Computational Fluid Dynamics (CFD) Simulation of Mixing Tank at Milk Powder Factory to Reduce Material Losses

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***Abstract* — Industrial milk powder production applies the principle of a spray dryer. In the powdered milk industry using a spray dryer, there are still some problems in actual conditions, such as fouling in the heat exchanger and losses. Losses are lost material or time that results in losses for the company. The importance of finding material losses as soon as possible it is possible to make a solution so that initially unknown material is wasted in vain and can be used as a finished good. Steps taken to resolve the problem of material losses are to identify problems and data by mapping losses according to actual conditions. The main contributor to material losses is in the mixing tank prior to the spray dryer due to foaming phenomena. After that, a CFD simulation of the mixing tank can be performed on Ansys with the aim of the simulation is to get the contour of the foaming phenomenon and find out the height the phenomenon of foaming (foam) with the properties setup begins at the beginning of making geometric designs with the size of the tank is 3.5 m and uses a marine propeller type, then proceeds with meshing In geometry, meshing here uses the automatic meshing method due to the limited analysis students. The solving stage is carried out by inputting data such as density, viscosity, and input multiphase (mixture), and viscous (Large Eddy Simulation), as the boundary conditions of the geometry, after that making a plane from the results of running to form a plane in geometry, then choose the results of the contour volume fraction to find out the phenomena that occur in mixing tank so that conclusions and solutions can be drawn. Based on the results of data analysis and the field in the form of mapping and data on quantity losses, there are still some material losses in the form of wet and dry losses that have not been identified, initially the percentage ratio of material losses is 40.57% to 9%. One of the biggest contributors to material wet losses is mixing tanks which are simulated until it is known that there is a foaming phenomenon. It interferes with the way it works level sensor, which causes less maximum withdrawal of milk liquid by the pump. The best way to reduce losses in the mixing tank is to close the valve mixing tank output when showing 1.8%, or it can be rounded to 2% for the safety pump. The liquid used as a product is 270 liters, equivalent to 113 kg. The company can store 8,505 kg/month of powder if the calculation is carried out.**

***Keywords* — Mixing tanks, Losses, Powder milk, Spray dryer**

I. INTRODUCTION

Indonesia has a very high dependence on milk imports. The main products imported from Australia to Indonesia are skim and whole milk powder, followed by cheese, whey, and butter (Nugroho, 2010). This is influenced by the market milk consumption growing around 6.6%/year with the largest percentage in the form of milk powder (59%), followed by liquid milk (20%) and sweetened condensed milk (21%). Meanwhile, domestic milk production in the last 3 (three) years has only increased by around 8% (CDMI and BPS, 2017). The high number of toddlers in Indonesia, makes Indonesia one of the main markets in the marketing of world growth milk. Indonesia and China are the countries with the largest growth milk consumption in the world[1].

The drying process is defined as the removal of liquid (usually water) from a product by evaporation, leaving solids in a dry state. Several different drying processes are used in the dairy, food, chemical, and pharmaceutical industries, such as spray drying, fluid bed drying, roller drying, freeze drying, microwave drying, and superheated steam drying[2]. Spray dryers often used in the milk powder industry have a working principle in the form of transforming the feed from a liquid state to a dry particulate form by spraying the bait into a hot drying medium. This is a continuous particle processing drying operation. The feed can be a solution, suspension, dispersion, or emulsion. The dried product can be in powder form, granules or agglomerates depending on the physical and chemical properties of the feed, the design of the dryer and the properties of the desired final powder. In the milk powder industry using a spray dryer, it is undeniable that there are several problems that occur in its actual conditions such as fouling in heat exchangers, reduction of heat transfer during evaporation, blocking of nozzle, low-quality powders that require product rework and losses. Losses are material or time lost to cause losses to the company[3]. Losses in the industry can reduce the product produced or yield where the material that should be maximized into finished goods turns out to be simply wasted. High material losses cause the company to continue to experience material losses without being able to make a settlement. Therefore, it is important to find arterial losses as soon as possible to be completed so that material that was initially unknown is wasted can be used as a finished good to increase production yields. One of the tools in the milk powder production process before feeding on the spray dryer is a mixing tank [4]. Mixing tanks are tanks where homogenize, hold, and circulate

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milk liquid. In propellant-based systems, mixing tanks are usually kept at a constant.

Temperature to ensure a consistent fill weight during charging operations[5]. After observations were made on the mixing tank with a capacity of 10,000 liters, there were material losses in the form of liquid products left behind, which were then wasted into industrial waste. The material losses should be able to be processed into milk powder and provide a large enough amount of profit for the company. The occurrence of arterial losses can be due to equipment damage or suboptimal equipment at work that has not been identified for its exact existence by the operator or employee [6]. Therefore, we conducted a study "Computational Fluid Dynamics (CFD) Simulation of Mixing Tanks at Milk Powder Factories to Reduce Material Losses" to find out about the phenomena that occur in mixing tanks so that they can draw conclusions on the root of the problem and provide ideas and advantages in the milk powder industry. Computational Fluid Dynamics (CFD) was originally developed from the achievements of pioneers such as Richardson and Courant, Friedrichs, and Lewy, which to gain insight into fluid motion prompted the development of powerful numerical techniques that had advanced the numerical description of all types of fluid flows. CFDs are now a powerful and pervasive tool in many industries. Each solution represents a rich tapestry of mathematical physics, numerical methods, user interfaces, and state-of-the-art visualization techniques. CFDs are widely used as design and optimization tools in the industry. With the use of CFDs, multi-phase flow modeling is made easy, thus providing a detailed understanding of flow distribution, weight loss, mass and heat transfer, particulate separation, and others. Generally, CFD simulation is done by running code or software on modern computing machines.

II. METHOD

A. Materials

In this study, it was carried out by the method of an experimental approach. The experimental approach is carried out by means of experiments through simulations using the Ansys Design Modeler 2022 program based on field studies to obtain valid results and can be applied to the milk powder industry.

B. Problem Identification

The first step is to identify problems that aim to determine the process of material loss in the mixing tank. This is done by direct observation in the field, namely one of the milk powder companies. Sampling of material losses in liquid form using tabulation manually in accordance with the safety procedure is then measured the volume and total solid to find out how many kilograms of milk powder can be produced from the liquid [7].

C. Data Analysis

Based on the samples that have been identified, the next step is carried out by analyzing data in the form of the capacity and size of the mixing tank and the material contained in the milk liquid. These data are the basis for the CFD simulation process using the Ansys application.

D. Simulation Procedure

Then with procedure simulation intended at this stage making modeling mixing tanks and their circulation in the software to find out the causes of losses that occur in mixing tanks. This simulation uses the Computational Fluid Dynamic (CFD) method with Ansys software [8].

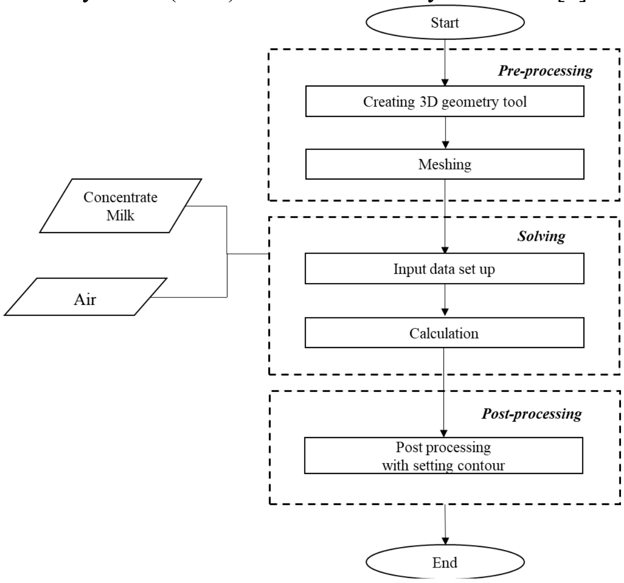

Figure 1. Flow Diagram for Simulation Procedure at ANSYS

1. Pre-processing Stage (Creating Geometry Design)

Making geometric design mixing tanks can be done in the ANSYS Design Modeler 2022 program, ANSYS Design Modeler is a 3-dimensional modelling application that provides solutions for modelling in general, with details of 3.1 m and a width of 2.2 m and a propeller speed of 915 rpm.

2. Meshing Stage

CFDs are run by the ANSYS Fluent Program which has the concept of finite volume method. Meshing serves as a divisor of geometry volume control into smaller and smoother elements with the aim of obtaining more convergent results in the analysis. The geometry that has been completed will be continued the meshing process. With an element size of 115 mm, and an average quality of 0.22904, and a note of 91,347 elements of 500,131.

3. Solving Stage

At this stage using Ansys, namely with the following steps:

1. Read the mesh from the stationary zone then append the case to read and merge with the moving zone.
2. Choosing the multiphase modeling used, which is mixture.
3. Choosing the equation to be used, namely viscous Large Eddy Simulation (LES). The principal idea behind LES is to reduce the computational cost by ignoring the smallest length scales. LES is a method of predicting turbulent flows which involves the solution of fully time-dependent, 3-dimensional flow fields by use of the Navier-Stokes equations [9].
4. Create a vertical field of observation.
5. Defining the materials for the simulation, namely water and milk.
6. Specifies operating conditions and limit conditions on the tested system.
7. Set the completion of the parameters that control, namely the solution method: SIMPLE and solution

control.
8. Calculate completion based on mathematical calculations on fluent programs that have been controlled with a time step of 0.01s and an iteration or time step of 20.
9. Create an observation field and set up a solution animation.

4. Post Processing Phase

The results of the run calculation mixing tank that has been completed, can be continued analysis with the CFD Post Processing program which is also contained in an ANSYS Workbench. Results will be obtained as a fraction volume contour (water volume fraction). Based on the simulation results, the phenomenon that occurs in the mixing tank can be known so that an action plan can be designed in the form of several solution suggestions based on operating conditions in the field and reviews of international journals to provide applicable advice.

III. Results and Discussion

The disposal of material in the mixing tank with a capacity of 10,000 liters is due to the removal of the tank before cleaning in place (CIP) so that the remnants of liquid in the mixing tank are drained or disposed of. Before the discharge, there was a sensor level that had not shown 0% so that it indicated that there was still liquid on the mixing tank but was not sucked in by the pump because of the presumption that the thing was completely foam detected by the sensor level so that it was simply thrown away. Based on the sampling results, most of the liquid (80%) disposed of was milk liquid with a total solid content of more than 40% plus foam at the top of the milk liquid. ± The accumulated material loss caused by this is as much as± 8.000 kg / month. Foam or foam is the dispersion of gas bubbles in a liquid, semi-liquid, or solid continuous phase. Foam is colloidal, since the film separating the gas cells has a colloidal thickness. Milk proteins are known to form a thick layer of foam with considerable mechanical strength [10] [11].

Forming foam requires gas, water, surfactants, and energy. Surfactants are needed to lower the surface tension between gas and water, thus facilitating small gas bubbles' formation. For milk foam, surfactants are proteins present in the system. The energy required in foaming is the energy produced by the stirring process [12]. Variables that affect foaming in the stirring process are the intensity and duration of stirring and the temperature of milk. Temperature greatly affects the formation of froth where the milk foam formed at a temperature of 50°C is much more stable than that formed at 70°C due to the lack of denaturation of whey proteins at this temperature can lead to the formation of a strong interface layer [13]. Foam can also be compressed, and if it is heavy enough to be pulled into the pump, the hydraulic system operates erratically creating unsafe conditions on the elevator and inaccurate movements that damage the finished product. In addition, excessive foam leads to more wear of components and overheating. Those are just a few of the potential reasons for the urgency of a quick fix that a single dose of antibody additives can possibly provide. Foam also causes the sensor level to work less optimally due to difficulty in monitoring emulsions and foams due to the presence of air bubbles in the liquid weakening / dispersing ultrasound waves [14].

The full tank capacity is 12.000 liters, but in accordance with the factory regulations, the tank filling ±80% of the full capacity so that the filling capacity of the compounding tank is 10.000 liters.

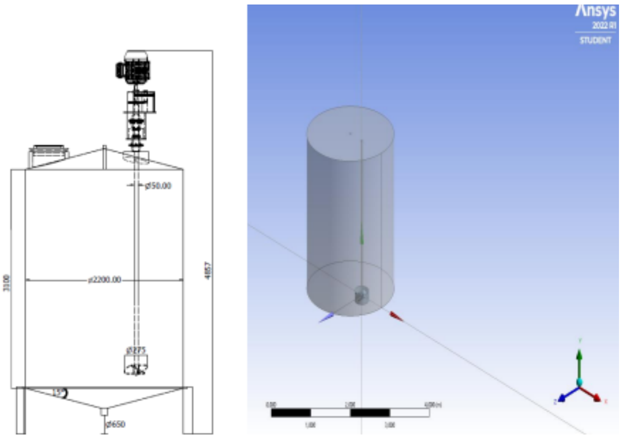

Figure 2. Design of Compounding Tank using ANSYS 2022

TABLE 1.
PROPERTIES SETTING AT MESHING

Information	Size (meter)
Diameter Tank	2.2
Tank Height	3.1
Conical Tank Degree	15°
Propeller Type	Marine Propeller
Propeller Width	0.275
Propeller distance	0.3
Shaft Propeller Width	0.05
Shaft distance to the center point of the tank	0.55

Meanwhile, after making geometry tanks, the meshing stage will be carried out with the following results.

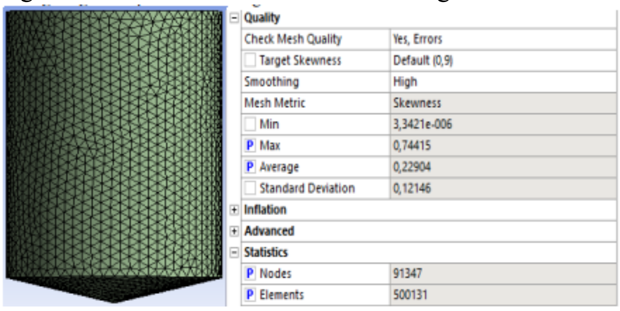

Figure 3. Meshing Result ANSYS 2022

The high quality of the mesh for solving fluid dynamics problems in the CFD model is essential for an accurate, stable, and fast convergent solution. The higher the mesh quality, the faster and more stable the solution will be under various boundary conditions [15]. Many metrics determines the quality of the mesh, the most common of which are the quality of the cell and the skewness (slope) where it has a dependence on the resulting solution. Fluent recommends minimum grid cell quality parameters greater than 0.01 for all cells individuals, while the overall average should be much higher. It recommends that the skewness should be below 0.95 for tetrahedral cells, and below 0.85 for hexahedral cells[16]. We use an automated mesh approach where the need for an automatic mesh generation method for CFDs has led to a hybrid approach alternative. This technique removes a layer of prism elements from the mesh of the skin covering the domain flow, with the aim of capturing the viscous boundary layer, and connecting it with an unstructured mesh or Cartesian in the remaining volume. The ease of use of this method has led to widespread industrial use, with many commercial CFD tools using hybrid meshing techniques. An automatic meshing approach like the following figure results in the mesh producing a good average mesh quality overall [17].

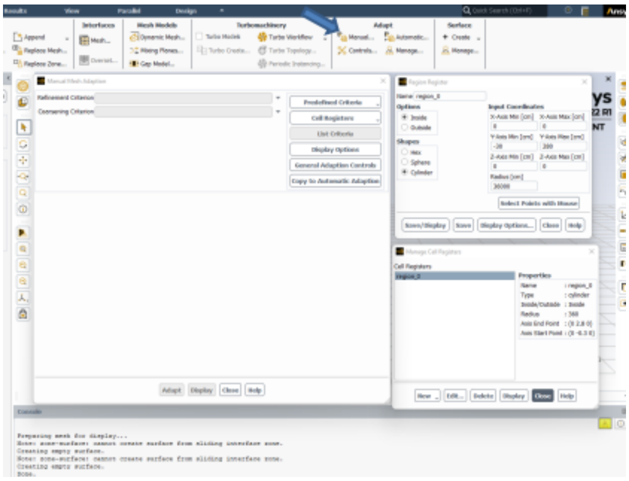

Figure 4. Properties Material Set Up Running

There are several processes simulated in compounding tanks, such as inputting the modelling used, as well as viscous, material properties, cell zones and boundary conditions, and methods. However, before that, in carrying out the running setup, the mixing process here in the tank is already filled with milk. Therefore, a patch is carried out in the tank according to the following figure, Properties of Material Setup Running.

1) In simulating a running setup, first prepare the patch that will be inputted.
2) Then create a new region (plane) that will be filled by the desired material.
3) Then choose Y Axis Min and Y Axis Max filled according to the condition of the tank which has been created.
4) Then proceed to the run calculation process.
5) That is when liquid milk is transferred into the compounding tank and when the volume.

Liquid milk has reached 10.000 liters, temporarily accommodated in compounding tanks. Then do a run calculation according to the condition of the tank. And here is the result of the phenomenon that exists when liquid milk is transferred into the compounding tank.

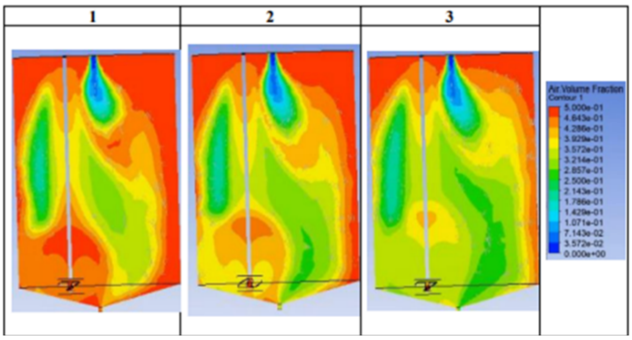

Figure 5. Results at liquid is transferred.

From the above results that has been carried out, several conclusions can be drawn that based on the results of the CFD simulation on Ansys, it can be known the foaming phenomenon shown by the color gradation between red (air) and orange (milk) then designed several solutions but the most suitable solution to be applied is the sensor level setting when showing 1.8% or can be rounded to 2% the output valve will close [18].

Based on the results of the run calculation with a time step of 50 seconds, the following figure results when the milk liquid is transferred, the contour image is obtained, so that it can be seen the phenomenon that occurs is a tank that is initially empty and automatically filled with air then milk liquid will go down divided into two by approaching the tank wall then attracted by the propeller at a speed of 915 rpm so that there is a stirring of the milk liquid. The flow of milk liquid driven by propeller moves upwards in the radial direction. The phenomenon of contour orange color gradation is a marker of air dispersion with milk liquid in the compounding tank. The buoyancy of a gas or air exceeds the pumping capacity of the propeller so that the gas or air rises in a vertical line to the surface and forms foam or foam [19].

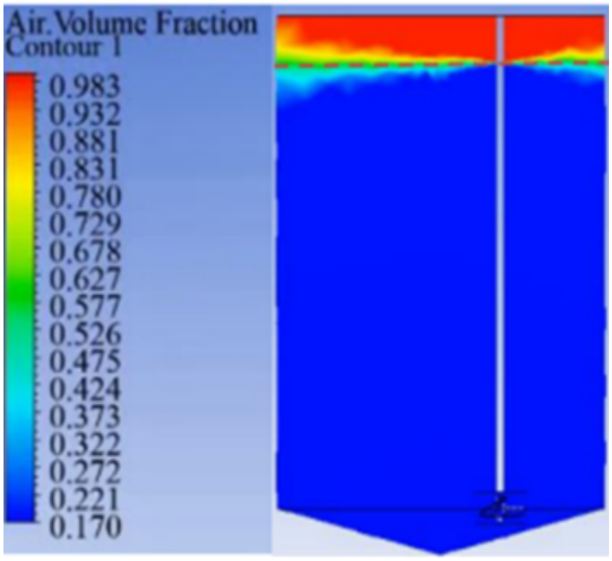

Figure 6. Result of Foaming Simulation

The dotted red line in Figure 6 The result of foam, represents roughly the two-phase interface between the upper foam layer and the milk phase where there is a color gradation between red (air) and orange (milk) [20]. The process of foam or bubble bubbles of foam begins during stirring, the air on the surface of the liquid is carried into the solubility and allows the formation of large bubbles. Under the shear, the bubbles then deform into elongated ones whose size depends on the nature of the fluid, on the ability of surface agents (surfactants, proteins, polymers) to stabilize the interface, and on the forced shear flow. At critical sizes, bubbles burst and form smaller bubbles [18]. The froth capacity depends on the total protein content as well as the ratio of casein or whey protein. The average bubble diameter obtained after 7 minutes of foam formation is greater than the initial average bubble diameter, where the value ranges from 247 to 102 mm for skimmed milk foam, and 144 to 114 mm for WP-enriched foam. The diameter decreases with increasing SMP or WPC concentrations [21].

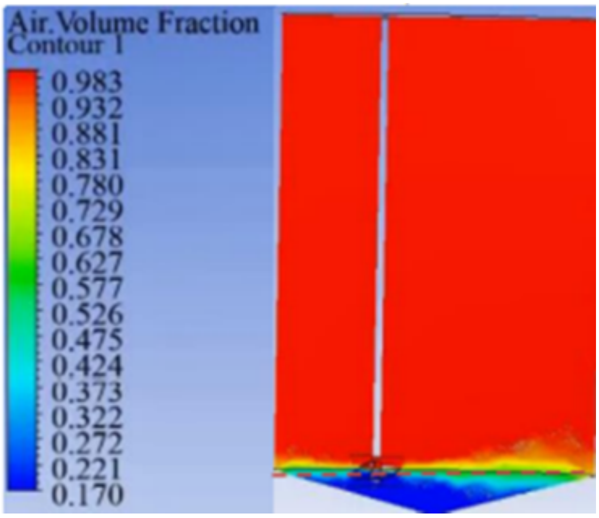

Figure 7. Results Air Volume Fraction Simulations

According to Volume Fraction Water Results, is an appearance when emptying occurs where when the output valve is closed there is still milk liquid left behind and according to the situation in the field as much as ±270 liters is shown by a dark blue to green contour. Then we indicate the presence of foam with gradations of yellow and orange colors.

IV. CONCLUSION

There are still unidentified losses that occur in the milk base powder production process which consisted of dry losses which were initially only 0.91% to 0.92% and wet losses initially only 0.21% to 0.81% with the highest contributor to wet losses is on the compounding tank due to the operator's presumption that it is all of it is foaming which is detected by the level sensor so it is discarded just like that. Based on the results of the CFD simulation on Ansys, it can be seen the foaming phenomenon indicated by a color gradation between red (air) and orange (milk) then several solutions were designed but the most suitable solution to implement is sensor level setting when showing 1.8% or can be rounded to 2% the output valve will close.

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