ANALYSIS OF OUTER TUBE CASTING PRODUCT REJECT USING COMPUTER AIDED ENGINEERING

Ahmad Juang Pratama

Department of Industrial Engineering, Faculty of Science and Technology, Al-azhar University Indonesia, Jl. Sisingamangaraja Kebayoran Baru, Jakarta Selatan, Indonesia
E-mail : juang@uai.ac.id

ABSTRACT

Parts of front fork motorcycle component are called the outer tube where the part is made by aluminium and processed by gravity casting method. The process will produce in gate, runner, gating, feeder, and outer tube product. Later only the outer tube part will be use as product while the other part will be melted back together with aluminium ingot. This casting process can be simulated by the help of 3D-CAD software and simulated by CAE software (Computer Aided Engineering). In the simulations, we analyse the direction of solidification and temperature inside the dies. The simulation in 3D environment give faster but reliable result, while the absence of the product physical test, by using CAE software even give lower prototype cost.

Key words: *Front fork, AC2B, in gate, runner, gating, feeder, OutertubeVA/VE, Value Analysis / Value Engineering, , 3 Computer Aided Design (3D-CAD), Computer Aided Engineering (CAE), Magmasoft, Quality managementg, Quality Engineering.*

1. INTRODUCTION

To be competitive in the competition, a world class company should satisfy need of the customer in term of product quality and lower cost structure (Shillito, 1994). To achieve this, XYZ Company comes up with Policy to conduct company efficiency programs. One of these programs is Value Analysis / Value Engineering evaluation that conducted in almost all departments. Product Engineering Department got the target from management to run product VA / VE for 4 items.

Activities to improve the product quality can be categorized into quality management and the quality engineering activities. As one company that has so 9001 predicate, XYZ Company has very good quality management capability to resolve product defects that have been produced. But based on reality, there are massive number defect for some product in mass production. Therefore the company is trying another approach to use quality engineering activities using CAE technology. Simulation using Computer Aided Engineering software will reduce the numbers of physical trial of products and significantly shorten the research time.

1.1. Project Goal

The goal of this project is to investigate the causes of mass product defects using a casting process simulation. By this simulation, the design flaws of casting can be found, as base for validation and design recommendations for further improvement.

1.2. Problem Formulation

Prior this project, quality management has been become the main basis for increasing products quality, but for certain manufacture product quality management activities alone cannot effectively solve the quality problems, we need also quality engineering approaches. Prior to this project, it is not really easy to conduct analysis and optimization to improve deficiency of the trial and error casting product design, this approach is no easy due to

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insufficient engineering validity, besides the physical trial takes higher cost and longer time. Before the application of CAE technology, activities in engineering quality often need complex scanning and material properties test.

2. THEORETICAL BACKGROUND

Casting is a manufacturing process in which the workpiece is formed through a process of melting of metal, then the metal is poured into a mold (mold / dies) and solidified to form a certain shape according the geometry of mold cavity (Runmann, 2001). Metals / materials used in the casting process at XYZ company is AC2B Modified aluminum alloy (JIS Handbook, 1997), with a more pure (free of impurities) called as KS1. The products produced in the form of the outer tube where the object will be mounted on the front fork of the motorcycle. Front fork is one of the shock absorbers products manufactured company XYZ.

2.1. Filling

First o all the KS1 molten aluminum is poured into mold cavities from furnace. Then the molten aluminum flow into the dies through the in gate, runner, gating, feeder and products to fill all cavity volume . In this stage, aluminum is still in liquid form.

Ideal flow condition

1. Hindrance free
2. Free from turbulence
3. The fluid has a constant density
4. Velocity and working pressure does Change with time

Based on Bernoulli's Equation, cont. Ideal flow can be formulated as follow:

$$P + \frac{1}{2}\rho v^2 + \rho g y = \text{constant} \qquad (1)$$

If we assume pressure value (P) is same as 1 Atm for P1 and P2, with density ρ also the same, the flow

$$V1 \times A1 = V2 \times A2 \qquad (2)$$

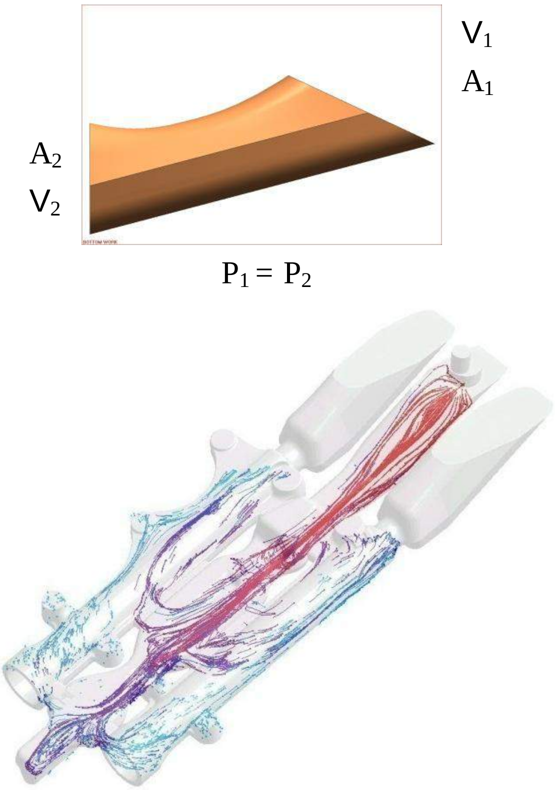

Figure 1. Fluid Flow

2.2 . Solidification

After aluminium entirely fill the volume of dies happen Because of the heat transfer from the hot liquid to coating and then to cavity wall to release the heat then cool the metal. The number of heat transfer is affected by the amount of mass and the area of wall cavity. This is expressed by Chvorinov's rule formula.

Chvorinov's rule - The solidification time of a casting is directly proportional to the square of the volume-to-surface area ratio of the casting (Callister, 1994, p.143)

$$TST = C_m\left(\frac{V}{A}\right)^n \qquad (3)$$

Where TST = total solidification time**; V =** volume of the casting; **A =** surface area of casting; **n =** exponent usually taken to have a value = 2**;** and **C_m** is mould constant. What Chvorinov's Rule tells us; a casting with a higher volume to surface area ratio cools and solidifies slower than one with a lower ratio, to feed molten metal to main cavity, TST for feeder must greater than TST for main casting. Since feeder and casting mould constants will be equal, design the feeder to have a larger volume to area ratio so that the main casting solidifies first, this minimizes the effects of shrinkage

Influence of metal cooling rate

1. Slow cooling rate will form coarse microstructure
2. Fast cooling rate will form fine microstructure
3. Fine microstructure will give better yield strength and ductility properties
4. Fine microstructure will reduce hotspot and crack

2.2. Molding Simulation process

The product geometry data with stereolithography extension (stl) used by casting simulation software (CAE) had to be generated and imported from independent 3D solid CAD program.

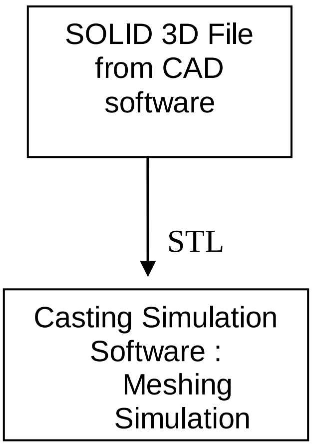

Figure 2. Simulation Process Using CAE Software

Casting simulation programs use the part geometry to define the mold cavity. Once in the simulation program, the STL mesh information is used to generate a compatible plastic melt flow model simulating the mold cavity, i.e., a. finite element mesh. The mesh generation is done automatically or manually by user intervention. In preparation for the simulation, import 3d geometry. Then, the designer selects from a material database the type of metal to be used. Processing conditions can also be modified by designer. But the database give default values for metal melt temperature and mold temperature are default values recommended for the metal selected. The filling rate may also be automatically computed by the simulation program based on the part geometry.

Analysing part while in Virtual prototyping domain gives user flexibility to examine a number of casting design alternatives to optimize the filling and solidification pattern. During the preliminary stages of design, a designer analyse the casting design alternative. The rapid feedback in these programs makes them easy to use for multiple product design and feeder iterations.

3. RESEARCH METHOD

The research is conducted with the following steps. First we did literature study for getting wider understanding and good theoretical understanding, then we select the model to be analysed based on pareto distribution of product defect, subsequently we made 3d design of the product using 3d software in stl extension as common standard for simulation. Furthermore, based on the design we conducted solidification and temperature analysis using magmasoft software. By simulation analysis It is expected to find design flaws as root causes of product defect.

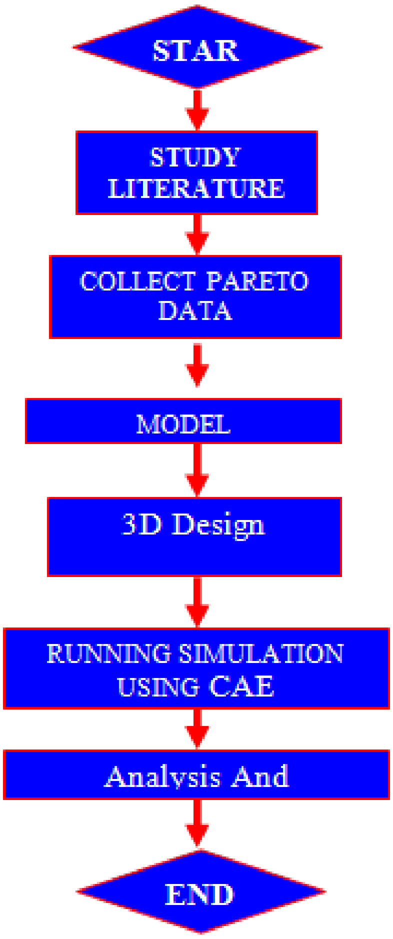

Figure 3. Methodology

4. RESULT AND DISCUSSION

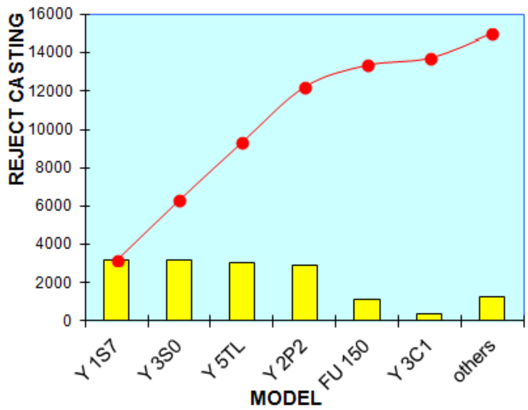

Figure 4. Pareto Distribution

Based on pareto distribution, to reduce reject rate of casting, the project is concentrated on model Y1S7 investigation. This is shown in the figure below.

Of a given product, there are some products that are visually defects in the form of porosity defects, rough surfaces and surface shape that does not match the contour of the dies cavity wall.

Figure 5. Casting Defecs Categoies

In the simulations we analyze the flow of molten metal and direction metal of solidification in the cavity. Of course, the results of these simulations are the basis for further improvement of the casting design, Having analyzed using the Magma software is then expected to help find the root cause or subtraction of mass. so that the result is perfect casting and liquid flow really smoothly.
Simulation sequence is as follows:

4.1. Modelling Meshing

Modelling and meshing are made by 3D-CAD software, while meshed using

CAE software magmasoft as shown below:

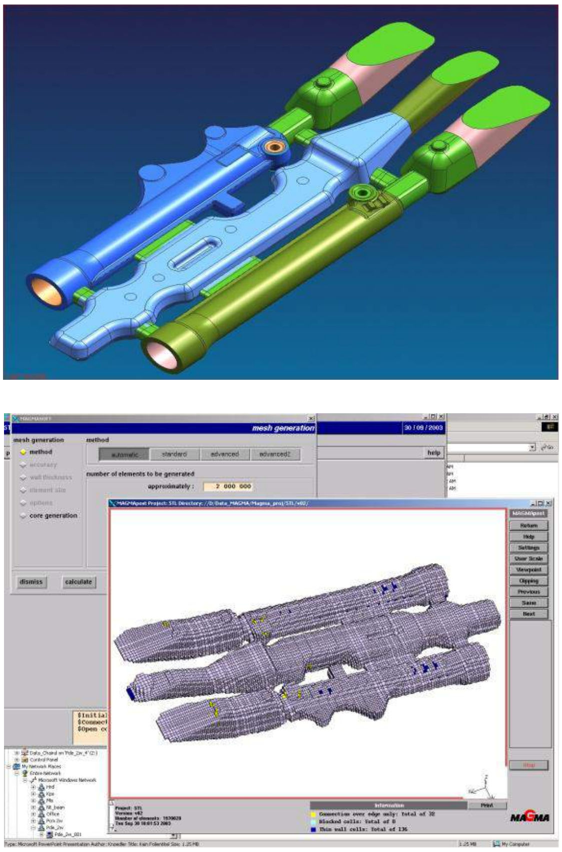

Figure 6. Meshing of 3D model

There are many consideration for doing good meshing;

1. The quality of the mesh has strong influences to the calculation results.
2. Attempt to get homogeneous mesh.
3. Not so much needle elements
4. Inlet should have at least 3 layer in the fill direction
5. No block cells existence
6. Minimize the thin wall and connection over edges (possible without them)
7. Minimum 3 layer for the casting walls
8. Big mesh leads to the long calculation time but accurate results
9. Too coarse mesh leads to the fast calculation speed but inaccurate calculation results

The next step material properties definition are need to be defined, includeliquidus and solidus temperatures; pouring temperature, specific heat capacity, thermal conductivity, density,viscosity, fraction solid, and heat transfer coefficient. Heat transfer coefficient describe how much heat can be transferred between two boundary (applied on the surface)

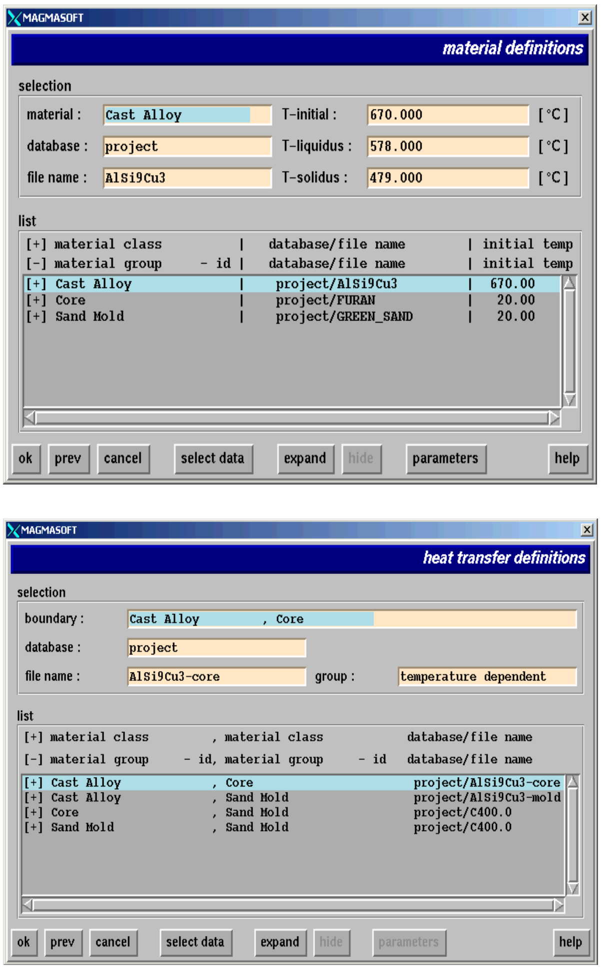

Figure 7. Material Properties Definition

4.2. Simulation Result Analysis

In the solidification analysis, it can be seen there are termination of molten supply from the feeder to casting. This happens because: The distance of feeder neck are quite long, it makes the material around small feeder area solidified first and blocks the molten metal from feeder into cavity.

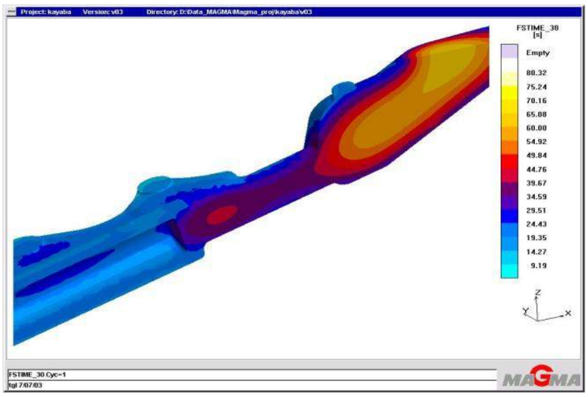

Figure 8. Solidification Analysis

From the simulation, dies temperature can be identified over 500°C, it will cause excessive oxidation on the surface of the casting, and porosity as sand angle effect (Gruzleski, 1990). The high temperature is caused by the casting design:

1. The distance between the feeder runner Cavity / casting too close so that the die temperature of the area to be hot
2. Contruction of mold/dies Do not allow additional cooling channels

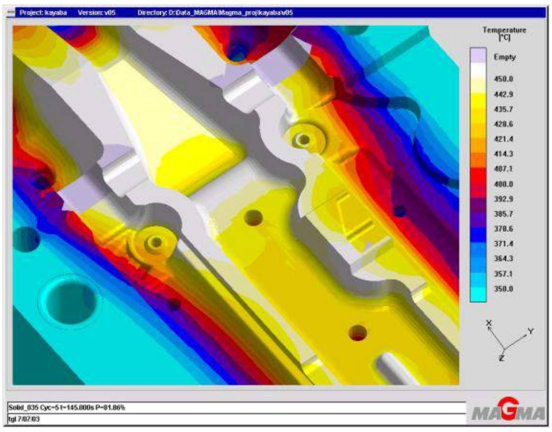

Figure 9. Dies Temperature Analysis

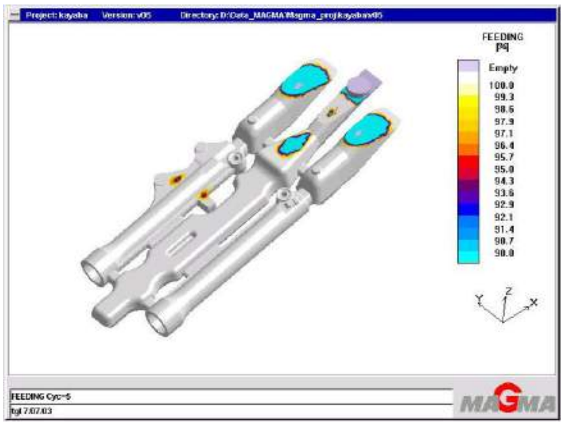

Figure 10. Porosity Caused by Sand Angle Effect

5. CONCLUSSION AND SUGGESTION

Defect that occurs is caused by design flaws that validated using CAE software. From the simulations, it is known that porosity defects found are caused by the long feeder neck design, resulting in incorrect solidification direction. With the termination of the supply molten aluminium, hotspot localization occurs in the casting. The hotspot causes porosity defects. Moreover, high Dies temperature triggers oxidation on the surface of the casting that make surface of the casting look rough.

Feeder neck size reduction could be one solution to produce defect free porosity. To reduce the temperature of the dies, because addition of cooling channels cannot be done, the alternative is to put a chiller on the areas that have excessive heat. Because the cooler dies the less oxidation occurs on the surface of the dies.

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AUTHOR BIOGRAPHIES

Ahmad Juang Pratama, is a lecturer in Department of Industrial Engineering, Faculty of Science and Technology, Al Azhar Indonesia University, Jakarta. he received her Master of Seciencel Engineering from Technical University Hamburg Harburg, His research interests are in the area of Product Planning & Development, Robotic and Design Product as well as managment She is a member of VDI (Verein Deutch Ingeneur) His email address is juang@uai.ac.id