INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS

ISSN(print): 2643-9840, ISSN(online): 2643-9875

Volume 09 Issue 06 June 2026

DOI: 10.47191/ijmra/v9-i6-49, Impact Factor: 8.685

Page No. 3701-3709

Research on Numerical Simulation of Pelletizing Process

Didik Ariwibowo[1], Sri Utami Handayani[2], Ireng Sigit Atmanto[3], Muhamad Firdaus[4]

[1,2,3,4]Mechanical Design Engineering Department, Vocasional School, Diponegoro University

ABSTRACT: Fish feed production is one of the efforts to overcome the main problems in fish farming. Fish feed production requires a fish pellet machine, one of the main components of which is an extruder. For the design to be carried out effectively and to obtain the right specifications, a simulation method can be used. This study aims to use the extruder component in a fish pellet machine as a research object using the computational fluid domain (CFD) method in the simulation process. The extruder component with a single screw type will be simulated with the add-in flow simulation in Solidworks software. From the simulation, the estimated performance of the extruder design can be known with data in the form of an average mass flow rate of 0.118 kg / s, a maximum torque of 224.33 Nm, a maximum force of 11,420.95 N, and an average pressure of 264,654 Pa..

KEYWORDS: Pellet; Extruder; Simulation; CFD; Solidworks

I. INTRODUCTION

Indonesia as a country with a large territory and a large population, food security is a very complex challenge and a serious agenda that must be addressed because it concerns the quality of human resources [1]. One way to meet food security needs is through fish farming. However, one of the problems fish farmers face is the price of feed produced by factories which is getting more expensive every day, burdening business actors [2]. According to previous research, the current use of fish feed on the market can cause the cost of feed to increase by up to 75% of the total operational costs [3]. Therefore, a solution is needed to reduce the feed cost so that this industry can continue to grow. One way that can be done to reduce these costs is to produce your feed using a fish pellet machine.

A fish pellet machine is a mechanical device that is operated manually or electrically and is used to make pellets through a pressing and molding process [4]. The fish pellet machine consists of various basic components such as a hopper to insert raw feed materials, an extruder to push the feed, and a die to mold the feed [5]. Based on this, it can be seen that the extruder component is one of the main components because it greatly influences the process of making fish pellets.

To design an extruder, proper planning is needed so that specifications can be obtained according to needs. One way to design a tool or component is to use a simulation method. The advantage of the simulation method is that it can determine the performance value of a tool or component such as pressure and temperature when given different force variations, and reduce the risk of failure of the component [6]. Therefore, the simulation method is the best way to design an extruder so that the performance of the extruder can be known.

Based on the literature search that has been carried out, there has been no simulation of fish pellet material processing using Solidworks software. The simulations that have been carried out mostly use Ansys software. Research on the flow of extruder components or similar components that have been carried out by other researchers includes Ahmed, A.M.A. and Seedahmed, A.I. (2022) conducted a single screw extruder simulation study on polypropylene processing using Ansys Polyflow. The simulation proved that the shear rate and viscosity values between the calculation results and the program had almost the same values [7]. Zhang, Li. et al (2021) conducted a simulation study of a variable-pitch screw vacuum pump using Ansys Fluent software. The simulation results showed that the smaller the clearance distance, the smaller the backflow value and the higher the vacuum degree value [8]. Prashanth, S.R. et al (2019) conducted a simulation study of a counter-rotating twin-screw extruder in solid hydrogen processing using Ansys Polyflow software. The study showed that increasing the pitch length or decreasing the mechanical gaps associated with decreasing the number of chambers or speeds would result in a smaller viscous dissipation rate [9]. Lewandowski, A. And Wilczynski, K. (2017) conducted a simulation study of a co-rotating twin screw extruder in polyflow

processing using Ansys Polyflow. From this simulation, it can be seen the effect of pitch variations in twin screw extrusion on the pressure that occurs in polymer materials [10].

Solidworks, which is widely used as design software in industry, can also be used to simulate flow. Research on flow simulation that has been carried out with Solidworks software, among others, by Macko, M. And Mrozinski, A. (2019) conducted a simulation study of rollers and dies machines in the manufacture of wood pellets using Solidworks Flow Simulation software. The simulation shows the conditions inside the extruder and the speed value of the wood pellet particles when the machine is working [11]. Tingzhou, N. et al. (2021) conducted a simulation study of a single screw extruder in polyvinyl chloride (PVC) processing using Solidworks Flow Simulation software. The results of the simulation show the distribution of temperature, pressure, and PVC particle speed parameters that occur in each part of the extruder [12]. From this study, it can be seen that Solidworks software is also capable of running flow simulations such as in Ansys software.

This study aims to simulate the process of printing fish pellets on an extruder using the computational fluid domain (CFD) method in the simulation process. The type of extruder used in this study is a single screw type. The extruder components will be simulated using the flow simulation add-in in Solidworks software. The results of the simulation can be used as a reference in designing a single screw-type extruder that suits industrial needs.

II. MATERIAL

A. Extruder

The design of the fish pellet machine extruder used in this study uses references from the SNI 7543:2009 standard regarding Wet Process Animal Feed Pellet Forming Machines so that the D Outer dimension = 150 mm is obtained [13]. While the other dimensions of the extruder are modified to D inner = 100 mm, P = 60 mm, e = 20 mm, and δ = 7º.

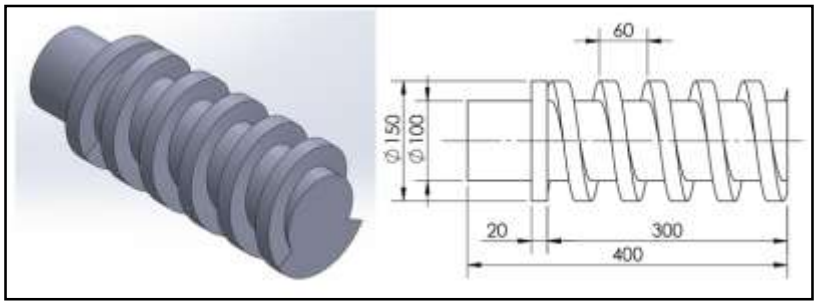


Figure 1. Single screw extruder design.

B. Fish Pellet Material

In this study, it is necessary to determine the specifications of the raw materials for fish pellets because the Solidworks software does not have a database on fish pellet materials. Therefore, the raw materials for fish pellets are assumed to be in granular condition so that they can be categorized as non-Newtonian fluids. The fish pellet material is made from a mixture of corn and soybeans with the specifications shown in Table 1. by the research results of Fraiha, M. 2011 and Raziye. 2008 [14,15].

Table 1. Specifications of fish pellet materials

Name	Fish Food Raw Material
Density	1.300 kg/m^3
Specific heat	2.125 J/(kg*K)
Thermal conductivity	0,1731 W/(m*K)
Viscosity	Power-law model
Consistency coefficient	6.710 Pa*s
Maximum dynamic viscosity	1.276 Pa*s
Minimum dynamic viscosity	96 Pa*s
Power-law index	0,31

III. METHODOLOGY

A. Determining Units

Solidworks software has several unit system options that can be used to display data in the simulation process. The International Standard (SI) is used as the unit system in the extruder simulation in this study.

Table 2. System unit settings

Unit System	Comment
CGS	cm-g-s
FPS	ft-lb-s
IPS	in-lb-s
NMM	mm-g-s
SI	m-kg-s
USA	USA

B. Simulation Type and Condition

The fish pellet extruder simulation in this study uses fluid simulation with internal analysis type, time-dependent, gravity, rotation, and free surface conditions according to Figure 2. Internal analysis was picked because the fish pellet material works in the barrel. Time-dependent was picked so that the fish pellet extruder could simulate the fish pellet material according to the actual conditions at every second. Gravity was picked so that the fish pellet material could enter the barrel due to the force of gravity. Rotation was picked because the extruder component performs a rotational movement at a certain speed. The free surface was picked so that the Solidworks software could simulate two different fluids at the same time.

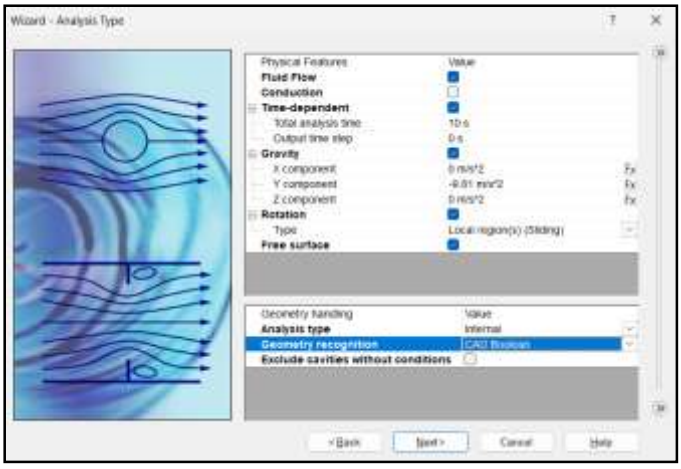


Figure 2. Setting the simulation type and conditions

C. Working Fluid

The working fluid in this simulation consists of air as a gas fluid and fish pellet material as a non-Newtonian fluid according to Figure 3. The air-fluid is selected according to the specifications available in the Solidworks database, while the fish pellet material fluid is made from a mixture of corn and soybeans according to Table 1.



Figure 3. Working fluid settings

D. Check Geometry

Check geometry aims to prevent simulation failures caused by the geometry of the fish pellet extruder design. For the internal simulation to run, each inlet and outlet or hole must be closed so that the SolidWorks software can determine the domain region. The results of the check geometry are shown in Figure 4.

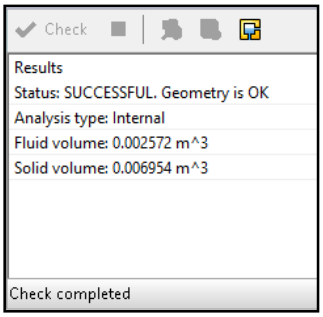


Figure 4. Results of using the check geometry feature

E. Boundary Condition

The boundary condition in this simulation aims to determine the conditions of the inlet and outlet sides of the fish pellet material and air according to Figure 5. On the inlet side or extruder funnel, adjust the fish pellet material so that the fish pellet material can enter by utilizing gravity. In addition, on some of the inlet sides or extruder funnels, adjust the ambient air conditions with atmospheric pressure so that air can enter/exit the simulation area to avoid a vacuum when the fish pellet material is pushed towards the exit side or mold. Furthermore, on the exit side or mold, adjust the ambient air conditions with atmospheric pressure so that the pellets can be pushed out of the mold due to the pressure difference.

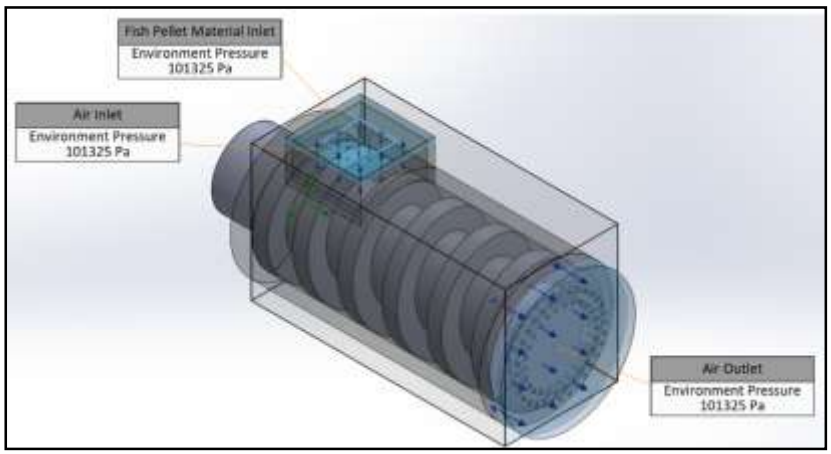


Figure 5. Setting the boundary conditions for the inlet and outlet sides.

F. Wall Motion

Wall motion in this simulation aims to determine the rotation speed conditions of the fish pellet extruder. In this simulation, the extruder speed is selected at 100 rpm according to Figure 6.

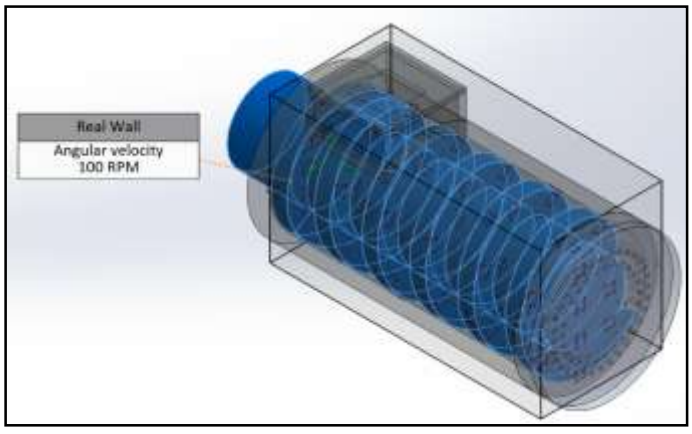


Figure 6. Setting wall motion

G. Meshing

The mesh settings in the Solidworks software are set at level 1 to level 7. The higher the level selected, the greater the number of meshes and the smaller the mesh size produced. By default, the Solidworks software sets the mesh at level 3. The mesh in this simulation is set at level 5 so that the results obtained are more accurate according to Figure 7.

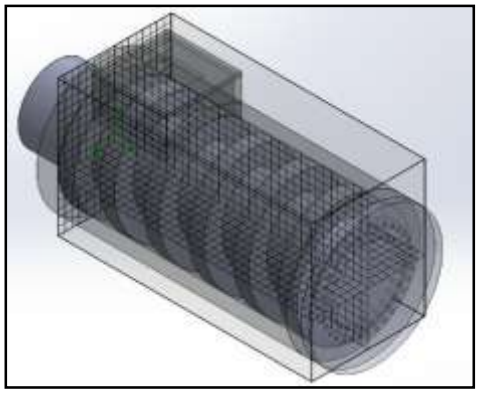


Figure 7. Meshing settings

H. Finish Condition

The simulation completion condition in this study is set after successfully simulating the extruder in real time for 60 seconds. For the results of this simulation to be able to see the conditions every second, the Transient Explorer menu needs to be selected according to Figure 8.

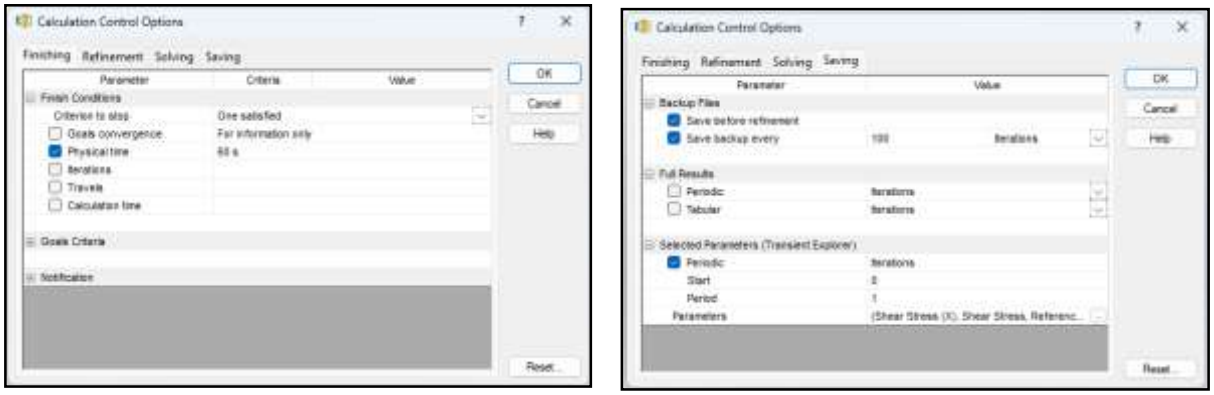
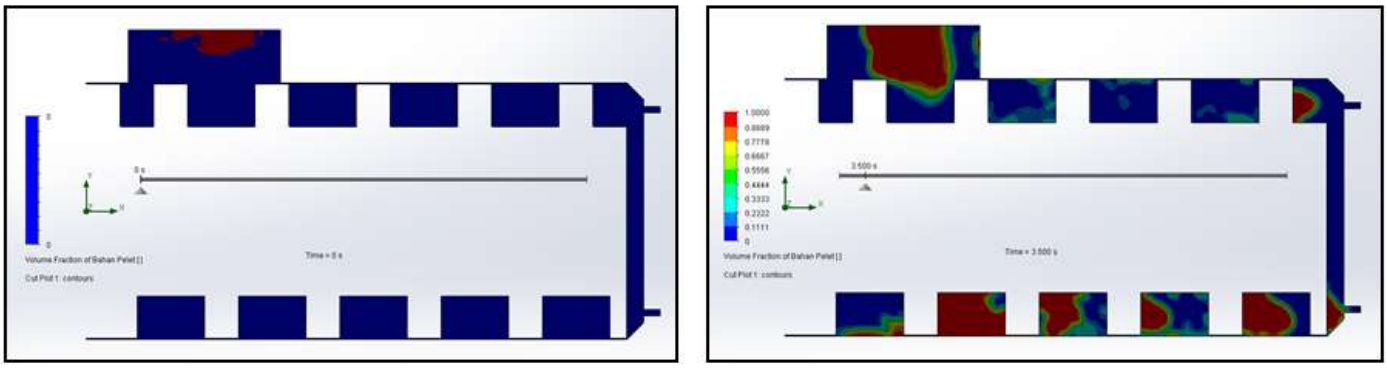


Figure 8. Setting finish conditions

IV. RESULT AND DISCUSSION

A. Extruder Condition

Based on the simulation results, the extruder conditions when simulated in real-time are shown in Figure 9. Initially, at 0 s the extruder is empty. Then, when the extruder is working, the fish pellet material pushed by the extruder reaches the end of the extruder at 3,5 s. Furthermore, at 7 s the pellet material begins to collect at the end of the extruder because it is blocked by the mold component so the pellet material begins to compress. Finally, at 20 s the fish pellet material has fully collected in the barrel so that it works stably.



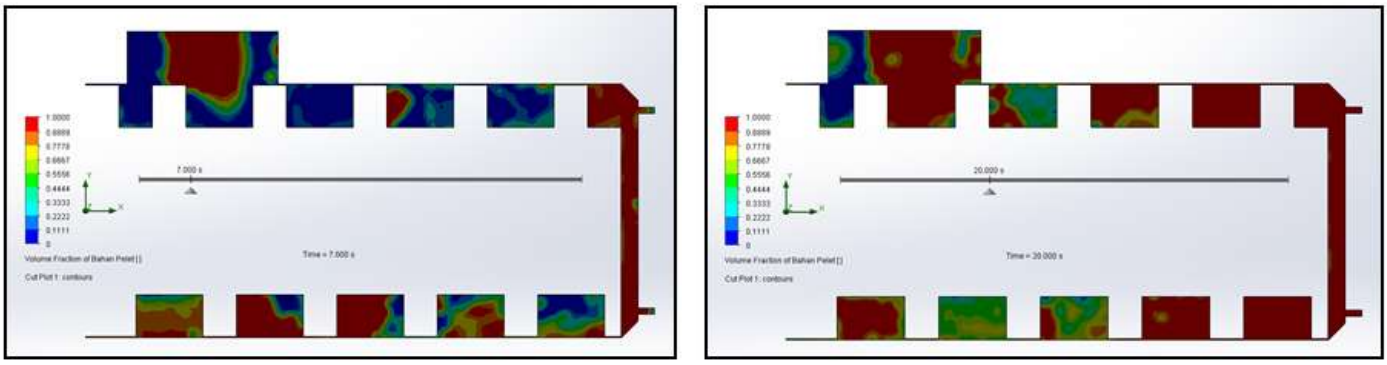


Figure 9. Extruder conditions every second

B. Mass Flow Rate

To measure the mass flow rate value of fish pellet material due to extruder rotation, it is necessary to install a surface goal at the end of the extruder. Because the fish pellet material comes out of the simulation flow region domain, the value recorded in the simulation result data is negative. Based on Figure 10, it can be seen that the mass flow rate fluctuation of the pellet material due to extruder rotation with a minimum value of 0.05 kg/s and a maximum value of 0.24 kg/s. If the average value is taken when the extruder is working stably, namely in the range 20 - 60 s, then the average value is obtained = 0.118 kg/s.

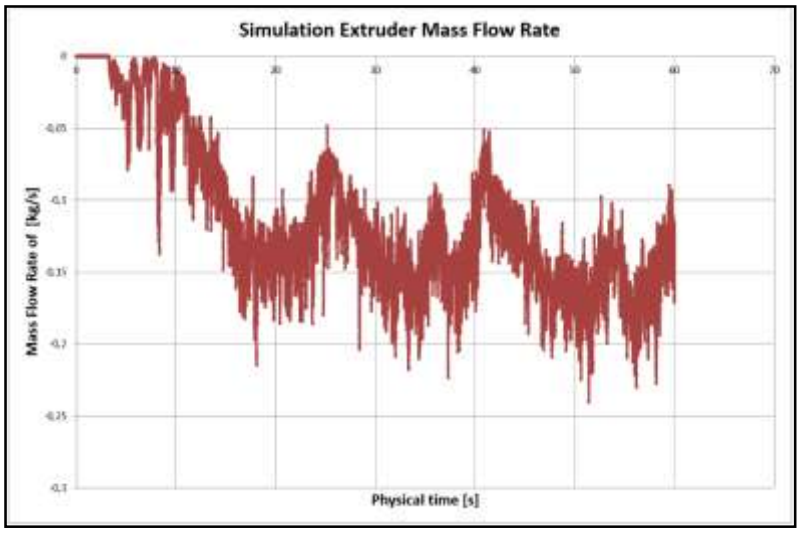


Figure 10. Graph of mass flow rate against time

To validate the results of the CFD simulation, the single screw extruder capacity calculation was used in the research of Polychronopoulos, N.D. and Vlachopoulos, J. (2018) [16].

$$\dot{m} = \frac{1}{2}\rho\pi DNH(p-e)cos^2\theta \quad \text{.....(1)}$$

If it is known that ρ = 1300 kg/m3, D = 150 mm, N = 100 rpm, H = 25 mm, p = 60 mm, e = 20 mm, and θ = 7º, then by using the formula the result is obtained $\dot{m}_{\text{calculation}}$ = 0.53 kg/second. The difference in simulation and calculation results is because the formula uses the assumption that there is no empty space/air in the extruder, and there is no effect of pressure differences and leaks in the gaps in the barrel walls. If the simulation is carried out without using air-fluid and without using dies components at the end of the extruder, then a steady state simulation can be carried out with the result $\dot{m}_{\text{steady state}}$ = 0.507 kg/s according to Figure 11.

Based on the data, it can be seen that the steady state simulation results have an error of 4.34% so it can be used as a reference in determining the maximum limit of the performance of an extruder that works without using mold components. Because the mass flow rate of the extruder simulation results that work using mold components does not exceed the mass flow rate of the calculation results or steady state simulations, the results of the simulation can be used.

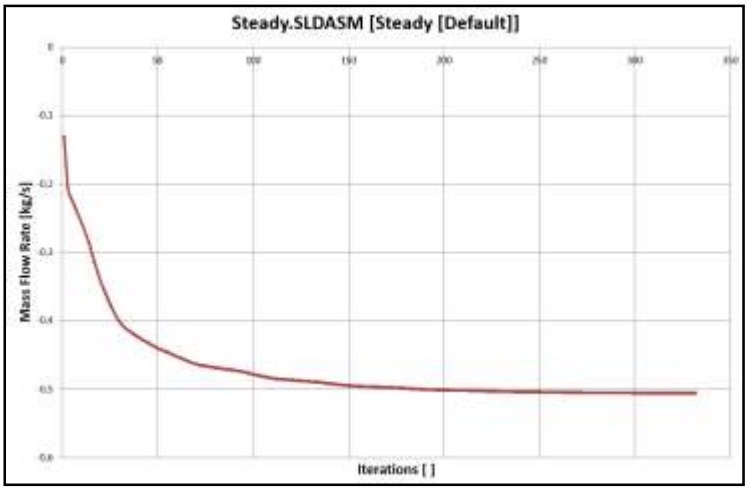


Figure 11. Mass flow rate graph when simulated in steady state conditions without dies components.

C. Torque

To push a certain amount of fish pellet material, the extruder will require a certain amount of power. By doing this simulation, the power required can be known by measuring the torque that occurs in the extruder. To measure the torque on the extruder, it is necessary to install a surface goal on the entire surface of the extruder. Based on Figure 12. it can be seen that the total accumulation of torque required by the extruder to push the fish pellet material is T_{max} = 224.33 Nm.

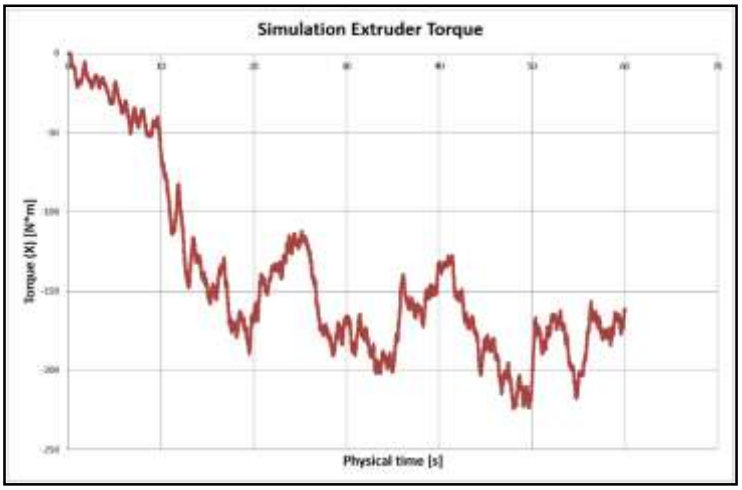


Figure 12. Torque versus time graph

To find out the amount of power on a rotating component, the power calculation formula is used in the book A Textbook of Machine Design (S.I. Units) by Khurmi, R.S. and Gupta, J.K. (2005) [17].

$$P = \frac{2\pi NT}{60} \quad \text{.....(2)}$$

If it is known that T max = 224.33 Nm and N = 100 rpm then the power value will be 2,347.99 W or 3.15 HP. Knowing this power can help in selecting the minimum specifications of the motor power needed in the fish pellet machine.

D. Force

When the extruder works to push the fish pellet material, a reaction force will occur in the extruder. This force will cause deflection in the extruder. If the deflection that occurs in the extruder exceeds the clearance dimension, the extruder can get stuck on the barrel wall so that the fish pellet machine cannot be used. To measure the force on the extruder, it is necessary to install a surface goal on the entire surface of the extruder. Based on Figure 13. it can be seen that the total accumulation of reaction forces acting on the extruder due to pushing the fish pellet material is F_{max} = 11,420.95 N. These results indicate that when the fish pellet machine is working, the force received on the extruder component does not solely come from the weight of the fish pellet material, but also from the influence of the reaction force due to the pressure of the fish pellet material when pushed by the extruder component. If the force that occurs in the extruder component is too large, it can cause excessive deflection which causes the extruder component to hit the inner wall of the barrel component. Therefore, the force value obtained from this simulation can be used in designing extruder components that are safe from the effects of excessive deflection.

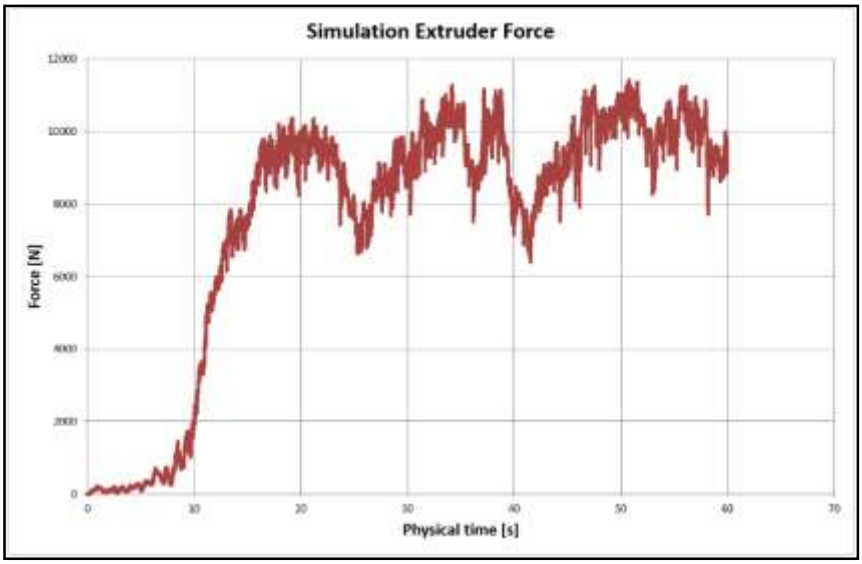


Figure 13. Graph of force versus time

E. Pressure

With the presence of dies at the end of the extruder, the fish pellet material is collected at the end of the extruder so that pressure will occur from the accumulation of collected pellet material. Knowing the pressure that occurs in the pellet material, will help in determining the minimum thickness of the barrel wall. To measure the pressure (absolute) due to the rotation of the extruder, it is necessary to install global goals in the entire simulation area. Based on Figure 14. it can be seen that the average pressure on the fish pellet material that occurs due to the rotation of the extruder is P_{avg} = 264,654 Pa. Knowing the amount of pressure due to the fish pellet-making process, can help engineers in determining the minimum thickness of the barrel wall and dies of the fish pellet machine.

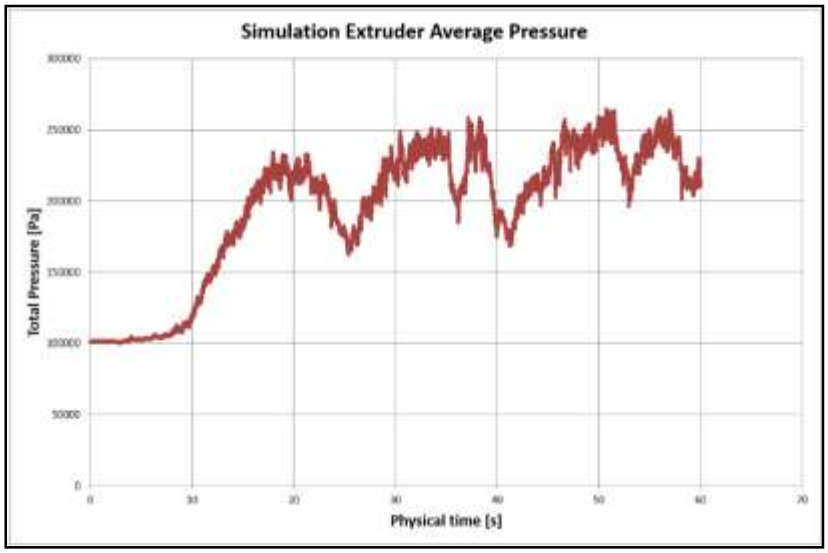


Figure 14. Pressure versus time graph

V. CONCLUSION

Based on the results of the CFD simulation, the following data were obtained:

1. Estimated performance data from the single screw extruder design simulation was obtained in the form of an average capacity when the extruder pushes fish pellet material of 0.118 kg/s. Furthermore, the maximum torque required by the extruder to push fish pellet material is 224.33 Nm. In addition, the extruder receives a maximum reaction force of 11,420.95 N and the pressure generated by pushing fish pellet material towards the mold is 264,654 Pa.
2. The CFD simulation results were validated using the calculation method showing an error value of 4.34% so that the simulation results can be used.
3. The data obtained from the CFD simulation can be used as a basis for designing other components of the fish pellet machine so that specifications are obtained according to industry needs.

REFERENCES

1) Kartikasari, M.D. (2021) "Self-Organizing Map Menggunakan Davies-Bouldin Index dalam Pengelompokan Wilayah Indonesia Berdasarkan Konsumsi Pangan," *Jambura Journal of Mathematics*, 3(2), pp. 187–196. Available at: https://doi.org/10.34312/jjom.v3i2.10942.
2) Bibin, M., Ardian, A. and Mecca, A.N. (2021) *MALLOMO: Journal of Community Service Pelatihan Budidaya Maggot sebagai Alternatif Pakan Ikan Desa Carawali*. Available at: https://jurnal.umsrappang.ac.id/mallomo/index.
3) Muntafiah, I. (2020) "Analisis Pakan pada Budidaya Ikan Lele (Clarias Sp.) di Mranggen," *JRST (Jurnal Riset Sains dan Teknologi)*, 4(1), p. 35. Available at: https://doi.org/10.30595/jrst.v4i1.6129.
4) Regupathi, E.R., Suriya, A. and Geethapriya, R.S. (2019) "On studying different types of pelletizing system for fish feed," *~ 187 ~ International Journal of Fisheries and Aquatic Studies*, 7(2), pp. 187–192. Available at: www.fisheriesjournal.com.
5) Nwaokocha, C.N. and Akinyemi, O.O. (2008) "Development of a Dual-Mode Laboratory-Sized Pelletizing Machine." Available at: http://ljs.academicdirect.org.
6) Jafari, A. *et al.* (2020) "Application of CFD technique to simulate enhanced oil recovery processes: current status and future opportunities," *Petroleum Science*. China University of Petroleum Beijing, pp. 434–456. Available at: https://doi.org/10.1007/s12182-019-00363-7.
7) Ahmed, A.M.A. *et al.* (2022) *Calculation and Simulation of Single Screw Extruder Metering zone for polypropylene using Ansys Polyflow*, *International Journal of Research in Engineering and Science (IJRES) ISSN*. Available at: www.ijres.org46|.
8) Zhang, L., Zhang, Y. and Chen, Z. (2021) "Effects of stable clearances on backflow in the variable-pitch screw vacuum pump," *Mechanics and Industry*, 22. Available at: https://doi.org/10.1051/meca/2021046.
9) Prashanth, S.R. *et al.* (2019) "CFD modelling and performance analysis of a twin screw hydrogen extruder," *Fusion Engineering and Design*, 138, pp. 151–158. Available at: https://doi.org/10.1016/j.fusengdes.2018.11.014.
10) Lewandowski, A. and Wilczyński, K. (2017) "Computer modeling for polymer processing co-rotating twin screw extrusion – nonconventional screw configurations," *Mechanik*, (4), pp. 282–287. Available at: https://doi.org/10.17814/mechanik.2017.4.47.
11) Macko, M. and Mrozinski, A. (2019) "Work parameters research of wood pellet machine," in *AIP Conference Proceedings*. American Institute of Physics Inc. Available at: https://doi.org/10.1063/1.5091899.
12) Tingzhou, N., Peng, Z. and Lanxiang, H. (2021) *RESEARCH ON NUMERICAL SIMULATION OF FORMING PROCESS FOR SINGLE SCREW EXTRUDER*, *ACADEMIC JOURNAL OF MANUFACTURING ENGINEERING*.
13) SNI, SNI 7543:2009 Mesin Pembentuk Pelet Pakan Ternak Proses Basah (Pellettizer), Badan Standardisasi Nasional Indonesia, 2009.
14) Fraiha, M., Domingos Biagi, J. and Carlos De Oliveira Ferraz, A. (2011) "Rheological behavior of corn and soy mix as feed ingredients."
15) İnce, R., Güzel, E. and İnce, A. (2008) *Thermal Properties of Some Oily Seeds*, *Journal of Agricultural Machinery Science*.
16) Polychronopoulos, N.D. and Vlachopoulos, J. (2018) *Computer Flow Simulation of Moffatt Eddies in Single Screw Extrusion*.
17) Khurmi, R.S. and Gupta, J.K. (2005) *A Textbook of Machine Design (S.I. Units)*, *Engg. Services*. New Delhi: EURASIA PUBLISHING HOUSE (PVT.) LTD.

There is an Open Access article, distributed under the term of the Creative Commons Attribution – Non Commercial 4.0 International (CC BY-NC 4.0) (https://creativecommons.org/licenses/by-nc/4.0/), which permits remixing, adapting and building upon the work for non-commercial use, provided the original work is properly cited.