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Design and Development of Hand Operated Injection Moulding Machine for Manufacturing Recycled Plastic Articles

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Abstract: ***A large quantity of plastics is wasted every day in the world and the waste accumulates polluting every place and environment. Recycling of wasted plastics would be a good alternate for fresh production of raw materials. Hence, design and development of hand operated injection molding machine for manufacturing recycled plastic articles for small scale industries and tertiary institutions were studied. In this work, recycled molten plastic materials are injected into a closed mold, where it solidifies and gives the desired shape as per the mold dimensions. The functional prototype machine was designed and developed for recycling waste plastic and to make useful products. Based on the phases of product design and development; customer need assessment, concept generation, concept selection, detail design, mold flow analyses and manufacturing were done. Design and manufacturing were done with the available materials and software. Manufacturing drawing and 3D model was prepared using Catia V5, machine fabrication and cost analysis was carried out. Finally, the performance of the injection molding machine mold flow was tested using virtual prototyping of selected plastic article with the help of solid works plastics 2014 software. Experimental procedure was done by preparing specimens of recycled Polypropylene plastic according to ISO 197-1 and ASTM D695-02a standard for impact and compression test respectively. The result of selected plastic article (plastic cap) obtained from simulation shows, pressure and flow front central temperature at the end fill was 0.8 MPa and 182^{0}c respectively. The pack time required for the plastic component was 7.5 seconds. The result obtained from experiment shows that the recycled Polypropylene manufactured using the developed machine attains average impact and low compression strength compared to the fresh raw material. Thus, the recycled material is useful to manufacture plastic articles which can reduce wastes considerably.***

Key words: Injection Molding, Polypropylene, Plastic article, Mold Flow Analysis

I. INTRODUCTION

Production industries are the main sector to creating job opportunities and enhancing economic development of one country. One of the main products of production industries are plastic materials that are not degradable, therefore their accumulation after use or their waste generates an environmental problem. Plastic wastes are among the large amount of wastes in many countries including our country Ethiopia. A plastic is defined as any natural or synthetic polymer that has a high molecular weight. Nowadays plastic consumption is more than metallic products due to its ease of production and high performance. Worldwide plastic consumption on 2014 is estimated at least 125,000 million pounds (by weight). About 36% is processed by extruders, 32% is processed by injection molding, 10% by blow molding and 22% using other processes [1]. Injection molding machine offers many advantages to alternatives manufacturing methods, including minimal losses from scrap (since scrap pieces can be melted and recycled), mass production is possible, complex parts produced easily and minimal finishing requirements. The thermoplastic materials are used primarily in injection molding. Injection molded components are a feature of almost every functional manufactured article in the modern world, from automotive products through to food packaging. This versatile process allows us to produce high quality, simple or complex components on a fully automated basis at high speed with materials that have changed the face of manufacturing technologies like PE, PP, ABS, PVC etc. From the versatile products of this machine plastic articles (small plastic components) are the main products of these machines. According to AIM processing of small plastic company, small plastic components are defined as roughly the size of your fingernail to the size of your hand [2]. Domestically fabrication of plastic articles is limited due to availability of these machines. A commonly known household and consumer plastic articles are plastic bottle caps, small plastic forks and spoons, toy components, electric switches and etc. Plastic caps are a product that used in household and consumer industries for closing plastic bottles. This research will look at on design and development of hand operated plastic injection molding machine for manufacturing recycled plastic articles. The proposed machine expected to use for small scale industries and tertiary institutions. The design and development of the machine considers cost, manufacturability, maintainability and locally the availability of the material.

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1.1. Problem Statement

Nowadays, a large amount of plastic wastes is available in the world. Taking these plastic wastes and recycle them for producing commercially viable products and reducing uncontrollable extreme environmental pollution needs small scale machines accessible all over the places.

Plastic injection molding machine is one of the most common method of plastic processing and this machine use either electric motors, pneumatic, hydraulic or combination of these systems for processing plastic materials. But due to its capacity and cost, its installation limited to only large-scale industries. The growth of small-scale industries and their capacity in developing countries including Ethiopia couldn't afford it. This machine is also costly to afford for laboratories in tertiary institutions for teaching and research purposes in developing countries. Additionally, spare availability, space requirement, expert requirement, etc needs development of small-scale plastic injection molding machine for recycling waste plastic materials. The development of this machine plays a vital role to fill the practical gap of fabricating small plastic articles domestically, to ensure make of small plastic spare parts for failed plastic components, to ensure waste material processing and to creating job opportunities for the community.

1.2 Objective

1.2.1 General Objective

The main objective of this study is to design and develop hand operated plastic injection molding machine for manufacturing recycled plastic articles.

1.2.2 Specific Objective

1. Conduct customer need assessment
2. Develop injection molding machine.
3. Conduct the performance test of injection molding machine.

1.3 Scope

The scope of this study addresses two main points. The first one is to design and develop hand operated plastic injection molding machine for manufacturing recycled plastic articles. And the second one is to conduct performance testing of the developed machine using virtual and experimental method. And compare the mechanical properties of recycled plastic with result of plastic material distributors.

1.4 Limitation of the study:

While conducting the study of design and development of injection molding machine; there was limitations which is written below.

- Due to unavailability of metal wax, the plunger was not pressurizing the material inside the mold as intended.
- Due to lack of budget and facility only one mold was prepared.

II. BACKGROUND

2.1 Polymers

The word plastic comes from the Greek word plastics, which means to be able to be shaped or molded by heat. 'Polymers' is a general term for all plastic materials and means that they are organic, carbon-based compounds whose molecules are linked together in long chain patterns. Plastics fall into two different groups, thermoplastics and thermosets. Thermosets will undergo a chemical reaction when heated and once formed cannot be re softened. The thermoplastics, once cooled, can be ground up and reheated repeatedly. Commonly thermoplastics materials are used in injection molding process such as PE, PP, PS, PVC, and nylon.

Polypropylene is a plastic material that grouped into thermoplastic material which melt over and over again due to weak bond between its molecules. Molecular structure, average molecular weight varies between 200,000-600,000 g/mol. Its dynamic load capacity is relatively high as compared to PE and engineering plastics such as ABS, PA, etc. its application is wide typically on automotive industry, household and consumer products.

2.2. Recycled plastics

Mahendrasinh M. Raj et al [3] on their thesis reported industrial waste can frequently be obtained from the large plastics processing, manufacturing and packaging industries. Rejected or waste material usually has good characteristics for recycling and will be clean. Once the plastic has been collected, it will have to be cleaned, sorted and changed to reduced sizes. Sorting of plastics can be by polymer type (thermoset or thermoplastic for example), by product (bottles, plastic sheeting, etc.), by color, etc. Size reduction is required for several reasons; to reduce larger plastic waste to a size manageable for small machines, to make the material denser for storage and transportation, or to produce a product which is suitable for further processing.

There are several techniques commonly used for size reduction of plastics. Cutting is carried out for initial size reduction of large objects and followed with scissors, shears and saw. Their studies result shows that the recycled polypropylene materials have near impact strength to virgin. This study helps the method used for preparing the waste plastic for better usage and waste plastics shows some promising properties for reusing them. Narinder Singh et al. [4] On their paper the recycling of a virgin plastic material can be done 2 to 3 times only, because, after every recycling, the strength of plastic material is reduced due to thermal degradation. Polyethylene and polypropylene are a major component of plastic waste from domestic refuse. Recycled plastic is highly used in manufacturing industries for the preparation of products. Industries are more interested in cost reduction; hence using recycled material is better choice for cost reduction.

2.2 Injection Molding

Injection molding is a method of fabricating a plastic product by injecting a material into the mold. The conventional injection molding machine as shown in the way of producing a plastic product with any complexity and size starts with the retraction of the ejector plate, followed by closing of the mold and the injection process starts with the feeding of a polymer through hopper to barrel then heated with the sufficient temperature to make it flow,

then the molten plastic which was melted will be injected under high pressure into the mold. After the product cools and gets its shape the platens will move away from each other in order to separate the mold tool which is known as mold opening and finally the molded product is ejected or removed from the mold. And the process will repeat itself as shown in Figure 1 [5].

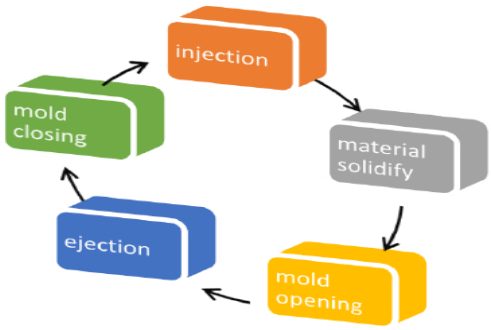

Figure:1 Injection molding cycle

2.3. Possible Problems on IMM

It's a common coincidence that imperfections in injection molding arise from the mold design problem (gate size and location), inappropriate material compounding, injection pressure, mold air vent location, inappropriate clamping force and melting temperature along with non-uniform setting times play the major role. The following table:1 shows the common defects that might arise in the production line of injection molding and their causes [5].

Table:1. Defects in Injection molding

S.No	Defects	Causes
1	Flash	Injection pressure is too high
2	Warping	Non uniform cooling Rate
3	Bubbles	Injection temperature is too high
4	Unfilled sections	Low injection pressure
5	Sink Marks	Injection pressure too low
6	Ejector marks	Ejection force to high
7	Shrinkage	Higher shrinkage percentage material usage

Many of the above defects are caused by a non-uniform cooling rate. A variation in the cooling rate can be caused by non-uniform wall thickness or non-uniform cooling time.

2.4. Identifying Customer Needs

The main goal of customer need is to ensure that the product is based on customer needs, identify latent or hidden needs as well as explicit needs, ensure that no critical customer need is missed or forgotten, provide a fact base for justifying the product specifications, create an archival record of the needs activity of the development process and develop a common understanding of customer needs among members of the development team. The process of identifying customer needs is an integral part of the larger product development process and is most closely related to concept generation, concept selection, competitive benchmarking and establishment of product specifications. Identifying customer need is itself a process, for which a five-step method is presented.

1. Gather raw data from customers
2. Interpret the raw data in terms of customer needs
3. Organize the needs into a hierarchy of primary, secondary and (if necessary) tertiary needs.
4. Establish the relative importance of the needs
5. Reflect on the results and the process

III. LITERATURE REVIEW

Rohit et al. [6] Their work focuses on fabrication of manual plastic IMM for the small-scale industries, low manufacturing cost, low maintenance cost, no skilled worker required. The main principle used for HPIMM is to compress the plastic material in a heating chamber (barrel) with the help of plunger and induction coil convert plastic polymer into molten state. Then the plastic polymer in predetermined quantity is forced through the nozzle into the die under pressure. After completing the process, final product is obtained from the die. This work helps to convince the production of small plastic articles by the uses of hand operated injection molding machine and the solid plastic changed into melt plastic was use an induction coil. Asha S. et al. [7] on their work for parametric analysis of injection molding machine for PET production company products to increase demands of their products an effective manufacturing output required this needs an effective cooling, clamping and injection system. This work is critically analysed with different engineering software like Solid work were utilized to determine the clamping force, injection pressure, pouring temperature of the molten plastic and material thickness as they affect performance of the injection molding system for quick PET plastic products production. Shamshad et al. [8] on their paper manually operated injection molding machine is used for cottage industries to manufacture plastic components. These machines capacities are weights from 15 to 50 grams of plastics. K.Kannakumar and Jithin.K [9] on their study reported Solidworks use as a tool to validate and optimize the design of plastic component before production in order to eliminate the use of trial and error method. The tool has been used in the design stage to reduce the losses to obtain the shortened lead time, high quality and achieving low cost of the mold. Ramanagouda B. et al. [10] on this study Catia and Solidwork are involved to model the parts and for theoretical and analytical analysis 40 kg or 400 N human forces applied on the lever. Allwin A. and Ramesha N. [11] On their study involve solidwork for single cavity mold core and cavity design and the material planned for producing the component is PP.

IV. METHODS AND MATERIALS

In this section data collection, analyzing and interpretation to provide solution for problems will be discussed. This approach helps to achieve the aim and objective of the design and development of HOIMM. The purpose of this section is to present methodology which will be followed to achieve the ultimate goal of the project which is specified at the beginning and the material used.

4.1 Data Collection

In order to address the problem, available data's regarding to IMM are considered to design and develop HOIMM. Data's has been gathered to induce solution for the problem. The relevant data were collected from the amazon shopping website, text books, other related works and other IMM production industries websites to strength the project work with facts and evidences of science and technology. Data was also gathered using interview, questioner and direct observation of the machine. Identifications of customer needs in different mechanism are highly considered as an integral part of the larger product development process and are most closely related with phases of PDD. In order to identify customer needs customer's segmentations are used for dividing the customers into different education and position level are considered using interview and questioners.

4.2 Data Analysis

The data analysing method first step starts by changing the gathered raw data from customers into a customer statement. Interpreting the raw data in terms of customer need was the next step.

The first things to do in the process were to set target specification, refining the specification, reflect on the results and the process. In establishing the target specification list of metrics was prepared then competitive benchmarking information was collected. As a first phase, Clarifying the problem and decompose the problem into sub problems were done. Next, concepts were searched externally using interview with researchers, searching the web for published literatures, consulting experienced researchers and searching for bench mark related products, books and journals. Concepts which are generated at this stage were existing concepts. Following the external search, internal search was conducted adding personal design ideas, advisor and co-advisor suggested design ideas and researchers suggested designs. Finally, by carefully looking at the steps followed the most appropriate method was selected. Concept selection was made based on decision matrices method for evaluating each concept with respect to a set of selection criteria based on external decision (that is based on customer needs) and based on personal reference.

Thereafter manufacturing of the machine component and machine assembly was made as shown in Figure 2 and Figure 3 respectively. Then cost analysis of the machine was made considering material (raw material, consumable and commercial), machine and labour costs. The cost provided for machine and labours was based on Mesfin Industrial Engineering.

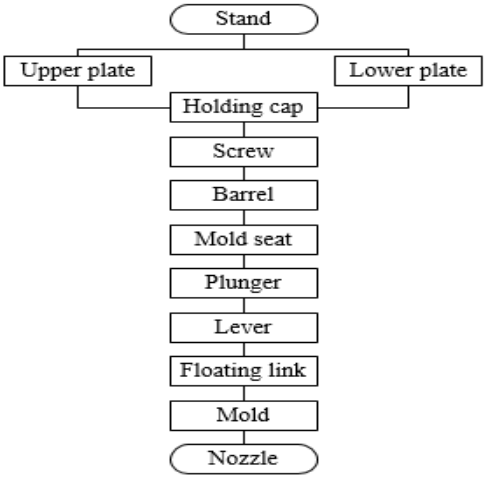

Figure: 2. Manufacturing flow chart of injection molding machine

Finally, the performance test of the machine was conducted using virtual and experimental methods. Virtually testing was conducted for checking the designed machine parameters capacity to make the plastic flow inside the mold and to observe defects of IMM during processing of plastics, with the help of solid work plastics by selecting one product which can represent plastic articles (plastic cap).

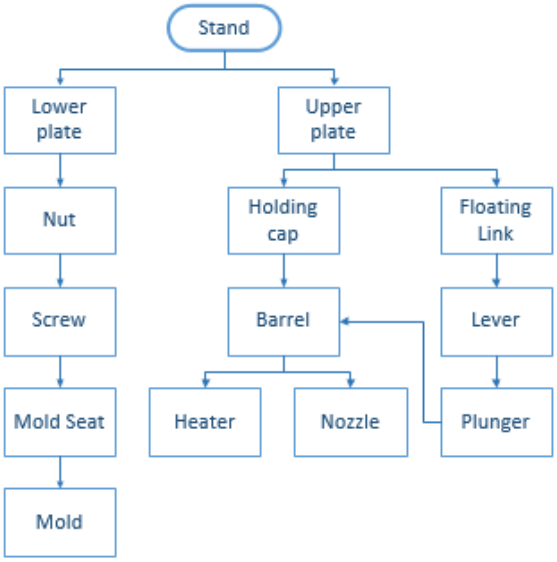

Figure 3: Assembly flow chart of injection molding machine

The aim of this test is not to fabricate plastic cap but to observe common defects arise in IMM while processing products. The plastic cap flow and pack simulation has done.

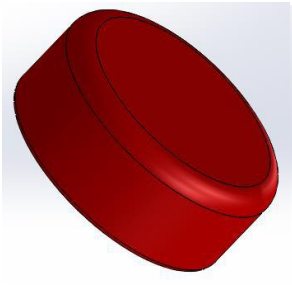

Figure 4: Imported model

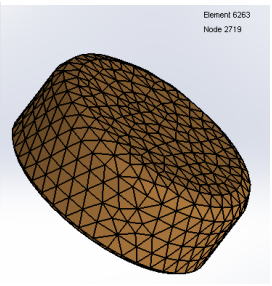

Figure 5: Mesh model

Importing the 3D model from catia V5 software, see in Figure.4. Meshing the model by using solid mesh, since the tetrahedral elements give a true 3D representation of the model, see Figure 5. The selected mesh has a good quality and it is acceptable for further analysis[16]. The report on Figure 6 shows that it's applicable.

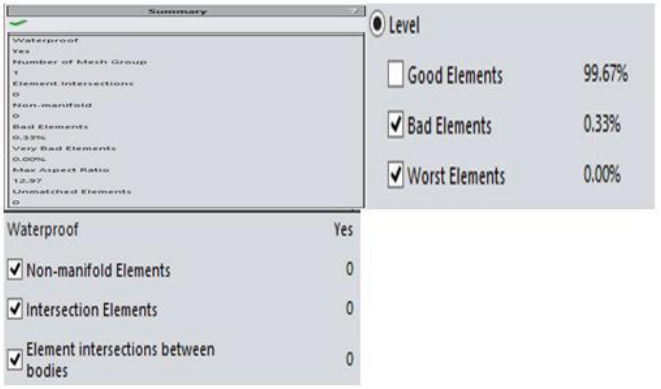

Figure 6: Mesh summary

Specifying the boundary condition, loads such as injection pressure (2 MPa), mold temperature (40 ^{0}c), melt temperature (220^{0}c), injection time (5 sec), material (polypropylene) etc.

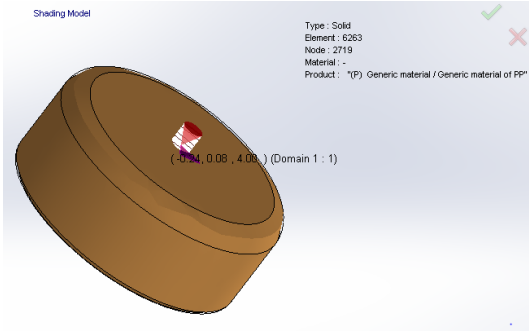

Figure:7. Building the gate location.

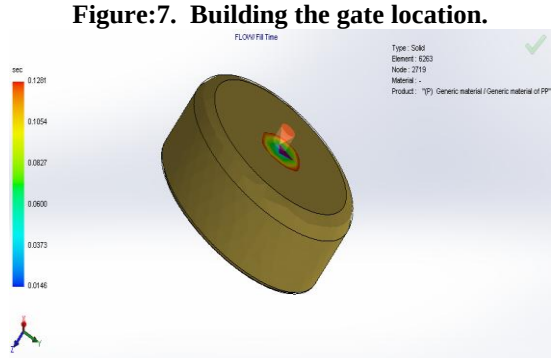

Figure:8. Run the analysis for different analysis types like fill, flow and pack.

4.3. Study the result and interpret them:

Experimental test was conducted for testing the proposed machine performance attainment of mechanical property of waste plastic. Mechanical properties of materials describe the behavior of a material under the application of mechanical forces. For conducting the test, test specimen was prepared for impact and compression testing according to ISO179-1 and ASTM D695-02a standard respectively. The results are compared with Prospector and MatWeb information given for comparative purpose of plastic material with using the same testing method. The waste material used for preparing specimens was collected from Mekelle Java cafe. The waste plastic was washed using pure water, dried at room temperature and chopped into small pieces using cutting tool (scissor).

Figure:9. Testing of machine A) Plastic cutting B) First time test without mold C) Recycled plastic inside the mold

Based on the size of the machine, a total weight of 50 gm PP was poured as granules into the barrel. The injection temperature of PP 220^{o}C was set on the temperature controller. When the temperature reached at the desired temperature of PP, the power supplied to the heating element was switched off automatically with the help of contactor and temperature controller. While melting the PP a temperature sensing device (thermocouple) was used to sense the temperature and tighten with the nozzle. The breaker was connected with a power source in order to supply power to the heating element and control system. It found on the left side of the machine. When the contactor switches off the supplied power, the PP plastic is ready to inject into the mold. Then using the hand lever, the melt plastic material was injected into the mold and after curing time the mold was opened and PP product was removed from mold, for testing the functionality of the machine.

Figure:10. Specimen preparation

4.4. Impact testing

Impact test used extensively to determine the impact resistance of a recycled PP material.

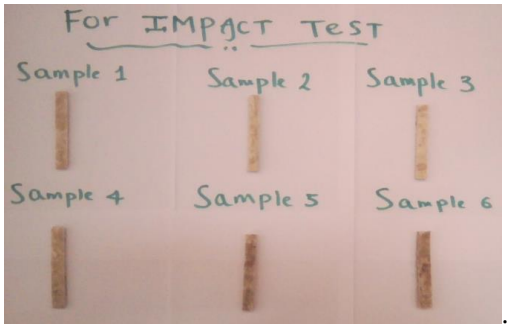

Figure 11: Impact test A) Specimens B) Impact testing C) Impact tested specimen

Using pendulum energy that employed for the testing purpose was having 12.5-kilogram weight mounted pendulum. The Charpy impact test was carried out for the samples with dimensions of 80mm x 10mm x 4mm in accordance with **ISO179-1** and 6 specimens were prepared. The specimens were cut to the required dimension using hand saw and for smooth surface finish a grinding machine with polishing disk were used.

4.5. Compression testing

Compressive strength of recycled PP was determined in accordance with ASTM D695-02a. The specimens were prepared to 79.4x19x3.2 mm. The test specimen performed using SI-1000 KN microcomputer controlled electro-hydraulic servo universal testing machine installed in civil engineering geology lab in Mekelle University.

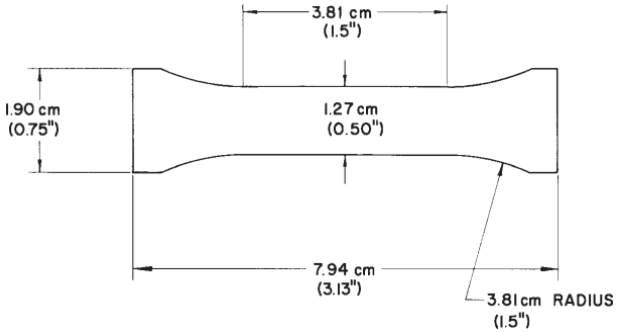

Figure 12: Compression test specimen dimension

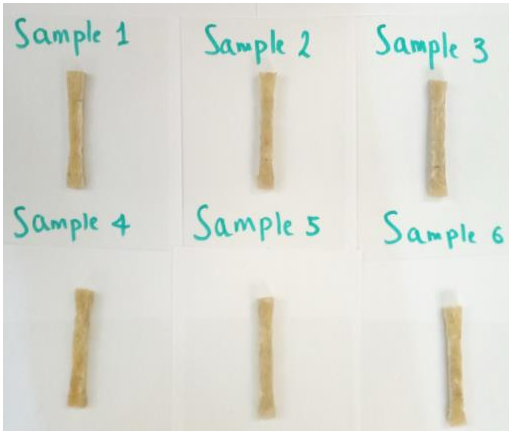

Figure:13 a) Specimens for compression test

Figure:13 b) Testing machine

Figure:13 C) Specimen placement location

V. RESULT AND DISCUSSION

This chapter deals specifically in the results of product development and testing of the injection molding machine. In this study the researcher has significantly followed the phases of the product design and development process

5.1 Product Development Process

The product development process starts with identifying customer needs and interpret the needs as gathered data. The interpretation follows these five guidelines: express the need in terms of what the product has to do, express the need as specifically as the raw data, use positive phrasing, express the need as an attribute of the product and avoid words must and should.

Organize the Needs into a Hierarchy

The goal of this step is to organize these needs into hierarchical list.

➢ The injection molding machine recycle common plastic waste materials.

➢ The injection molding machine fabricate required product

*** ! The injection molding machine changes waste plastic into useful products

*** ! The injection molding machine produce good quality products

➢ The injection molding machine easy to operate

** The injection molding machine can be made to operate easily.

* The injection molding machine operation steps can be simplified.

➢ The injection molding machine required less skilled operator

** The injection molding machine operated by less skilled machine operator

** The injection molding machine can be maintained by less skilled maintenance operator.

➢ The injection molding machine is low cost

** The injection molding machine can be designed with affordable price.

** The injection molding machine required for small scale industries.

** The injection molding machine can be designed to install with low price.

➢ The injection molding machine efficiency can be further increased for satisfying the customer.

➢ The injection molding machine safe to the operator

*** The injection molding machine provides good ergonomics for the operators.

*** The injection molding machine provides safety for the operators.

➢ The injection molding machine utilize less space

* The injection molding machine can be designed in small size.

** The injection molding machine is required for small scale industries.

➢ The injection molding machine setup can be easy to manufacture.

Note: Importance ratings for secondary needs are indicated by the number of * S, with *** denoting critically important needs. Latent needs are denoted by !.

5.2. Establish the Relative Importance of the Need

Table 2: Customer needs for the injection molding machine and their relative importance

No	Setup	need	imp
1	The injection molding machine	Recycle common waste plastic materials	5
2		Change waste plastics into useful products	5
3		Produce good quality products	5
4		Easy to operate	3
5		Simplified	2
6		Operated by less skilled machine operator	3
7		Maintained by less skilled maintenance operator	4
8		Low cost of installation	4
9		Low machine price/affordability	5
10		For small scale industries	4
11		Good efficiency	4
12		Good ergonomics	4
13		Safe	5
14		Small size	1
15		Easy to manufacture	5
16		Life time	4

5.3. Establishing Target Specifications:

The process of establishing target specifications contains three steps.

1. Prepare the list of metrics
2. Collect competitive benchmarking information
3. Set ideal and marginally acceptable target values.

Table 3: List of metrics for the injection molding machine

Metric No.	Need No.	Metric	Imp.	Units
1	1	Heating element power	5	W
2	2	Compressive strength	5	MPa
3	2	Impact strength	5	MPa
4	3	Injection pressure	5	MPa
5	3	Injection temperature	5	0C
6	3	Wall thickness	5	mm
7	3	Holding time	5	S
8	3	Clamping force	5	N
9	3	Cavity pressure	5	MPa
10	3	Special tools required for design	5	List
11	4,6	User friendly	3	Subjective
12	5	Simple machine	2	Subjective
13	6	Time to adjust the machine for use	3	min
14	6	Automatic controller	3	List
15	7	Time to assemble/disassemble for maintenance	4	hr.
16	7	Tools required for maintenance	4	List
17	8	Machine installation cost	4	birr
18	9	Machine manufacturing cost	5	birr
19	9	Machine weight	5	kg
20	11	Injection time	5	sec
21	10	Barrel volume	4	m3
22	10	Product production time	4	Sec
23	12	Height of handle	4	m
24	12	Height of mold seat	4	m
25	13	Selection of materials	5	List
26	13,14	Height of the machine	4	m
27	14	Width of the machine	1	m
28	14	Depth of the machine	1	m
29	15	Manufacturing lead time (machine)	5	day
30	15	Special accessories required for manufacturing	5	List
31	16	IMM cycle to failure	4	Cycles

5.4. Mold Design and Modelling of Plastic Cap and Specimen :

In order to estimate the amount of material required to prepare plastic cap and specimen for testing the machine both of them are modeled as follows. Molds (core and cavity) are designed using Solid work 2014 and Components are modeled using Catia V5R20 software, specimen were prepared according to standard ASTM D695 as shown in Figure 4.2 and the plastic cap dimension is taken 50x50x20 mm based on medium size of plastic article for representing all plastic articles.

Product: Specimen and plastic cap

Volume of specimen and cap: 8.029 cm3 and 15.1 cm3 respectively taken from CAD.

Projected area of specimen and cap: 60 cm2 and 90 cm2 respectively taken from CAD.

Mass of specimen and cap: 7.6 gm and 14 gm respectively taken from CAD.

Component Material: Polypropylene

Molding type: Single cavity injection mold tool

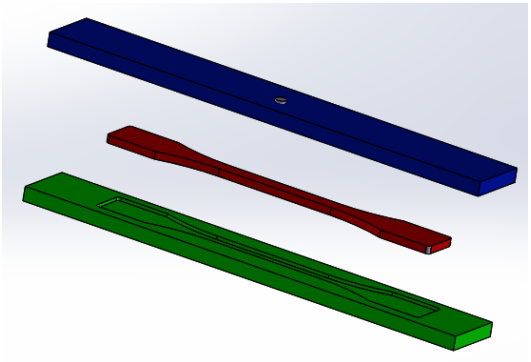

Figure 14: Specimen mold design

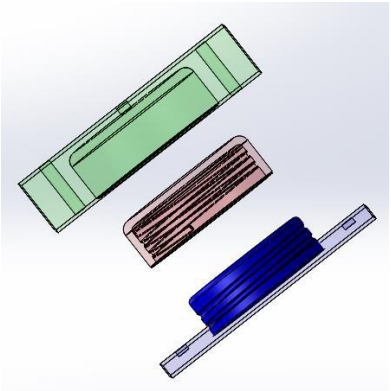

Figure 15: Plastic cap mold design

5.5. Mold Flow Analysis Result:

The mold flow simulation result of selected plastic article (plastic cap) after analysis was shown as follow figures.

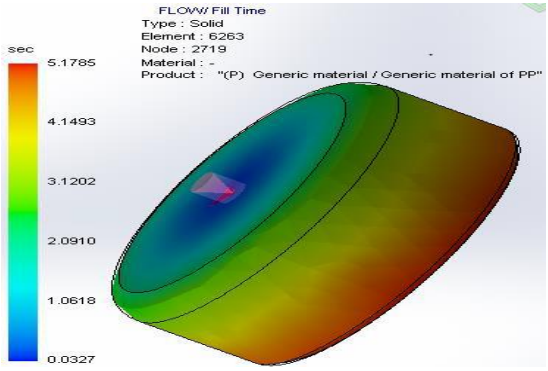

Figure 16: Flow Vs Time

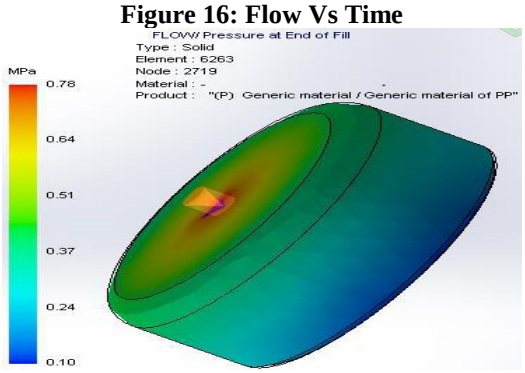

Figure 17: Flow Vs Pressure

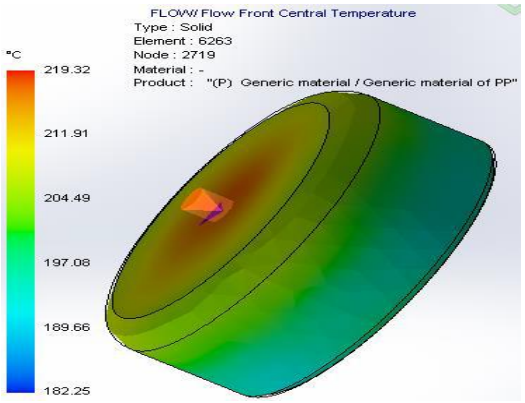

Figure 18: Flow front central temperature

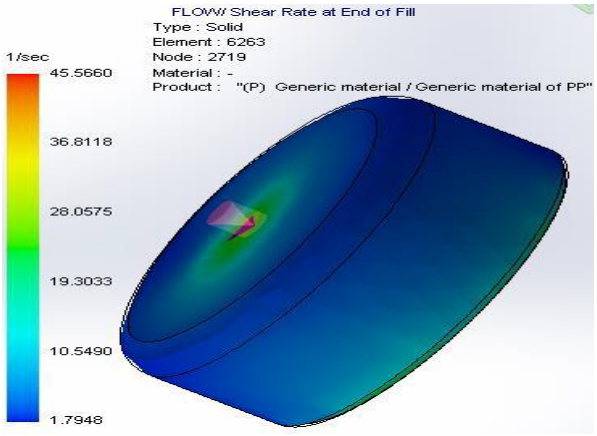

Figure 19: Flow vs Shear rate

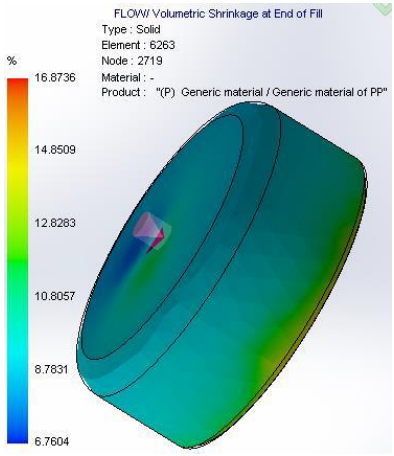

Figure 20: Shrinkage at the end of fill

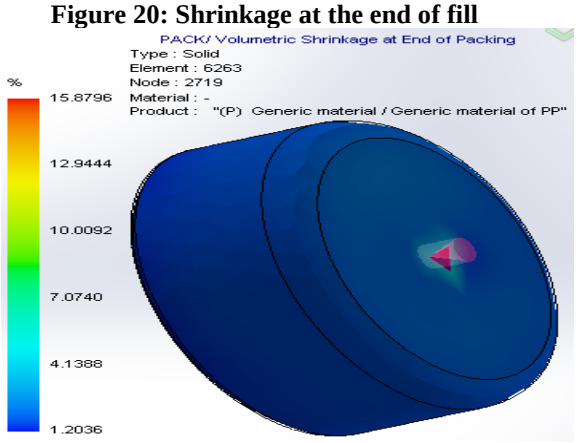

Figure 21: Shrinkage at the end of packing

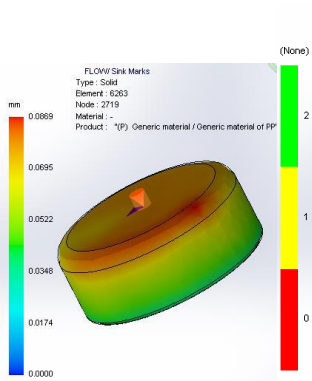

Figure 22: Sink mark

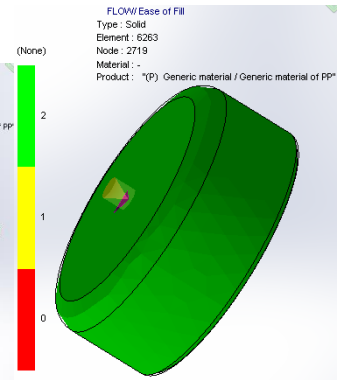

Figure 23: Easy of fill

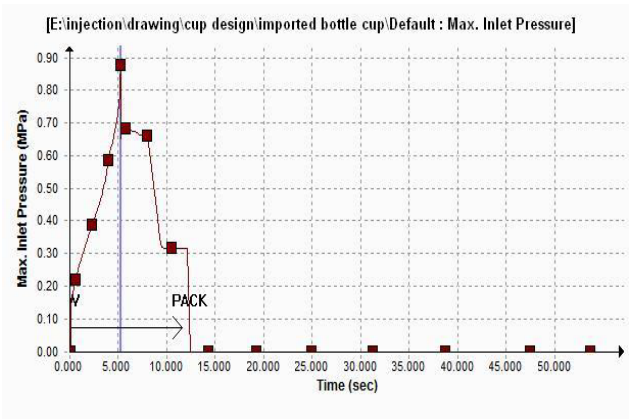

Figure 24: Required pack time

The result of simulation that has been done could show flow of plastic fluid entering all of cavities successfully with an injection pressure of 0.8 MPa, this implies mold of plastic articles could be successfully filled with injection pressure of less than the machine capability (2.1 MPa) or the injection pressure required to fill is less than 66% of the maximum injection pressure limit specified for this analysis, which means the plastic articles was well under specified limit as shown in Figure 24: - Mold flow advisor report. The flow front central temperature at the end of fill was 182 0C, which mean the temperature required to fill all areas of plastic article mold was around 220 0C, this was 55 % of machine capacity and the material temperature at the end fill of plastic article was around 182 0C as shown in Figure 19. The volumetric shrinkage at the end fill of the product and at injection location were 16.8 % and 6.7 % respectively. The volumetric shrinkage at end fill was high relative to other areas, to avoid this effect additional material should be added and pack time was analyzed as shown Figure 23 and its value was reduced to around 2%. The product requires 7.5 second pack time and pressure at the end of packing was 0.3 MPa as shown in Figure 24, which implies during plastic article fabrication addition to fill time, around 7.5 second pack time is required. Sink mark value was too low and the maximum was occurred at the injection location of the mold, its 0.08 mm as shown in Figure 22. As shown in Figure 23: - the green colour indicates all mold cavities were filled under normal injection pressure. Therefore, as a mold flow result shows the machine is capable to fabricate plastic articles with this pressure, temperature and pack time, common defects of IMM while processing a product are not affect the product quality and productivity.

5.6. Experimental Method Result

The mechanical properties obtained from the experiment shows the average charpy impact strength of recycled PP material using the developed setup are 28.33 KJ/m^2 and the samples impact resistance variation are close to each other as shown in Figure 26.

According to Prospector and international association of plastics distribution [12] the data provided for comparison purpose of plastic material the interval given to PP was 4.62 KJ/m2 to 52.5 KJ/m2, means PP plastics have impact strength between this data are applicable for making products as per application areas. The impact strength recycled plastic is equal to average impact strength PP of the given data, so the recycle plastic waste fabricated using this machine have an enough impact strength to manufacture small PP plastic articles that need medium and low impact strength.

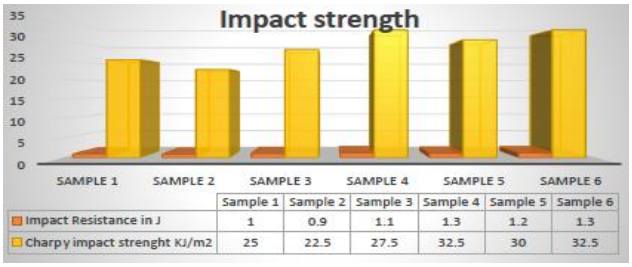

Figure.25: Charpy impact strength of recycled PP

The average compression strength of recycled PP using the developed setup was 27.38 MPa and the average maximum compressive load the material can bear was 1.11 KN as shown in Figure 27. The compression strength of PP is 24 – 55 MPa [13] and MatWeb data reported, the average compressive strength of PP using ASTM D695 is 40 MPa [14]. So the result obtained from the setup attains 69 % of compressive strength [15] of waste PP material, means the machine can be capable to regain 69 % of waste PP plastics compressive strength and it has low compressive value. This recycled plastic material uses for manufacturing small plastic products that not bear high compressive load.

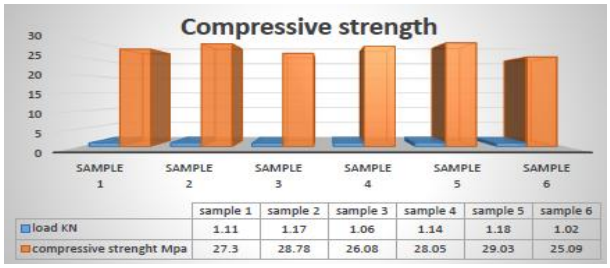

Figure: 26.Charpy Impact Strength of Recycled PP

Table:4 Final specification of IMM

No	Metric	Units	Value
1	Heating element power	W	900
2	Compressive strength	Mpa	27.38
3	Impact strength	Kj/m^2	28.33
4	Injection pressure	MPa	2.1
5	Injection temperature	^oC	220
6	Wall thickness	mm	3.2
7	Holding time	s	7.5
8	Clamping force	KN	12.6
9	Cavity pressure	MPa	2.1
10	Tools required for design	List	CAD(Solid works, Catia)
11	Use friendly	Subjective	YES
12	Simple machine	Subjective	YES
13	Time adjust the machine for use	Min	10
14	Automatic controller	List	T^o
15	Time to assemble/disassemble for maintenance	hr	1/2
16	Tools required for maintenance	List	Wrench's tester screw driver
17	Machine installation cost	birr	300
18	Machine manufacturing cost	birr	18,591
19	Machine weight	Kg	28.2
20	Injection time	sec	5
21	Barrel voume	Cm^3	28.86
22	Product production time	sec	12.5
23	Height of handle	m	0.54
24	Height of mold seat	m	0.3
25	Selection of materials	List	Pass
26	Height of the machine	m	1.2
27	Width of the machine	m	0.5
28	Depth of the machine	m	0.4
29	Manufacturing lead time(machine)	day	6
30	Accessories required for manufacturing	List	Conventional Machines
31	IMM cycle to failure	Cycles	-

CONCLUSION

Plastic waste recycling has become a new focus throughout the world because of the need to recover plastic and reuse them. In this study attempt has been made to manufacture hand operated injection molding machine, less than 50 gm capacity for producing small plastic article from recycled plastics. The total material required to fabricate single specimen and plastic cap were 8.2 gm and 15.33 gm respectively, its less than the machine capacity (50 gm). Therefore, the machine was capable to prepare specimen and plastic articles regards to its mass. The developed machine performance test was analysed through simulation and experimental procedure. The simulation was done using solid work plastic flow simulation by preparing virtual prototype of one selected plastic article (plastic cap) for representing plastic articles and the cap was filled successfully with pressure and temperature less than 66 % of machine capability and the pack time required to fabricate plastic articles is around 7.5 second, therefore the machine can be fabricating plastic articles without affecting the product with common defects of IMM. The experimental procedure was examined through preparing specimens using the developed machine for conducting mechanical properties of recycled PP plastics. The experiments that are carried out to evaluate mechanical property were impact and compression test. From the impact test result the recycled PP strength attains average impact strength of virgin PP plastic and the compression test result shows the recycled PP attains 69 % compression strength of virgin PP. The manufacturing cost value of the machine was less than marginal acceptable target value.

RECOMMENDATION

Generally, the result shows that it is possible to produce small plastic articles from developed machine and it imply

- It can be kept clean environment from the non-biodegradable plastic wastes.
- The design and development of small injection molding machine is an area of interest for small scales industries to manufacture broken parts and small reputable components with cost wise.
- By changing the shape of the mold, other small plastic articles can be molded.
- Converting the manual lever mechanism in to hydraulic or pneumatic system, the pressure of the injection molding machine and product output size and quality can be increased.
- Other materials out of PP that can be melted and injected less than 400 0C can be molded.

FUTURE WORK

The design and development of the machine is constructed in assumption of further development. Hence, interested researchers can deal with the following developments as a future work.

- The injection molding machine mechanism can be developed from manually operating to hydraulic, pneumatic and motor can also be checked.
- For checking the functionality of the machine, only PP material was used. However other materials can be checked in future studies.
- The recycled PP plastic with additives can be checked for better mechanical property.
- Due to limitations only mechanical properties were conducted, so far environmental and thermal properties can be conducted in future studies.
- The plastic waste was cut using scissors, shredder machines prepared for cutting the plastics can be added for future work.

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