Manufacturing of HDPE Pipes. A case study in Seti Plastics, Nepal

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Abstract:

This study aims to analyse the needs of process of producing HDPE (high quality density polyethylene) pipes in developing countries and investigate their current state of product's mechanical properties such as strength, durability, thermal resistivity and the weight. A set of questionnaires was performed for understanding suppliers and consumers experience. Also, the processes and machines involved in the pipe production was studied. Qualitative and quantitative analysis were performed to investigate factors affecting the production rate and mechanical properties of pipes being produced. The project consisted of studying melt flow characteristics of HDPE and how the die structure should be set to get the desired HDPE pipes. The drag flow and pressure flow were then extracted from the screw parameters which lead into the calculation of the operation point and the operating pressure for the die. It was also possible to calculate the mass flow rate and the velocity drop. And finally die optimization of extruded circular profile is done. The results showed that the quality of HDPE pipes were good constituting durability and reliability of the products. The major problem observed in the study was the manual processes involved in the production lines which were adversely affecting the direct cost involved in the production. Furthermore, we can conclude that, automation of HDPE pipes production methods must be executed in developing countries to reduce the direct expenses involved in the production.

Keywords:	Resin, Extruder, Extrusion, FlowIndex, Standard Dimension Ratio , Test-Temperature, Plastic Pipe Industry, Nepalese Society for Testing and Materials
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Nomenclature

P: Pressure (N)

N: Screw revolution (rpm)

H: Channel depth of the screw (m)

∅: Helix angle of screw

L: Length of the screw (m)

D: Diameter of the screw (m)

V: Viscosity (Pa.s)

γ: Shear rate (S-1)

τ: Shear stress

n: Power law index

ρ: Melt density (kg/m3)

SDR: Standard Dimensional Ratio

Dn: Min outside diameter

En: Min wall thickness

MOP: Maximum Operating Pressure

°C: Degree Celsius

V: Volt

kVA: Kilo (Volt X Amps)

Sec: Second

L/D: ratio of the flighted length of the screw to its outside diameter.

NSTM: Nepalese Society for Testing and Materials

PPI: Plastic Pipe Industry

QA/QC: Quality Analysis/ Quality Control

Glossary

Shear viscosity: Fluid's flow resistance to shearing action

Shear rate: Rate of shearing measured by the velocity gradient across the radius of a flow channel.

Extrusion: A polymer processing technology carried out by pouring plastic pellet into hopper.

Extrusion pressure: The pressure developed by screw pressure, which is area ratio of system and the screw; are responsible for filament to get out from the die.

Granules: Palletized plastic particles produced as for raw material for plastic part production.

Screw: A part of extruding unit the helps to melt and transport plastic from the hopper to die.

Cooling time: The time it takes for an extruded molten plastic to solidify down to room temperature.

Flow length: A length that a molten plastic flows through barrel under predefined set of conditions.

Volume flow rate: A volume of fluid flowing through a certain cross-sectional area per unit time.

Parameter: A set of measurable factors defining a certain operation system.

Viscosity: Describes a fluid that is thick, sticky and does not flow easily.

1 INTRODUCTION

1.1 Background

Seti Plastic Industry is located in far western region of Nepal, Seti Zone Masuria Ward No 5 and started manufacturing and supplying HDPE pipes locally since 2009. This thesis is entirely based on, how HDPE pipes are made in the factory. Although, the production company was in rural place of Nepal, the infrastructures were not very bad. The extrusion blow moulding machine and the pipe extruding machine were very simple. The local village workers were working there and almost 20 people are employed including pipe cutters, raw materials processors, operators, cleaners and other technical settings were managed by the plastic engineers from Dhangadhi City when required.

Initially, there was a major struggle with electricity in-order to produce HDPE pipes as it wasn't supplied constantly and no track of time as when electricity power was going off. As Nepal being a developing country, twenty-four/seven electricity was a big issue with problems like load-shedding occurring on daily basis. According to the founders of factory, that was a waste of time because as pipe is being manufactured, in the middle of process no electricity would cause them to redo the process again from the start. They would have certain qualities and requirements from the customers and no power would cause the process to be redone various times without certainty. That was a depressing factor until they decided to buy expensive inverter generator which had to be very high voltage. Even with the required resources available, the constant power crisis was being harmful for the factory owners. The start-up budget was around 400,000 Euros which has now grown to 750,000 Euros worth which is a massive growth. Furthermore, this thesis is focused on manufacturing HDPE pipes in Seti Plastics Manufacturing, Kailali, Nepal.

HDPE are High-Density Polyethylene, a kind of polymer. Polymers can be defined as the group of monomers formed after polymerization. HDPE usages are constantly rising in order to make wide range of production and are very easy to process. Machining, shape processing, welding can be performed in theses polymers. Pipes are the most commonly produced products in plastic industries. Since plastic-based pipes were made, it was an evolution in plumbing and transporting water to various stops from its original sources. Long and heavy metal pipes were left behind for better advancement in pipe productions.

Water is very essential element for survival of living entities. Day by day water demand in many sectors are rising with equal demand of safe drinking water. Running water is now very common in all over the world, excluding who are still striving for clean water to drink. Quality improvement of these pipes can significantly reduce the hurdles that we face due to problems in pipe-lines and hence reduce the cost factor, time factors associated with these problems. Plastic pipes are light weight, durable and efficient for engineers to travel and stall the pipes for plumbing or irrigation systems. There are many types of plastic pipes that are available made from different types of polymers.

It is reported that the HDPE pipes carry a big share in worlds market and the current trends show a dramatic increase in demands of these pipes. Especially, in developing countries, these pipes have a lot more demands and the industries cannot fulfil the needs of the market. The pipes production methods and quality control are not that effective, hence leading to a high cost of production.

Following figure shows the global market demand of HDPE and the expected trend in the coming future. ("U.S. bureau of industrial survey"). We can see that the demand will be increasing at a higher rate and rise to 90 billion USD by 2024.

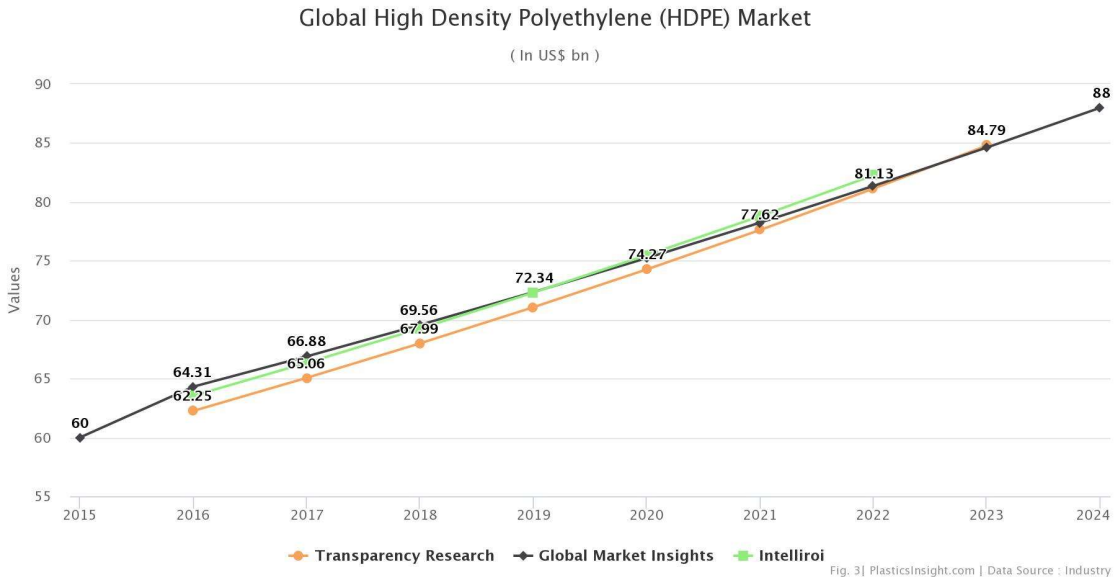

Figure 1. Graph showing the rise of HDPE usages in US with respect to time (Anon., 2018)

1.2 Applications of HDPE Pipes

HDPE pipes are vital on our daily life such as water supply, irrigation, electric wirings, sewage management line and a lot more. Here are enlisted the major applications of HDPE pipes over the world:

1.2.1 Agriculture & Irrigation

- Flood Irrigation (Suction & Delivery pipes in pump sets)
- Sprinkler Irrigation (Crops, Lawns, Golf course, Gardens)
- Drip irrigation (Plantations, Orchards, Nurseries)

1.2.2 Water Supply

- Potable water supply
- Water mains
- Distribution
- Service Pipes

1.2.3 Sewage & Industrial Effluent Disposal

- Domestic Sewage System
- Sanitary System
- Petrochemical Industry
- Fertilizer Industry

1.2.4 Ducting

- Air-conditioning & Refrigeration
- Extraction of Fumes
- Telecommunication, as conduits for OFC

1.2.5 Electrical Installations

- Conduits for Cables

1.2.6 Drainage Pipes

- Surface & Rain water
- Waste Water Mains
- Sub-soil water (Anon., 2015)

The effective utilization of HDPE Pipes isn't restricted to the previously mentioned applications. It has various helpful applications. For example, when the need to convey water over a stream emerges, building a bridge for a surface pipeline would not be a financially savvy arrangement. Further a submerged pipeline of other regular materials would be vulnerable to crack on the undulating river because of saltiness. HDPE channels being adaptable and chemically inert are the solution. The pipeline might be amassed, drifted on the water, adjusted and afterward sunk by only filling it with water. That is the comfort in establishment no other pipe can offer. These flexible channels may likewise be utilized in cooking gas dissemination systems, transportation of corrosive chemicals, chilled water and compacted air inside a plant, transportation of items such as milk, edible oils and so on. (Anon., 2015)

1.3 Structure of the study

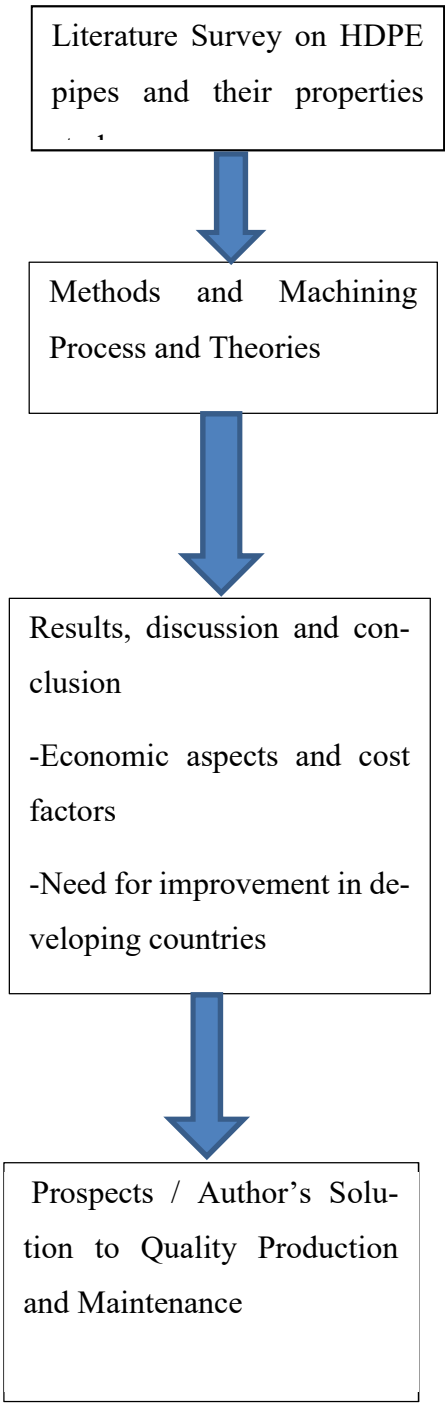

Figure 2. Structure of the research conducted in a step-wise manner

1.4 Need for Research and Its Objectives:

Nepal is an under-developed country which is rich in water resources, therefore the demand of HDPE pipes is at much higher amount. The number of industries available for supplying HDPE pipes are not enough and the quality of pipes supplied is another major problem. Since, there is a high demand with increasing number of projects every day, there is a need for producing good quality of HDPE pipes and at a faster rate. This study was conducted at Seti Plastic Udyog, Kailali, Nepal. This factory is supplying HDPE pipes since past 9 years to almost $1/6^{th}$ of whole Nepal.

A set of questionnaires were asked with the factory workers, authorities and the local dealers of the pipes, overall response of the team was good, they mentioned that the product is usually good, durable and reliable. They get good feedbacks from local consumers and government contractors as well.

The only problem they face is that the pipe gets fractured easily when they do not get good supply of resins i.e. raw materials and then is overweighed sometimes.

The set of machineries used and the overall process for final product was analysed.

The objectives of the research are listed below:

- Research about the quality of HDPE pipes in the market of Nepal.
- Research about the tools, machineries, and methods used for the final product.
- Find the ways to make the process cost effective.
- Produce quality HDPE in faster way.
- Seek alternatives to the problems.

1.5 Scope of The Thesis

A combined study of experimental procedures and theoretical procedures have been carried out to improve the quality of HDPE pipes production. The studies were carried out to analyse the mechanical properties and production process, hence reduce the expenses caused by the damage in HDPE pipes.

The fracture of pipes produced were studied and the factors affecting the durability of HDPE were studied.

The following chapters can be divided into three parts. The first chapter gives overview of literature research done to the previous research carried out to improve the HDPE industry and release the gaps present between the current study and the recent studies.

Seconds chapter involves the process of production. i.e. pipe extrusion and details of the machine parts.

The third chapter involves the final production of the industry where the research was carried out. It also discusses the importance of recycling process to make the whole process cost effective.

The final part discusses the prospects of studies and provide a better visualization on the commercial aspects of the studies. Especially, in a least developed country like Nepal, which have high demand of HDPE pipes need improvement for the systematic production of HDPE pipes. It describes the methods that can be implemented to make a clear picture of the goals and advantages to the HDPE pipes production.

2 LITERATURE REVIEW

This chapter is emphasized on focusing the existing studies and research made for addressing this problem. Various documents and research papers were studied, and excessive internet research was made to investigate the existing problems and findings. The questionnaire was made with industry owners and public to address the most common problems they face by using the HDPE pipes and the expenses for getting rid of the problem.

Review of existing studies:

Following researches were found to be studied and carried out to minimize the hurdles present in HDPE pipe industry and study the mechanical properties of the production.

- **Investigation to carry out fractured properties at Blekinge Institute of Science**

This study was carried out to study the fracture properties of the HDPE pipes. Microscopic examination to study the textures involved in fractures of pipes were carried out.

This study also involves numerical simulation(ABACUS) to find good shear test match for avoiding fracture mechanism. This study primarily focuses on the mechanism of fracture but lacks the application from commercial aspects and improvisation of economic factors involved. (Kang, 2014)

- **Investigation of durability and reliability of HDPE pipe for large diameter water transmission applications at the university of Texas at Arlington**

This research primarily focuses on the use of HDPE pipes in water transmission lines. It emphasizes on the satisfaction rate of consumers who use large diameter HDPE in water transmission. Results have shown that the users of this product are highly satisfied and did not face much hurdles in a long-term run. The only problem involved was about the joint fittings involved in the process. From this research, we can assume that HDPE pipes are a good product and can be used for water transmission lines in long run. (Shree, 2014)

- **Investigation of root cause of polyethylene pipe leaks & bursts**

This study provides a clear picture on the fact of increasing demand of HDPE pipe demands and their application. They have assumed that the chlorinated water transmission at early stages of polyethylene pipes showed frequently occurring pipe burst and leakages. From this study, we can estimate the need for improvisation of mechanical strength of the pipes and hence find ways to make it cost effective. Also, find the preventive measures to avoid these problems, consequently, increase the durability, reliability of the final products. (Dr. Jeremy Leggoe, 2017)

2.1 What is Resin?

Resins are plastic granules generally ranged in various sizes. There are many types of resin available. Selection of resin is done according to product required. Common resins used all over plastic industries are HDPE, LDPE, PVC, PE and more. Different resin follows the different standard of melt flow index, since all the materials have different melting point and crystallisation temperature (Bikales, 2004).

2.2 HDPE

HDPE also known high density polyethylene and made up from polyethylene which makes largest family of polymer. It is very important to consider its molecular structure and polymer chain during polymer synthesis. Structures are generally found in repeating format. These repeating chains of units determine how densely it is packed and the materials molecular weight, crystallinity depends upon the bonds between the units of polymers.

HDPE has very good thermal and mechanical properties which makes it widely selected materials in making of different product. Compressive tensile strength and stiffness is very high in HDPE polymers alongside with high melting and great crystallization point. Among the polymers HDPE has the high strength for long term.

To produce high quality pipes, high density polyethylene plastics are considered good in plastic industries. HDPE pipes are corrosive free and flexible to work with, which makes pipes more handy and durable. HDPE pipe made are lightweight and consumes less energy while manufacturing.

However, there are other polyethylene that differs in densities, hyper-branched, crystallinities to their molecular weight and chain structure. The processing temperature for HDPE in general is 160ºC -250ºC and shrinkage rate is considered 1.5%-3%. High heat withstand ability, flexibility and machinability makes HDPE as leading polymer in making varieties of plastic products. The products like pipes, detergent bottles, automobile parts are made from HDPE polymer. (Cheng, 2008)

General temperature used inside the barrel for HDPE pipe manufacturing are;

Zone 1 = 162°C

Zone 2 = 162°C

Zone 3 = 176°C

Zone 4 = 190°C

Zone 5 = 190°C

Actual temperature standard is different, depending on grade of resin used.

2.3 Extruder

Extruder is a wide range production machine used in manufacturing varieties of products. Any industries which needs constant and large amount of productions widely uses extruder machine. Many experiments with extruders are increasing much-more possibilities day by days in product making industries. Many companies use it to get desired products. The extruders generally consist of feed hopper, a heating barrel, screw and die. Screw consists of five heating zone channels, through which raw materials is melted inside till it is homogeneous in state. When melt mixture reaches the die, the required product will be produced. The varieties of die give many different type of product, however hopper, screw, barrel remains the same in manufacturing process. (Harold F.Giles, 2004)

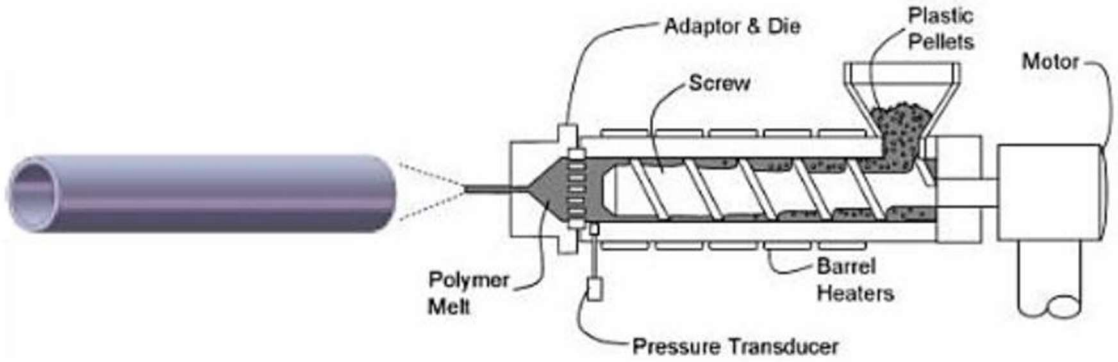

Figure 2. Showing Extruder (Kazmir, 2017)

2.3.1 Feed Hopper

Feed is considered a mouth of the extruder; all the raw materials are first poured in feed where they are pre-heated. All the raw materials pass through feed throat smoothly and reaches the heating barrel for further process. Material must reach to the other end of the barrel starting from feed hopper or also called feeding zone. Supply of feed in the hopper should be sufficient to create required pressure to continue the materials towards other

zones of barrel. Therefore, the design efficiency of hopper also plays the great role in passing the resins to melt smoothly in the process. (Bikales, 2004)

2.3.2 Barrel

Extruder barrels are made of Nitriding steels, powder metallurgy steels or Bi-metals. Apart from what extruders are made up of, it can be also grouped according to the external surface feature. In some extruder, the surface of the barrel can be machined or smooth. Smoothing or machining the outer surface of extruder is directly related to the heat dispersion rate while extruding. (Harold F.Giles, 2004)

2.3.3 Screw

An importance of the screw in extruding is the shape of the screw. The screw used in extruders are helical. Its unique shape produces much friction and heat required for melting and pushing raw materials forward. In general, a long screw inside the extruder can be further divided into feed section, transition section and metering section. The length of the screw (L/D) is described as a ratio of length divided by the screw diameter that is measure at flight. In feed section, all the raw materials get down from feed throat by gravity to base of rotating screw and get in contact with screw and further process of extruding begins. (Harold F.Giles, 2004)

2.3.4 Die

Die plays an important role in determining the shape of the product. There are various types of dies available for different products. Some common dies that most of extruding companies uses are cast film dies, sheet dies, twin wall dies and more. Flat dies are also available nowadays. (Harold F.Giles, 2004)

2.3.5 Water Cooling Tub

When hot extrudate comes out of the die, it is supposed to be hot and soft. For cooling process extrudate pipe further process through long chamber to bath tub. The specific amount of heat is loss in water which results in the solidification of profiles. The used or

hot water return water back to the central cooling unit. And this cooling cycle continues throughout the process of cooling pipes or plastic profiles (Harold F.Giles, 2004).

2.4 What Is Extruding?

First resin is chosen for the product and some additives together needed for desired properties of final product. Extruder is preheated first and made temperature stable before pouring the raw materials. When the resin is added all the materials goes through the feed hopper and reach the base of barrel by gravity. Then the helical screw inside the barrel pushed the materials forward to the feed section where material gets gently heated and massive amount of pressure is created inside the barrel pushing the materials towards the melting zone. Screw rotates in controlled RPM of the motor. In melting section, all the materials transform from pellets to melted liquid form and all the materials flows towards the metering section, in this section melted mixture goes through to get more homogeneous in state and thus finally resin moves towards die and gets in desired shape (Crawford., 2005).

2.5 Extrusion

The materials like metals, polymers, food products or ceramics are processed or extruded to make wide range of industrial products, this process is called extrusion. There are various extrusion as listed follows:

2.5.1 Direct Extrusion

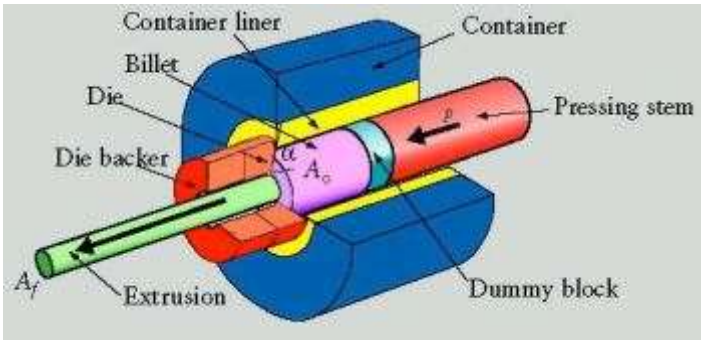

Figure 3. Direct extrusion (Kalpakjian, 2003)

A tube which are hollow in structure from inside can be easily extruded by this method. To extrude tube by this method, hollow billet and mandrel should be attached to the dummy block. It is also called forward extrusion process since billets moves along with ram and punch. (Chandramouli, n.d.)

2.5.2 Indirect Extrusion

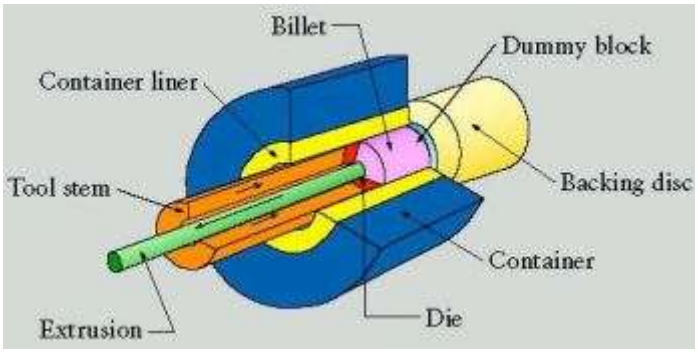

Figure 4. Indirect extrusion (Kalpakjian, 2003)

Opposite to the direct extrusion in this method, the billet moves opposite to punch so it is also called backward extrusion. In this type of extrusion, the pressure required is lower than the direct extrusion process. Indirect extrusion is not able to extrude very long extrudes. Both methods direct and indirect can be combined to make many components (Chandramouli, n.d.).

2.5.3 Hydrostatic Extrusion

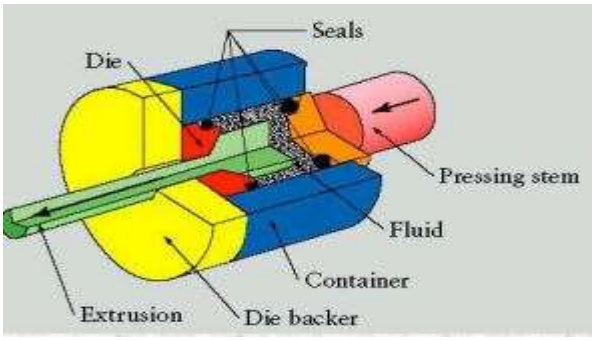

Figure 5. Hydrostatic extrusion (Kalpakjian, 2003)

In this type of extrusion method, very highly brittle materials can be extruded. In this method, a container is filled with fluid and pressure is applied through fluid to the billet. This process is also friction less process since billet and walls of container don't contact.

Hydrostatic extrusion is employed for making aluminium or copper wires-especially for reducing their diameters. Ceramics can be extruded by this process. (Chandramouli, n.d.)

2.5.4 Impact Extrusion

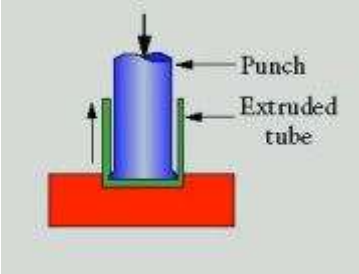

Figure 6. Impact extrusion (Kalpakjian, 2003)

Containers like toothpaste and cups are manufactured by this method. Impact extrusion method follows striking the slug through punch in high speed with high load impact. Usually metals like copper, aluminium, lead are impact extruded. (Chandramouli, n.d.)

2.5.5 Tube Extrusion

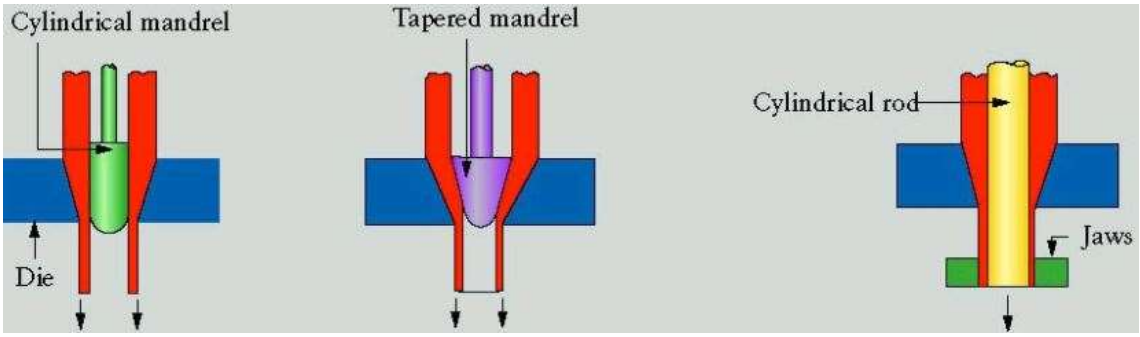

Figure 7. Showing methods of tube drawing (Kalpakjian, 2003)

Employing hollow billet and a mandrel at the end of the ram, hollow sections such as tubes can be extruded to closer tolerances. The mandrel extends up to the entrance of the die. Clearance between the mandrel and die wall decides the wall thickness of the tube. The mandrel is made to travel along with the ram to make concentric tubes by extrusion. (Chandramouli, n.d.)

2.5.6 On-Of Controller in Extrusion

In on-off control, the power is on or off. When the temperature is below the setpoint, the power is fully on and when extruder reaches the required or measured temperature the power is off. When the temperature is below the set point, the power will turn on again therefore the temperature difference in extruder results the on and off cycle of the controller. The advantage of on-off control is that it is simple, and the average temperature is right at the setpoint. The disadvantage is that the actual temperature always cycles with a variation that can be quite large, as much as 10 to 20 °C. The larger the extruder, the greater the temperature variation tends to get. (Rauwendaal, 2010)

2.6 Melt Flow Index Data

MFI or melt flow index is the measure of grams of polymer passing through a capillary under a standard load over 10 minutes to characterize polymers. The value obtained through this test is a single data point. The viscosity of the material can be easily determined from this test. Higher the melt flow indexes, the viscosity of material will be very less. The test shows how smoothly can a resin flow of thermoplastic polymers in gram per minute. For extruding or injection moulding the materials, MFI gives all the data needed to process the polymer easily. High melt flow index shows the poor mechanical strength of the polymer. Different weight load would produce different MFI results so noticing mass during test is very important. The testing of MFI is according to ISO 1133 standard or NSTM D1238 standard depends on a choice. It is expressed in terms of grams of polymer that flows out per minute period (g/min). (Pipe, 2010)

3 METHODOLOGY

Profile wall corrugated HDPE pipe is generally produced with one or more variations of a vacuum forming process or an extrusion process. Fittings are generally produced utilizing a blow, vacuum, injection or a rotationally molding process.

3.1 Equipment Used

- Extruder
- Controller
- Die
- Compressor
- Motor
- Roller
- HDPE resin
- Six-meter water bathtub for cooling and
- Manual pipe cutter

The following figures show the pictures of machineries used in the Seti plastic industry.

3.1.1 Extruder

Figure 8. Pipe extruder machine at Seti Plastics (Nishan Devkota, 2017)

3.1.2 Drying Tools

Figure 9. Drier and mixture at Seti Plastics (Nishan Devkota, 2017)

3.1.3 Air Compressor

Figure 10. Air compressor at Seti Plastics (Nishan Devkota, 2017)

3.1.4 Control Panel

Figure 11. On-off temperature control I at Seti Plastics (Nishan Devkota, 2017)

Figure 12. On-off temperature control II at Seti Plastics (Nishan Devkota, 2017)

3.1.5 Die

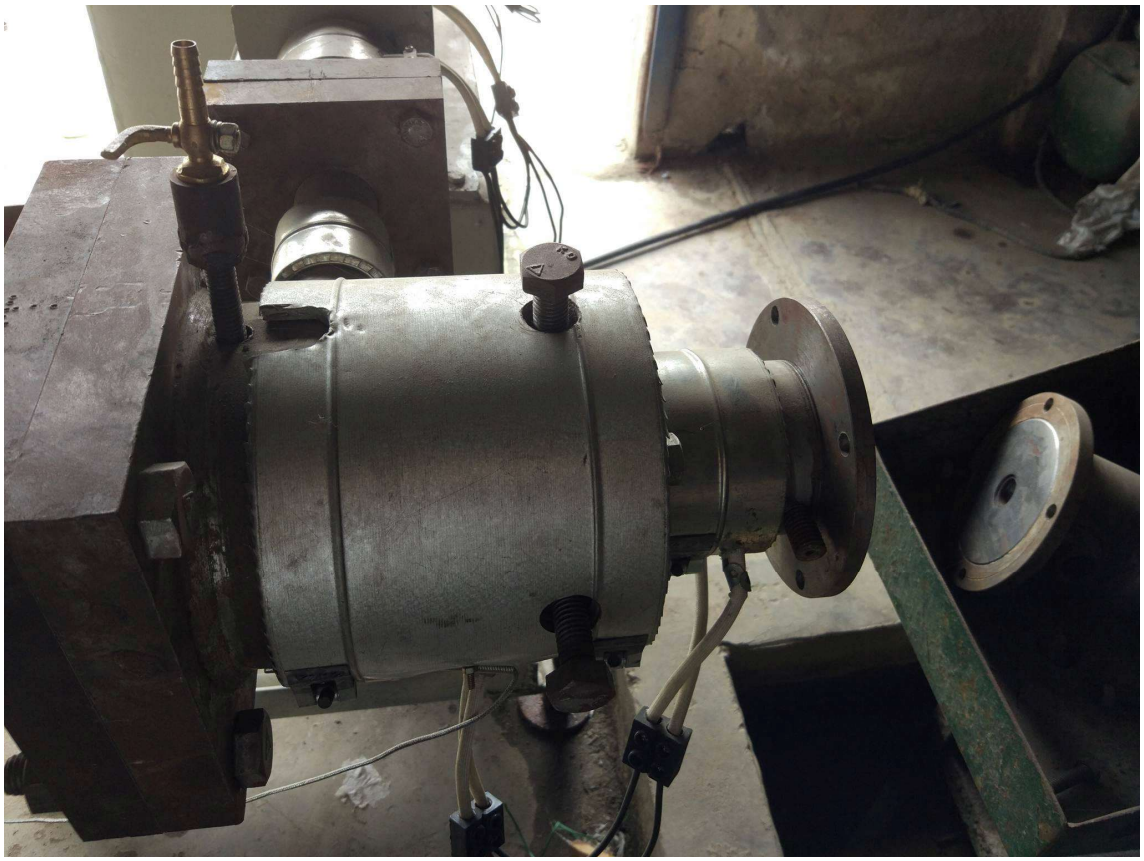

Figure 13. Die head at Seti Plastics (Nishan Devkota, 2017)

Figure 14. Showing varieties size of die at Seti Plastics (Nishan Devkota, 2017)

3.1.6 Polymer Resin

Figure 15.HDPE resins and black colour at Seti Plastics (Nishan Devkota, 2017)

3.1.7 Water Bathtub for Cooling

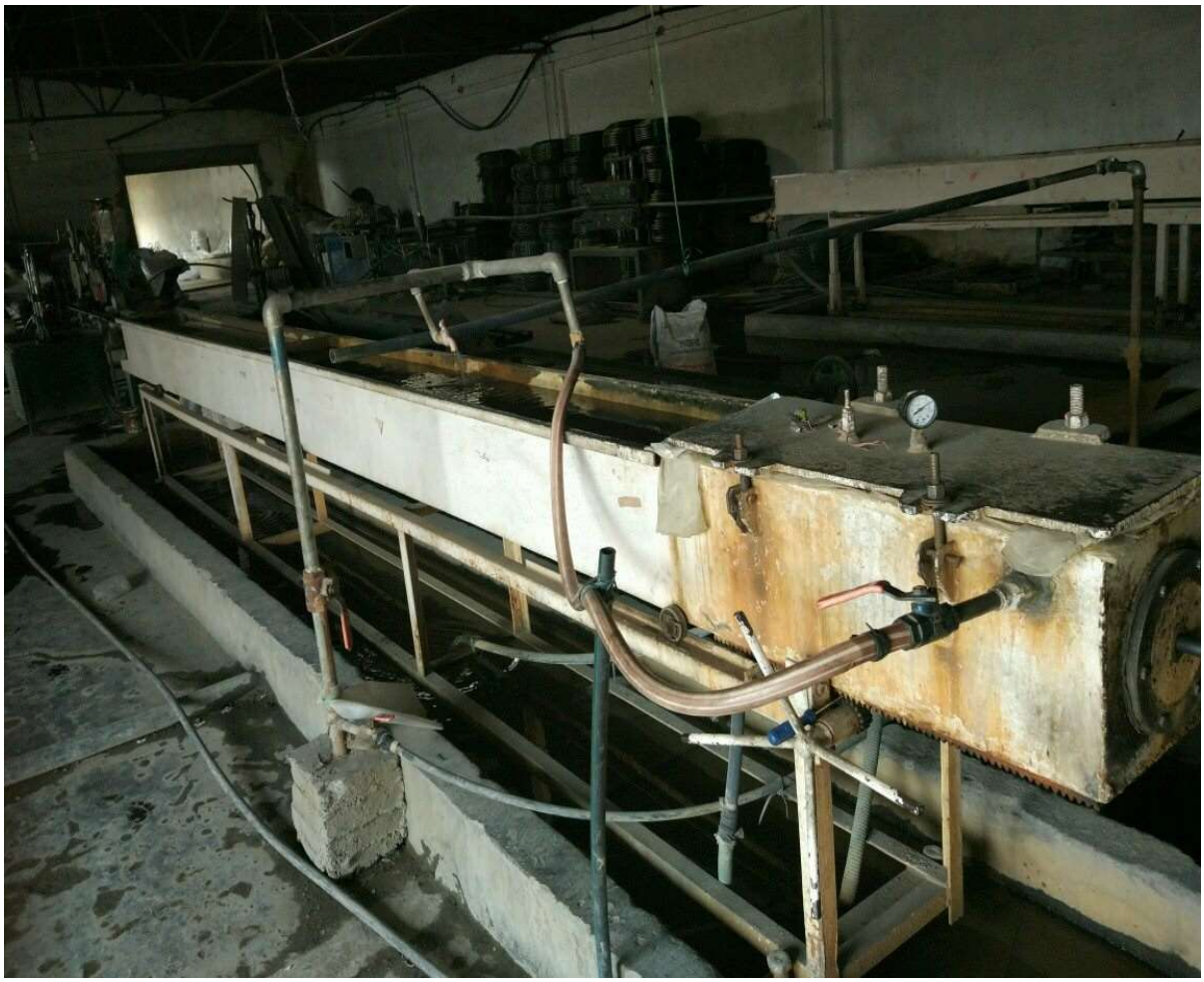

Figure 16. Six-meter water bathtub at Seti Plastics (Nishan Devkota, 2017)

Figure 17. After cooled in bathtub at Seti Plastics (Nishan Devkota, 2017)

3.2 Parameters

To extrude plastic pipes, it is very important to consider all the necessary parameters, temperature and pressure readings according to material chose to be processed. Factors like melting temperature, drying temperature, pressure, speed of screw, motor, placement of die greatly affects the possible extrudate in extrusion.

3.3 Standard Dimension Ratio

It is abbreviated as SDR and is defined as the ratio of pipe's outside diameter to the wall's thickness. It is the method of rating pipe's durability over pressure.

Or, $SDR = \frac{d}{s}$

where d is outside diameter and s is thickness of the wall.

Which can be also described as higher the SDR, thinner the walls of the pipes.

Here, relationship between SDR and pressure rating is given by Lames formula for the Hoop Stress in thick wall cylinders.

$$S = \frac{P(dn-en)}{2en}$$

Or, $S = \frac{P(SIDR-1)}{2}$

Here, S= the maximum hoop stress and P= internal pipe pressure.

Hoop stress is design stress for materials divided by design coefficient C.

Now, $\frac{MRS}{C} = \frac{P(SDR-1)}{2}$

Or, P = $\frac{2MRS}{C(SDR-1)}$

Where P= maximum operating pressure (MOP)

Therefore, MOP=2MRS/C(SDR-1)

Note: units of MRS and MOP is MPa and bar respectively.

It was noted that Seti Plastic industry produces pipes with 9 different SDR labelling's and the most common were of SDR65 and SDR35. They were at the highest demand on irrigation pipelines and sewage pipelines. Pipes with SDR 65 means 65 times the thickness of the wall. So high SDR pipes have low pressure ratings and vice-versa. (Anon., 2006)

3.4 Process

In the continuous process of pipe extruding in Seti Plastics, firstly the resins were carefully checked and then dried in the mixture chamber. Seti Plastic Industry gets its raw materials from Birgunj city of Nepal. Resins are first imported to India from Arabic Countries and then to Nepal.

1.2% moisturising powder was mixed as an additive to resin. Temperature in dryer was ranged from 80°C up to 90 °C.

Whole extruders efficiency depends upon how well extruder is heated and functions smoothly with resins.

The extruder was pre-heated on each channel.

Temp zone 1=162°C

Temp Zone 2=161°C

Temp Zone 3=165°C

Temp Zone 4=185°C

Temp Zone 5=187°C

Control Box The control box input supply from a minimum 240V generator suitable to drive inductive loads and phase cut systems, commonly of about 5kVA capacity was chose for extruding process. Control boxes included safety devices to prevent voltages greater than 42V AC for a 40V system being present at the control box output. In emergency safety device operates in less than 0.5 sec

The preheating of the extruder lasted for 30 min and the extruder was ready to operate. Single screw extruder was taken of 30L/D. The granules were fed manually into the hopper after drying 2.5 hrs in drying chamber. Then the raw materials were immediately passed through the throat of hopper via gravity. When the materials reached at base, the screw began to push the materials. The heat generated via friction and external heat pushes and melts resins mixture forward, towards Temp zone 1 and 2. The temperature was kept 162°C -161°C respectively.

Resins was starting to melt slowly and moving further to Temp zone 3, the temperature of the zone 3 was 165°C. When the resin passed Temp zone 4 and reached Temp zone 5, the mixture of raw materials was completely melted and in nice homogenous state. The Temp in zone 4 and 5 was 185°C and 187°C, respectively. The extrudate was then passed through a chamber for cooling. A extrudate needed to be dimensionally accurate without any sags or thickened regions, therefor centrepiece of the die was shift downwards.

Now the pipe went through long water tub for cooling. Water in the tub was in room temperature ranging from 22°C -26°C. The supply of water to the tub was continuous

flow of water. When the pipe reached the end of the bath tub and finished cooling process, the extrudate pipes were cut to size at the end manually.

Table 1. showing series of extrusion test temperature for making 5 different SDR pipes at Seti Plastics

Experiment trials	Material	T1(°C)	T2(°C)	T3(°C)	T4(°C)	T5	Outer diam-eter (mm)	Min wall thick-ness (mm)
1	HDPE	149	150	160	175	187	16	1.6
2	HDPE	150	163	164	175	188	25	2.3
3	HDPE	155	160	164	180	195	40	3.7
4	HDPE	157	165	165	180	195	65	5.9
5	HDPE	160	161	170	190	195	110	10.0

The Power consumed by Extruder= 220000 watts/day

Pressure used = 35,5584 Psi - 142.233 Psi (according to demand)

Pressure of Vacuum Tank 300 Psi - 500 Psi

3.5 Results in images of Manufacturing Process

The following figures show the final products of the Seti-Plastic industry.

Figure 18. Pipes ready to be delivered I at Seti Plastics (Nishan Devkota, 2017)

Figure 19. Pipes ready to be delivered II at Seti Plastics (Nishan Devkota, 2017)

3.6 Winding Process

Figure 20. Winding machine and rolling a HDPE pipe at Seti Plastics (Nishan Devkota, 2017)

As shown in figure above the rolling machine for pipe is very simple and works manually. A worker in factory continuously spins the wheel for pipe to get rolled. Little bit of oil maintenance is done occasionally for smooth spinning and good efficiency.

3.7 Cutting Process

Cutting process of the pipe is also done manually, workers use local cutting tools i.e. Saw instead of modern cutting laser cutters. Therefor cutting personnel should be very careful to keep exact dimensions of profile like pipes.

3.8 Recycle Process

Recycling system was not in large scale in Seti Plastic Industry. But small recycling was machine was helping very much to keep local village and environment cleaner. Below is an image of simple recycling of used plastics collected locally.

Figure 21. Recycling of local community plastic waste at Seti Plastics (Nishan Devkota, 2017)

4 MY APPROACH TO QUALITY CONTROL AND QUALITY ASSURANCE IN SETI PLASTICS

Assuring the good quality raw materials to be used in the production of pipes is the first essential and significant condition for compliance with the specific needs of the finished product. HDPE resins used to make polyethylene pipe must be analysed, tested and approved for use to ensure NSTM portrayal necessities. Resin supplier's accreditation portraying the material and communicating consistence with all essentials must run with all unrefined raw materials used in the production of the pipe. The pipe maker's commitment includes testing, randomly picked samples from each part lot for certifying density, melt index, tensile strength and environmental stress crack resistance. For reference and gathering process control purposes, recognized material packages should be doled out recognizing numbers. Permanent records should be kept. Control of the idea of the pipe delivering process is the accompanying fundamental and essential condition for consistence consolidates the going with.

Controlling the manufacturing process is the next significant step. A highly recommended quality control program for manufacturing process are as follows:

• serious examination of every movement using visual and in addition automated inspection procedures

• testing trial of the finished pipe, done at predetermined frequency (NSTM/ PPI)

Despite records of the above things, and to ensure traceability of the made pipe, quality control reports must record the plant, date and move of manufacture, production line and resin. Each modifying thing ought to be identified with enduring markings exhibiting the manufacturer, creating plant, date of production, applicable specific task and the pipe's nominal diameter.

Standard QA/QC (Quality Analysis/ Quality Control) program will fuse irregular audits of the feasibility of the program itself. Such surveys will generally address:

• evaluation of manufactured pipe and fittings in stock

• examination and recalibration (if fundamental) of QC testing instrument

• QC examination and reporting systems

• raw material reviewing, testing and package control systems

• product accreditation techniques

• collecting customer feedbacks; helpful exercises

• processing of recommendations from plant personnel (PPI, 2018)

5 DISCUSSION AND CONCLUSION

The extrusion process was investigated using the screw characteristics, die characteristics and material characteristics. There were different die structures used for producing pipes of various SDR. Die structure was varied to produce the required size and weight of weight. The melt flow characteristics study showed that they depend upon screw rotation speed and die-structure used. Also, we found that melt flow of the raw materials has an inverse relationship with pressure involved and the rotation speed of screw. The shear stress was kept balanced by maintaining constant supply of raw materials along with the constant heat and pressure during the extrusion. It was also known that the pipes production was best at the maximum amount supplied and reduced non-uniformity present in SDR of the products and the weight.

It was really a great opportunity to look inside and to work with pipe factory members in Kailali, Nepal. From this study, I learnt the core mechanism and simple working formula are important than the upgrades. Factory was not old, but the infrastructures used to extrude plastic were old-fashioned. I learnt how simple things works together to give complex products. Winding and cutting were done manually, which is very difficult to perform precise cutting, but was done nicely by experienced cutter in factory. Since extrusion process is long and continuous process the factory had accommodation services to all their employees. Infrastructure for good and experienced engineers are lacking in the factory. Regular updates in machines and collaborating with good Plastics Engineers, the number of products and quality of the products in factory can be increased.

The processes can be automated to increase the rate of HDPE pipes production. Consequently, the number of labours used for the processes are eliminated and hence decrease the direct cost for the final product. Also, cutting the pipes and making the raw materials manually is a risky process, i.e. a lot of human risk factors are involved since it involves use of sharp tools continuously for long time.

Amount of recycled waste at local level can be increased, since the factory does not always get the raw material at time and of good quality sometimes. On the other hand, it can provide employment opportunities at local level and can also, decrease the direct cost of product. It will help the surrounding communities to promote green-ecosystem by reducing Plastic Wastes.

The following is the list of properties of Pipe products that needs to be ensured for quality products and good feedback:

- Minimum inside diameter
- Liner thickness
- Length
- Perforations
- Pipe stiffness
- Pipe flattening
- Environmental stress cracking
- Brittleness
- Joint integrity (for fittings) (PPI, 2018)

6 FUTURE DEVELOPMENTS

The extruder used in this company seem a bit old fashioned. The extruder takes lot of energy as the design efficiency is not quite seen developed comparing European extruders. The use of the insulation on the barrel are considered as more efficient. If the barrel could use aluminium or copper block heater including the glass fibre or carbon fibre insulation it could greatly save power usage around 75%. Besides the laser cutter could save

work force used. It could increase the speed and help to maintain the rigid structure of the barrel which can be operated using less torque on the screw. This also minimizes the wearing and breaking of the screw as the screw is highly brittle and made using brass to conduct more heat.

Furthermore, the most important steps to follow during production process must be strictly following Plastic Pipe Industry Nepal and Nepalese Society for Testing and Materials test procedures, trying to pass their criteria in terms of selecting raw materials to every step. It's not mandatory to pass the quality test from NSTM and PPI however if they ask, the products must meet the criteria.

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APPENDIX I

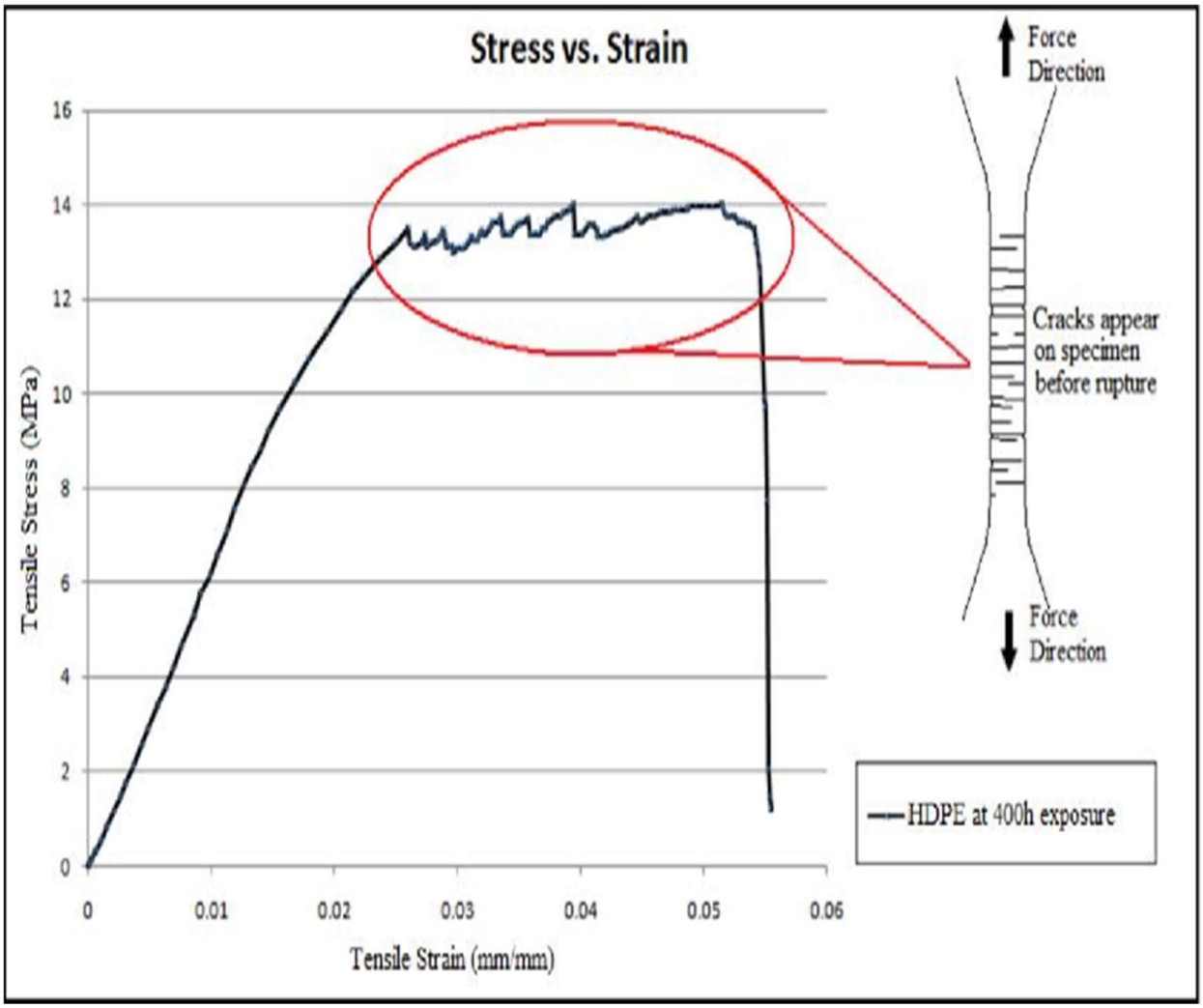

Figure 22. The stress-strain curve of the weathered HDPE of 400h of exposure (Zainudin, 2012)

APPENDIX II

Table 2. showing mechanical and thermal properties of HDPE (Pipes, 2010)

HDPE	Value
Property Unit Value Density	0.942– 0.965 (g/cm³)
Melting point	120°C - 135°C
Tensile Strength	20MPa - 40MPa
Strain at break	100 – 1000 (150%) 21
Tensile modulus	413MPa- 1241MPa
Elastic modulus	0.2- 1.2 (GPa)
Glass transition temperature	110°C
Coefficient of Thermal expansion	100 - 120×10-6 m/m °C
Thermal conductivity	0.38- 0.51W/Mk
Notched Impact strength (charpy)	2 -12 kJ/m²
Resistance	Above 100°C
Crystallinity	Greater than >90% (high crystalline)
Flexibility	More rigid

APPENDIX III

Questionairres

1. How relevant is recyclabiltiy of plastics in Seti Plastics?
   = Highly

2. What percent of customers believe in recycling?
   = 25-50

3. What are the minimum required strength for PE100 and PE80?
   = 10 Mpa and 8Mpa respectively