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Research Article

Designing CVT Slide Piece Molds for Cavity 24 Pieces on Injection Molding Machine

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A B S T R A C T

Composite materials are often used in the industrial world, one of which is in the automotive industry. Material composite based on polypropylene high impact (PPHI) and natural fiber can be used to create slide piece components on the CVT of automatic motor vehicles. In this study, we will design molds from injection molding on an industrial scale on masse, producing a slide piece product made from composite materials. This research is a development of the previous injection molding mold. In the study, the solidworks software will compare three types of multi-cavity, namely circular, series, and parallel, to get more efficient and effective molds. This multi-cavity type is designed to print PPHI material and pineapple fiber with a volume fraction of 20% and a mesh of 170. The mold material designed is made of stainless steel 2316 for cavity and core parts with a size of 180mm x180mm. Using simulation plastic on solidworks, the simulation results obtained a type of circular type that can be applied to injection machine molds because it has the most effective pressure value of 4.8 MPa and its geometric shape. Then obtained a fill time of 1,89s and volumetric shrinkage at the end of fill at a max of 17.56%, which is more efficient.

1. INTRODUCTION

Composite materials are currently very developed, along with the increasing use that is increasingly widespread, so it is widely used in both small-scale and large-scale industries in the industrial sector [1]. The use of natural fibrous polymer composite materials in the automotive industry is currently experiencing rapid development and is trying to shift the existence of synthetic polymer composite materials commonly used as reinforcements in composite materials, where research has been carried out on mechanical characterization of PPHI high impact polypropylene matrix composites with random fibers with a hand lay-up method for automotive components [2]. Automotive industry is competing to make vehicle parts components with composite materials [3].

Polypropylene impact High (PPHI) is a polymer commonly used in the Indonesian automotive industry. Resistance to high impact loads makes PPHI very promising to be used as a binder in biofiber-reinforced polymer composites, where PPHI is used as a binder, and pineapple fiber serves as a reinforcing material with varying volume fractions [4]. The selection of pineapple leaf fiber is one of the efforts to use pineapple leaves which are often discarded and considered waste even though

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pineapple leaf fiber can be used as a material for making composites because pineapple leaf fiber is a type of fiber derived from plants (vegetable fiber) obtained from pineapple plant leaves. The use of pineapple leaf fiber as a composite material is an alternative in making composites scientifically, where pineapple leaf fiber is known for its strength, where pineapple leaf fiber has good quality with a smooth surface [5]. Meanwhile, the selection of matrices with this type of PPHI was chosen because this type of polymer has yet to be commonly used, especially in the Indonesian automotive industry. Previous research has developed a high impact polypropylene (PPHI) material reinforced with pineapple fiber with a volume fraction of 20% for forming a composite material based on which the injection molding process is carried out to produce good strength [4]. Injection molding is the process of processing polymer material that is heated to the melting level, then flowing into the mold cavity until it is in the form of a product [6]. Mold is one of the critical parts of the injection molding process. The mold forms a liquid material into the desired geometry of the product. The mold consists of 2 parts, namely moving plates and moving plates [7], where molding is the initial process of producing a product on a large scale [8]. In the previous research, the making of molds design and simulation development of slide piece print research hand press method [3]. Moreover, developed using an industrial-scale injection molding machine that aims to get the quality of printed products in the form of spare part slide pieces [9], but less than compelling.

Therefore, the purpose of this study will be to design molds from injection molding on an industrial scale on a mass basis that is more effective to produce a slide piece product located on the CVT of an automatic motorcycle vehicle made of composite material made from PPHI and pineapple fiber with a volume fraction of 20% mesh 170. This research will use the Solidworks software, and the parameters that become a reference are Fill of time, pressure at end fill and temperature at end Fill with the specification of the injection molding machine hand press planned in the previous study [10].

On the use of automatic transmission system in motorcycles called CVT (Continuously Variable Transmission) [11]. CVT is a transmission system that can automatically change the ratio of speed and torque without having to be operated by the driver in the process of transferring the acceleration level [12]. Where the slide piece is a CVT component that has a function to maintain the position of the roller housing that moves translationally [3].

Stainless steel is an alloy steel that contains at least 11.5% chromium by weight. Stainless steel has properties that are not easy to rust like other steel metals [13]. Stainless steel 2316 has the characteristics of resistance to corrosion and penetration in the specifications of martensitic stainless steel. Because of its good resistance to high corrosion, it is very appropriate to apply to the use of tools with a molding system because, in this process, the corrosion level caused is very high. After all, the material used has a degree of aggressiveness to corrosion, such as polymers [14].

2. BIBLIOGRAPHY REVIEW

This mold design process uses equations 1 and 2 to find out the fill time and colling when it can be applied to the injection machine. Equation 1 is filling time. To get the fill time value, a formula is needed to calculate the *fill time*. Here is equation 1 used [9].

$$t_f = \frac{2\ V_s \ x\ \rho_j}{P_j} \tag{1}$$

where:

t_f = Fill Time
V_s = Volume Shot
ρ_j = Recommended Pressure
P_j = Injection Power

Equation 2 is the cooling time where to get the cooling time value. Here is equation 2 used [15].

$$t_{cooling} = \frac{h^2}{2\pi\ x\ \alpha}\ x\ \ln\left[\frac{4}{\pi}\ x\ \left(\frac{T_{Melt} - T_{Mold}}{T_{Eject} - T_{Mold}}\right)\right] \tag{2}$$

where:

$t_{cooling}$ = Cooling Time
h^2 = Plate Thickness
α = Thermal Divisiveness
T_{Melt} = Melt Temperature
T_{Mold} = Temperature Mold
T_{Eject} = Injection Temperature

As for the calculation of the composite material characteristics used, it can be seen in equation 3 [16]. The density of composite material:

$$\rho_c = \rho_m . V_m + \rho_f . V_f \tag{3}$$

where:

ρ_m = Density of Matrix Material
V_m = Matrix Volume Fraction
ρ_f = Density of Reinforcing Fiber Material
V_f = Volume Fraction of Fiber Matrix

The process carried out to manufacture recycled slide pieces. This study includes literature studies [4][5][6].

3. METHODOLOGI

This mold design research begins with data collection to determine the dimensions of slide piece products, the specifications of the injection molding machine, and the type of material as the primary material for the formation of Slide Piece, which is then processed by simulation using the SOLIDWORKS software. In the simulation process, three types of modeling are obtained that will be applied to the mold, the results of which will be selected based on the criteria corresponding to the injection molding machine.

To get the dimensions of the slide piece, the measurement process is carried out using a measuring instrument where the size is adjusted to the size of the components on the slide piece of the Honda Beat 110 esp motorcycle. After getting the size, a slide piece model is made using the Solidworks software. This can be seen in figure 1 below.

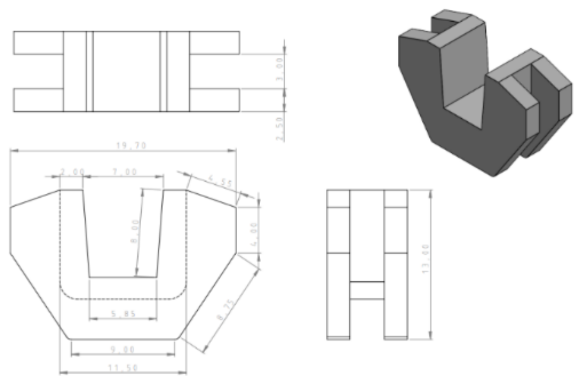

Figure 1. Slide Piece Modeling

In the research process, the design of this slide piece mold uses a Bole 170 EKH Series type injection molding machine, along with the specifications of the Bole 170 EKH Series type injection molding machine. It can be seen in table 1

Table 1. Specification of Injection Molding Machine

Type	Bole 170 EKH Series
Injection Pressure	235 MPa
Machine Dimensions	5.1m × 4.1m × 2.2m (L×W×H)
Machine Weight	5.1 Ton
Ejector Stroke	150mm
Screw Diameter	45mm
Pump Motor	16.4 kw

Table 1 shows the machine's specifications used in this mold design research. Where the design of this mold must have several criteria that can later be applied to the injection molding machine, this design criteria must follow the machine's specifications. It can be seen in Table 2, namely some criteria for the design of slide piece prints.

Table 2. Criteria of Mold Design

Specifications	Obtained requirements
Materials	• Able to conduct heat well • Molding material exceeds PPHI melting point • Has good resistance to heat, rust and scratches or friction • It has a long service life
Geometry	• The shape adapts to the predetermined standard • The Support Plate can be disassembled
Production	• Easy and fast machining process
Ergonomic	• It can be used in injection molding machines • It can be used several times during the injection molding process
Salvation	• Safe in operation

After obtaining the design criteria and selecting mold materials (mold), this slide piece mold material uses stainless steel 2316 and St 37. The

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material used in this cavity plate and the core plate is stainless steel material 2316, equivalent to AISI 420 [17]. In comparison, the St 37 material is used for supporting plates such as the top plate, bottom plate, locating ring, support core plate, spacer block, ejector plate, and ejector retainer plate. Stainless steel material has parameters following the criteria in the design, including good thermal conductivity if given proper heat treatment. It has advantages in terms of performance besides being easily formed. You can see the specifications of the printed material in table 3.

Table 3. Molded Material Specifications

Cavity Plate and Core Plate Mold Material	
Material Type	Stainless Steel
Type	2316
Thermal Conductivity	24.9 $\frac{W}{m.K}$
Melting Point	1450 – 1510 ℃

In selecting material from the slide piece, it must be able to meet the criteria for making a slide piece, namely composite material. The composite material used in making this slide piece is PPHI and natural fiber in pineapple fiber with a volume fraction of 20% and a filtration density (mesh) of 170. This composite property has several advantages: high impact resistance, environmentally friendly natural fiber material, ability to withstand temperatures up to 130 °C, low density to make the product lighter, and good rigid properties.

Multi cavity modeling determines the multi-cavity system applied to the mold. There are 3 (three) types of model shapes of a multi-cavity, including circular modeling, series modeling, and parallel modeling, which can be seen in the figure below.

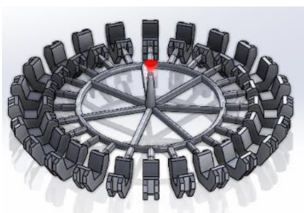


Figure 2. Circular modeling

This circular modeling has a circular position characteristic with the number of gates 24, runner 32, and sprue 1, as shown in figure 2.

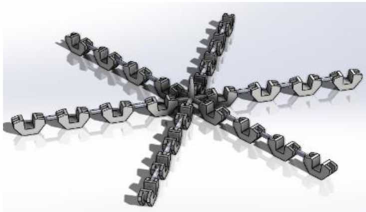


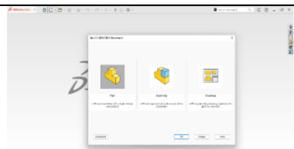
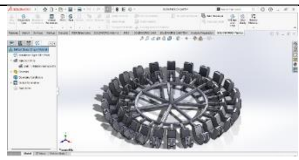
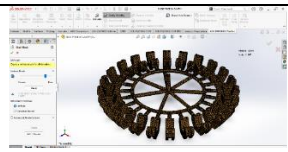
Figure 3. Series Modeling

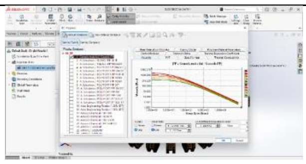
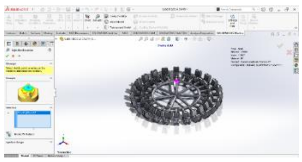
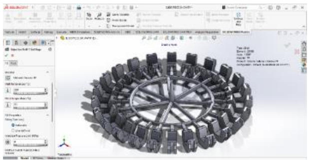
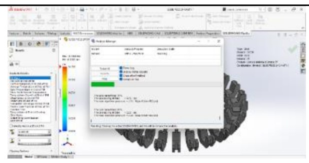
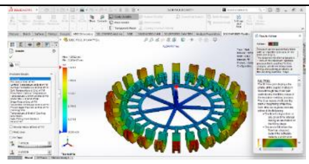
The modeling of this series has a characteristic position that is interconnected and parallel to the number of gates 42, runner 24, and sprue 1, as shown in figure 3. This parallel modeling has position characteristics facing each other and parallel to the number of gates 24, runner 32, and sprue 1, as shown in figure 4.

Figure 4. Parallel Modeling

After modeling the multi-cavity, a simulation was conducted to determine the most efficient and effective type of runner and gate to be applied to the injection molding machine. This simulation process uses simulation plastic in the Solidworks software. It can be seen in the four simulation steps in the Solidworks software.

Table 4. Simulation steps

Picture	Command
	Modeling setup steps
	Enter the plastic simulation process
	Mesh Process modeling multi-cavity

	Slide piece material selection
	Selection of Injection Location on the sprue that has been made
	Fill setting process, entering injection molding parameters
	Process, simulation in progress
	Results of the simulation process

This slide piece mold uses a shape and geometry type SC 1823, a type of two-plate mold. It can be seen in figure 5.

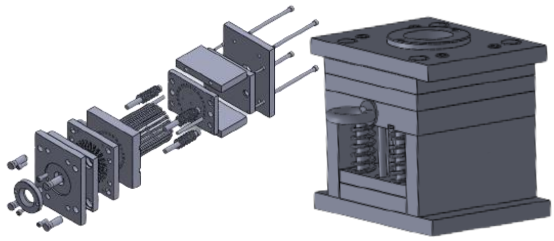


Figure 5. SC 1823 Two Plate Type Mold Type

This mold follows the standards of the predetermined type of injection molding machine to be used. In this mold, there are several components in it, including a top Plate, locating ring, cavity plate, core plate, support core plate, spacer block, ejector plate, ejector retainer plate, ejector pin, ejector pin, spring, bottom Plate, guide pin, return pin, and bolt.

4. RESULT AND DISCUSSION

After the analysis process was carried out in selecting the multi-cavity model, there were three models with a reasonably variable volume of each shape. In each model, the multi-cavity has some cavities, and the core slide piece is 24. It can be seen in table 5.

Table 5. Multi Cavity Modeling Results

Kind Modeling	Circular	Series	Parallel
Number of Cavity & Core Slide Piece	24	24	24
Dimensions Runner & Runner Distance	Ø 3mm and Ø 65mm	Ø 3mm	Ø 3mm
	26mm x 6,5mm	6mm	70mm x 30mm x 6,5mm
	Ø 3mm	Ø 3mm	Ø 3mm
Number of Runners	32	24	32
Number of Gates	24	42	24
Volume Count	60.719 cm^3	54.444 cm^3	66.117 cm^3

The simulation process's results were also obtained from determining the multi-cavity. In this simulation, the results of the parameters sought or desired are filling time, pressure at the end of fill, the temperature at the end of cooling, volumetric shrinkage at the end of fill, and cooling time. It can be seen in table 6.

Table 6. Plastic Simulation Process Result

Model Gate	Circular Runner Gate	Seri Runner Gate	Parallel Runner Gate
Fill Time	1.89s	1.71s	1.93s
Pressure at the end of the fill	4.8 MPa	6.0 MPa	5.2 MPa
Temperature at the end of cooling	Min: 52.2°C Max: 141.6°C	Min: 50.7°C Max: 153.8°C	Min: 51.6°C Max: 141.4°C

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Volumetric shrinkage at end of fill	Min: 16.60% Max: 17.56%	Min: 16.26% Max: 18.25%	Min: 16.97% Max: 18.20%
Cooling time	11.33s - 59.25s	10.26s - 48.72s	11.81s - 58.74s

Judging from table 6, there is this simulation process in obtaining more efficient modeling results where the modeling chosen is a circular type because it is more effective and efficient than the fill time value of 1.89s, pressure at the end of fill 4.8 MPa, the temperature at the end of cooling at a minimum of 52.2℃ and a maximum of 141.6, ℃ volumetric Shrinkage at the end of fill minimum 16.60% and maximum 17.56% and cooling time 11.33s – 59.52s which is quite good compared to series and parallel type modeling.

After the simulation process is carried out, a comparison process is carried out to determine the parameters that can be applied to the injection molding machine.

Table 7. Circular Type Comparison Results

Parameter	Injection Molding (Manual Calculation)	Injection Molding (Simulation Plastic)
Fill Time	0.03 s	1.89 s
Pressure At End of the Fill	4.8 MPa	4.8 MPa
Cooling Time	27.22 s	11.33s -59.25s

In addition to determining parameter comparisons using a simulation process, it also compares parameter calculations manually. Where the central cavity chosen is circular modeling, judging from several parameters and modeling. So circular modeling is chosen to be carried out to compare manual calculations and simulation processes. It can be seen in table 7.

Table 7 shows that the results of this parameter comparison show a difference in the manual calculation where the result in the manual calculation of the fill time value it gets is 0.03s. The result of the simulation is 1.89s using the same pressure, namely 4.8 MPa factor from the difference because, in the simulation process, there is no value of injection power, so it can be focused on the process of the result.

5. CONCLUSION

The manufacturing of this circular modeling mold is designed using the solidworks software with a size of 180mm x 180mm. The material used is stainless steel 2316 with a melting point of 1450 – 1510 °C and thermal conditions of 24.9 W/m.K. The material St 37 is only used for support plates such as the top plate, bottom plate, locating ring, support core plate, block spacer, ejector plate, and ejector retainer plate. The mold designed is a two-plate mold of type SC1823 which follows the standard and from the type of injection molding machine used. From the results of the multi-cavity modeling circular model, the result of pressure at the end of Fill was obtained by 4.8 MPa, where the result is the lowest compared to the series model, which has a pressure at the end of fill result of 6.0 MPa and the parallel model has a pressure at the end of fill result of 5.2 MPa. The value of volumetric Shrinkage at the end of fill of these three multi-cavity modeling shows that the circular modeling type has good results compared to the series and parallel modeling types. It does not affect the results of the designed product. So that the circular type can be applied to injection machine molds because it has more efficient parameter values and appropriate geometric shapes.

6. REFERENCE

[1] Pramuko I Purboputro., 2006. "Pengaruh Panjang Serat Terhadap Kekuatan Impak Komposit Enceng Gondok Dengan Matriks Poliester."

[2] A. E. Latief. et al., 2019. "Karakterisasi Mekanik Komposit Matriks Polipropilena High Impact Dengan Serat Alam Acak Dengan Metode Hand Lay Up Untuk Komponen Automotive," Jurnal Rekayasa Hijau, Vol. 3, No. 3.

[3] A. E. Latief. et al., 2021. "Metal: Jurnal Sistem Mekanik Dan Termal Perancangan Cetakan Injection Molding Hand Press Untuk Produk Slide Piece CVTY Menggunakan Fem".

[4] N. Desi A. et al., 2020. "Seminar Nasional-Xix Analisis Bending Pada Komposit PPHI (Polypropylene High Impact) Berpenguat Serat Nanas Dengan Fraksi Volume 20% Yang Dibuat Menggunakan Injection Molding," pp. 1–5, Dec.

[5] H. Fahmi And H. Hermansyah, 2011. "Pengaruh Orientasi Serat Pada Komposit Resin Polyester/ Serat Daun Nenas Terhadap Kekuatan Tarik," [Online]. Available: Www.en.wikipedia.org/composite

[6] I. Mawardi And D. Hanif, 2015. "Analisis Kualitas Produk Dengan Pengaturan Parameter Temperatur Injeksi Material Plastik Polypropylene (PP) Pada Proses Injection Molding."

[7] H. Widiastuti. et al., 2019. "Identifikasi Cacat Produk Dan Kerusakan Mold Pada Proses Plastic Injection Molding," [Online]. Available: http://jurnal.polibatam.ac.id/index.php/jatra, https://jurnal.polibatam.ac.id/index.php/jatra

[8] L. Khoirul Miftakhul N. et al., 2017. Muhammadiyah Yogyakarta Jl Lingkar Selatan Tamantirto, "Desain Dan Optimasi Injection Mold Sistem Slider Pada Produk Preform Stick T15," Jurnal Rekayasa Mesin, Vol. 8, No. 3, pp. 155–165.

[9] R. Muhammad K. et al., 2022, "Perancangan Bracket Cetakan dan Simulasi Injection Molding Untuk Komponen Slide Piece CVT," Vol.02 no.01, April 2022, pp. 74–82.

[10] L,.Alfan E., et al., 2022, Perancangan Cetakan Injection Molding Handpress Material Komposit PPHI dan Serat Alam, Vol. 8 no. 2, Jurnal Teknik Mesin, pp. 2502–2040.

[11] R. Salam. et al. 2016, "Pengaruh Penggunaan Variasi Berat Roller Pada Sistem CVT (Continuously Variable Transmission) Terhadap Performa Sepeda Motor Honda Beat 110 cc Tahun 2009."

[12] R.A. Anugrah, 2021, "Troubleshooting Analysis of CVT (Continuously Variable Transmission) System On Honda Beat Motorcycles," Motivation: Journal of Mechanical, Electrical And Industrial Engineering, Vol. 4, No. 1, Pp. 1–8, Doi: 10.46574/Motivation.V4i1.98.

[13] Sumarji, 2011, "Studi Perbandingan Ketahanan Korosistainless Steel Tipe Ss 304 Dan Ss 201 Menggunakan Metode U-Bend Testsecara Siklik Dengan Variasi Suhu Dan Ph," Rotor, Vol. Volume 4, Pp. 1–8.

[14] S. Anggoro. et al., T. Mesin, V. Universitas, M. Yogyakarta, J. Lingkar Selatan, 2017, "Seminar Nasional Mesin Dan Industri (Snmi Xi) 2017 Riset Multidisiplin Untuk Menunjang Pengembangan Industri Nasional Lombok."

[15] T. Kimerling. 2002, "Injection Molding Cooling Time Reduction And Thermal Stress Analysis."

[16] H. Sanjaya And N. Desi Anggraeni, 2017, "Pengaruh Temperatur Cetakan Komposit Matriks Polypropylene High Impact (PPHI) Berpenguat Serat Nanas Terhadap Cacat Shringkage dan Sink Mark Menggunakan Solidworks."

[17] J. Pearson, 2021, "Atlas Quality Management Scope: National Doc: Information Notice Stainless Steel 420 Grade Data Sheet."