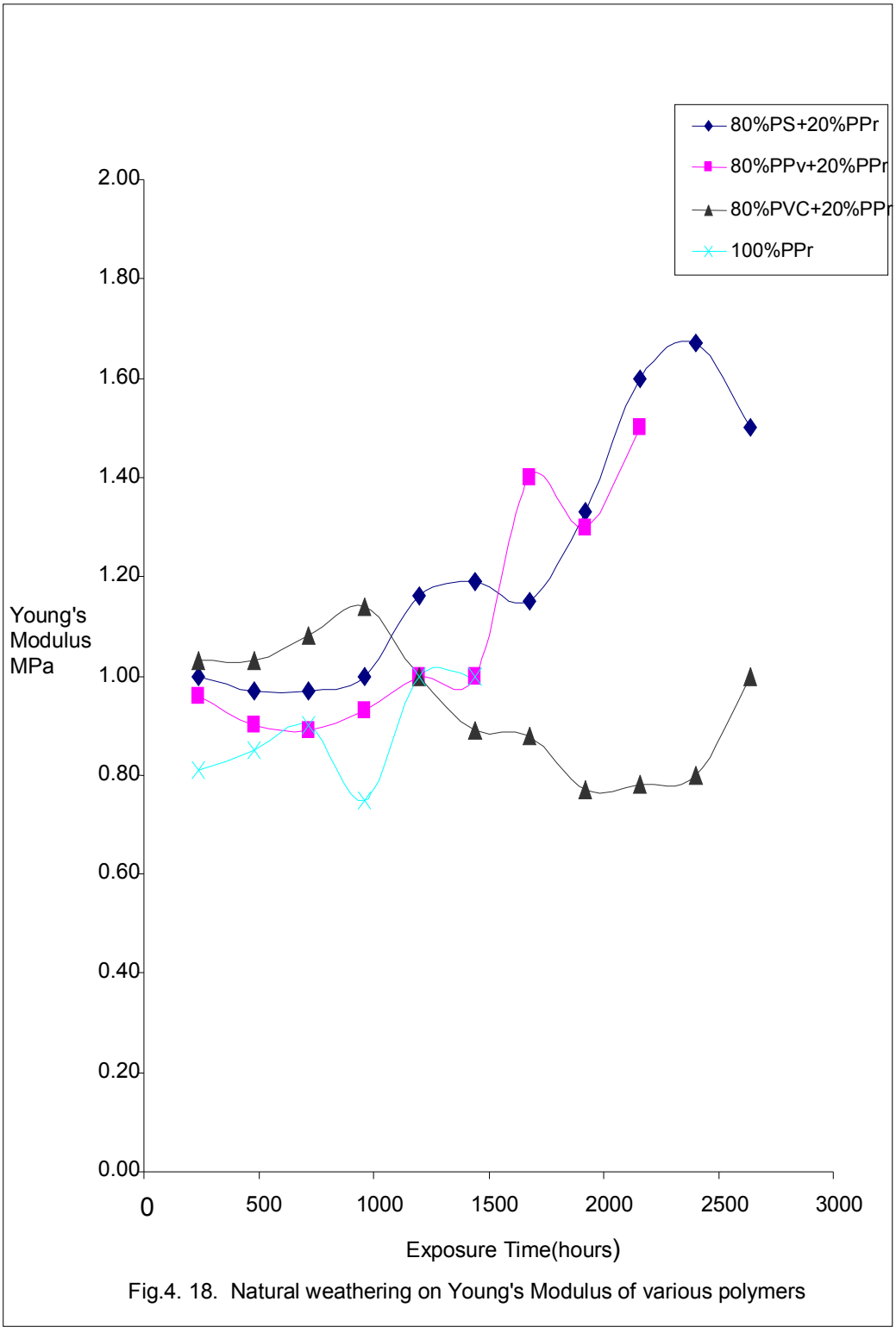


Fig.4. 18. Natural weathering on Young's Modulus of various polymers

4.4 EMBRITTLEMENT

Generally, when polymeric materials are exposed to weathering, such polymer will be attacked by heat, humidity etc. the molecular structure of such polymer will be altered (especially with u.v) thereby change its mechanical properties, the effects on molecular structure are; chain scission (breaking of the polymer molecule) and cross linking (connecting of two polymer molecule). Chain scission results in lower molecular weight causing loss of ductility; this is observed by reduction of elongation and stress at rupture. The effects of cross linking are high yield strength and young modulus. In most polymers both chain scission and cross linking occur, but the former usually prevails after some time and the main effect of photo degradation in solid polymer is weathering.

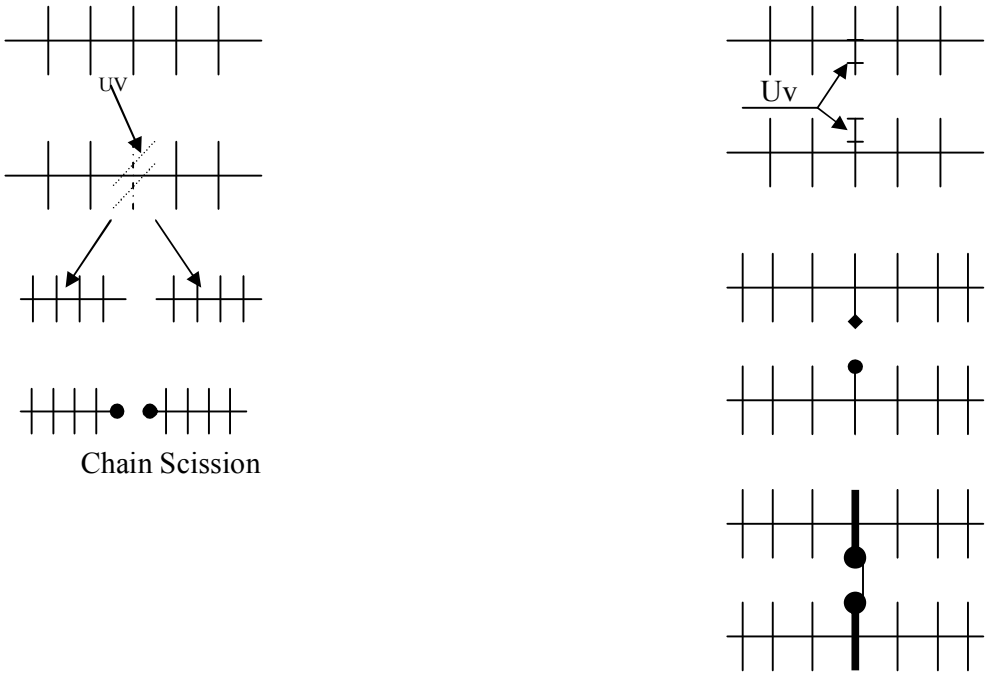


Fig.VI Chain scission and cross linking in polymer molecule

Fig. 19. Show the graph of embrittlement against percentage composition of the blends. As the percentage of the virgin polymers in the blends increases so is the embrittlement time increasing. This is because incorporation of virgin polymers in the recycled ameliorates to a reasonable extent the damaging effect of degradation. The figure also shows that the blends of PS have high embrittlement time than other two blends of PPr and PVC.

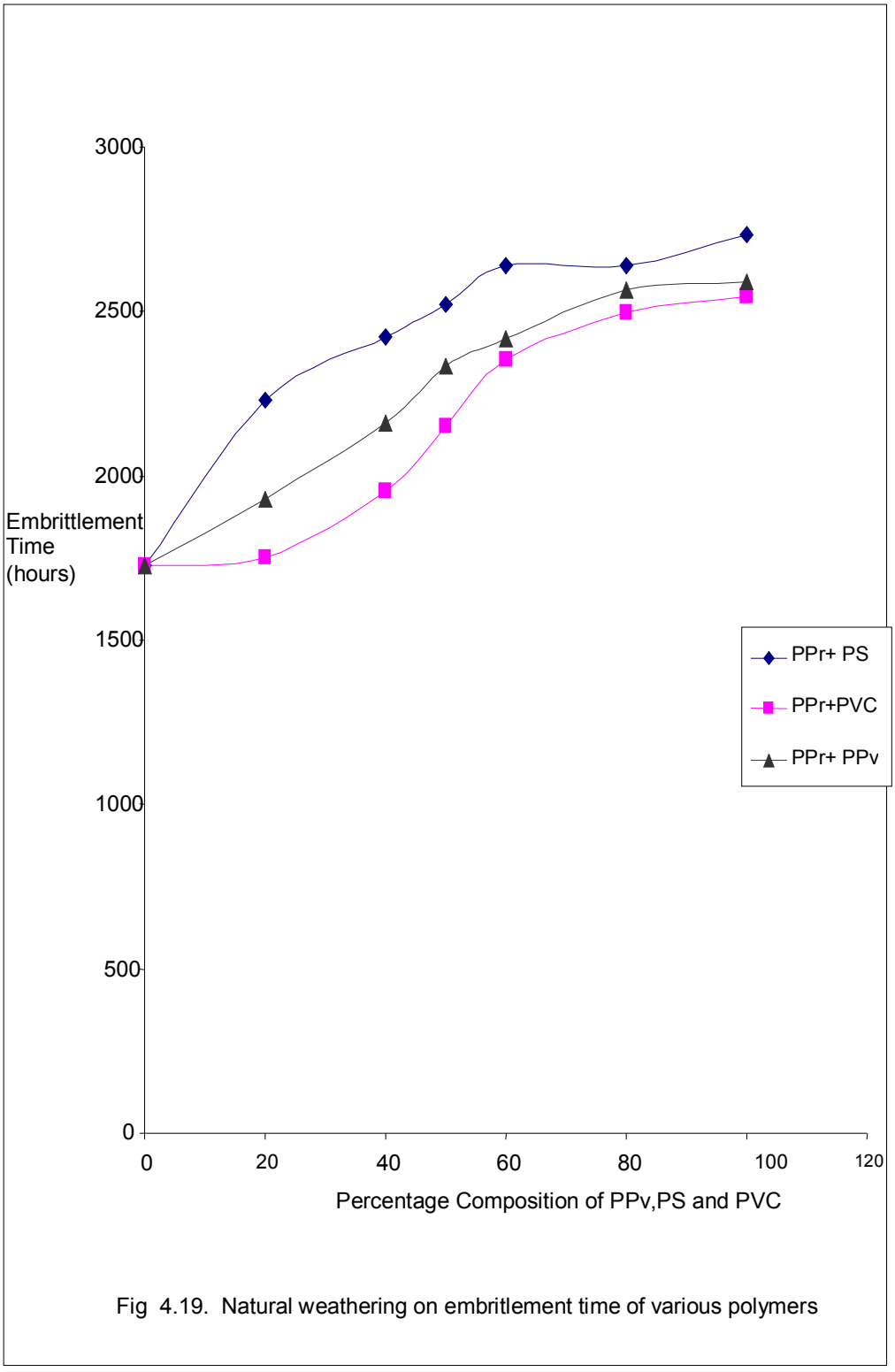


Fig 4.19. Natural weathering on embritlement time of various polymers

5.1 CONCLUSION

The work revealed that some of the mechanical properties of recycled polypropylene can be improved by blending with polystyrene, polyvinylchloride and virgin polypropylene. Blending in the right proportion or percentages can even produce a better material (polymers) that has peculiar characteristics.

This therefore explains that if ultimate tensile strength is the required property, then at 20-30% the blend of PPv and PPr will be considered good enough, also, if the requirement of the end product is elongation, then at 20%PS in the PPr blend can also be considered good.

Young modulus also follows the same pattern which reflects that 20%of the polymers PS, PVC and PPv in the blends of PPr show a good rise in young modulus. When considering embrittlement, the PS blend resists embrittlement more than the other two polymers(PVC and PPv.)

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APPENDIX.

Table 1(a); Mechanical properties of Recycled polypropylene and polystyrene blends

EXPOSURE TIME (HRS)	LOAD (N)	CROSS-SECTION AREA(mm2)	ULTIMATE TENSILE STRENGTH. (MPa)	MODULUS (MPa)	ELONGATION (%)	EMBRITLEMENT TIME (HOURS)
SAMPLE 1 20%PS + 80% Recycled PP						
240	23	0.0375	613.33	1.00	19	
480	18	0.0375	480.00	0.70	16	
720	16	0.0375	426.67	0.72	12	
960	13	0.0375	346.67	0.88	9	
1200	10	0.0375	266.67	0.78	4	
1440	12	0.0375	320.00	0.71	2	
1680	8	0.0375	213.33	0.90	0	
1920	7	0.0375	186.67	2.00	0	
2160	3	0.0375	80.00	0.00	0	
2400	0	0.0375	0.00	**	0	**2232**
SAMPLE 2 40%PS + 60% Recycled PP						
240	24	0.0375	640.00	1.00	22	
480	20	0.0375	533.33	0.90	19	
720	17	0.0375	453.33	0.84	15	
960	14	0.0375	373.33	1.08	12	
1200	**	0.0375	0.00	1.00	7	

1440	13	0.0375	346.67	1.00	**	
1680	9	0.0375	240.00	0.89	5	
1920	7	0.0375	186.67	0.80	3	
2160	4	0.0375	106.67	0.25	0	
2400	1	0.0375	26.67	**	0	**2424**
SAMPLE 3 50%PS + 50% Recycled PP						
240	26	0.0375	693.33	0.93	24	
480	24	0.0375	640.00	0.88	21	
720	20	0.0375	533.33	0.86	18	
960	19	0.0375	506.67	0.83	14	
1200	16	0.0375	426.67	1.13	12	
1440	14	0.0375	373.33	1.08	9	
1680	11	0.0375	293.33	1.11	7	
1920	10	0.0375	266.67	1.17	5	
2160	7	0.0375	186.67	1.00	2	
2400	3	0.0375	80.00	0.00	0	
2640	0	0.0375	0	**	0	**2520**
SAMPLE 4 60%PS + 40% Recycled PP						
240	31	0.0375	826.67	1.00	26	
480	29	0.0375	773.33	1.00	24	

720	25	0.0375	666.67	0.95	21	
960	20	0.0375	533.33	0.90	18	
1200	18	0.0375	480.00	0.89	15	
1440	**	0.0375	0.00	1.15	12	
1680	15	0.0375	400.00	1.20	10	
1920	10	0.0375	266.67	1.11	6	
2160	6	0.0375	160.00	0.83	4	
2400	3	0.0375	80.00	1.11	0	
2640	1	0.0375	26.67	0.83	0	**2640**
SAMPLE 5 80% PS + 20% Recycled PP						
240	34	0..375	906.67	0.97	31	
480	31	0.0375	826.67	1.00	29	
720	28	0.0375	746.67	1.00	25	
960	25	0.0375	666.67	1.08	21	
1200	22	0.0375	586.67	1.14	20	
1440	19	0.0375	506.67	1.20	19	
1680	15	0.0375	400.00	1.13	16	
1920	12	0.0375	320.00	0.86	13	
2160	8	0.0375	213.33	0.82	9	
2400	5	0.0375	133.33	0.60	5	
2640	3	0.0375	80.00	0	1	**2640**

SAMPLE 6 100% PS						
240	58	0.0375	1546.67	1.00	35	
480	54	0.0375	1440.00	1.00	30	
720	51	0.0375	1360.00	1.00	28	
960	45	0.0375	1200.00	1.00	25	
1200	40	0.0375	1066.67	1.15	21	
1440	36	0.0375	960.00	1.26	17	
1680	30	0.0375	800.00	1.11	14	
1920	25	0.0375	666.67	0.80	10	
2160	22	0.0375	586.67	0.91	8	
2400	18	0.0375	480.00	1.20	5	
2640	12	0.0375	320.00	1.00	1	
2800	4	0.0375	106.67	0.40	0	
						2736

Table 1(b); Mechanical properties of Recycled polypropylene and polyvinyl chloride blends.

EXPOSURE TIME (HRS)	LOAD (N)	CROSS-SECTION AREA(mm^2)	ULTIMATE TENSILE STRENGTH. (MPa)	MODULUS (MPa)	ELONGATION (%)	**EMBRITLEMENT TIME (HOURS)**
SAMPLE1 20%PVC + 80% RecycledPP						
240	16	0.0375	426.67	0.84	15	
480	12	0.0375	320.00	0.75	12	
720	10	0.0375	266.67	0.83	10	
960	7	0.0375	186.67	0.78	8	
1200	6	0.0375	160.00	1.50	6	
1440	4	0.0375	106.67	2.00	3	
1680	1	0.0375	26.67	**	3	
1920	0	0.0375	0.00	**	1	**1752**
SAMPLE 2 40%PVC + 60% Recycled PP						
240	22	0.0375	586.67	1.00	23	
480	16	0.0375	426.67	0.84	21	
720	12	0.0375	320.00	0.80	16	
960	10	0.0375	266.67	0.83	13	
1200	9	0.0375	240.00	1.29	**	

1440	7	0.0375	186.67	**	12	
1680	5	0.0375	133.33	1.00	9	
1920	3	0.0375	80.00	1.00	5	**1952**
2016	1	0.0375	26.67	**	0	
SAMPLE 3 50% PVC + 50% Recycled PP						
240	23	0.0375	613.33	0.96	27	
480	20	0.0375	533.33	0.95	22	
720	17	0.0375	453.33	0.94	21	
960	15	0.0375	400.00	1.07	18	
1200	12	0.0375	320.00	1.00	15	
1440	9	0.0375	240.00	1.00	13	
1680	5	0.0375	133.33	0.71	**	
1920	2	0.0375	53.33	0.40	6	
2106	1	0.0375	26.67	0.50	2	**2152**
SAMPLE 4 60%PVC + 40% Recycled PP						
240	25	0.0375	666.67	0.96	27	
480	22	0.0375	586.67	0.92	24	
720	18	0.0375	480.00	0.86	22	
960	15	0.0375	400.00	0.83	**	

1200	14	0.0375	373.33	0.93	16	
1440	12	0.0375	320.00	1.00	13	
1680	9	0.0375	240.00	0.90	**	
1920	7	0.0375	186.67	1.17	9	
2160	4	0.0375	106.67	1.00	5	
2400	0	0.0375	0.00	**	2	**2352**
SAMPLE 5 80% PVC + 20%Recycled PP						
240	32	0.0375	853.33	1.03	35	
480	30	0.0375	800.00	1.03	35	
720	27	0.0375	720.00	1.08	31	
960	24	0.0375	640.00	1.14	27	
1200	20	0.0375	533.33	1.00	**	
1440	17	0.0375	453.33	0.89	20	
1680	14	0.0375	373.33	0.88	16	
1920	10	0.0375	266.67	0.77	14	
2160	7	0.0375	186.67	0.78	**	
2400	4	0.0375	106.67	0.80	5	
2640	1	0.0375	26.67	1.00	0	**2496**
SAMPLE 6 100% PVC						
240	34	0.0375	906.67	0.97	42	
480	32	0.0375	853.33	1.07	35	
720	29	0.0375	773.33	1.04	31	

960	26	0.0375	693.33	1.04	**	
1200	24	0.0375	640.00	1.14	24	
1440	20	0.0375	533.33	1.18	20	
1680	17	0.0375	453.33	1.21	13	
1920	14	0.0375	373.33	1.40	11	
2160	10	0.0375	266.67	1.25	8	
2400	6	0.0375	160.00	1.20	5	
2640	2	0.0375	53.33	2.00	0	**2544**

Table 1(c); Mechanical properties of Recycled polypropylene and virgin polypropylene blends.

EXPOSURE TIME (HRS)	LOAD (N)	CROSS-SECTION AREA(mm^2)	ULTIMATE TENSILE STRENGHT (MPa)	MODULUS . (MPa)	ELONGATION (%).	EMBRITTLEMENT TIME. (HOURS)
SAMPLE 1 10%Recycle PP&90% Virgin PP						
240	35	0.0375	933.3	0.97	36	
480	32	0.0375	853.3	0.97	33	
720	31	0.0375	826.7	1.07	29	
960	**	0.0375	0	0.00	0	
1200	26	0.0375	693.3	1.30	20	
1440	23	0.0375	613.3	1.21	19	
1680	19	0.0375	506.7	1.12	17	
1920	**	0.0375	0	0.00	0	
2160	12	0.0375	320	0.80	15	
2400	6	0.0375	160	0.67	9	
						2592
SAMPLE 2 20%Recycled PP&80% Virgin PP						
240	34	0.0375	906.7	0.96	35	
480	32	0.0375	853.3	0.90	32	
720	30	0.0375	800	0.89	29	
960	27	0.0375	720	0.93	25	

1200	25	0.0375	0	1.00	19	
1440	24	0.0375	640	1.00	16	
1680	18	0.0375	480	1.00	13	
1920	12	0.0375	320	1.40	9	
2160	9	0.0375	0	0.75	5	
2400	3	0.0375	80	1.50	3	
2640						**2568**
SAMPLE 3 30%Recycled PP&70% Virgin PP						
240	32	0.0375	853.3	1.00	32	
480	28	0.0375	746.7	0.97	29	
720	**	0.0375	0	0.00	**	
960	24	0.0375	640	1.14	21	
1200	15	0.0375	400	0.75	20	
1440	19	0.0375	506.7	0.90	21	
1680	16	0.0375	426.7	0.94	17	
1920	8	0.0375	213.3	0.62	13	
2160	6	0.0375	160	0.86	7	
2400	2	0.0375	53.3	0.67	3	
						2448
SAMPLE 4 40%Recycled PP&60% Virgin PP						
240	27	0.0375	720	0.92	30	
480	25	0.0375	666.7	0.87	29	

720	21	0.0375	560	0.85	25	
960	18	0.0375	0	0.82	22	
1200	17	0.0375	453.3	0.00	19	
1440	15	0.0375	400	1.08	15	
1680	12	0.0375	0	0.90	12	
1920	10	0.0375	266.7	1.40	9	
2160	5	0.0375	133.3	2.00	5	
2400	2	0.0375	53.3	0.00	2	
2640		0.0375		0.98	**1**	
						2420
SAMPLE 5 50%Recycled PP&50% Virgin PP						
240	25	0.0375	666.7	0.97	27	
480	21	0.0375	560	1.02	24	
720	18	0.0375	480	0.92	22	
960	15	0.0375	400	0.95	20	
1200	17	0.0375	453.3	0.88	19	
1440	14	0.0375	373.3	1.04	14	
1680	10	0.0375	0	1.09	9	
1920	7	0.0375	186.7	1.06	6	
2160	4	0.0375	106.7	1.11	3	
2400	0	0.0375	0	1.10	0	
						2332

SAMPLE 6 60%Recycled PP&40% Virgin PP						
240	24	0.0375	640	1.00	26	
480	19	0.0375	506.7	0.90	23	
720	17	0.0375	453.3	0.94	20	
960	14	0.0375	373.3	1.08	17	
1200	13	0.0375	340	1.00	14	
1440	12	0.0375	320	1.00	12	
1680	8	0.0375	213.3	0.89	10	
1920	4	0.0375	106.7	0.80	5	
2160	1	0.0375	26.7	0.25	2	
						2160
SAMPLE 7 70%Recycled PP&30% Virgin PP						
240	22	0.0375	586.7	1.00	22	
480	16	0.0375	426.7	0.84	19	
720	12	0.0375	320	0.80	15	
960	10	0.0375	266.7	0.83	12	
1200	7	0.0375	186.7	1.00	7	
1440	**	0.0375	0	0.00!	**	
1680	6	0.0375	160	1.20	5	
1920	5	0.0375	133.3	1.67	3	
2160	1	0.0375	26.7	0.50	2	
						2016

SAMPLE 8 80%Recycled PP&20% Virgin PP						
240	21	0.0375	560	1.05	24	
480	14	0.0375	373.3	0.88	20	
720	10	0.0375	266.7	0.77	18	
960	9	0.0375	240	0.90	14	
1200	7	0.0375	186.7	0.78	10	
1440	4	0.0375	106.7	0.80	12	
1680	3	0.0375	80	1.00	8	
1920	2	0.0375	53.3	2.00	5	
2160	0	0.0375	0	0.00	4	
						1928
SAMPLE 9 90%Recycled PP&10%Virgin PP						
240	16	0.0375	426.7	0.84	19	
480	12	0.0375	320	0.75	16	
720	10	0.0375	0	0.83	12	
960	7	0.0375	186.7	0.78	9	
1200	6	0.0375	160	1.50	4	
1440	4	0.0375	106.7	2.00	2	
1680	0	0.0375	0	0.00	0	
						1752

SAMPLE 10 100% Recycle PP						
240	13	0.0375	346.7	0.81	10	
480	11	0.0375	293.3	0.85	7	
720	9	0.0375	240	0.90	6	
960	6	0.0375	160	0.75	3	
1200	2	0.0375	53.3	1.00	1	
1440	1	0.0375	26.7	1.00	0	
1680	0	0.0375	0	0.00	0	
						1728
SAMPLE 11 100% Virgin PP						
240	42	0.0375	1120	1.29	45	
480	38	0.0375	1013.3	1.29	42	
720	35	0.0375	933.3	1.28	40	
960	32	0.0375	0	1.25	36	
1200	31	0.0375	826.7	1.25	32	
1440	29	0.0375	773.3	1.20	30	
1680	20	0.0375	533.3	1.11	27	
1920	12	0.0375	320	1.04	24	
2160	10	0.0375	266.7	1.10	20	
2400	6	0.0375	160	0.95	19	

2640	2	0.0375	0	0.71	17	
						2592