COMPARATIVE STUDY ONMANUFACTURING PROCESSES OFA SWIRLER CASING

by

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Dissertation submitted in partial fulfillment of the requirement for the
Bachelor of Engineering (Hons) (Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
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Approved by,

____

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TRONOH, PERAK
May 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

AHMAD FAIZ BIN MD YUNUS

ABSTRACT

Process planning is a systematic method to determine the engineering processes and systems to manufacture a product competitively and economically. In this project, the process plan is subjected to analysis for fabrication process of swirler by machining and casting. The scope of study covered process sequence, machine tools and fixtures. The comparative study of fabrication swirler casing will be based on the analysis from machining and casting process plan that include the process time and cost consumption. Most of data for this study were obtained from literatures and experiments. The total process cost by casting is lower than machining process with RM 10113 for casting and RM 12578 for machining. However, total estimated process time for casting higher than machining which are 151 hr and 139.6 hr respectively. These findings have significant implications for the commercial application of manufacturing processes.

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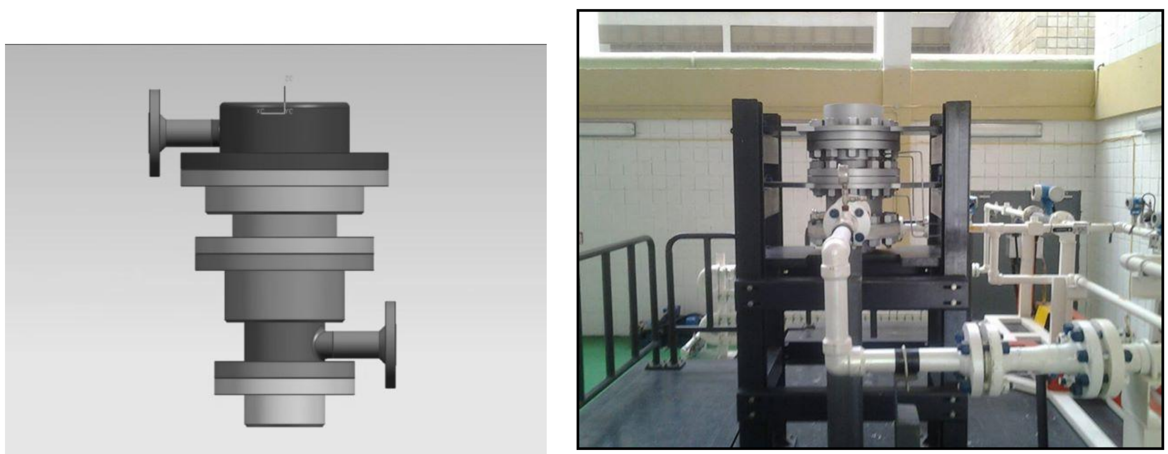
CHAPTER 1: INTRODUCTION

1.1 Background of Study

The swirler is one of units in the wet gas dehydration prototype for replacement of existing glycol dehydration system at offshore platform for PETRONAS Carigali Sdn Bhd- Sarawak Operation (SKO) as shown in figure 1.1 (b). The development of wet gas dehydration system is an initiative to meet the gas sales specification for exportation. For export, the separated gas need to be compressed and dehydrated (remove moisture) prior to transmission. The system also functioned for increasing the capacity of natural gas for export by providing alternative gas source for gas re-injection compressor.



(a) (b)

Figure 1.1: Schematic Design of Swirler Prototype (a) and Wet Gas Dehydration System for Simulation Test (b) [photo taken at UTP BaroniaResearch Centre]

Figure 1.1 (a) shows the schematic design of swirler prototype and been fabricated for simulation testing purpose. It consists of four different main components which are top cover, throttle, water collector, and water container. Previously, the fabrication processes of the components done by machining process. Nevertheless, these components also may fabricate by casting. Hence, comparative study on manufacturing process of the swirler casing by machining and casting should be considered.

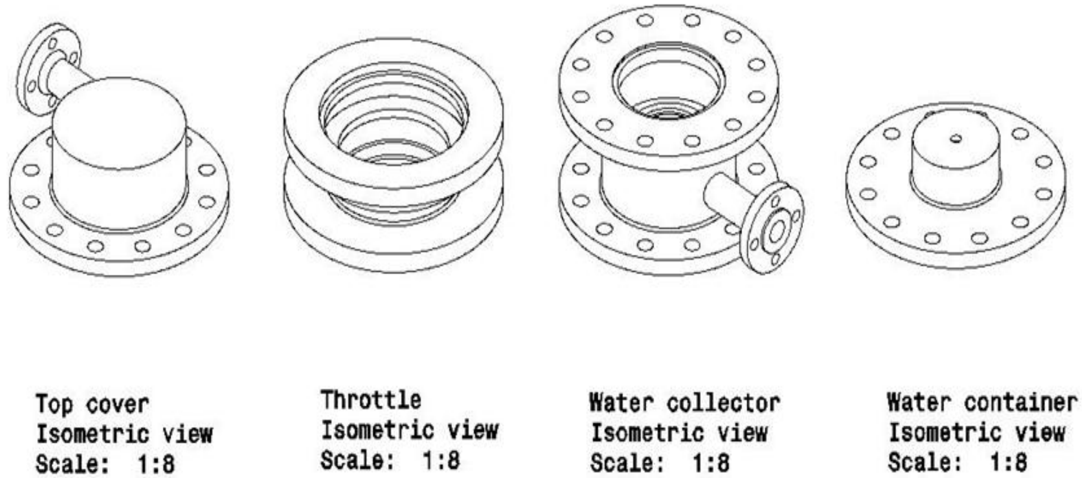


Figure 1.2: Schematic Drawing of SwirlerComponents

Figure 1.2 shows the schematic drawing of swirler components. The main focus of this project is to analyze and compare fabrication process of the swirler components by machining and casting process. According to Agapiou, (1992), the combination of the minimum production cost and minimum production time is the most effective objective since neglecting either requirement alone does not do justice to the problem at hand.Agapiou (1992) has investigated this concept extensively. Hence, the selection of minimum production cost and minimum production time are the most important intention in developing the manufacturing process planning of machining and casting operation. However, the process of determining the optimum cutting condition for machining is not underthe scope of this project. The value will be referred to the existing research. Forthe casting operation, the selection of type of casting is the most crucial part to achieve the minimum cost and time process.

Fundamentally, machining and casting are different kind of approach in manufacturing processes. The manufacturing processes can be classified into three main categories: shaping, joining and finishing processes as shown schematically in Figure 1.2 (M. F. Ashby, 2005).The selection of a particular process from a wide range of choices for a given application requires the identification of process feasibility and efficiency in order to determine the most appropriate technique to be used.

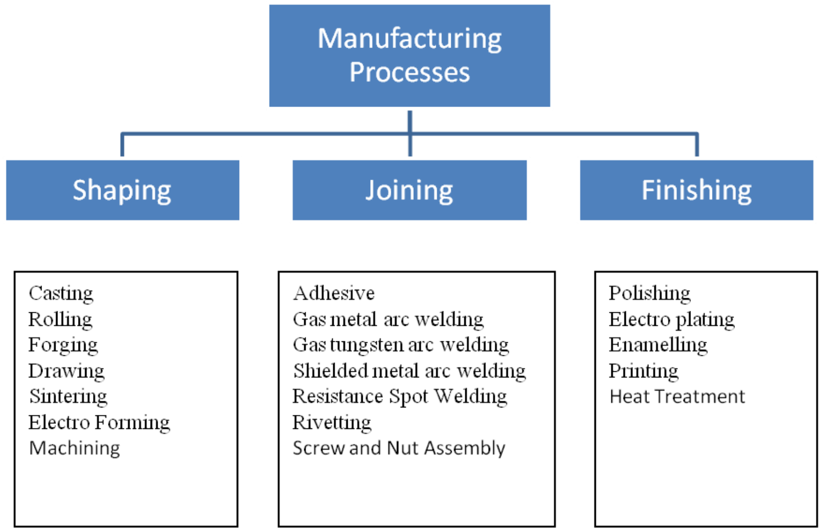


Figure 1.3: Different classes of manufacturing processes (M. F. Ashby, 2005)

Based on Figure 1.3, machining and casting process are categorized under shaping process. The shaping process is defined as process of changing shape of the raw material according to intended design parameter (M. F. Ashby, 2005).Both processes will perform similar task to fabricate the external part of swirler components (casing). The analysis on both processes will be involved from material selection, process planning including machines, tooling and fixtures requirements for manufacturing the swirler. Lastly, the process times and production cost estimation to manufacture the swirler casing will be determined for machining and casting processes.

1.2 Problem Statement

Time and cost consumption is an important component in manufacturing production. Increasingly competitive environment put the manufacturing companies under pressure to not only produce the product faster, but also with lower cost and required quality. Selection the appropriate manufacturing process is one of factor that can reduce the cost and time consumption. The previous fabrication process of the swirler casing unit had been done by machining process. There are several works involved in that fabrication process starting from design stage until the finishing process. Without any plan, the fabrication process can be consumes a lot of times and waste of money. It is important to schedule the work to ensure the progress work efficient and proper organized. Besides, it also can reduce waste material and labour works. It is important to select the most appropriate machines, tools and fixtures for the fabrication process to ensure feasibility and efficiency of work progress. The process must ensure the swirler casing meet all design requirements. Then, the process planning for the fabrication of swirler casing should be developed in order to eliminate unnecessary operation and reduce time waste. Since the swirler casing was fabricated from alloy steel, it also possible for manufactured by casting process. Hence, the comparative study on machining and casting should been done. Analysis should include estimation of process times and cost estimation to fabricate the swirler casing by machining and casting process.

1.3 Objective

The objective of this project is to conduct a comparative study on manufacturing processes for swirler casing by machining and casting. Analysis involve from material selection, process planning including machines, tooling and fixtures requirement for manufacturing the swirler. The analysis also includes estimation of process times and cost estimation to manufacture the swirler casing.

1.4 Scope of Study

The scopes of the study for the project are:

1. The analysis covers from process selection and develop the process planning for fabrication a single unit of swirler casing. The swirler is based on the fabricated swirler for Baronia Research Center located at the Block N in UniversitiTeknologiPetronas (UTP). Fabrication process is not required in this project.
2. This project will only focus on the casingof the swirler. There are four main components for the swirler casing. The development of process planning for the swirler casing will be divided into machining and casting process.
3. The comparative study on manufacturing processes for swirlercasing only between machining and casting process.

CHAPTER 2: LITERATURE REVIEW

2.1 Manufacturing ProcessPlanning

Every successful fabrication process has a plan or strategies in order to achieve the targets and know the direction of process flow clearly. The identification of technologically feasible manufacturing process and the determination of processing cost and quality issues are a vitally important aspect of concurrent product development.Hence, process planning plays a vital role in manufacturing processes.

Process planning is defined as the systematic determination of the engineering processes and systems to manufacture a product competitively and economically. (R. Kesavan, 2009) It consists of devising, selecting and specifying processes, machine tools and other equipment to convert raw material into desired products. The process planning must assure the process run according the schedule and eliminate unnecessary operation. The unnecessary operations and delay can cause the increasing of labour cost and eventually affect the total cost and time production. The process should be flexible enough to accommodate the reasonable changes in design. (M. P. Groover, 2002). The procedure for the process planning is shown in figure 2.1.

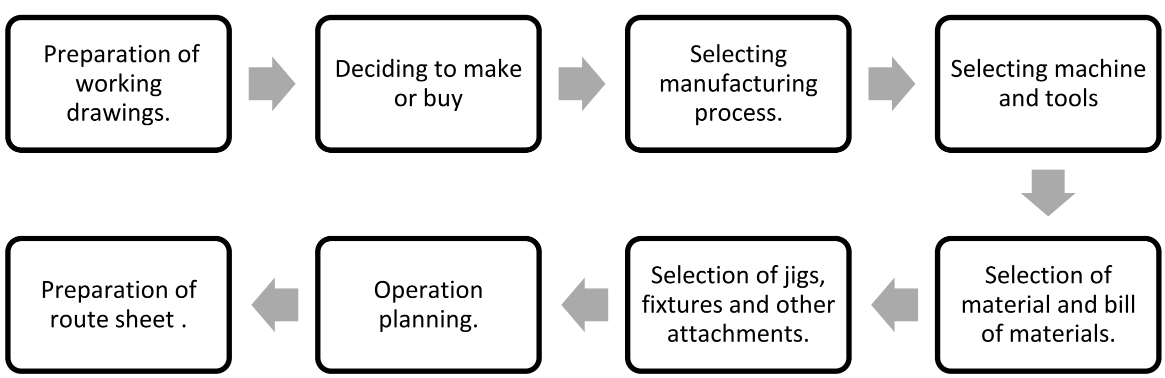


Figure 2.1: Process Planning Procedure (R. Kesavan, 2009)

There are various computer-based manufacturing technologies to perform the process plan such as Computer-aided design (CAD), Computer-aided manufacturing (CAM), Computer-assisted tolerance (CAT), Manufacturing Resource Planning (MRP), Management Information System (MIS) and etchave been developed. For this project, the process planningis performed manually by referring experienced process planners who study the drawing of thepart, select data from the machinability data handbook, check tools and fixtures availableand then select the metal-cutting operations on the shop floor that are necessary to produce the swirlercasing parts. The manufacturing process planning for fabrication of swirler will be focusing on machining and casting process.

The process planning considers the functional requirements of the product, quantity,tools and equipment.Eventually, the costs for fabrication and time consumption will be compared and analyzed. According to M.P. Groover (2002), the role of process planning in manufacturing process is to determine the most appropriate processes and their sequence in which they should be performed to produce a given part or product specified by design drawing. The quality of process planning has a tremendous influence on the productivity, economy, and quality of production. According to R. Kesavan (2009), the purpose of process planning is to determine the most suitable process for each operation so that it required:

1. Specific requirements are established for which machines, tools and others equipment can be designed or selected.
2. The efforts of all engaged in manufacturing the product are coordinated.
3. A guide is furnished to show the best way to use the existing or the providing facilities.

Process planning is an intermediate stage between product design and manufacturing operation (Figure 2.2). Where the product design ends, the process planning begins. In brief, the engineering drawing of the swirlercomponents are interpreted in terms of the manufacturing process to be used during process planning. For each part of the swirlerwill be analyzed to determine the overall scope of the project. A detailed routing will be developed and it is concerned with the preparation of a route sheet.

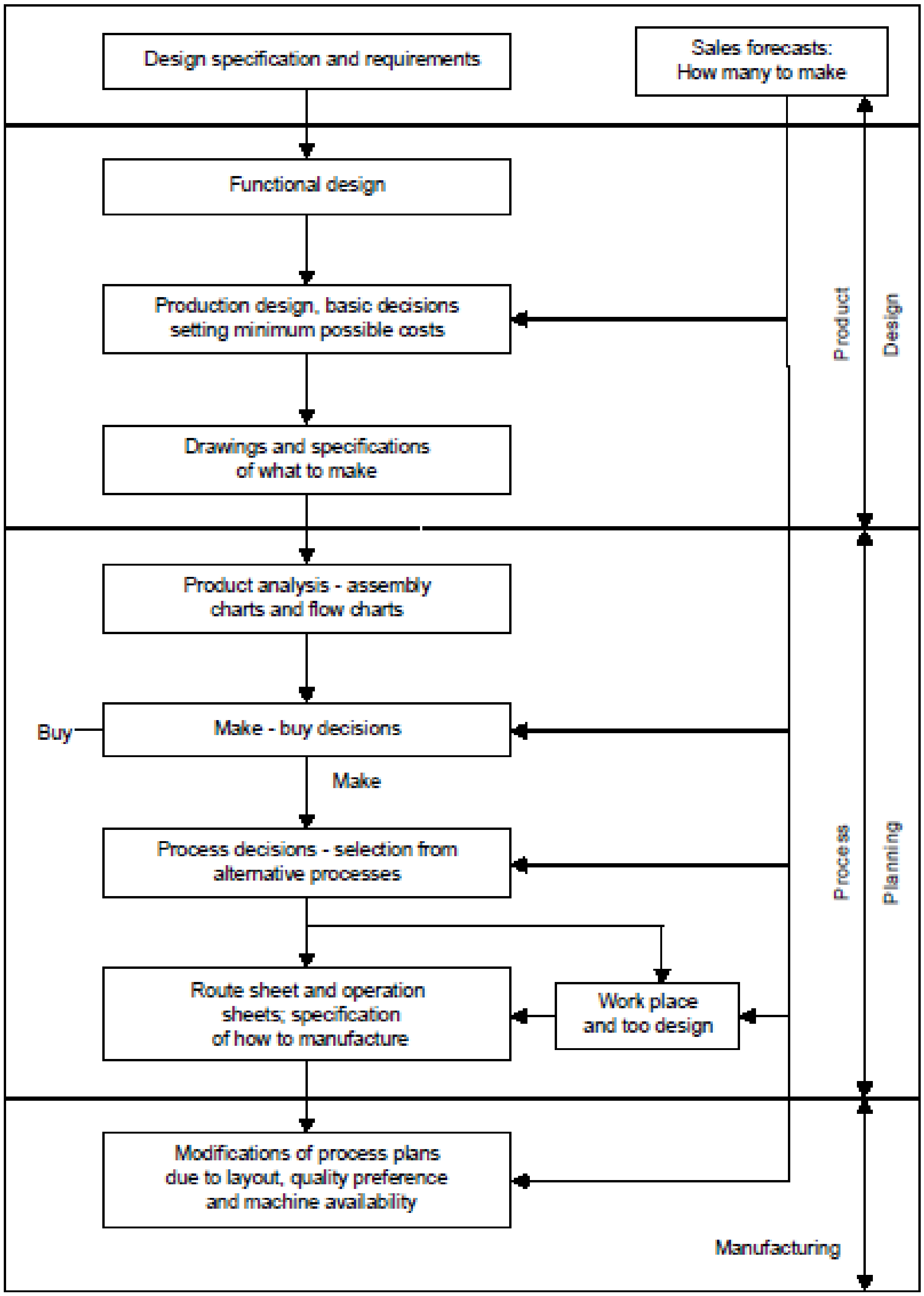


Figure 2.2: Overall Development of Processing Plans(R. Kesavan, 2009)

2.2 Machining Process Planning

Machining is the process subtracting excess material in the form of chips from a workpiece through a certain type of cutting tool to achieve the desired geometric dimensions. Most machining process has very low set-up cost compared to forming, moulding, and casting processes. However, machining is much more expensive for high volumes production. The machining process can be classified into traditional and non-traditional as shown in figure 2.3.

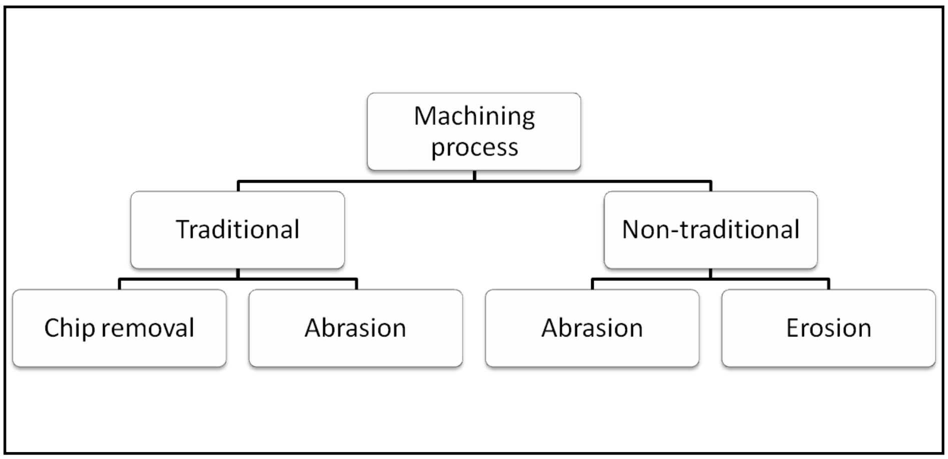


Figure 2.3: Classification of Machining Processes (M. F. Ashby, 2005)

Based on above figure, traditional machining process consists of chip removal and abrasion process while the non-traditional consists of abrasion and erosion. Traditional machining method can be defined as a group ofmetal removal process using sharp cutting tool by applied the mechanical (motion) energy such as turning, drilling, shaping and milling. Whereas, for non-traditional machining method, it utilizes other techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for traditional manufacturing processes. Hence, the classification of machining process is based of cutting tools usage. Selection of traditional process more feasible, satisfactory and economically due to several reasons as outlined below:

- Material not very hard and fragile to clamp for traditional machining

- Spare parts of traditional machines are easily available compare to non-traditional machines.
- Non-traditional tools are very expensive than the traditional tools.
- The shape of the swirler components is not too complex.

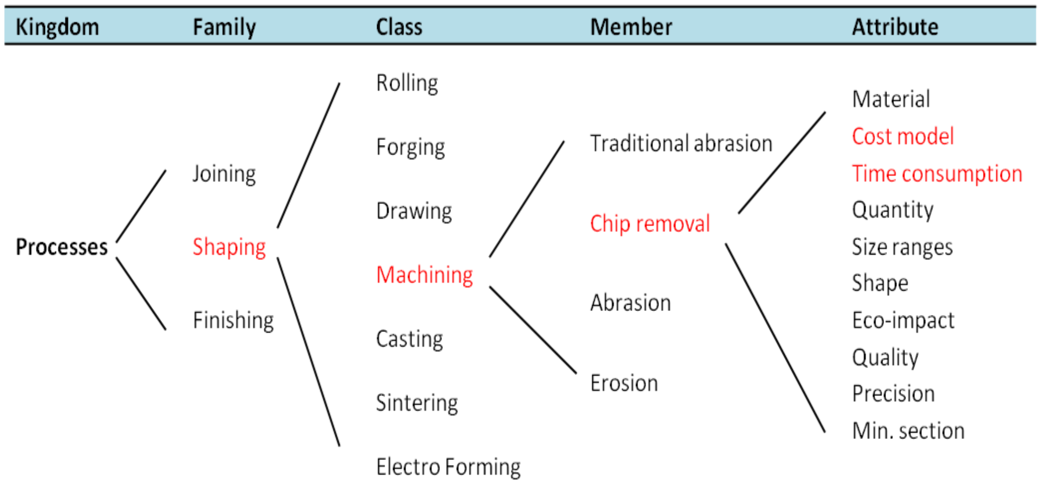


Figure 2.4: Taxonomy of Process with Part of the Shaping Family [M. F. Ashby, 2005]

Figure 2.4 indicates the type of machining process that will be used in this project. The cost and time consumption is the major priorities in the selection of operation.The machining parameters are one of factors in reduction of time and cost for fabrication process. There are many method has been reported to solve optimization problems for machining parameters. These methods include various nomograms (Brewer and Reuda, 1963), graphical methods (Sen et al, 1993), performance envelope (Crookall, 1969), linear programming (Ermer and Patel, 1974), Lagrangian multipliers (Ham et. al, 1970),geometric programming (Petropoulos,1973), dynamic programming (Shin and Joo, 1992) and artificial intelligence (Razfar and Ridgway ,1994).

Some researchers optimized machining parameters only based on a single variable without considering any constraint [Kaczmarek, (1976) and Shaw, (1984)]. However the real optimum values of machining parameters cannot be achieved without considering all variables and con-strains simultaneously.

Significant work has been done to optimize cutting parameters based on machining science and economic considerations. A comprehensive literature review of optimization techniques in metal machining processes has been provided by Mukherjee and Ray (2006)

2.2.1 Milling process

Milling process include as highly versatile machining operation that can produces parts with various external and internal configuration. Milling is the process removal material by feeding a workpiece pass through a rotating multiple tooth cutter. The process will undergo by using the milling machine. Milling process can produced slots of various shapes, making flat surfaces, grooving, slitting, and parting. The basic type of milling operation can be classified as shown in table 2.1. All of the basic milling operation will be used in this project by only changing the type of cutter at the milling machine's holder.

Table 2.1: The basic types of milling operations (Schmid, 2010)

Milling operation	Description
Face Milling	Machining flat surfaces which are at right angle to the axis of the cutter
Plain Milling (Peripheral)	Process of production of the plain, flat, horizontal surface parallel to the axis of rotation.
End milling	The cutter can remove material on both its end and its cylindrical cutting edges. It can produce a variety surfaces at any depth, such as curved, stepped and pocketed.

The optimal combination of milling parameters proposed by Yan and Li (2013) shows that spindle speed of 100 m/min, feed rate of 300 mm/min, depth of cut of 0.4 mm and width of cut of 15 mm. The optimum parameter for milling operations tabulate as shown in table 2.2. Moreover, according Simsek et al (2013), following general results can be achieved on the cutting conditions:

- To minimize the consumed energy, low cutting speed and feed rate are required.
- To minimize the surface roughness, low feed rate must be selected.

- All the cutting parameters must be selected at their low levels to maximize the tool

Table 2.2: The Optimum Parameter for Milling Operations (Yan and Li,2013)

Cutting speed (m/min)	Feed rate (mm/rev)	Depth of cut (mm)
100	**0.3**	**0.4**

2.2.2 Turning Process

Turning is the removal process of the outer diameter for cylindrical in part shape by a cutting tool using lathe machine. The work piece rotates in the lathe, with a certain spindle speed (n), at a certain number of revolutions per minute (rpm). The cutting speed is constant if the spindle speed and part diameter remains the same (M.Khaladkar,2012).Factors that influenced the machining operation are cutting speed, feed, depth of cut, machinability and tool angles. According to G. Barrow (1992), it is clear that in determining the optimum cutting conditions one has to estimate the tool life and cutting forces with reasonable accuracy since many of the constraints are influenced by these parameters. However, there is a case where due to several difficulties with empirical approach during the mass production operation, the machining theory has been used in determining the optimum cutting condition (P.L.B. Oxley,1989) instead of optimum parameters. This indicates that the parameter value from the machining theories can be used in this project. After doing a further research, the optimal combination of process parameters had been obtained at 150 m/min for cutting speed, 0.25mm/rev of feed rate, 2mm depth of cut and 0.4 mm nose radius by refer to SauravDatta (2010).The optimum parameter for turning operations tabulate as shown in table 2.3. Influence of the depth of cut on the tool wear rate is negligibly if the machining is carried out at the optimum cutting time. (Kamal Hassan, 2012).

Table 2.3: The Optimum Parameter for Turning Operations (Saurav Datta,2010)

Cutting speed (m/min)	Feed rate (mm/rev)	Depth of cut (mm)
150	**0.25**	**2**

2.2.3 Drilling and boring process

Drilling and boring process are categorized as a hole making process. Hole making process is among the most important operation in manufacturing, and drilling is the major process. Drilling isthe operationof production a circular hole in the workpiece by using rotating cutter called drill. The time taken to drill a hole depends upon the cutting speed and feed given to the tool. The parameter for drilling operations tabulate as shown in table 2.4 based on the recommended ranges for drilling speeds and feeds are given in Appendix B.

Table 2.4: The Optimum Parameter for Drilling Operations (Schmid, 2010)

Cutting speed (m/min)	Feed rate (mm/rev)
30	**0.3**

Boring is the process of enlarging a hole that has already made through method such as drilling, casting, extrusion, flame cutting, etc. A boring tool canbe inserted into the drilling machine and bore any size holeinto which the tool holder will fit.A boring bar with a tool bitinstalled is used for boring on the larger drilling machines. Tobore accurately, the setup must be rigid, machine must be steady, and power feed must be used. Based on previous research done by Gaurav, Palwinder and Harsimran (2013) referring to analysis and optimization of boring process parameter using Taguchi method, the optimum value will be achieved when the spindle speed is 108.687 m/min, feed rate 0.1 mm/rev and depth of cut 1.03535 mm as tabulate in table 2.5. In this case, the parameter value of depth of cut and cutting speed are to most influencing parameter followed by the feed rate.

Table 2.5: The Optimum Parameter for Boring Operations (Harsimran.el,2013)

Cutting speed (m/min)	Feed rate (mm/rev)	Depth of cut (mm)
108.687	**0.1**	**1.03535**

2.2.4 Process Fixture for Machining Process

The clamp, jig, and fixture are the common word for work holding devices used in manufacturing operation on mass scale. According to Steven R. Schmid, clamps are described as a simple multifunctional work holding devices, and jigs have various reference surfaces and points for accurate alignment of parts or tools for processing. Fixtures generally are designed for specific purposes. Other work holding devices are chuck, collects, and mandrels, many of which are usually operated manually. Some work holding devices, such as power chuck, are designed and operated at various levels of mechanization and automation, and are driven by mechanical, hydraulic, or electrical means.

a. Clamping

The clamping device is required to hold the workpiece securely in a jig or fixture against the forces applied over it during on operation. The variety of clamps used with jigs and fixtures are illustrated in figure 2.5. Chuck, vices and screw clamp will be used in this project due to their feasibility.

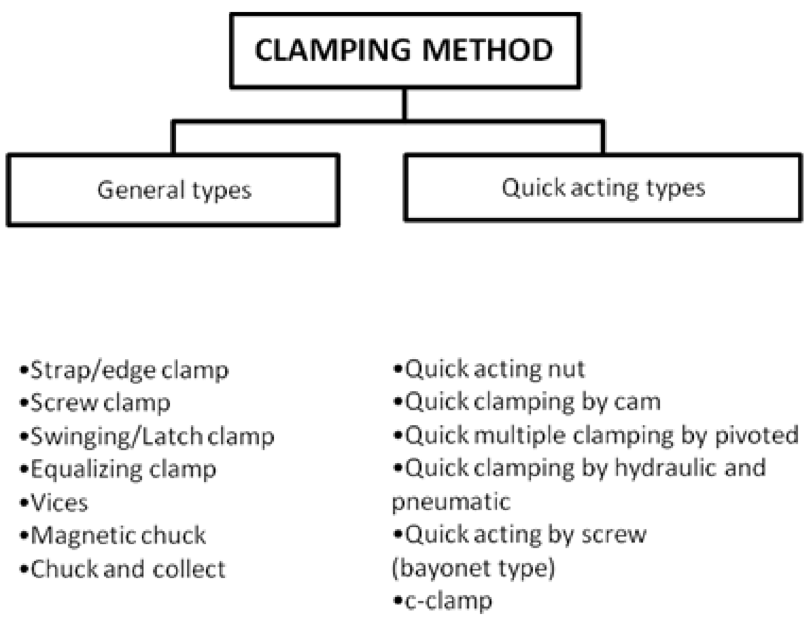


Figure 2.5: Type of Clamping Devices (Schmid,2010)

b. Jigs and Fixtures

Jigs and fixtures are devices used to facilitate mass production (assembling, interchange work process, and inspection) with guiding, setting, and supporting the tools at economically way. The types of fixtures are classified into three classes as shown in figure 2.6. A jig guided the cutting tool while fixture provided supports and holds the workpiece to accurate location. Both eliminate the need for special set up for each individual part and reduce cycle time but at the same time saving the cost production. Once a jig or fixture is properly set up, any number of duplicate parts may be readily produced without additional set up.

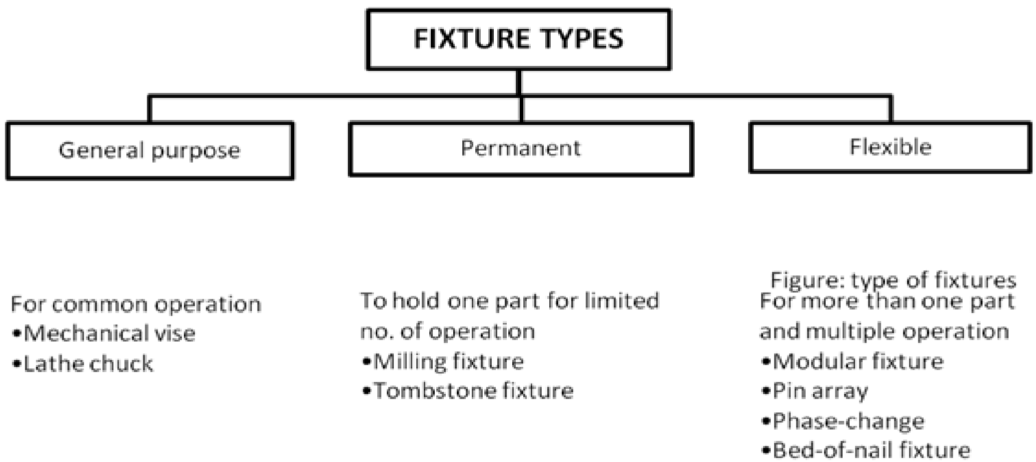


Figure 2.6: Type of Fixtures (Schmid,2010)

2.3 Casting Process Planning

Casting is one of oldest processes used to shape metals which basically involved pouring molten metal into a mould cavity. After the molten solidify, the metal copied the shape of cavity and remove out from the mould. Casting process can be defined as a manufacturing process involves pouring of liquid metal into a mould cavity and then allowing it to solidify. The casting processes are generally categorized as permanent-mould and expendable-mould processes (Schmid,2010) as shown in table 2.6 as per below:

Table 2.6: Classifications of Casting Processes (Schmid, 2010)

Classification of Casting Processes	
Permanent mould	Expendable mould
• Gravity die casting • Continuous casting • Pressure die casting • Centrifugal casting • Reaction injection moulding • Injection moulding • Rotational moulding • Compression moulding	• Investment casting • Plaster mould casting • Ceramic mould casting • Sand casting • Shell moulding • Vacuum moulding • Expanded polystyrene

The expandable mould is non reusable mould and usually destroyed to remove out the solidified cast. In contrast, the permanent can be reuse to make other casting. Expendable mould is suitable for very complex shaped parts and material with high melting point. However, the rate of production is limited compare to permanent mould. For this project, this situation gives the advantage to expendable mould due to the fabrication process of the swirler only limit to a single unit.

The casting process planning has been given little attention compared to machining process because of very little information is available regarding the casting process planning. According to R.G. Chougule (2003), out of the available literature most of the work is related to casting process selection that forms the first step for the process planning. Based on the analysis of the general characteristic of casting process as shown in Appendix A, the sand casting was selected as the first step before further step in developing the process planning. In previous work,in order to select the casting process, Sirilertworakulhad developed the knowledge base for alloy and process selection for casting (Sirilertworakul et al, 1993). There are various ways for selecting the casting process.Darwish had used preliminary casting process selection expert system (PCPSES) using Rule Master (Darwish et al, 1996), Er was used the knowledge-based expert system (Er et al, 1996), and Akartehad used AHP for the casting process selection (Akarte et al, 1999), which was later extended to product-process-producer compatibility evaluation (Akarte, 2002).

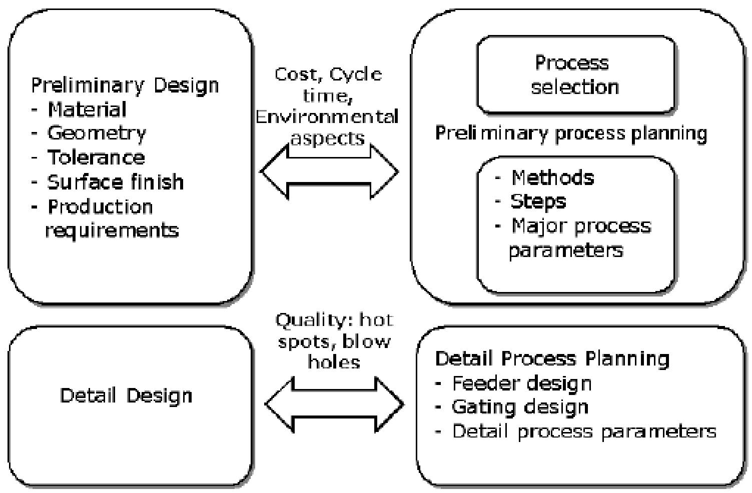


Figure 2.7: Casting Process Planning. R.G. Chougule (2003),

For this project, a manual approach been used for casting process planning as shown in figure 2.7. The casting process planning was divided into preliminary process planning and the detailed process planning.The preliminary process planning is focusing ondetermine the type of casting, sequential steps and majorprocess parameters (type of mold or core sand, pouring temperature, etc.). At the detailed process planning stage, the activities that involves are determining all necessary process parameters, including detailed design of feeding and gating systems.

2.3.1 Sand Casting Process

The sand casting process is one of the most versatile processes in manufacturing because it is used for most metals and alloys with high melting temperatures such as iron, copper, and nickel. In this project, sand casting is selected because of suitable for small capacity production (see Appendix A). The sand casting also is cheap and suitable as a mould material because can withstand high-temperature with its high melting point characteristic. The figure 2.8 shows the selection of casting process during the preliminary stage of process planning. There are three basic types of sand moulds: green –sand, cold-box and no-bake moulds. The green sand moulding is the cheapest method of making moulds, and the sand is recycled easily for subsequent reuse (Schmid,2010).

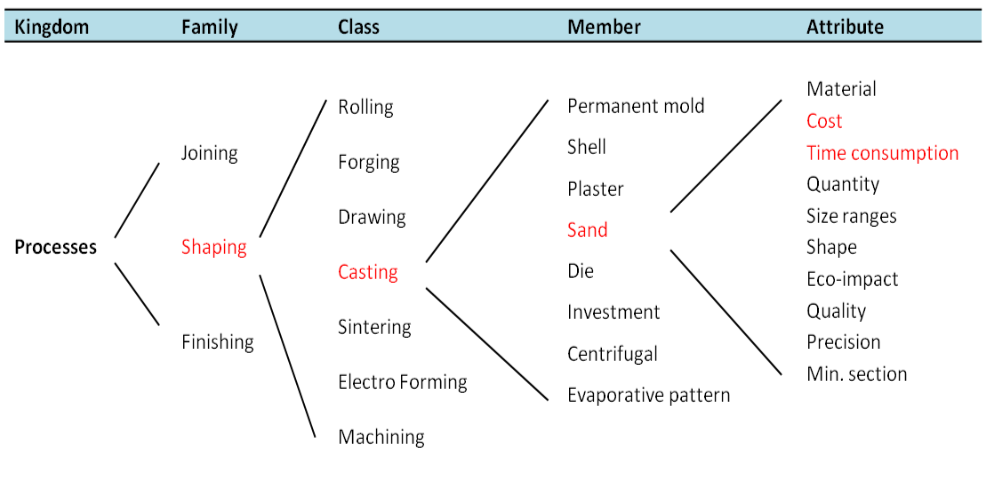


Figure 2.8: Taxonomy of process with part of the shaping family (M. F. Ashby, 2005)

According to Schmid (2010), sand casting consist of (a) placing a pattern (having the shape of the desired casting) in sand to make an imprint, (b) incorporating a gating system, (c) removing the pattern and filling the mold cavity with molten metal, (d) allowing the metal to cool until it solidifies, (e) breaking away the sand mold, and (f) removing the casting (see figure 2.9). For finishing processes, the casting product can be machined to remove surface imperfections or to add new features by standard machining methods such as milling, turning, grinding, and polishing. The detailed of process will be discussed later in the methodology section.

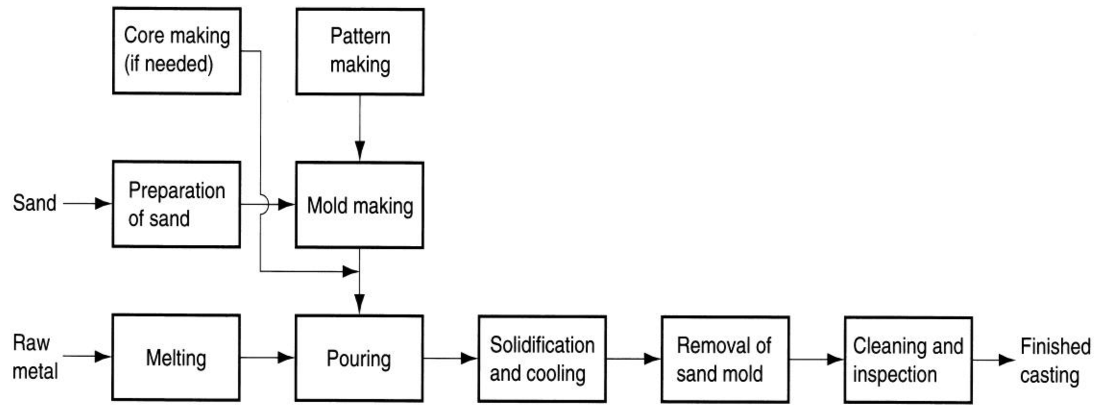


Figure 2.9: Outline of Production Steps in a Typical Sand Casting Operation,(Schmid, 2010)

Many research works were done for determining optimal values of casting process factors to improve the quality of castings using various techniques. The optimal process factor settings are defined as the best level for each factor that optimizes the process response. Guharaja et al. (2006) used the Taguchi's method to determine the optimal process factor settings for the green sand casting process. Apart from Taguchi's method applied to the green sand casting process, Makino et al. (2003) applied a computer simulation technique to develop a mathematical model. Karunakar and Datta, 2003 and Karunakar and Datta, 2007 used artificial neural networks and genetic algorithms to obtain optimal properties of the green sand mold. Kundu and Lahiri (2008) employed a systematic experimental design based on a central composite rotatable design method on green sand mold prepared from Allahabad sand with calcium bentonite.

2.3.2 Sand Casting Mould

In casting process, the raw materials are considered as "formless" substance as liquid and being poured into mould to become solid body. In this technique, the mould is acting as manufacturing equipment whereas the raw materials been used called sintering which come in powder or granular form. The quality of the sand casting depends on the quality and uniformity of green sand material that is used for making the mould. Figure

2.10 schematically shows a two-part sand mould, also referred to as a cope-and-drag sand mould. The molten metal is poured through the pouring cup and it fills the mould cavity after passing through downsprue, runner and gate. The core refers to lose pieces which are placed inside the mould cavity to create internal holes or open section. The riser serves as a reservoir of excess molten metal that facilitates additional filling of mold cavity to compensate for volumetric shrinkage during solidification. (John A Schey, 2000)

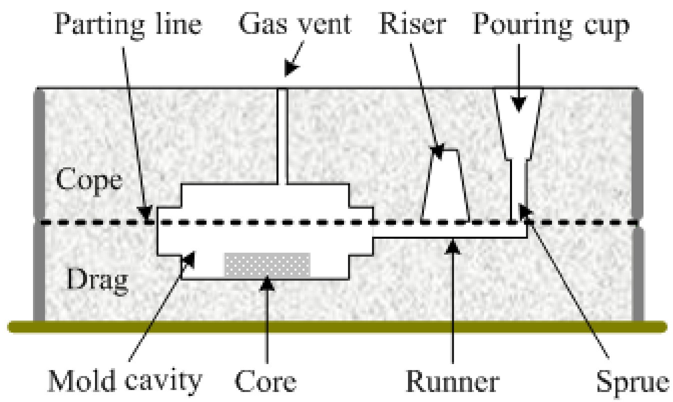


Figure 2.10: Schematic Set-up of Sand Moulding / Casting Process (John A Schey, 2000)

The sand used in the sand casting process is typically bonded with bentonite and water to mold the sand. Kundu and Lahiri (2008) stated that the composition of moulding sand mixture was very vital to the properties of the sand mold. If the proportion of bentonite and water is not appropriate, the bonding strength of the sand mold would be reduced. The green compression strength decreased as the proportion of water increased when all other components were kept constant. This result agreed with previous research studies (Kundu and Lahiri, 2008 and Webster, 1980). Similarly, the green compression strength increased as bentonite content increased. This result also agreed with previous research studies (Chang and Hocheng, 2001 and Kundu and Lahiri, 2008).

Many methods have been developed to recover green foundry sands for the production of moulds and cores (Heine, 1983) (EPA, 1997 and Schleg, 2000). Green sands can be reused again and again for moulding operations without any significant refinement. The sand is sieved to remove large particles and new additional sand is added to account for the lost sand, then the material is remoulded for a different metal piece (mulling operation).

Metal casting industry is very energy consuming, involving pattern making, melting metal, mould and coremaking, heat treating, and post-casting operations. Thus, energy required in melting and heating in a typical metal casting facility is 60–70% of total energy (Saha, 2010; Eppich and Naranjo, 2007). Thus, other production steps such as mouldmaking, coremaking and post-casting (finishing processes) represent more than a 30% of the total energy costs. Casting energy cost distribution is shown in figure 2.11:

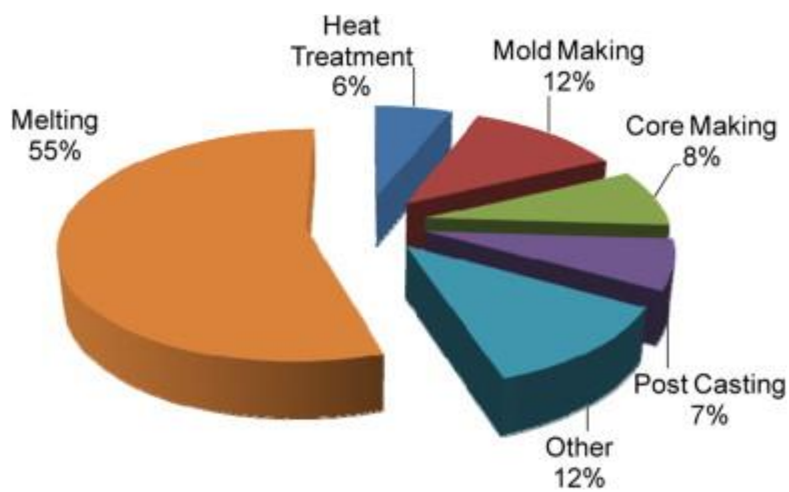


Figure 2.11: Distribution of Casting Process Energy Costs (Eppich and Naranjo (2007))

2.4 ProductionCost and Time in Manufacturing

In manufacturing process, apart from obtaining the accurate dimensions, achieving the lower production cost and time are also important. Figure 2.12 shows the three major stages in calculating the production cost and time in manufacturing of the swirler.

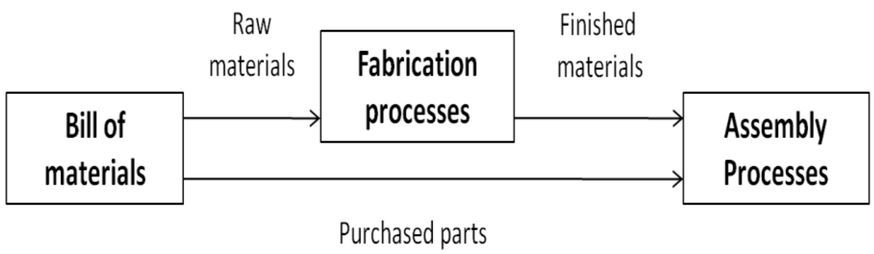


Figure 2.12: Production Cost and Time Assessment Stages. (Kesavanet. Al, 2009)

The first step in production cost and time assessment was the creation of a complete structure bill of materials (BOM). The BOM incorporates the material for components with the estimated cost. Following the development of a detailed BOM, the major manufacturing processes of machining and casting were identified. All the information regarding on equipment, tooling, processing time, and material used for fabrication were gathered in the route sheet. Each component of swirler casing has a specific time and cost values. In this project, the assembly processes was neglected since the fabrication is not involving the whole part of swirler unit.

Cost estimation in fabrication swirler casing can be defined as the forecasting budget that must be incurred to produce the components. It is importance to estimate the cost in order to determine the most economical process, tooling or material for making the swirler casing components. Besides, the estimating the production cost can control the actual operating costs by incorporating it into the general plan of cost accounting. There are three major component of manufacturing cost as shown in figure 2.13:

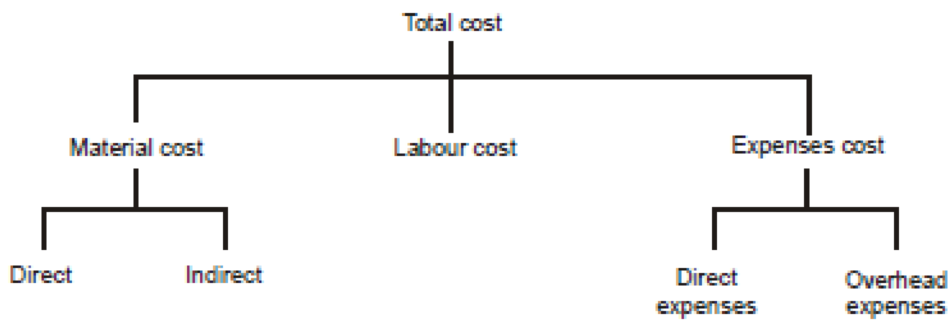


Figure 2.13: Major Component of Manufacturing Cost(R. Kesavan, 2009)

Material cost consist of the cost of material which are used in the manufacture of product such as raw material, general tools, coolants, screw and others. Labour cost is the salaries, wages, and overtime of the employees. Apart from the material and labour cost, the other expenditures in manufacturing cost are known as overhead or expenses. The expenses is all other expenditure except for direct material and direct labour cost such as cost of jig and fixture, factory expenses (equipment, rent, insurance, storage), administrative expenses (transportation, finance, management), and selling expenses.

In this project, the cost that accounted for comparative of machining and casting process were direct materials cost and direct labour cost only. In brief, the accounted cost consists of raw materials to produce finished product and labour cost which involve in actual works to convert the final shape.

For calculating time required for a particular job, the following considerations should be taken into account:

i. Setup time
ii. Operation time (not include the delay and handling time)
iii. Dismantling time

The miscellaneous allowances such as personal allowance, fatigue allowance, disposing scrap, cleaning, tool sharpening were neglected.

CHAPTER 3: METHODOLOGY

3.1 Project Flow Chart

Figure 3.1 shows the overall project flow.

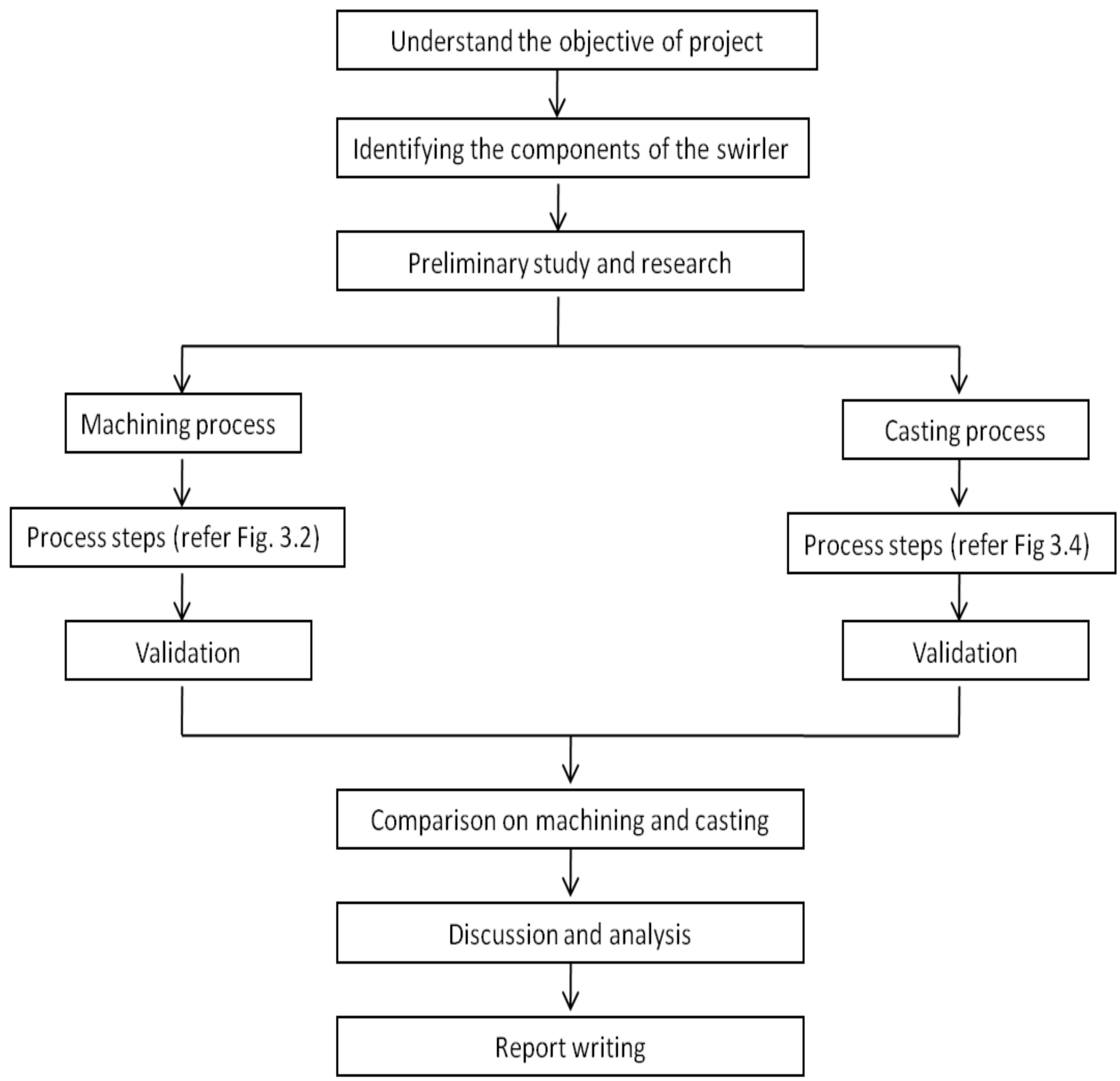


Figure 3.1: Workflow for Project Activities

Based on figure 3.1, the detail workflow for this project was set to be conducted as the following procedure:

1. The main objective of this project to compare the fabrication process of swirler by machining and casting process.
2. The swirler consists of four components which are top cover, throttle, water collector, and water container.
3. Interpret the engineering drawing of the swirler components in terms of the manufacturing process. Gather all the data needed to develop the process plan for both processes; machining and casting process.
4. Develop the process planning for fabrication of swirler casing. The workflow for machining process shows in figure 3.2 while workflow for casting process shows in figure 3.3.
5. Compare the estimation and time consumption for fabrication of swirler by machining and casting. List out the pros and cons of both processes.
6. Analysis should include estimation of process times and cost estimation to fabricate the swirler by machining and casting process.
7. All activities and report submission followed FYP Gantt Chart timeline.

3.2 Research Methodology

This project is done in order to gain knowledge regarding the machining and casting process. All the process equipment, tool and fixtures are identified while developing the process planning to fabricate the swirler by machining and casting process. The sources of information are coming from manufacturing handbook, Process Planning and cost estimation handbook, e-journal, thesis, research articles and consultation with the experts in manufacturing field.

The next steps of research are:

1. To identify the related the machines, tools, fixtures and clamps for machining and casting process.
2. To develop process plans for machining and casting process in manufacturing of swirler casing.
3. To estimate the production cost and time to manufacture the swirler casing by machining and casting process
4. To compare the machining and casting process in term of production cost and time for manufacture the swirler casing.

3.3 Machining Process Flow

Figure 3.2 shows the process flow the fabrication process of swirler casing by machining.

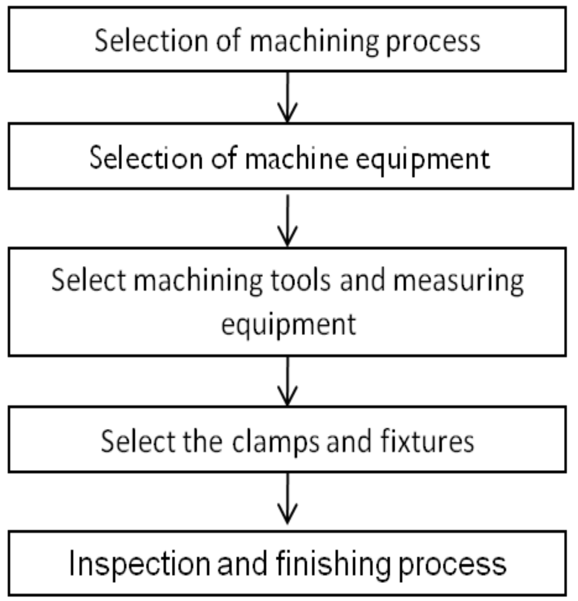


Figure 3.2: Workflow for Machining Process

Based on figure 3.2, the detail workflow for fabrication of swirler casing bymachining process is set to be conducted as the following procedure:

1. The selected machining processs are milling, turning, drilling and boring process. The swirler components fabricated by near-net or net-shape method.
2. The machine required in this processes are milling machine, lathe machine, drilling machine and boring machine.
3. Select the tool required in casting and machining proces. For casting process, all equipment setup follow the sand casting requirement.
4. Select clamps and fixtures for machining proces.
5. The swirler component will be inspect and require finishing process before the product ready for use. Overall machining process shown in figure 3.3.

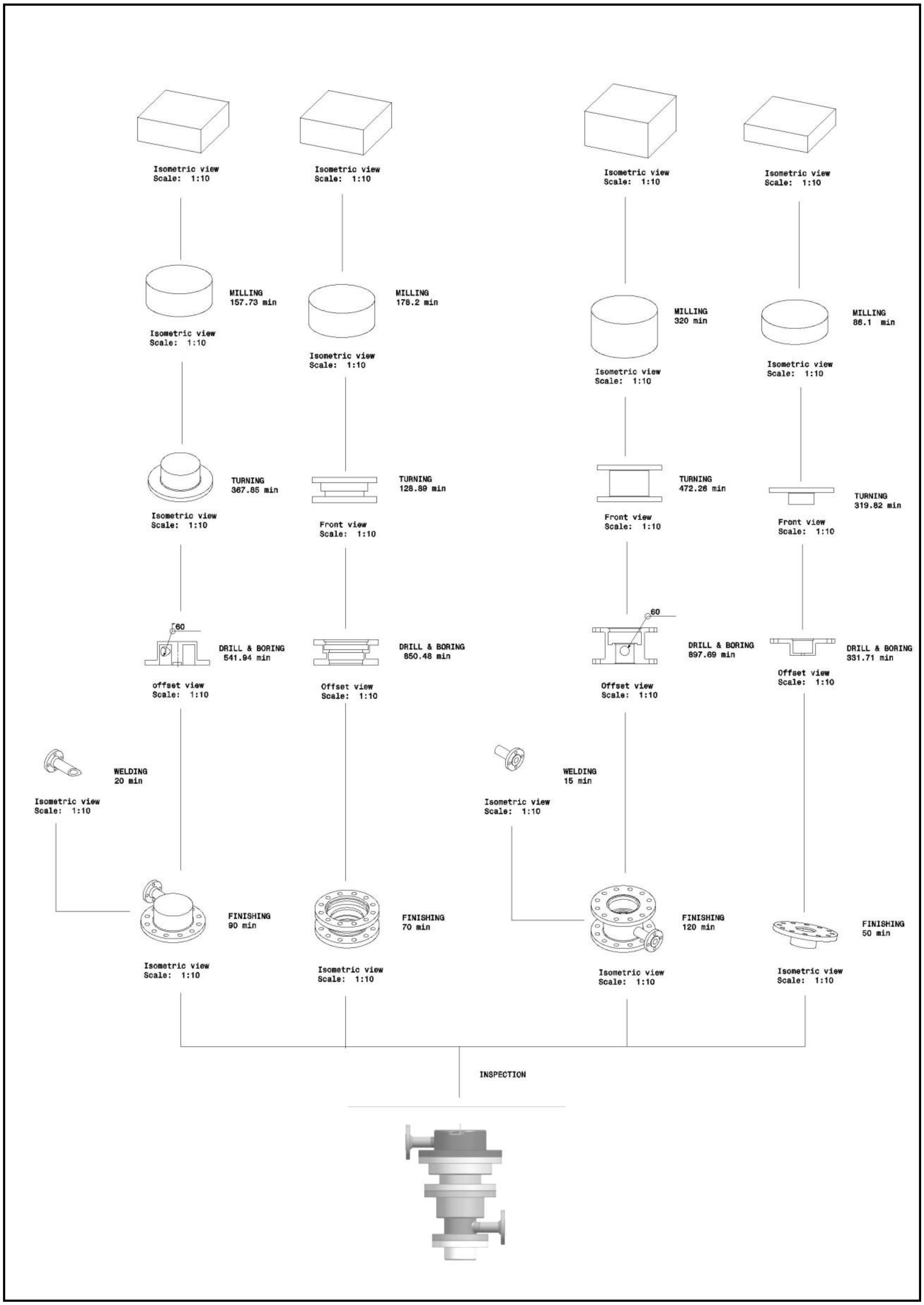


Figure 3.3: Overall Sequence of Fabrication Process of Swirler by Machining.

3.4 Casting Process Flow

Figure 3.4 shows the process flow the fabrication process of swirler by casting

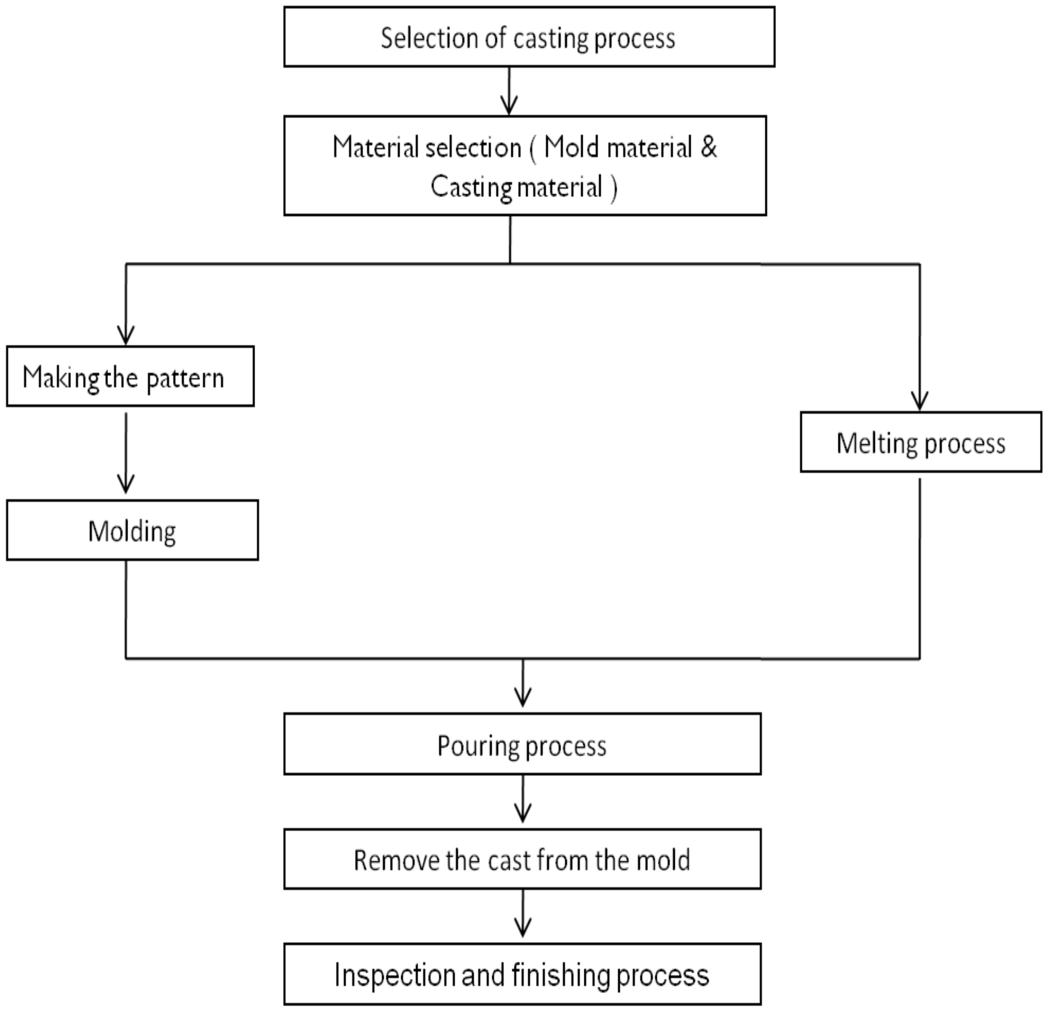
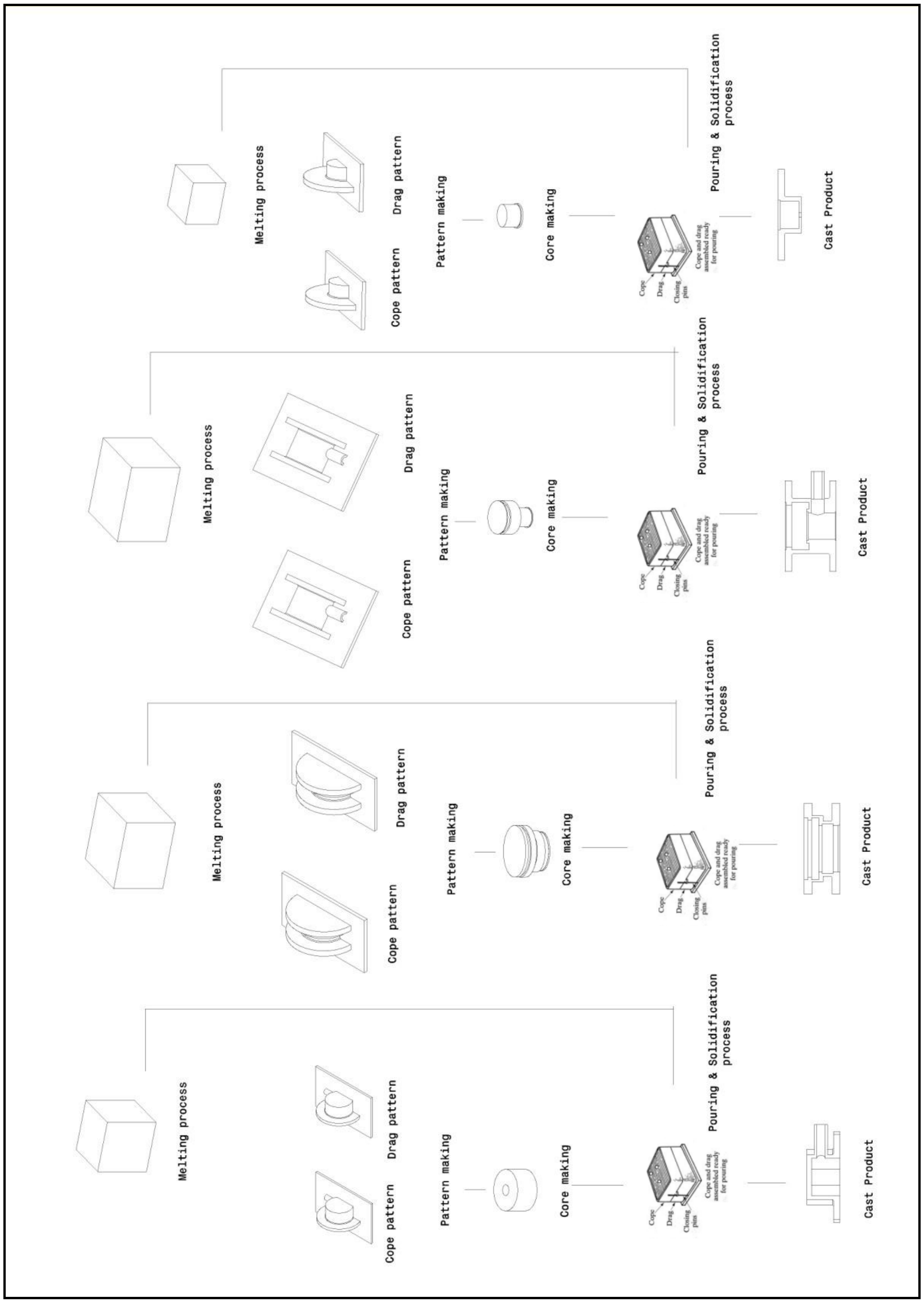


Figure 3.4: Workflow for Casting Process

Based on figure 3.4, the detail workflow for fabrication of swirler casing bycasting process is set to be conducted as the following procedure:

1. For this project, the sand casting method will be used to fabricate the swiler components.
2. The swriler is made of alloy steel and the mould material made by silica sand (SiO_2).
3. The pattern is a physical model of the casting used to make the mould. The additional cores refer as cores are used to form cavities. When the pattern is withdrawn, it imprint follow the casting design geometry.
4. The melting and molding process can be done simultaneously. The alloy steel melted during the melting process to become molten metal. In the molding process, all preparation for receiving molten metal will be done.
5. Then, the molten metal is poured into the sand mould.
6. When the molten metal is solidified, the sand mould will be destroyed to remove out the cast.
7. Finally, the casted product will be given further processing via machining as the finishing process before been used. Overall machining process shown in figure 3.5

Pre-form by Sand casting process



Pre-form by Machining process

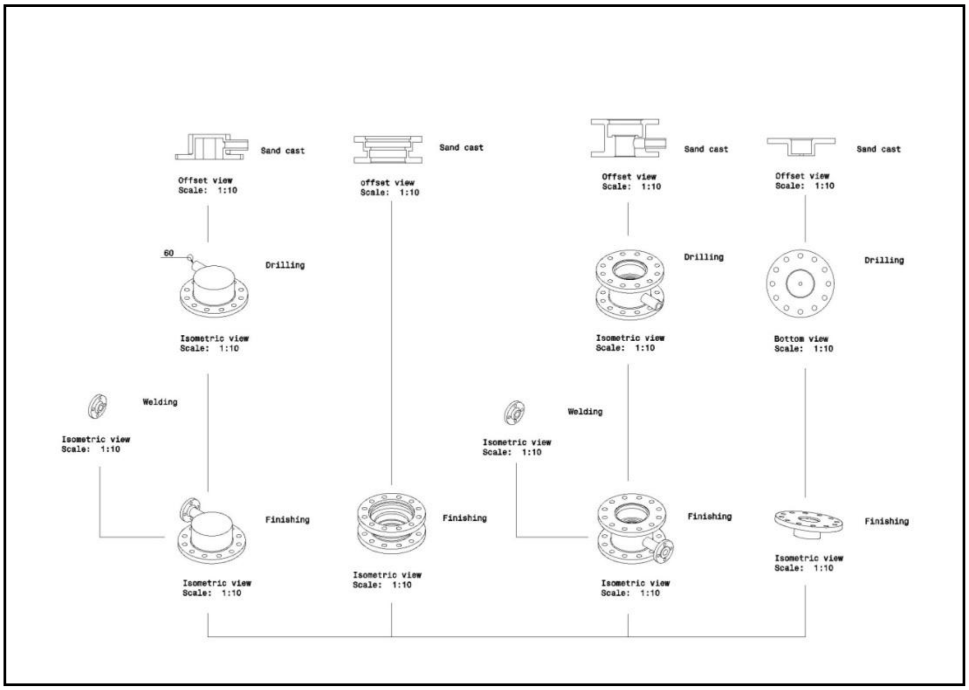


Figure 3.5: Overall Sequence of Casting Process

3.5 Governing Equations for Machining Process

There are three fundamental machining parameter; cutting speed (V), depth of cut (d), and feed (f). The cutting speed is the velocities of cutting tool or workpiece. The depth of cut is distance the cutting tool penetrates the workpiece. The feed is movement of cutting per revolution. The formula for machining parameter obtained from manufacturing handbook written by Schmid, (2010).

The equation for cutting speed is

$$v = \frac{\pi DN}{1000} \text{ m/min} \tag{3.1}$$

The equation for depth of cut is

$$d = \frac{Di - D}{2} \tag{3.2}$$

The equation for rotational speed of the workpiece, rpm is

$$v = \frac{1000 \times V}{\pi \times D} \text{ rpm} \tag{3.3}$$

and the feed is

$$f = \frac{\text{axial speed, mm/min}}{N} \tag{3.4}$$

Then, the material-removal rate can be calculated after the Eq.3.2 ,Eq.3.3 and Eq. 3.4 by equation

$$MRR = \pi D_{avg} dfN \tag{3.5}$$

i. Turning process

According to Schmid (2010), The actual time to cut the workpiece in turning process is calculated by equation

$$\mathrm{Tm} = \frac{\mathrm{l}}{\mathrm{f} \times \mathrm{N}} = \frac{\text{length}}{\text{feed} \times \text{rotational speed}} \qquad (3.6)$$

ii. Drilling and boring process

According to Schmid (2010), the most accurate holes in workpieces generally are produced by the following sequence of operation:

1. Centering
2. Drilling
3. Boring
4. Reaming

Yet, according to Schmid (2010), the equation for calculating the actual time for drilling process given as per below

$$\text{Time for Drilling} = \frac{\textit{Depth of hole to be produced}}{\text{feed} \times \mathrm{N}} \qquad (3.7)$$

The time taken for boring operation is obtain from equation (Schmid,2010)

$$\text{Time taken for boring operation} = \frac{\text{length of cut}}{\text{feed} \times \text{rotational speed}} \qquad (3.8)$$

iii. Milling process

$$\text{Time for milling } = \frac{l + lc}{\text{v}} \tag{3.9}$$

Where

$$l = length\ of\ cut, mm$$

$$lc = extent\ of\ cutter's\ first\ contact\ with\ the\ workpiece$$

$$\text{v} = \text{feed rate, mm/min}$$

3.6 Governing Equations for Casting Process

Prediction of Melting Time

According to Colton (2011), the procedure to calculate melting time as follows:

Heat to melt (energy required)

$$H = \rho V \left[c_s \left(T_{melt} - T_{initial} \right) + H_f + c_l \left(T_{pour} - T_{melt} \right) \right] \qquad (3.10)$$

Where

H = heat [J]

r = density

V = volume

c = specific heat (*s* = solid, *l* = liquid)

Hf= heat of fusion

Time consume estimate by

$$\text{Time for melting } = \frac{Energy}{\text{Power}} \qquad (3.11)$$

Mold Filling Time Estimate (Pouring Process)

According to Colton (2011), the mould filling can be calculate by equation below

$$\text{Mould filling time } = \frac{Volume\ of\ mould}{\text{Gate area x Gate volume}} \qquad (3.11)$$

Prediction of Solidification Time: Chvorinov's Rule.

According to Schmid (2010), the procedure to calculate solidification time as follows:

For a cylinder of diameter D and height H

$$\text{Volume, } V = \pi r^2 h \tag{3.12}$$

$$\text{Area, } A = 2\pi r^2 + 2\pi rh$$

These observations are reflected in Chvorinov's rule, which states that ts , the total solidification time, can be computed by:

$$\text{Solidification time, } Ts = B\,(V/A)^n \quad n = 1.5 \text{ to } 2.0 \tag{3.13}$$

The total solidification time is the time from pouring to the completion of solidification; V is the volume of the casting; A is the surface area; and B is the mould constant, which depends on the characteristics of the metal being cast (its density, heat capacity, and heat of fusion), the mould material (its density, thermal conductivity, and heat capacity), the mould thickness, and the amount of superheat.

3.7 Activities/Gantt Chart and Milestone

Table 3.6: Activities/Gantt Chart for FYP I

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Title	■	■													
2	Preliminary Research Work		■	■	■	■										
3	Submission of Extended Proposal Defence						●		Mid-semester break							
4	Proposal Defence											●				
5	Process planning for machining											■	■	■		
6	Process planning for casting												■	■	■	
7	Submission of Draft Report														●	
8	Submission of Report															●

● Key milestone

■ Process

Table 3.7: Activities/Gantt Chart for FYP II

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	**Gathering the Information:**								Mid-semester break							
	• Study the detail of design drawing	■														
	• Find the literature review for casting and machining process.		■	■	■											
	• Selection of method for fabrication process.				■											
	• Find the optimum parameter for machining and casting process.				■											
	• Selection of material for the swirler					■										
	• Select the machine tool to be used					■										
	• Select the jigs & fixture to be used.					■										
	• Find the factor for cost reduction in fabrication process					■										
2.	**Draw The Swirler's Components by CATIA**		■													
3.	**Process planning for machining process**															
	• Develop the sequence of process for fabrication process.						■									
	• Prepare the route sheet							■								
4.	**Process Planning For Casting Process**															
	• Develop the sequence of process for fabrication process.						■									
	• Prepare the route sheet							■								
5.	**Submission of Progress Report**									■						
6.	**Comparative Study on Machining And Casting**															
	• Mathematical calculation the fabrication process based on theoretical formulae.									■						
	• Analyzed the process planning of machining and casting process.									■	■					
	• Compare the estimated time and cost consumption by machining and casting .										■					
7.	**Pre-SEDEX Poster & Presentation**											■				
8.	**Submission of Draft Report**												■			
9.	**Submission of Dissertation & Technical Paper**													■		
10.	**Oral Presentation**														■	
11.	**Submission Of Report**															■

■ Process

CHAPTER 4: RESULT AND DISCUSSION

4.1 Swirler Casing Drawing

The concept design drawing of swirler casing were created by using CATIA V5 as illustrated in figure 4.1. The design of swirler casing shall withstand the design pressure and water extracted from high flow during simulation process in Baronia Research Centre. In this project, the manufacturing process plan of swirler casing divide into two different methods; machining and casting for comparison study purpose.

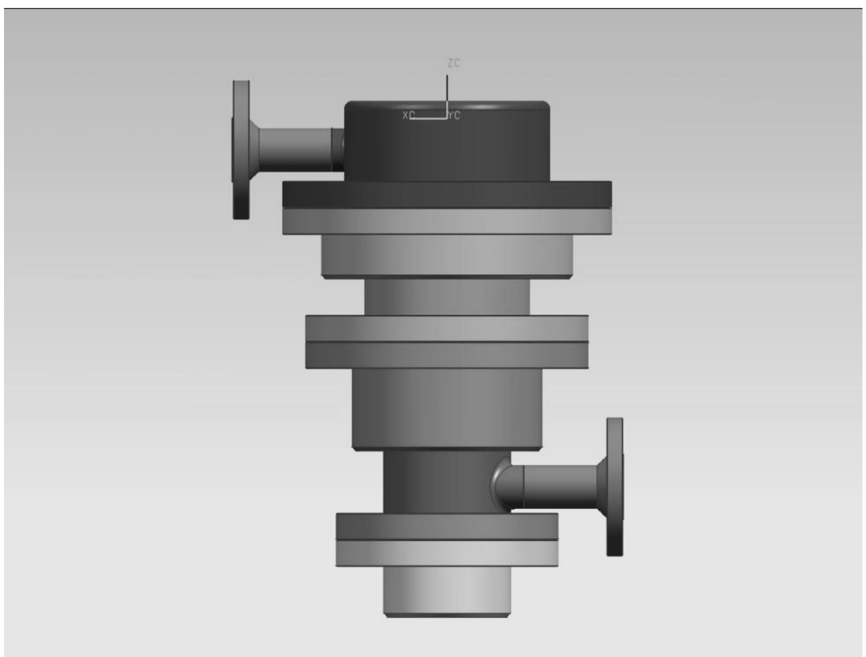


Figure 4.1: Schematic Design of Swirler Casing at Baronia Laboratory

There are four components of swirler which are top cover, throttle, water collector, and water container. The Figure 4.2 illustrated the cut section of CATIA model for all the swirler casing components:

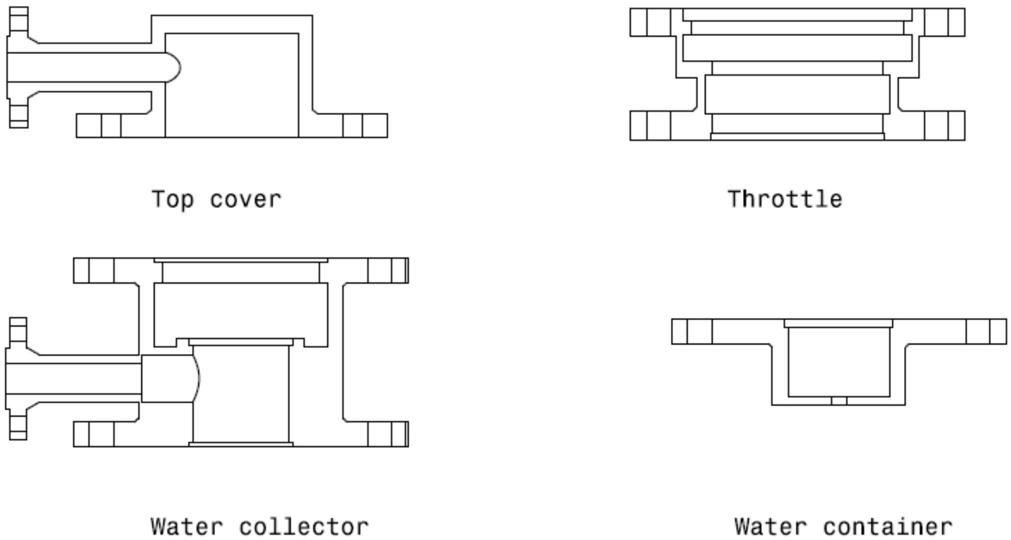


Figure 4.2: Cut Section of CATIA model for Swirler Casing

The detail dimension of these component part are generated in engineering drawing will be shown next.

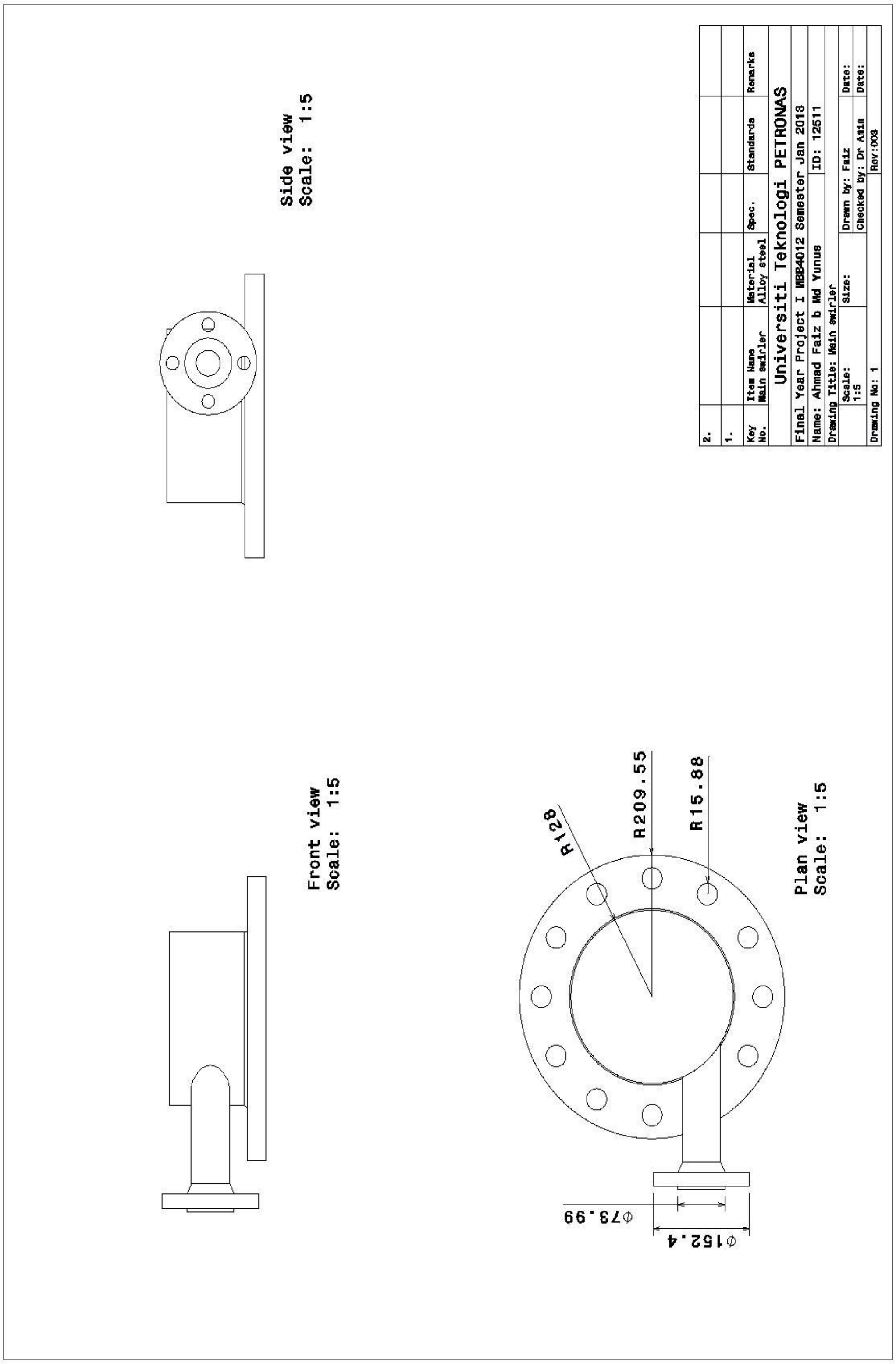


Figure 4.3: Concept Drawing of Top cover (component 1)

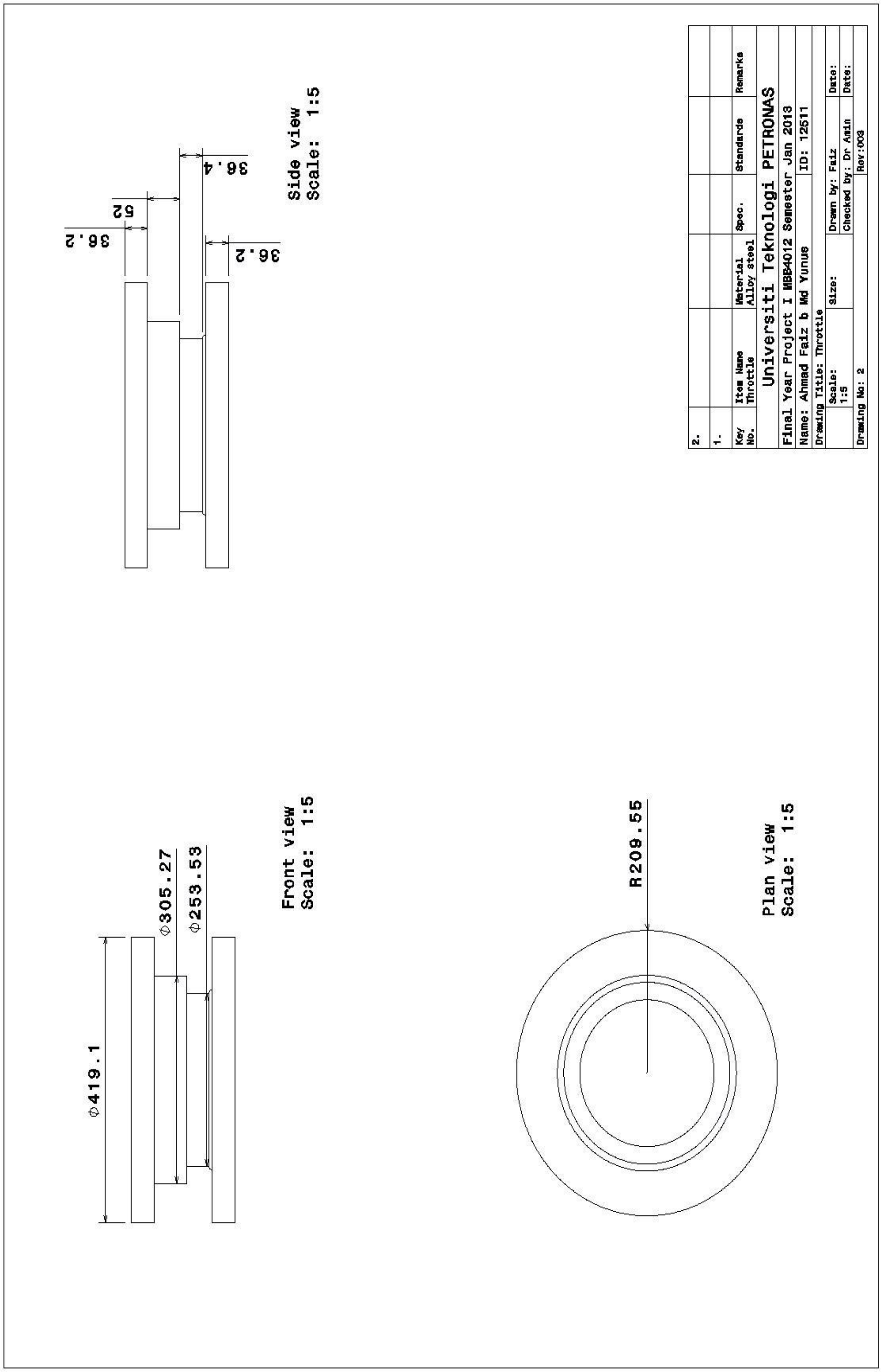


Figure 4.4: Concept Drawing of Throttle (component 2)

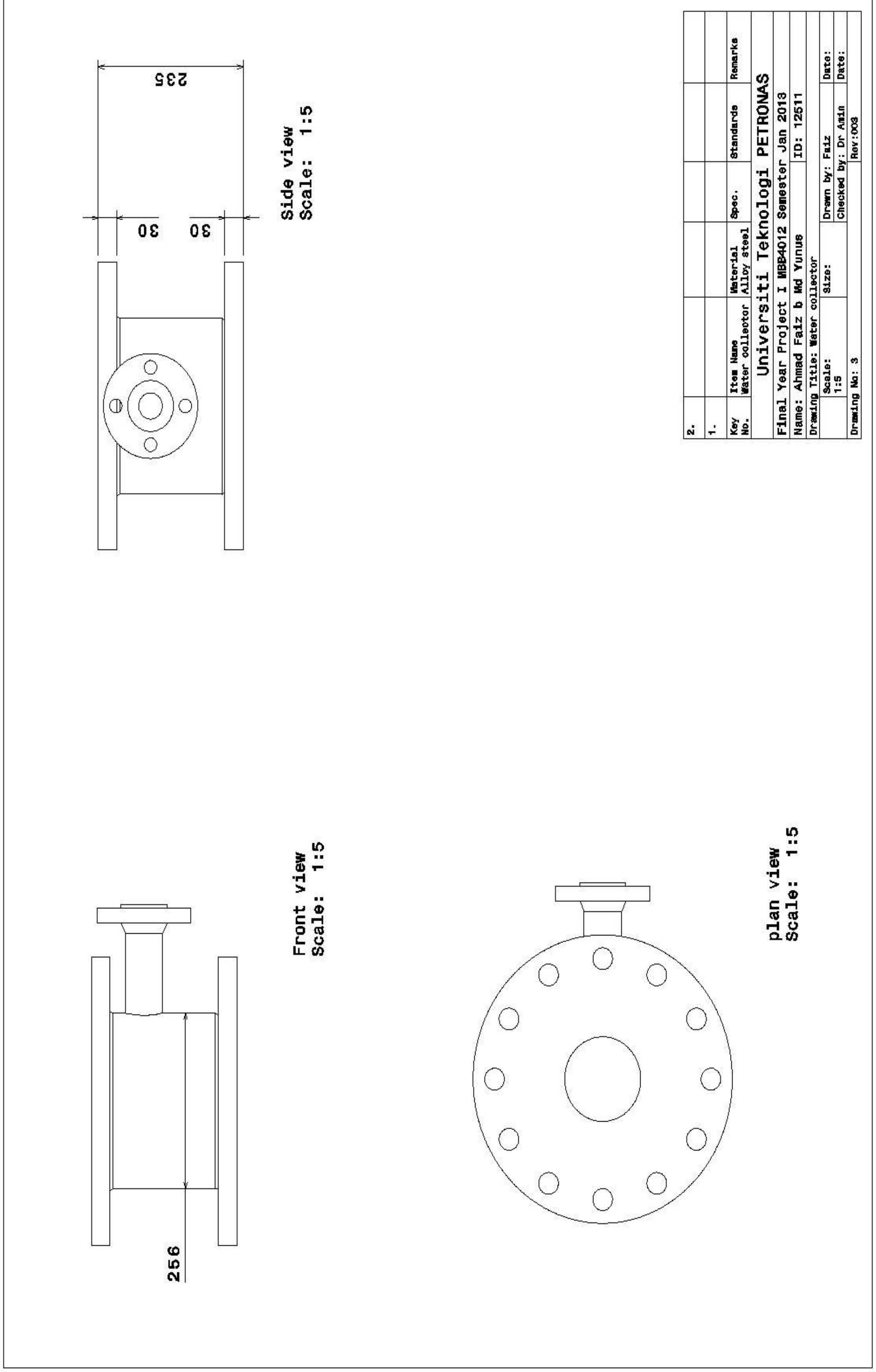


Figure 4.4: Concept Drawing of Water Collector (component 3)

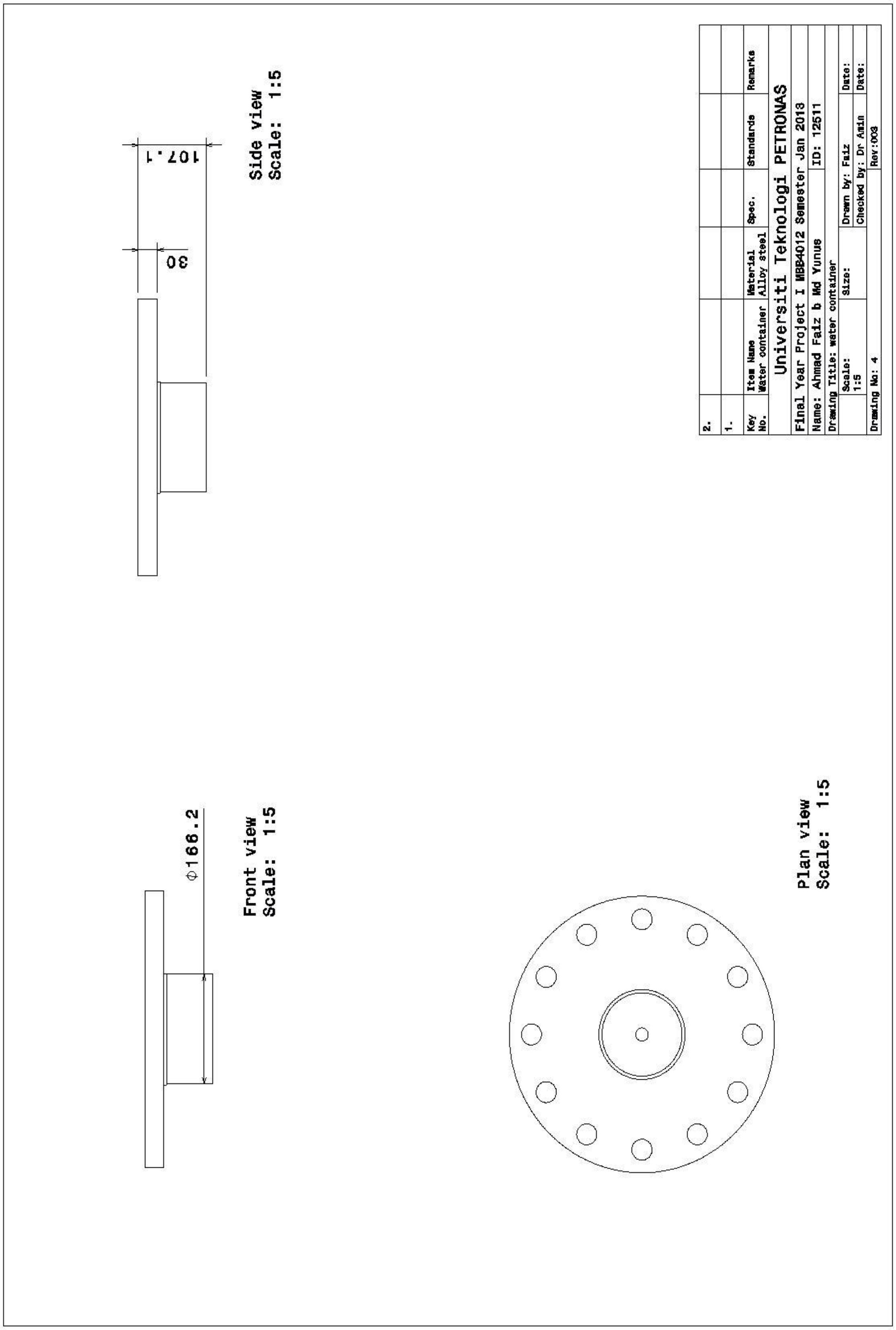


Figure 4.6: Concept Drawing of Water Container (component 4)

The exploded view of the CATIA model for swirler casing are shown below

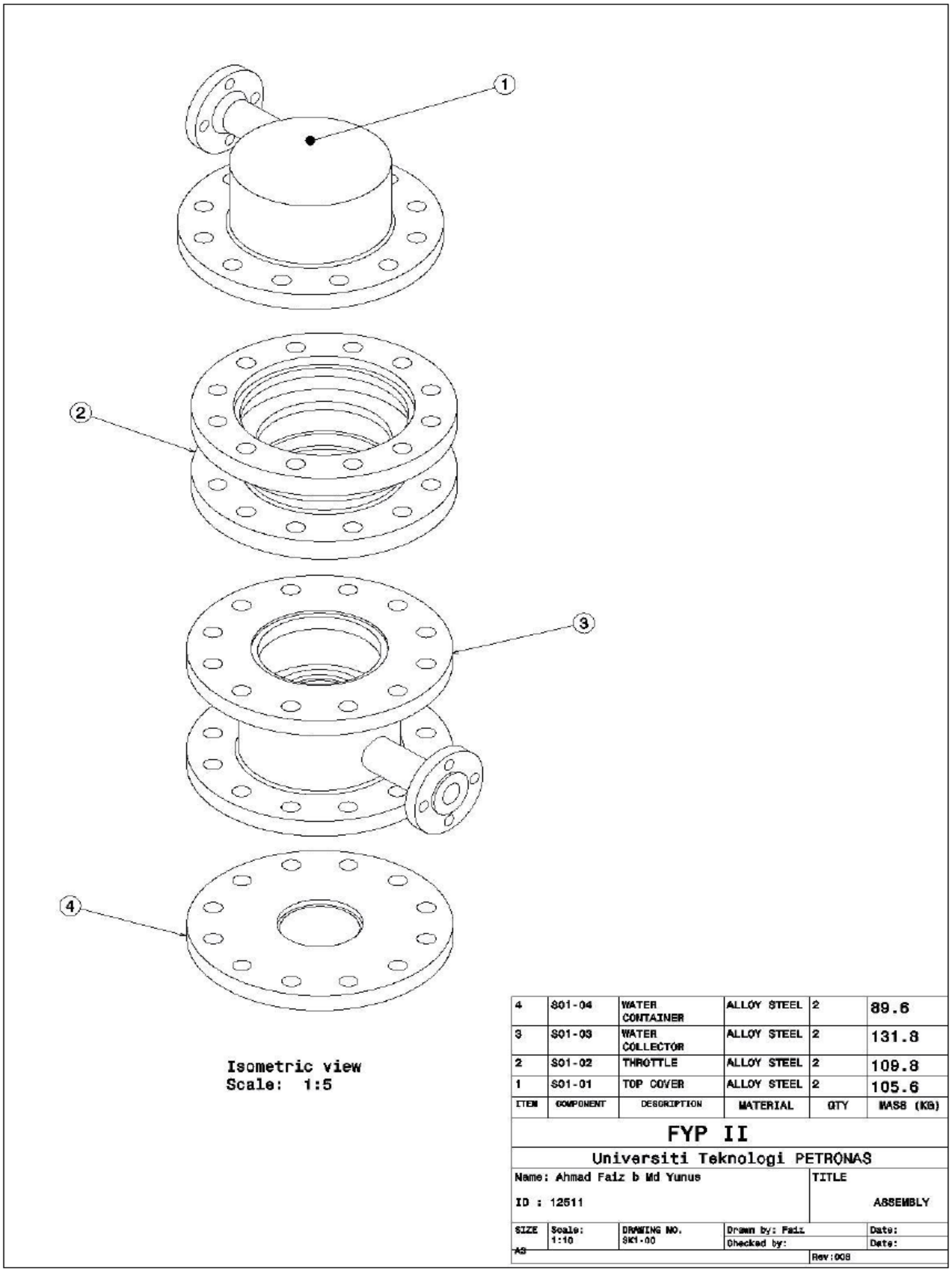


Figure 4.7: Exploded view of the CATIA Drawing

4.2 Bill of Material

Table 4.1: Bill of Material Swirler Casing for Machining Processes

4	001-04	Water container	Alloy steel	1	0.02	1200
3	001-03	Water collector	Alloy steel	1	0.07	4200
2	001-02	Throttle	Alloy steel	1	0.05	3000
1	001-01	Top cover	Alloy steel	1	0.03	1800
ITEM	PART NO.	DESCRIPTION	MATERIAL	QTY	Vol. (m^3)	Price (RM)

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Table 4.2: Bill of Material Swirler Casing for Casting Processes

4	001-04	Water container	Alloy steel	1	0.01	600
3	001-03	Water collector	Alloy steel	1	0.06	3600
2	001-02	Throttle	Alloy steel	1	0.04	2400
1	001-01	Top cover	Alloy steel	1	0.02	1200
ITEM	PART NO.	DESCRIPTION	MATERIAL	QTY	Vol. (m^3)	Price (RM)

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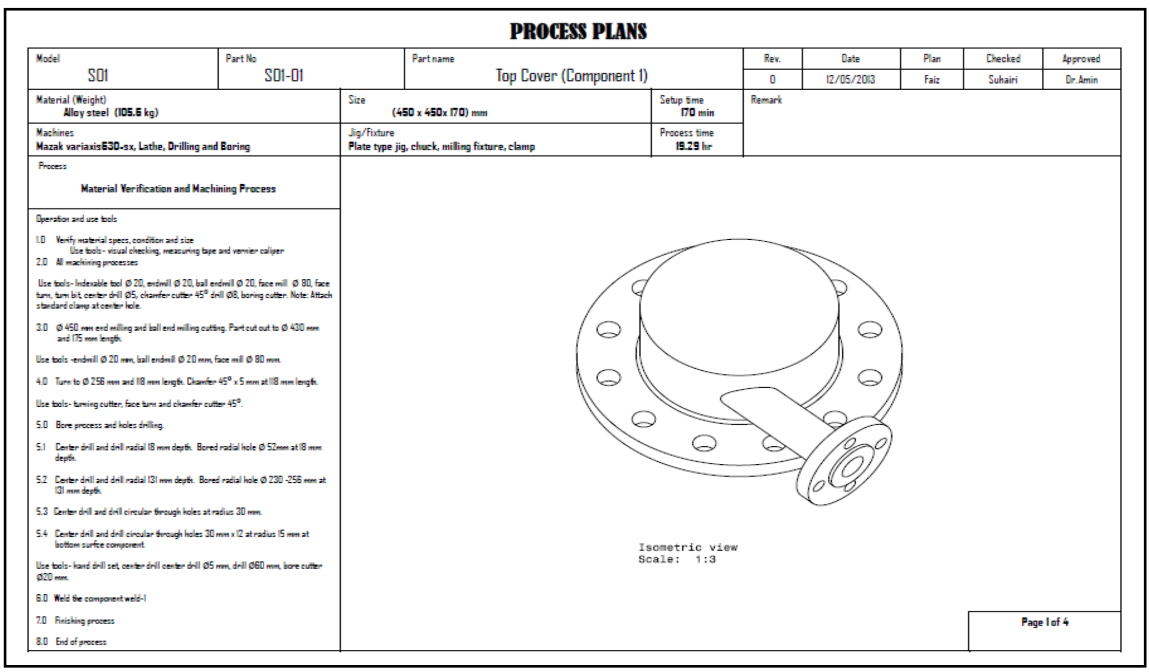
Based on table 4.0, each components of swirler casing made of by alloy steel either by machining and casting process. The total quantity of alloy steel block required were four with different volumes. For machining process, the volumes required were 0.03 m^3, 0.05m^3, 0.07m^3, and 0.02m^3. For casting process, the volumes required were 0.02m^3, 0.04m^3, 0.06m^3 and 0.01m^3. The total raw material cost for machining and casting are RM 10,200 and RM 7,800 respectively. The casting process has lower raw material cost.

4.3 Process Planning

To ensure the manufacturing of swirler casing components adhered to design requirement, detail process plan were prepared for machining process and casting process. The process plans were based on Mazak CNC machining center.

4.3.1 Machining Process Plan

For Top cover, the process began with the milling process to get the cylinder in shape. The process continued by rough turning to 421mm diameter and finish turning to 419.1 mm diameter. Face and turning shoulder to 259 mm diameter and 123 mm length. Follow by the Drilling process through holes 31.78 mm x 12 at radius 175mm and Drill radial holes 15mm depth. Then, bored radial hole 52mm diameter at 15 mm depth. The process ended by fine machining process.


PROCESS PLANS

Model	Part No	Part name	Rev.	Date	Plan	Checked	Approved
S01	S01-01	Top Cover (Component 1)	0	12/05/2013	Faiz	Suhairi	Dr.Amin

Material (Weight) Alloy steel (105.6 kg)	Size (450 x 450x 170) mm	Setup time 170 min	Remark
Machines Mazak variaxis630-sx, Lathe, Drilling and Boring	Jig/Fixture Plate type jig, chuck, milling fixture, clamp	Process time 19.29 hr	

Process

Material Verification and Machining Process

Operation and use tools

1.0 Verify material specs, condition and size
Use tools- visual checking, measuring tape and vernier caliper

2.0 All machining processes

Use tools- Indexable tool Ø 20, endmill Ø 20, ball endmill Ø 20, face mill Ø 80, face turn, turn bit, center drill Ø5, chamfer cutter 45° drill Ø8, boring cutter. Note: Attach standard clamp at center hole.

3.0 Ø 450 mm end milling and ball end milling cutting. Part cut out to Ø 430 mm and 175 mm length.

Use tools -endmill Ø 20 mm, ball endmill Ø 20 mm, face mill Ø 80 mm.

4.0 Turn to Ø 256 mm and 118 mm length. Chamfer 45° x 5 mm at 118 mm length.

Use tools- turning cutter, face turn and chamfer cutter 45°.

5.0 Bore process and holes drilling.

5.1 Center drill and drill radial 18 mm depth. Bored radial hole Ø 52mm at 18 mm depth.

5.2 Center drill and drill radial 131 mm depth. Bored radial hole Ø 230 -256 mm at 131 mm depth.

5.3 Center drill and drill circular through holes at radius 30 mm.

5.4 Center drill and drill circular through holes 30 mm x 12 at radius 15 mm at bottom surfce component.

Use tools- hand drill set, center drill center drill Ø5 mm, drill Ø60 mm, bore cutter Ø20 mm.

6.0 Weld the component weld-1

7.0 Finishing process

8.0 End of process

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Figure 4.8:Machining Process Plan for Top Cover

ForThrottle, the process began with the milling process to get the cylinder in shape. The process continued by rough turning to 257 mm diameter and finish turning to 254 mm diameter. Follow by bored radial holes217.76mm diameter at 16.597 mm depth, 215.72mm diameter at 33.194 mm depth, 230.6mm diameter at 16.597 depths, 216.72mm diameter at 49.791 mm depth, 267.08mm diameter at 24.896 mm depth and 87.62mm diameter at 8.30 mm depth. Then assemble the component by welding process and ended by fine machining process.

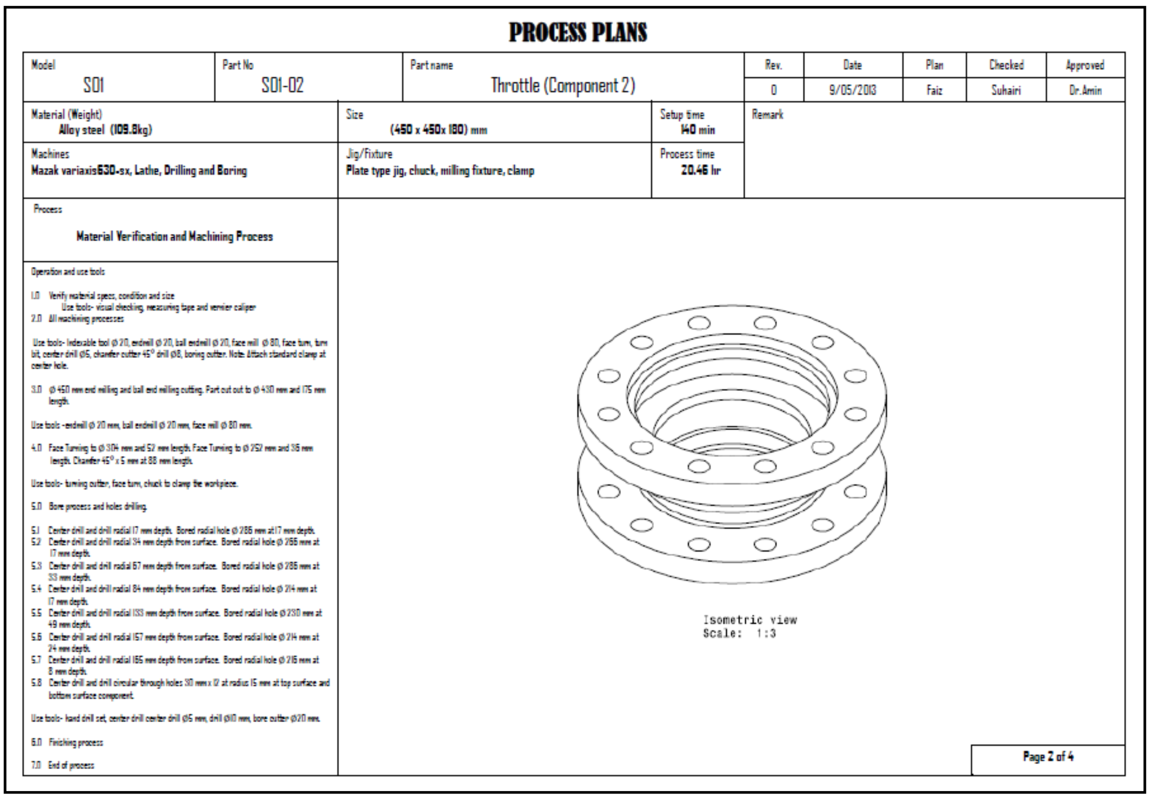


Figure 4.9: Machining Process Plan for Throttle

For Water collector, the process began with the milling process to get the cylinder in shape. The process continued by rough turning to 258 mm diameter and finish turning to 256 mm diameter. Follow by the Drilling process through holes 31.78 mm x 12 at radius 175mm and Drill radial holes 15mm depth. Then, bored radial hole134 mm diameter at 117.5 mm depth. The process ended by fine machining process.

PROCESS PLANS

Model	Part No	Part name	Rev.	Date	Plan	Checked	Approved
S01	S01-03	Water Collector (Component 3)	0	9/05/2013	Faiz	Suhairi	Dr.Amin

Material (Weight) **Alloy steel (131.8kg)**	Size **(450 x 450x 250) mm**	Setup time **235 min**	Remark
Machines **Mazak variaxis630-sx, Lathe, Drilling and Boring**	Jig/Fixture **Plate type jig, chuck, milling fixture, clamp**	Process time **30.17 hr**	

Process

Material Verification and Machining Process

Operation and use tools

1.0 Verify material specs, condition and size
Use tools- visual checking, measuring tape and vernier caliper
2.0 All machining processes

Use tools- Indexable tool Ø 20, endmill Ø 20, ball endmill Ø 20, face mill Ø 80, face turn, turn bit, center drill Ø5, chamfer cutter 45° drill Ø8, boring cutter. Note: Attach standard clamp at center hole.

3.0 Ø 450 mm end milling and ball end milling cutting. Part cut out to Ø 430 mm and 245 mm length.

Use tools -endmill Ø 20 mm, ball endmill Ø 20 mm, face mill Ø 80 mm.

4.0 Straight turning to Ø 419 mm and 235 mm length. Face Turning to Ø 266 mm and 175 mm length. Chamfer
45° x 5 mm at 30 mm and 200 mm length.

Use tools- turning cutter, face turn, chuck to clamp the workpiece.

5.0 Bore process and holes drilling.

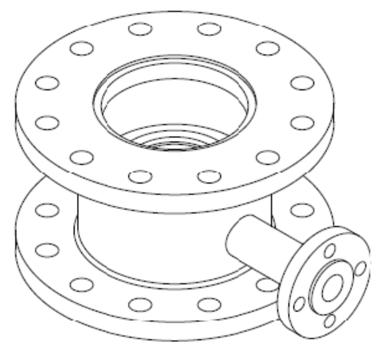
5.1 Center drill and drill radial 5 mm depth. Bored radial hole Ø 216 mm at 5 mm depth.
5.2 Center drill and drill radial 30 mm depth from surface. Bored radial hole Ø 195 mm at 25 mm depth.
5.3 Center drill and drill radial 100 mm depth from surface. Bored radial hole Ø 216 mm at 70 mm depth.
5.4 Center drill and drill radial 110 mm depth from surface. Bored radial hole Ø 160 mm at 10 mm depth.
5.5 Center drill and drill radial 118 mm depth from surface. Bored radial hole Ø 130 mm at 8 mm depth.
5.6 Center drill and drill radial 125 mm depth from surface. Bored radial hole Ø 120 mm at 122 mm depth.
5.7 Center drill and drill radial 5 mm depth from surface. Bored radial hole Ø 130 mm at 5 mm depth.
5.8 Center drill and drill circular through holes 30 mm x 12 at radius 15 mm at top surface and bottom surface component.
5.9 Center drill and drill circular through holes at radius 30 mm.

Use tools- hand drill set, center drill center drill Ø5 mm, drill Ø10 mm, bore cutter Ø20 mm.

6.0 Weld the component weld-3

7.0 Finishing process

8.0 End of process



Isometric view
Scale: 1:3

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Figure 4.10: Machining Process Plan for water collector

For Water container, the process began with the milling process to get the cylinder in shape. The process continued by rough turning to 419.1 mm diameter and finish turning to 107.1 mm length. Follow by the Drilling process through holes 31.78 mm x 12 at radius 175mm. Then, bored radial hole 1136.22 mm diameter at 75.5 mm depth. The process ended by fine machining process.

PROCESS PLANS

Model	Part No	Part name	Rev.	Date	Plan	Checked	Approved
S01	S01-04	Water Container (Component 4)	0	30/05/2013	Faiz	Suhairi	Dr.Amin

Material (Weight)	Size	Setup time	Remark
Alloy steel (89.6 kg)	**(450 x 450x 120) mm**	**150 min**	
Machines	Jig/Fixture	Process time	
Mazak variaxis630-sx, Lathe, Drilling and Boring	**Plate type jig, chuck, milling fixture, clamp**	**13.13 hr**	

Process

Material Verification and Machining Process

Operation and use tools

1.0 Verify material specs, condition and size
Use tools- visual checking, measuring tape and vernier caliper
2.0 All machining processes

Use tools- Indexable tool Ø 20, endmill Ø 20, ball endmill Ø 20, face mill Ø 80, face turn, turn bit, center drill Ø5, chamfer cutter 45° drill Ø8, boring cutter. Note: Attach standard clamp at center hole.

3.0 Ø 450 mm end milling and ball end milling cutting. Part cut out to Ø 430 mm and 115 mm length.

Use tools -endmill Ø 20 mm, ball endmill Ø 20 mm, face mill Ø 80 mm.

4.0 Turn to Ø 166 mm and 72 mm length. Chamfer 45° x 5 mm at 72 mm length.

Use tools- turning cutter, face turn and chamfer cutter 45°.

5.0 Bore process and holes drilling.

5.1 Center drill and drill radial 10 mm depth. Bored radial hole Ø 136 mm at 10 mm depth.

5.2 Center drill and drill radial 96 mm depth. Bored radial hole Ø 126 mm at 86 mm depth.

5.3 Center drill and drill circular through holes at radius 10 mm.

5.4 Center drill and drill circular through holes 30 mm x 12 at radius 15 mm at bottom surfce component.

Use tools- hand drill set, center drill center drill Ø5 mm, drill Ø60 mm, bore cutter Ø20 mm.

6.0 Finishing process

7.0 End of process

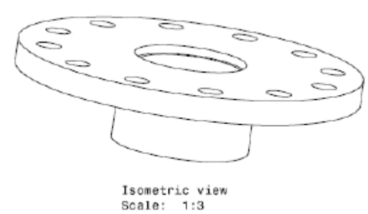

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Figure 4.11: Machining Process Plan for water Container

4.3.2 Casting Process Plan

Pre formed by casting process

The mould is made of two parts, the top half is called the cope, and bottom part is the drag. Interior surfaces are generated by inserts called cores. Cores are made by baking sand with some binder so that they can retain their shape when handled. The mould is assembled by placing the core into the cavity of the drag, and then placing the cope on top, and locking the mold. The molten alloy steel flows into the mould cavity. The geometry of the mould cavity is created by the pattern which made of by wood. The shape of the patterns is (almost) identical to the shape of the part we need to make. After the solidification process was done, breaking away the sand mold, and remove the casting.

To compensate for any dimensional and structural changes which will happen during the casting process, 0.5 mm allowance applied during the making pattern process. Lead time is the total time required to manufacture the swirler casing parts, from the time the order is received until the parts are shipped. The lead time depends on several factors including the design and manufacturing time of any required tooling, the equipment setup time, and the production rate of the process. Since the material were similar for each component, the difference of the lead time depends on the volume of material needed and the shape complexity. The assumption had been as tabulate in table below :

Pre formed by machining process

To ensure the manufacturing of swirler casing components adhered to design requirement, detail process plan were prepared for machining process based on Mazak CNC machining center as illustrated as per below:

PROCESS PLANS

Model	Part No	Part name	Rev.	Date	Plan	Checked	Approved
S01	S01-01	Top Cover (Component 1)	0	12/05/2013	Faiz	Suhairi	Dr.Amin

Material (Weight) **Alloy steel (105.6 kg)**	Size **(450 x 450x 170) mm**	Setup time **170 min**	Remark
Machines **Mazak variaxis630-sx**	Jig/Fixture **Plate type jig, chuck, clamp**	Process time **19.29 hr**	

Process

Material Verification and Machining Process

Operation and use tools

1.0 Verify material specs, condition and size
Use tools- visual checking, measuring tape and vernier caliper

2.0 All machining processes

Use tools- Indexable tool ø 20, center drill ø5, drill ø8, boring cutter.
Note: Attach standard clamp at center hole.

4.0 Center drill and drill circular through holes at radius 30 mm.

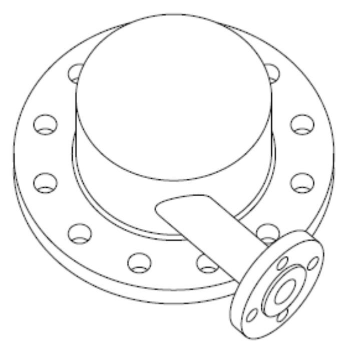
5.0 Center drill and drill circular through holes 30 mm x 12 at radius 15 mm at bottom surfce component.

Use tools- hand drill set, center drill center drill ø5 mm, drill ø60 mm, bore cutter ø20 mm.

6.0 Weld the component weld-1

7.0 Finishing process

8.0 End of process



Isometric view
Scale: 1:3

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Figure 4.12: Pre-form Machining Process Plan for Top Cover

PROCESS PLANS

Model	Part No	Part name	Rev.	Date	Plan	Checked	Approved
S01	S01-02	Throttle (Component 2)	0	9/05/2013	Faiz	Suhairi	Dr.Amin

Material (Weight) Alloy steel (109.8kg)	Size (450 x 450x 180) mm	Setup time 140 min	Remark
Machines Mazak variaxis630-sx	Jig/Fixture Plate type jig, clamp	Process time 20.46 hr	

Process

Material Verification and Machining Process

Operation and use tools

1.0 Verify material specs, condition and size
Use tools- visual checking, measuring tape and vernier caliper

2.0 All machining processes

Use tools- Indexable tool Ø 20, center drill Ø5, drill Ø8, boring cutter. Note: Attach standard clamp at center hole.

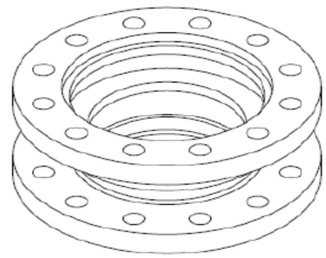
3.0 Bore process and holes drilling.

3.1 Center drill and drill circular through holes 30 mm x 12 at radius 15 mm at top surface and bottom surface component.

Use tools- hand drill set, center drill center drill Ø5 mm, drill Ø10 mm, bore cutter Ø20 mm.

4.0 Finishing process

5.0 End of process



Isometric view
Scale: 1:3

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Figure 4.13: Pre-form Machining Process Plan for Throttle

PROCESS PLANS

Model	Part No	Part name	Rev.	Date	Plan	Checked	Approved
S01	S01-03	Water Collector (Component 3)	0	9/05/2013	Faiz	Suhairi	Dr.Amin

Material (Weight) Alloy steel (131.8kg)	Size (450 x 450x 250) mm	Setup time 235 min	Remark
Machines Mazak variaxis630-sx	Jig/Fixture Plate type jig, clamp	Process time 30.17 hr	

Process

Material Verification and Machining Process

Operation and use tools

1.0 Verify material specs, condition and size
Use tools- visual checking, measuring tape and vernier caliper

2.0 All machining processes

Use tools- Indexable tool Ø 20, center drill Ø5, drill Ø8, boring cutter . Note: Attach standard clamp at center hole.

3.0 Bore process and holes drilling.

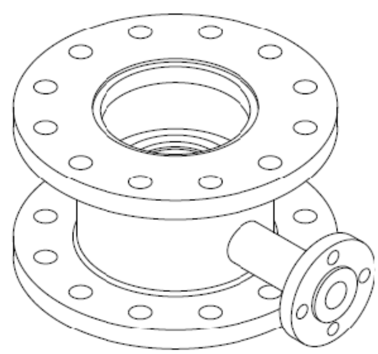
3.1 Center drill and drill circular through holes 30 mm x 12 at radius 15 mm at top surface and bottom surface component.
3.2 Center drill and drill circular through holes at radius 30 mm.

Use tools- hand drill set, center drill center drill Ø5 mm, drill Ø10 mm, bore cutter Ø20 mm.

4.0 Weld the component weld-3

5.0 Finishing process

6.0 End of process



Isometric view
Scale: 1:3

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Figure 4.14: Pre-form Machining Process Plan for Water Collector

PROCESS PLANS

Model	Part No	Part name	Rev.	Date	Plan	Checked	Approved
S01	S01-04	Water Container (Component 4)	0	30/05/2013	Faiz	Suhairi	Dr.Amin

Material (Weight) **Alloy steel (89.6 kg)**	Size **(450 x 450x 120) mm**	Setup time **150 min**	Remark
Machines **Mazak variaxis630-sx**	Jig/Fixture **Plate type jig, chuck, fixture, clamp**	Process time **13.13 hr**	

Process

Material Verification and Machining Process

Operation and use tools

1.0 Verify material specs, condition and size

Use tools- visual checking, measuring tape and vernier caliper

2.0 All machining processes

Use tools- Indexable tool Ø 20, , Ø 80, center drill Ø5, chamfer cutter 45° drill Ø8,. Note: Attach standard clamp at center hole.

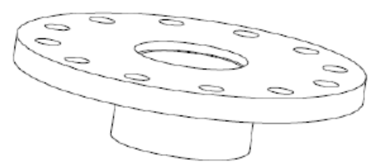
3.0 Center drill and drill circular through holes at radius 10 mm.

4.0 Center drill and drill circular through holes 30 mm x 12 at radius 15 mm at bottom surface component.

Use tools- hand drill set, center drill center drill Ø5 mm, drill Ø60 mm, bore cutter Ø20 mm.

5.0 Finishing process

6.0 End of process



Isometric view
Scale: 1:3

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Figure 4.15: Pre-form Machining Process Plan for Water Container

In the perform machining process, all of components only involved in drilling process and finishing process where exactly similar to drilling process done in machining part.

4.4 Result of Estimated Production Cost and Process Time

Table 4.3: ProcessTime and Cost for Machining Process

Milling operation				
	Process time (min)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	157.73	2	26	46
Throttle	178.2	2	29	49
Water collector	320	3	53	83
Water container	86.1	1	14	24
Assumption : Machine rate: RM10/hrLabour rate : RM10/hr				
Turning operation				
	Process time (min)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	367.85	1	49	71
Throttle	128.89	1	17	31
Water collector	472.26	1	62	88
Water container	319.82	1	42	63
Assumption : Machine rate: RM8/hrLabour rate : RM10/hr				
Drilling & Boring operation				
	Process time (min)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	541.94	7	90	160
Throttle	850.48	5	141	190
Water collector	897.69	8	150	230
Water container	331.71	3	50	80
Assumption : Machine rate: RM10/hrLabour rate : RM10/hr				
Welding operation				
	Process time (min)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	20	25	2	7
Water collector	15	25	2	6
Assumption : Machine rate: RM8/hrLabour rate : RM10/hr				
Finishing operation				
	Process time (min)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	367.85	1	49	71
Throttle	128.89	1	17	31
Water collector	472.26	1	62	88
Water container	319.82	1	42	63
Top cover	367.85	1	49	71
Assumption : Machine rate: RM5/hrLabour rate : RM10/hr				

Table 4.4: ProcessTime and Cost for CastingProcess

Pattern making operation				
	Process time (hr)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	5	2	50	70
Throttle	5	2	50	70
Water collector	5	2	50	70
Water container	5	2	50	70
Assumption : Machine rate: RM10/hrLabour rate : RM10/hr				
Core making operation				
	Process time (hr)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	2	2	10	40
Throttle	5	2	25	70
Water collector	4	3	20	70
Water container	2	2	10	40
Assumption : Machine rate: RM5/hrLabour rate : RM10/hr				
Mold making operation				
	Process time (hr)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	3	2	15	50
Throttle	3	2	15	50
Water collector	3	2	15	50
Water container	3	2	15	50
Assumption : Machine rate: RM5/hrLabour rate : RM10/hr				
Melting operation				
	Process time (hr)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	4	2	80	60
Throttle	5	2	100	70
Water collector	6	2	120	80
Water container	3	2	60	50
Top cover	4	2	80	60
Assumption : Machine rate: RM20/hrLabour rate : RM10/hr				

Pouring & solidification operation				
	Process time (hr)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	3	1	-	5
Throttle	4	1	-	5
Water collector	5	1	-	5
Water container	2	1	-	5
Top cover	3	1	-	5
Assumption : Labour rate : RM10/hr				
Dismantlingoperation				
	Process time (hr)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	10	-	-	2
Throttle	10	-	-	2
Water collector	10	-	-	2
Water container	10	-	-	2
Top cover	10	-	-	2
Assumption : Labour rate : RM10/hr				
Drilling operation				
	Process time (min)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	69.24	2	10	30
Throttle	138.48	2	20	40
Water collector	138.48	2	20	40
Water container	69.24	2	10	30
Assumption : Machine rate: RM10/hrLabour rate : RM10/hr				
Welding operation				
	Process time (min)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	20	25	2	7
Water collector	15	25	2	6
Assumption : Machine rate: RM8/hrLabour rate : RM10/hr				
Finishing operation				
	Process time (min)	**Setup time (hr)**	**Machine cost (RM)**	**Labour cost (RM)**
Top cover	367.85	1	49	71
Throttle	128.89	1	17	31
Water collector	472.26	1	62	88
Water container	319.82	1	42	63
Top cover	367.85	1	49	71
Assumption : Machine rate: RM5/hrLabour rate : RM10/hr				

Table 4.5: Total Estimated Cost for Machining and Casting

Total estimated cost	Machining	Casting
Labour cost (RM)	1381	1394
Material cost (RM)	10200	7800
Process cost (RM)	897	919

Table 4.6: Total Estimated Time for Machining and Casting

Total estimated process time (hr)	
Machining	Casting
139.6	151

Based on table 4.4, the total process cost by casting is lower than machining process with RM 10113 and RM 12578 respectively. Besides, the material waste can be reduced by casting.

Based on table 4.5, total estimated process time for casting higher than machining. However, based on figure 4.2 and table 4.3, the casting required less setup and labour work. The casting process overall depend on the machine work.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

By the end of the assessment, the objectives of project have been achieved. Process plan for machining and casting has been successfully developed. From the analysis on both process plans, the fabrication process of the swirler casing more appropriate carried out using casting process compared to machining.

Both processes have strengths and weaknesses. The process planning used to evaluate the feasibility and suitability of fabrication process. The total process cost by casting is lower than machining process with RM 10113 and RM 12578 respectively. Besides, the material waste can be reduced by casting. However, total estimated process time for casting higher than machining. The selected processes for machining process are turning, drilling and boring. The machine require for machining process are lathe, drilling and boring machine. The sand casting method had been selected to compare with machining process due to feasibility and economically factor.

As the objective of this project has been focusing on comparative study of machining and casting process, deeper analysis on the reduction of production cost and time consumption have not been carried out including the optimum parameter for each of process. Since establishment of efficient machining parameters has been a problem that has confronted in manufacturing industries, this opens up for future research work in this area. The significant improvement in process efficiency may be obtained by process parameter optimization in the regions of critical process control factors leading to desired outputs This report also will be serves as a basis for best practices in machining and casting process to produce not only fast, but lower cost, high quality, and reduce waste of materials.

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APPENDIX

Appendix A: General Characteristic Of Casting Process (J.A. Schey,2000)

	Sand	Shell	Evaporative pattern	Plaster	Investment	Permanent mold	Die	Centrifugal
Typical material cast	All	All	All	Non ferrous (Al, Mg, Zn, Cu)	All	All	Non ferrous (Al, Mg, Zn, Cu)	All
Weight (kg) Minimum Maximum	 0.01 No limit	 0.01 100+	 0.01 100+	 0.01 50+	 0.001 100+	 0.1 300	 0.01 50	 0.01 5000+
Typical surface finish (Ra in μm)	Coarse	Good	Coarse	Good	Excellent	Good	Excellent	Good
Porosity	Mid to high	High	Mid to high	High	High	Low	Low	Very low
Shape complexity	High	High to mid	High	High	Very high	High to mid	Mid to low	Mid to low
Dimensional accuracy	Medium	High	Medium		Very high	Very high	Very high	Medium
Section thickness (mm) Minimum Maximum	 3 Unlimited	 2 -	 2 -	 1 -	 1 75	 2 50	 0.5 12	 2 100
Typical dimensional tolerance (mm)	1.6-4	~0.003	-	+0.005-0.010	+0.005	~0.015	+0.001-0.005	0.015
Equipment cost	Low	Mid to high	Low to mid	Medium	Low to mid	High	Very high	Very high
Pattern/die cost	Low	Low to mid	Low to mid	Low to mid	Mid to high	High	Very high	Very high
Labor cost	Low to mid	Low to mid	Medium	High	High	Medium	Low	Low
Typical lead time[2]	Days	Weeks	Weeks	Days	Weeks	Weeks	Weeks to month	Months
Typical production rate[2] (part/mold-hour)	1-20	5-50	1-20	1-10	1-1000	5-50	2-200	1-1000
Minimum quantity[2]	1	100	500	10	10	1000	10000	10-10000

Appemdix B: General recommendations for Speeds and Feeds in Drilling (Schmid, 2010)

TABLE 23.11

General Recommendations for Speeds and Feeds in Drilling

Workpiece material	Surface speed		Feed, mm/rev (in./rev)		rpm	
			Drill diameter			
	m/min	ft/min	1.5 mm (0.060 in.)	12.5 mm (0.5 in.)	1.5 mm	12.5 mm
Aluminum alloys	30-120	100-400	0.025 (0.001)	0.30 (0.012)	6400-25,000	800-3000
Magnesium alloys	45-120	150-400	0.025 (0.001)	0.30 (0.012)	9600-25,000	1100-3000
Copper alloys	15-60	50-200	0.025 (0.001)	0.25 (0.010)	3200-12,000	400-1500
Steels	20-30	60-100	0.025 (0.001)	0.30 (0.012)	4300-6400	500-800
Stainless steels	10-20	40-60	0.025 (0.001)	0.18 (0.007)	2100-4300	250-500
Titanium alloys	6-20	20-60	0.010 (0.0004)	0.15 (0.006)	1300-4300	150-500
Cast irons	20-60	60-200	0.025 (0.001)	0.30 (0.012)	4300-12,000	500-1500
Thermoplastics	30-60	100-200	0.025 (0.001)	0.13 (0.005)	6400-12,000	800-1500
Thermosets	20-60	60-200	0.025 (0.001)	0.10 (0.004)	4300-12,000	500-1500

Note: As hole depth increases, speeds and feeds should be reduced. Selection of speeds and feeds also depends on the specific surface finish required.