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Pellet moulding machine design and simulation analysis of the effect of angle variation in the mold hole on pellet alloy pressure

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Abstract

The development of aquaculture in Indonesia has increased every year. However, in reality, farmers find failed fish harvests arising from fish feed problems. Various problems in the field occurred by fish farming business actors due to the incompatibility of the pallet molding machines used with the quality of raw materials and the high price of fish feed. For this reason, it is necessary to have a new technology in the form of a pellet molding machine to overcome the problems that often occur. This study aims to design a pellet molding machine with modifications to the angle of the mold hole and analyze changes in pressure values and production rates from the effect of the angle given to the mold to obtain a good mix of pellets and a shorter production speed. The method used is design and simulation, with machine variables that have been designed using angles of 30º, 45º, and 60º. The highest pressure value data is obtained at an angle of 45º with a maximum pressure value of 11.86 Pa and the lowest pressure value is at an angle of 30º with a maximum pressure value of 10.62 Pa. The highest speed value is obtained at an angle of 45º and 60º with a value of 4 .8 m/s and the lowest value is obtained at an angle of 30 o with a value of 4.7 m/s. In a pellet molding machine that uses an unmodified mold, the maximum pressure value is 10.36 and the speed is 4.6 m/s, which means that the angle at the mold hole gives an increase in pressure and production speed which will make the pellets have better mix and faster production time.

Keywords: Aquaculture, pellet printing machine, screw, mould, pressure, production speed rate.

1 Introduction

Fishing is a line of business that will help Indonesia become the country with the largest economy in 2030. Meanwhile, lately, in general, many fish farmers have found a lot of disappointment.

Basically, the problem experienced by fish farmers is in terms of feed that is commonly called fish pellets [1]. Fish pellets are a type of artificial feed that is produced using several types of complementary ingredients which contain supplements for fish growth. Pellet size ranges from 1-2 mm according to the size of the fish. So pellets are not shaped like flour, nor are they in the form of a solution [2]. In general, fish pellets are arranged into three types of categories according to the sinking resistance of the pellets themselves, the types of pellets are submerged pellets, semi-floating pellets, and floating pellets.

The three types can be distinguished by looking at the time it takes for the feed to sink [3]. Of the three types of pellet categories, the manufacture of floating pellets is still rarely done with local cultivating communities. Various problems in the field occurred by fish farming business actors considering the incompatibility of the pellet machine used with the quality of raw materials and the high price of fish feed [4].

While the pellets float has many advantages over sinking fish pellets. Very little research has been done on the most common way to make floating pellets, especially using machines with extruder systems that manage local raw materials. Treatment of the proper manufacturing conditions will be a reference for cultivators in making floating pellets [5].

About these problems, technologies are needed to be a solution in overcoming disappointments, especially in the manufacture of fish feed so that fish farming achieves the expected results [1]. Pellet making machine is a tool specifically intended for making fish feed. Pellet-making machines have high productivity by utilizing the rules of the screw conveyor function which distributes the material and presses it towards the end of the cylinder to pass through the planned shape so that it will make the material into a strong (compact) pellet [6]. One method that can be used to improve the machine is by utilizing mathematical modeling (numerical analysis) [7].

So far, achieving the best quality of pellets is performed by studying the parameters of the pellet material, in addition, the quality of the pellets is also determined by pressure and the shape of the inlet hole from the mold [8]. Based on the description above, one way to solve the problem of pellets making machine is by modification of geometry and the form of inlet angle to the mold hole. Then the analysis is needed to understand how much the modification has influence the pressure value of the pellet. Therefore according to previous researcher, one of the techniques that can be used to advance the design is by utilizing modeling and mathematical reproduction or numerical simulation [9].

In this study, the purpose of this work is to design a pellet molding machine with variations in the angle of the mold hole and examine how much influence the variation of the angle of the mold hole that has been novated with a slope of 30º, 45º, and 60º has on the pressure value and production speed rate in the planned pellet machine.

In Ariefin's works, he has discussed the Effectiveness of Modifying Mold Holes on the Characteristics of Wood Pellets. The results obtained that the modification of the shape of the hole gets better results than the usual mold. Rasyid also conducted several experiments with three-hole shapes, where an inlet that has an angle or a tapered shape produces better pellets because the pellet production process is slower and continuous. Therefore, this research studies the influence of the entry angle of the mold hole which produces better pressure values and production rate.

2 Research methods

This research was started by designing certain components for a fish pellet-making machine then the calculation results were realized using the Autodesk Fusion 360 application, after that the corner shape was modeled and simulated using the Ansys Workbench 2021 RI application to get the cutting angle. To have good pressure and productivity, a simulation is carried out with the help of the Computation Fluid Dynamic (CFD) application using Fluent tools.

2.1 Design of Pallet Machine's Components

Preliminary plan data on pellet molding machine design: Electric Motor: 1.5 Hp / 1450 Rpm. Load: 20 kg. Gearbox: Ratio 1:10. There are also several component plans that must be calculated to get results that are in accordance with the desired specifications.

a. Shaft and Stake Planning

Shaft diameter can be calculated using the Eq. 1:

$$d_s = \sqrt[3]{\frac{5{,}1}{\tau_a} K_t C_b T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where d_s *is* shaft diameter(mm), C_b is bending factor, M is bending moment$(kg \cdot mm)$, K_t is correction factor for torsional moment, T is Torque$(kg \cdot mm)$.

After obtaining the diameter of the feeding shaft, the height and width of the pegs can be determined according to the diameter of the shaft.

b. Selection of Bearing

Bearings are one of the machine components that support the pile of axle piles, so that the turning can occur without hindrance, safety and long life. Bearings must be strong enough to allow the shaft and other machine components to work properly.

c. Design of Pulley

Determining the size of the pulley diameter must be done after obtaining a ratio of the ratio between the large pulley and the small pulley, therefore it can be calculated as follows (Eq. 2):

$$\frac{n_1}{n_2} = \frac{d_{p2}}{d_{p1}} = i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where n_1 is small pulley rotation, n_2 is large puli round, d_{p1} is small puli diameter, d_{p2} is large puli diameter

Then to determine the diameter of the pulley in accordance with the ratio ratio can be determined using the Eq. 3:

$$D_p = d_p \times i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where D_p is large puli diameter, d_p is small puli diameter, i is ratio,

d. Screw planning

Pellet moulding machine *screw* shown in Fig. 1

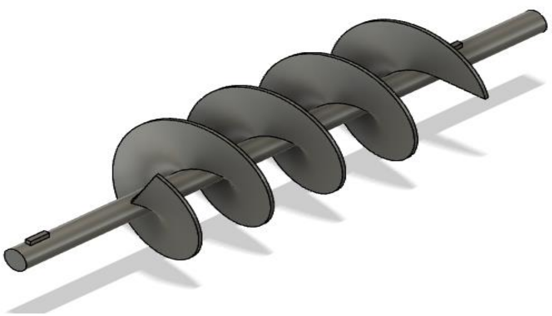


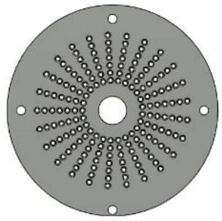
Fig. 1. Pellet Moulding Machine *Screw*

Determination of the capacity of *the screw* can be calculated using the following Eq. 4:

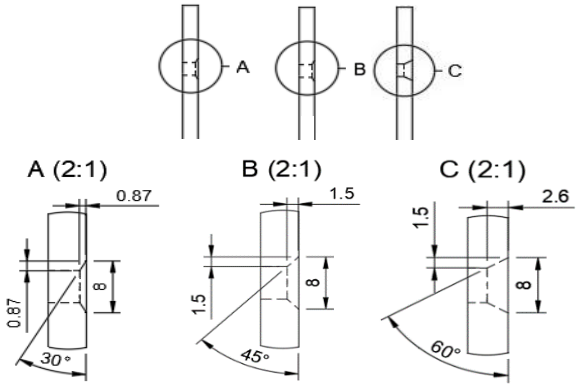
$$Q = A \times P \times n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where A is area of *screws*, P is *Pitch Distance*, n is rotation speed.

e. Mold Design



(a)



(b)

Fig. 2. (a) Printing on a pellet printing machine; (b) Angle of the hole in the mold.

In mold design shown ini Fig. 2, researchers innovate different inlet hole molds where mold holes circulate on pellet molding machines in general. The hole in the mold has a diameter of 5 mm and is given a varying angle of 30º, 45º, and 60º on the front surface of the hole which aims to influence the speed of the production rate and does not reduce the quality of the pressure to produce a good mix of pellets.

2.2 Simulation Method

The simulation process is carried out in several stages, starting with the creation of the model, then determining the boundary conditions and machines that are adjusted to the object to be simulated. The stages in implementing the simulation are as follows:

- Problem Analysis

Determine the object to focus on and then examine and determine the right type of model for the case. The object to be analyzed is to study the pressure that occurs in each mold with a different angle and the production speed of the pellet molding machine.

- Drawing of Mold Components and Geometry

In this stage, the mold components are drawn using the Autodesk Fusion, the application components geometry is based on the results from calculations in the designing process that carried out in the previous stage.

- Meshing

For CFD works, component of the ANSYS Fluent application was used which containing the idea of the Finite Volume Method. This application can be adjusted from large components or volumes to simpler or finer volumes or components completely as a meshing process which aims to get results that are more accurate and closer to the true value. In this study the selection of meshing geometry is focused for three parts, namely for the body, screw, and mold.

- Model Set Up

In determining the model to be analyzed, there aspects should be assigned before running calculations using the fluent tools. Such as multiphase variables along with their phases, boundary conditions, materials and operating conditions.

- Solution Setup and Calculation

To run the simulation process there are several steps of the method and calculation to tobe assinged to carried out the solutions, the steps are based on the model and data that has been previously inputted. The right model and data selection is important since it will maximize the convergent value efficiently.

- Data Analysis and Discussion

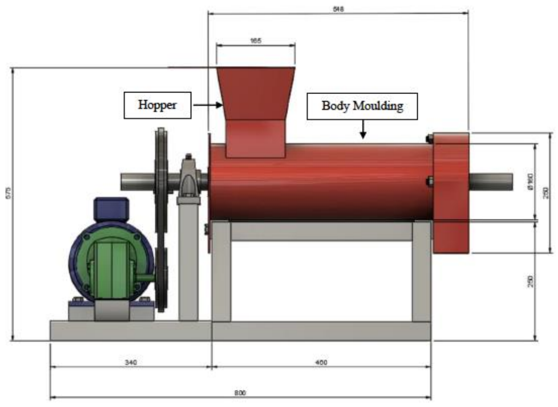
The presented results can be analyzed using the CFD Post Processing program which is also memorized for ANSYS Workbench. The result will be in animated shapes and contours with the helping of molecular dynamic analysis. The results obtained can be used to measure and to compare of the experimental data.

The final results explored are used to fulfil the data sources and suitable to simulation presence factors which close to the result of verification tests. Later, the data can be reused at any time under various limit conditions.

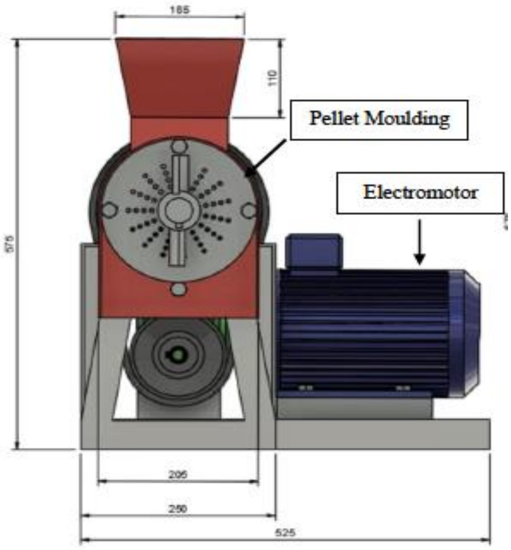
3 Results and Discussion

3.1 Calculation Results of Design Components

Illustration of a fish pellet making machine shown in Fig. 3 (a) and (b)



(a) Side view



(b) Front view

Fig. 3 Fish pellet making machine

Table 1 . Shaft And Stake Planning Data

NO	Planning Data	Mark
1	Power	1.1 kW
2	Round	85rpm
3	Correction Factor	1,3
4	Plan Power	1.4 kW
5	Permissible Shear Stress	4.3 kg/mm ^{2}
6	Correction Factor for Torsional Moment (K_t)	1.5
7	Flexure Factor (C_b)	1,3

Before performing a simulation of a pellet-making machine, it is necessary to carry out several stages of calculation to the components of the pellet-making machine, including the following:

- Design of Shaft and stopper

In this study the shaft material used was carbon steel engine construction (JIS G 4501) with a the tensile strength value (σ_B) = 52 kg $/ mm^2$. The design data of the shaft and stopper are as follows.

The torsional moment that may occur on the shaft can be calculated using the following Eq. 5.

$$T = 9{,}74\,.\,10^5 . \frac{P_d}{n} \quad \text{..........................(5)}$$

$$= 9{,}74\,.\,10^5 . \frac{1{,}43}{85}$$

$$= 16.386\ kg.mm$$

And the shaft diameter can be calculated using Eq. 1 as follows.

$$d_s = \sqrt[3]{\frac{5{,}1}{\tau_a}\ K_t C_b T}$$

$$d_s = \sqrt[3]{\frac{5{,}1}{4{,}3}\ 1{,}5\ .\ 1{,}3\ .16.386}$$

$$d_s = 33{,}5\text{mm}$$

The diameter of the shaft obtained from the calculation is 33.5 mm. So for the safety factor and the shaft durability factor, the 35 mm shaft is chosen.

After obtaining the diameter of the shaft, it can be determined the dimensions of the pin seen from the diameter of the shaft that has been determined, then the dimensions of the stopper obtained are b = 8; h = 7 according to the table of Standard Dimensions and Sizing of Sularso's book, Basic Design and Selection of Machine Elements.

- Selection of Bearing

The bearing was selected with code W 6207-2Z which an inner ring diameter of 35 mm and an outer ring diameter of 62 mm with a dynamic capacity value of 2010 kg and a static capacity of 1430 kg as can be seen in Sularso's book, Basic Design and Selection of Machine Elements.

- Design of Belt and Pulley

The selection of belt type is determined based on the design power and rotation of the small pulley. For the design power value of 1.43 kW and for the small pulley rotation of 145 rpm, a type b belt is obtained according to what is contained in Sularso's book, Basic Planning and Selection of Machine Elements.

Transmission of machine rotation has carried out in two stages, firstly by using a gearbox with a ratio of 1:10 and secondly by using a pulley. The transmission ratio is calculated by using the Eq. 2.

$$\frac{n_1}{n_2} = \frac{d_{p2}}{d_{p1}} = i$$

$$i = \frac{1450\ RPM}{10\ RPM} = 145$$

$$i = \frac{145\ RPM}{85\ RPM} = 1{,}7$$

Size of small pulley diameter of the small pulley was chosen to be $d_p = 125\ mm$, and to determine the diameter of the large pulley can be calculated using Eq. 3 as follows.

$$D_p = d_p \times i$$
$$= 125\ mm \times 1{,}7$$
$$= 212{,}5\ mm$$

- Design of Screw

In the selection and calculation of Screw Conveyor, the specifications and parameters that have been determined are used machine specifications: machine capacity: 20 kg/hour, *screw rotation*: 85 RPM, *pitch distance*: 10 cm, tilt angle: 15 º, density of pellets: 0.5735

Then the screw diameter can be calculated using Eq. 6:

$$D = \sqrt[3]{\frac{4\ x\ Q}{60\times \pi \times S \times n \times \Psi \times \gamma \times C}} \quad \text{.........................(6)}$$

$$= \sqrt[3]{\frac{4\ x\ 20}{60\times 3{,}14\times 10 \times 85 \times 0{,}4 \times 0{,}5735 \times 0{,}7}}$$

$$= 0{,}145\ m = 145\ mm$$

With a diameter obtained of 0.145 m or 5.7 inch, the *screw specification size is selected* according to the standard table ie 6H304 with a diameter of 6 inches (152.4 mm). In the study, Tatang Suryana explained that the ratio of diameter and length on *the screw conveyor* was 1:3, so that the length of *the screw* was 457.2 mm with *a pitch distance* equal to the size of the diameter.

Then the flow rate can be calculated at each *pitch screw* by using equation 7:

$$V = \frac{S.n}{60} \quad \text{.....................................(7)}$$

$$= \frac{152{,}4\ .85}{60} = 21.8\ \text{cm/s} = 0.21\ \text{m/s}$$

- Design of Mold

Dies or molds function in forming pellets of the materials that is carried by screws and pass through the die holes according to the existing size. In the study, the holes diameter was 5 mm with a plate thickness of 5 mm which was innovated by providing a hole angle with an angle value of 30º, 45º, 60º.

- Design of Barrel and Frame

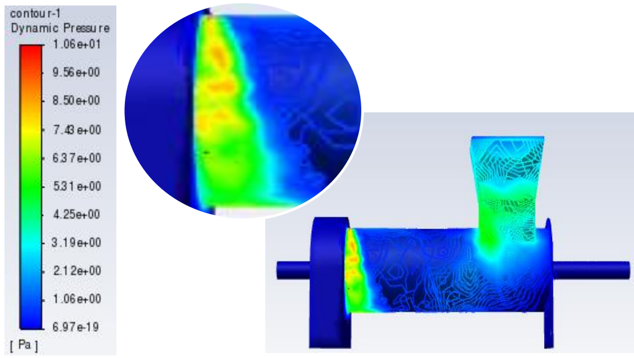
To ensure the continuity of the process, the ratio of screw diameter and barrel diameter is recommended to be 0.005 - 0.002 inches, therefore for selecting the distance between the screw diameter and barrel diameter of 0.5 mm, the barrel diameter is 154.4 mm and was coated using aluminum with a thickness of 1 mm, so that the final diameter is 153.4. The objective of aluminum coating inside the barrel is because the product processed is a feed ingredient for the animals. Therefore, the quality of the raw material must maintain from the feed so that it is not contaminated with substances or material from the barrel. The structure and the farme of the machine are made from hollow iron with a size of 40 mm x 40 mm.

Table 2. Simulation data results from each hole angle variation

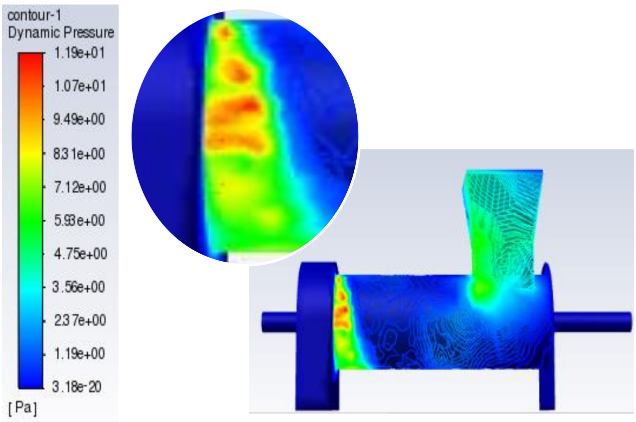
No	Mold Hole Angle	Pressure(Pa)	Velocity (m/s)
1	30°	Min = 6.7 Pa ; Max = 10.62 Pa	4.7m/s
2	45 °	Min = 3.1 Pa ; Max = 11.86 Pa	4.8m/s
3	60 °	Min = 3.2 Pa ; Max = 10.49 Pa	4.8m/s

3.2 Simulation Results

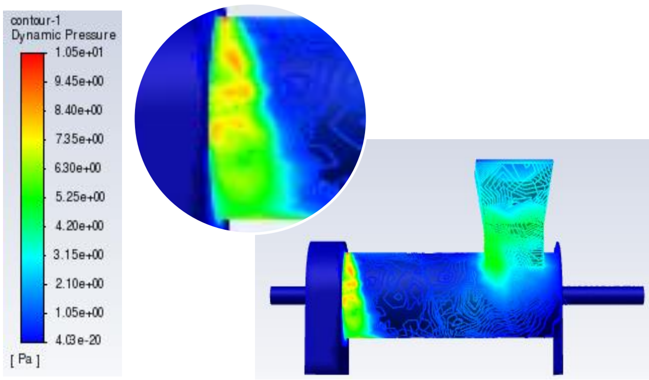
After the designing stage has been carried out, an analysis is performed to find out the pressure value and production rate based on the mold angle that has been innovated. For the simulation process, the Ansys Workbench 2021 with the Fluent tools was used, The simulation result shown in Fig. 4:



Angle 30 º



Angle 45 º



Angle 60 º

Fig. 4. Appearance of the Simulation Results

From the Fig. 4. it can be seen that the pressure in the pellet molding machine is occured at the end of the barrel where the raw material meets with the mold. Becouse of the pressure, then the pellet produce in the forms of small circles according to the holes size in the mold. Table 2 shows the simulation data results from the hole with different angle.

3.2.1 Effect of Mold Hole Angle on Pressure

Fig. 5. shows the influence of hole angle on the pressure. From the Fig. it can be seen that the pressure the highest pressure value obtained at the angle of 45º with pressure is 11.86 Pa. From these results, the quality of pellets produced using molds with an angle of 45º have better alloy quality than those from other molded inlet hole angle. To have better quality of pallets produce the influence of the pressure has play a significant role, because higher value of pressure could maximize the mixing process and the density of the raw materials. However, the carriying capacity of each product with the variations of inlet angle of the die cannot measured, because the carrying capacity value only can measured by conducting the experimental tests.

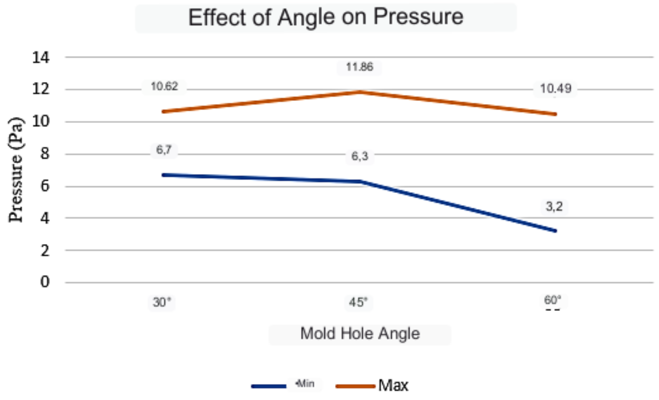


Fig. 5. Effect of Mold Hole Angle

In Ariefin's works [10], it is explained that after changing the hole geometry of the mold, the density value of the pellets was better compared with the results resulted from the mold as a whole. Molds that have been given an angle with a slope of 45° (2 mm in depth) are treated with a reduction in segments from areas with angles (modification areas) to small areas (grooves) resulted in less pores of the fish pellets so that the pellet become more dense and increase the density of the pellets. According to the references taken, it can be ascertained that to get fish pellets that have the better quality interm of cohesiveness or are not easily soluble in water, it requires higher pressure.

3.2.2 Effect of Mold Hole Angle on the Pellet Speed

In Fig. 6. It shown that the angle of 45º and 60º produce slightly higher production speeds and pressure comparing with the pressure at the angle of 30^0.

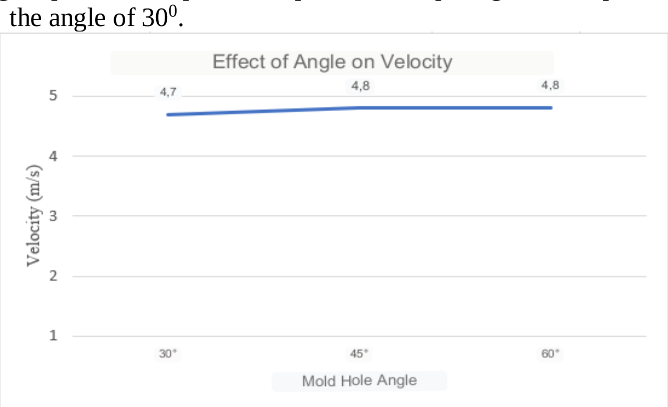


Fig. 6. Effect of Mold Hole Angle on Velocity

It can conclude that to get higher productifity of the product an angle of 45º has agood option because it has produce higher pressure.

3.2.3 Comparison of Preasure Values With Angle Variations And Without Angles

After making modifications to the mold, it can be seen that by giving an angle to the mold hole, you get an increase in the pressure that occurs in the pellet molding machine. The difference lies in each angle variation with a higher value compared to the mold hole without a corner. The modified hole with various angles is treated to reduce the cross section from a large area (corner area of the hole) to a small area (pass hole). Especially at an angle of 45^0 which has the maximum slope angle so that the results obtained are better than other angles.

Fig. 7 expose the the comparison of the pallet using inlet angle and non inlet angle on pressure and velocity. The Fig. shows that the hole with angle modification have increase in the pressure compare to the mold without modification of the hole inlet, however to the velocity have only increase in speed for mold that has angle modification. More differences result lies on the angle variation with a higher value of pressure compared to the lower pressure value resulted from the mold that has no inlet angle. The modified hole with various angles is treated to reduce the cross section in diameter from a large area (corner area of the hole) to a small area (thru hole). Spesifucally for an angle of 45^0 has the maximum slope angle, in this way the quality of pellet produced is better than pellet with other angles.

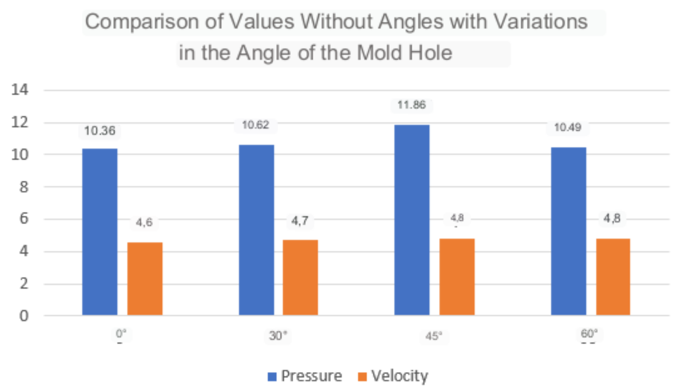


Fig. 7. Comparison of Values Between Production with an Angle of 45º and Without an Angle

5. Conclusion

Based on the data obtained from the results, several conclusions can be drawn as follows: The results of the simulation data that have been carried out explain that providing the angle to the mold hole has an impact on the increasing of the pressure value and the production rate. The lowest pressure value of 10.36 Pa occurred in the mold with no modification of inlet hole angle. The highest pressure resulted in the hole angle inlet of 45^0 with the value of 11.86 Pa. To produce higher pressure and production rate the modification of hole angle inlet should neithe be too small nor to high in order to get better quality of pellets and production rate.

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