INVESTIGATION ON HYBRID GEOMETRIC MODELLING CONSTRUCTION FOR INJECTION MOULD USING CAD SYSTEM

By:

NOOR ATIKAH BINTI ABDUL MALEK

(Matric No. : 125418)

Supervisor:

Dr. Mohd Salman Abu Mansor

June 2018

This dissertation is submitted to

Universiti Sains Malaysia

As partial fulfilment of the requirements to graduate with honors degree of

BACHELOR OF ENGINEERING

(MANUFACTURING ENGINEERING WITH MANAGEMENT)

School of Mechnical Engineering

Engineering Campus

Universiti Sains Malaysia

DECLARATIONS

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed: ..... (Noor Atikah binti Abdul Malek)

Date: ….....

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/ references are appended.

Signed: ..... (Noor Atikah binti Abdul Malek)

Date: ….....

STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available outside organizations.

Signed: ..... (Noor Atikah binti Abdul Malek)

Date: ….....

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervisor of the thesis laid down by Universiti Sains Malaysia.

Signed: ..... (Dr. Mohd Salman bin Abu Mansor)

Date: ….....

ACKNOWLEDGEMENTS

"In the name of Allah, the Most Beneficent and the Most Merciful." All praises are due to Allah, Lord of the worlds. He had blessed me with good health, strength, patience and a decent time to accomplish this project and His wills, this thesis has been able to be completed. "Indeed, He is the best planner".

First of all, this project would not have been possible without the help from the supervisor, Dr. Mohd Salman Abu Mansor, lecturer of School of Mechanical Engineering. My greatest gratitude to him who are responsible for monitoring and patiently guiding all the works that have been done from the start until the end. His understanding helps me a lot in completing my project.

Not to forget, both of my parents and my family who are constantly giving an unfailing support for me to pass through all the hard time during working on this project. I am grateful for all their prayers that kept me to stay strong until this project successfully finish. They are my source of strength for me to keep working for the good end.

Last but not least, I also want to thank all the lecturers, technicians, fellow friends and staffs of School of Mechanical Engineering, USM who are directly or indirectly helping me to complete this project. All the knowledge, support and cooperation that I have received are very much appreciated. Thank you.

NOOR ATIKAH BINTI ABDUL MALEK

JUNE 2018

TABLE OF CONTENTS

Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CAE	Computer Aided Engineering
CAIMDS	Computer Aided Injection Mould Design System
B-Rep	Boundary Representation
F-Rep	Function Representation
CSG	Constructive Solid Geometry
IMOLD	Intelligent Mould Design

ABSTRAK

Penggunaan proses pengacuan suntikan menjadi semakin popular kerana ia membawa pulangan yang menguntungkan bagi industri pembuatan plastik. Kebolehannya dalam menghasilkan pelbagai jenis produk plastik telah membuat proses pengacuan suntikan digunakan secara meluas dalam industri. Mengambil masa yang lama dan tahap kerumitan yang tinggi dalam merekabentuk acuan suntikan telah membawa kepada pembinaan model geometri hibrid yang boleh digunakan dalam merekabentuk acuan dengan mengunakan sistem CAD yang kemudiannya akan digunakan dalam proses pengacuan suntikan.

Sistem yang terdiri daripada gabungan dua skim perwakilan akan menghasilkan reka bentuk acuan dari model produk. Algoritma untuk kedua-dua skema perwakilan disepadukan untuk menghasilkan skema hibrid yang kemudiannya boleh menghasilkan reka bentuk acuan tanpa menggunakan cara yang kompleks. Kajian ini bertujuan untuk mempermudahkan kaedah yang sedia ada dalam mewujudkan teras dan rongga untuk acuan.

Pada akhir kajian ini, algoritma yang dibina dapat mengesan topologi untuk sesuatu bahagian model . Ia dapat mengenali ciri-ciri model dan mentafsirkannya dalam bentuk data topologi. Kemudian, ia boleh menghasilkan reka bentuk untuk pasangan teras dan rongga untuk acuan suntikan. Kerja mereka bentuk untuk acuan boleh dipermudahkan.

ABSTRACT

The use of injection moulding process is becoming more popular recently due to its profitable returns in plastic manufacturing industry. Its flexibility in changing the product type have made injection-moulding process widely used. Time consuming and complexity in designing the injection mould has led to developing a hybrid geometric modelling construction that can be used in designing a mould with CAD system for injection moulding process.

A system that consist of a combination of two representation schemes will produce a mould design from the product part model. The algorithm for the two representation schemes are integrated to produce a hybrid scheme that later can generate mould design without a complex way. This research is aiming on simplified the current method in creating the core and cavity for the mould.

At the end of this study, the developed algorithm able to detect the topology for the part model. It able to recognise the characteristic of the model and interpret it in form of topology data. Then, it can develop a design for pair of core and cavity for injection mould. The designing work for mould can be simplified.

CHAPTER 1

Introduction

1.1 Project Overview

Injection moulding process is widely used in manufacturing industry especially in plastic product manufacturing industry since it can produce large quantity of product with low cost involved within a short time of process. In injection moulding process, the flexibility in changing the product design is the main criteria in using this process. The product design is determined by the mould design, which is consist of two separate parts that are core and cavity. Therefore, design of the mould is the most important factor to be taken note since it will affect the product outlook. In order to achieve a flexible production process by producing various types of product design, designing process for injection mould should be easier and not time consuming.

Designing the injection mould can be within minutes for a simple product design or few days for complex product design. In line with the current technology trend, which is the Industry 4.0, designing process can have so much improvement [18]. Advances in technology nowadays have given a big impact on manufacturing industry. Moving from Industry 1.0 to Industry 4.0, there are many changes and improvements have been done to the technologies and approaches used in the current industry. Industry 4.0 is the current trend of technologies used in manufacturing industry. It is about the automated technologies and computerised data controlling that enable to improve the quality of the industry [1].

One of the approach to achieve the Industry 4.0 stage is by implement a flexible programmable tool that will help in improving the industry performance such as use of computer software [22, 23]. Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Computer Aided Engineering (CAE) and other computer software are the examples of technologies that used in current industry. These computer software help in facilitate the parts designing processes since it includes constructing,

combining, modification and even analysis processes. Work of designing can be easier with aid of these tools.

In CAD system, geometric modelling construction is one of its functional programme [2]. It is use to display, generate and analyse the part model of the product by applying mathematical description as its functions. Even though geometric modelling is not the final goals in engineering, however it is the basic requirement in running an analysis and simulation for the product. Geometric modelling will present the complete part or product by including the topological and geometrical data. Topology is about the link of the part entities [3]. It specifies the information that relates between the two object entities, which is shape of edges while the geometry will determine the shape and dimension of the part [9].

In latest technology, many things have improved. Process of generating a mould are no longer complicated [18]. Design of mould that is used in injection moulding process that includes two separate parts, can be generated at the same time without complex process [10]. In previous time, design for these two core and cavity are generated separately. From the part model, the geometric of the part is determined then, the design for core and the cavity are generated by constructing them separately. With nowadays technology [6], there are computer software that can straight away generate the mould design for injection moulding process by using the part model design.

The investigation on hybrid geometric modelling construction for injection mould is one way to overcome the current weakness that occur in each approach [4]. Therefore, by combining two geometric modelling techniques, limitation in each techniques probably can be solved and lead to current technology improvement [5]. In addition, this approach is one of the achievement that can lead to industry's trend nowadays that is Industry 4.0. This study is to achieve an automatic design recognition for the design of the mould from the part model by implementing the hybrid between two techniques of geometric modelling construction. The approach of hybrid techniques is relevant since it can improve weaknesses in current techniques.

1.2 Problem Statement

The purpose of this project is to solve certain problems that involved in current injection mould designing process. There are correlation between time and profit gain. This is due to competition with the others. High time consuming in mould designing process will drag down the profit gain due to lost to competitor. Hence, reducing the lead-time in designing the injection mould can be a great achievement in industry since high time consuming can lead to profit lost due to competition. Other than that, complexity in current techniques due to their limitation. The weakness caused by the limitations that occur in each geometric modelling technique can lead to difficulty in producing CAD model for the injection mould. The idea of combining the geometric model hopefully can solve the limitation problems that occur in current geometric modelling techniques.

1.3 Objectives

This study was carried out with the main objective is to improve the current method that used in constructing a design for injection mould using CAD system. The specific objectives are as follow, which involves the using of software

1. To study the various geometric modelling construction that have been use in CAD system.
2. To produce the hybrid geometric modelling construction algorithm for injection mould in CAD system.
3. To evaluate the hybrid representation scheme for producing the injection mould using CAD system

1.4 Scope of Project

In this project, an interest in investigating the hybrid geometric modelling construction for injection mould by using CAD system is arisen. A hybrid geometric modelling is believed to have high impact of benefits in designing the injection mould in current industry trend where people are trying to move towards Industry 4.0. A study

on the basic requirement of the geometric modelling for CAD is a must since it is the core information in building the hybrid model.

This project is basically involves studying the principle of geometric modelling for CAD, investigating the pros and cons for each techniques and based on that, an algorithm for the model that will solve the weakness in certain geometric modelling techniques will be built. Later, a validation on the algorithm is done as to prove whether the hybrid model is work or not. At the end of this project, the aim is to obtain a hybrid model that will be easily handled, not time consuming and probably versatile with no complex process involved.

1.5 Outline

This thesis is divided into five main chapters with each chapter being divided or subdivided into further sections and subsections.

Chapter 1 provides a general introduction to the research interest. A brief discussion on problem statement will be presented. The main objectives, problem statement and the scope of work in conducting this study is discussed.

Chapter 2 will provide a comprehensive literature review on basic information of geometric modelling, injection moulding technologies and their improvements. It is also provide a review about current finding that relate injection-moulding process with CAD system.

Chapter 3 will explain on the methods in which the whole research project has been conducted. Some consideration, analysis and statements with regard to the hybrid geometric modelling algorithm is introduced. Furthermore, the software used for the developing and evaluation as well as the verification of the study will be presented.

Chapter 4 will present the results of the model verification process as well as the finding for the whole research. The result will be discussed in chronological order of the research objectives.

Chapter 5 will summarizes the research finding and presents the conclusion on this study. Based on these, the recommendations for the future work are also discussed. Lastly, future developments in hybrid geometric modelling for injection mould prediction concludes this study.

CHAPTER 2

Literature Review

2.1 Industry 4.0

The speed of technology development in the impact of daily life is inevitable by all people. Technology development usually keep changing from time to time to be more advances. This changing can lead the world be better a world. In manufacturing industry, Industry 1.0 has developed throughout the time until it becomes Industry 4.0. Industry 4.0 is a current trend that also known as fourth industrial revolution in industry. It is the industrial production transformation towards smart manufacturing which occupied nine technology trends in running the overall operations [11]. The nine pillars that lead to this technological advancement are as shown in Figure 2.1. The automation and simulation are one of the factors that contribute to the formation of Industry 4.0. These factors can lead to the development of software in facilitating task in operating the industry.

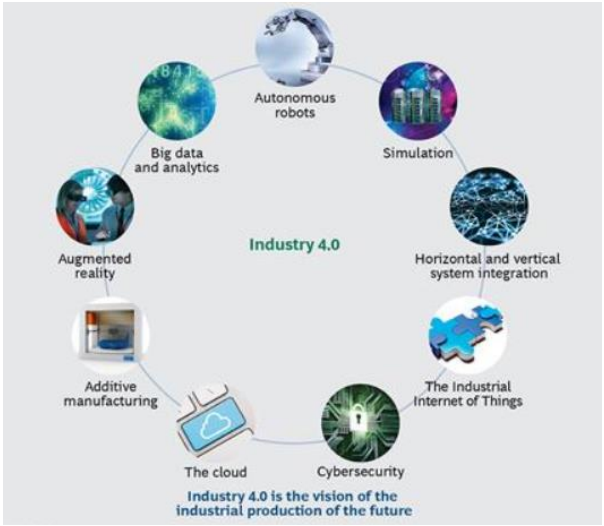

Figure 2. 1: Nine advance factors that form the foundation of Industry [11]

Other than that, in order to fulfil the current demand, the improvements however are causing the system becoming more complex and hard to handle. At the same time, it has to coop with customer demand that pursuing for flexibility in producing the

product design. Rapid changing of product demand make them want to achieve flexible production method. So that, changing from one product to another will not consume too much time and does not cost much. According to these problems, combination of injection moulding and additive manufacturing in the Industry 4.0 technologies [12] seems can deal with the issues that arise before. By combining these three elements, the production can be in cost-effective manner since it use an automated system.

2.2 Injection Moulding Process

Based on research done by Chan et al [6], injection moulding is a process that used in industry for producing products or parts that usually made from plastic polymer material. It is about 30% of plastic products are being manufactured by injection moulding process [13, 16]. This process involves injecting the material into the mould which made of core and cavity [20] as shown in Figure 2.2. The most crucial part in this overall process is in designing the mould. This part will determine the geometry, functionality and the final looks for the product or part produced. In nowadays industry trend, injection-moulding process is widely used in manufacturing industry since it can produce large amount of products, involves low cost and flexible in producing variety of product types.

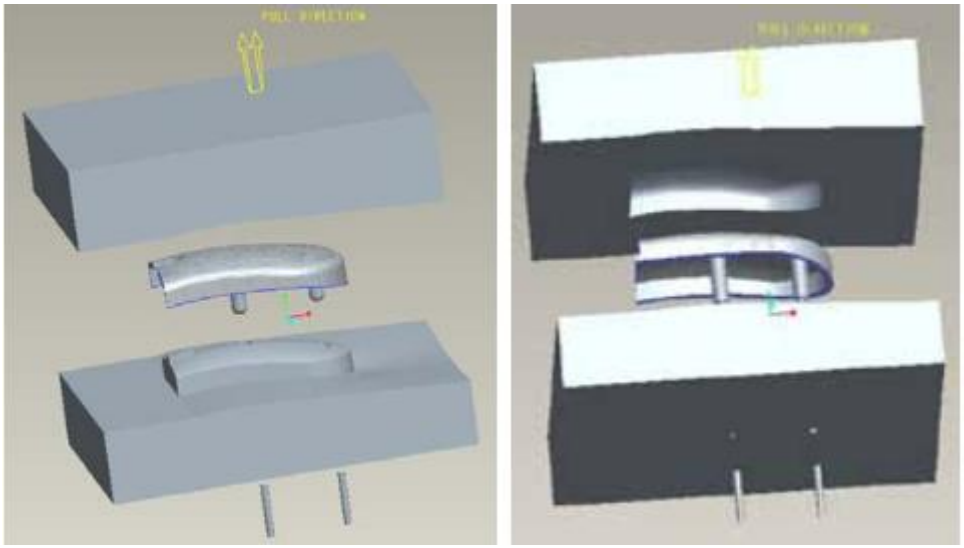

Figure 2. 2: The core and the cavity for injection mould [23]

Injection moulding is one of the option because it can coop both of quality and of productivity. Quality and productivity should move parallel in order to capture demand from market. Quality that injection-moulding offers are producing complex-shape plastic products and at the same time, it can produce product with good dimensional accuracy within short cycle [14]. Quality and productivity can be optimize by applying the right and suitable parameters during injection moulding process. The parameters that involve during the injection moulding process are temperature, time, injection pressure and it might involves amount of gas release during the process [15].

When talking about the flexibility in producing various types of product, it is about changing the mould only. This is because, the other process is still same or not much different. The mould will determine the design and quality of the product part that have been produced. Seeing that mould design contribute an important role in injection moulding process, an approach to improve the mould designing process is take into consideration. This is because every second ticking is about money for manufacturing companies. Therefore, here is why they want to reduce both design and manufacturing lead-time in their processes. For this case, the thing that tried to be reduce in manufacturing lead time by implementing automatic designing process for mould. In addition to that, a development on computer aided injection mould design system (CAIMDS) has been a focus for some researcher [17].

2.3 Geometric Modelling

2.3.1 Techniques in geometric modelling

There are three geometric modelling methods that available in industry, which are wireframe, surface and solid modellers [8]. These three geometric modelling systems have their own advantages and disadvantages. Among these three systems, wireframe modeller is the simplest model as shown in the Figure 2.3. In this model, basic features such as straight line, conics or simple spline curve are used to generate the boundaries of the part model. However, because of its simple features, the surface information is not very clear, this can cause some difficulty in interpreting the image, and even impossible to manufacture a 3D object [24].

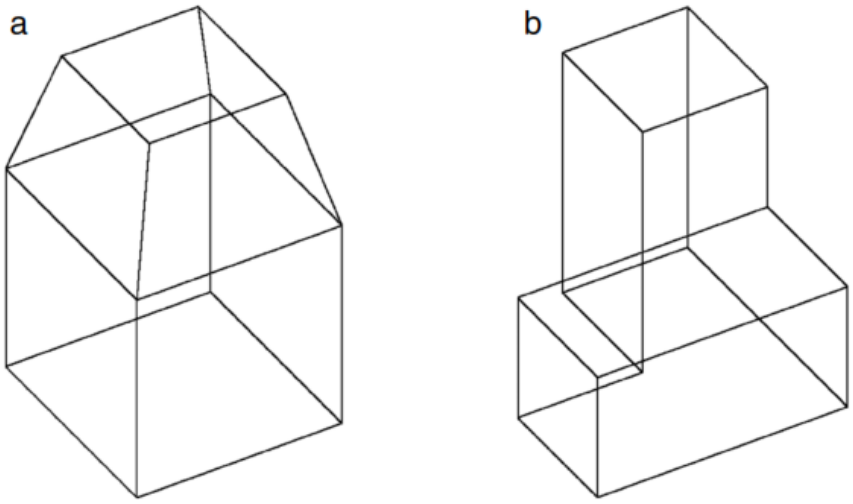

Figure 2. 3: Wireframe lines drawing [21]

The second and the third geometric modelling systems, which are surface and solid models. These two models are more sophisticated compared to wireframe model [21] . These two models can overcome the weakness that occur in first model. A more complex shape can be done by using these two techniques. Overall, there are two basic approaches for these three techniques. There are transfinite interpolation and discrete approximation and interpolation. In first approach that is transfinite interpolation, the surface is construct as if it would pass through the given collection of curves. While for the discrete approximation, it construct the surface that interpolates with a given set of data points. Table 1 shows the summarize of advantages and disadvantages for every geometric modelling techniques.

Table 2. 1 The list of advantages and disadvantages for each techniques [9]

Types of techniques	**Advantages**	**Disadvantages**
Wireframe modelling	• Simple to construct • Needs less memory space	• Difficult to determine the undercut
Surface modelling	• It is less ambiguous. • Complex surfaces can be easily identified.	• Difficult to construct. • Difficult to calculate mass property. • More time is required for creation.

	• It removes hidden line and adds realism.	• Requires high storage space.
Solid modelling	• Complete modelling. • Unambiguous. • Best suitable for calculating mass properties. • Very much suitable for automated applications. • Fast creation. • Gives huge information.	• Requires large memory. • Slow manipulation.

2.3.2 Representation schemes for rigid solids

Moving to the more advanced world that equipped with various types of latest technologies, previous method and conventional way have been integrated in order to achieve something new or some sort of improvement in current achievement. A study done by Alexander [5], issue discussed is about the hybrid approach in geometric modelling construction. There are several options in developing hybrid method in geometric modelling. Since geometric modelling is built by more than one field. In geometric modelling, hybrid method can be apply either in the representation scheme, techniques, programming languages, operating systems, computer systems, modern graphic hardware or software-hardware algorithm implementation. These different work fields involve different expertise.

One of the important element in solid modelling is the representation scheme. Representation scheme is the symbolic structure that used to build the object [5]. The scheme is built by mathematical expression, which carries a particular function for every mathematic equation. Different representation schemes perform different function and give different outcome too [19]. Several schemes usually used in developing 3D model or system. However, the most popular scheme that widely used is the Boundary representation scheme (B-rep). B-rep is about describing the boundary of the solids that usually sufficient for basic visualisation. Started to be used in the

middle of 1970s, B-rep represents objects in term of the surfaces, edges and vertices [27]. Vertices use to bound the edges, edges use to bound the face and faces are meet at certain edge to produce an object. The basic B-rep perform faster than other representation scheme.

Other than B-rep, there is another representation that used to describe geometric object, which is Functional representation scheme (F-rep). F-rep use real continuous function in representing the geometric of objects [25]. Other than real continuous function, the signed distance function also have been used in interpreting the f unction. This method has advantage in fast developing visualisation algorithm. However, this function is more restrictive. Another advantage of this F-rep is easy to implement the nonlinear transformations and other complicated operation in representing. F-rep has two classes of visualisation algorithm, first is polygonization based which transform F-rep inti B-rep and the second class is ray tracing based which it straight away visualise from observers' viewpoint without convert.

The next representation scheme is parametrized primitive instancing. This scheme is based on assumption of family objects [5]. Every member of the family is different from each other by a few parameters. The object family is called generic primitive. For the individual object in the family, it is called primitive instances. This scheme is simple but very flexible. However, by combining them with other scheme, it is favourable to describe the basic primitive. When a mechanism for constructing more complex object is added, it will remove the main weakness of this scheme. In current developing process, combination this scheme with GSC is possible.

The other existed representation scheme is Constructive Solid Geometry (CSG). It used Boolean construction or other combination primitive through regularized set in presenting the rigid solid. In current trend, the use of CSG and boundary representation is the most popular scheme to represent the solid. CSG is unambiguous however, this scheme is not unique. It depends on the half space, which it uses the set of primitive solid and the combination of operator. CSG itself has several leaking in its operation.

The restrictions have make this scheme not convenient to user since it is not suitable for union between two object. Other than that, it also lack of closure, difficult to ensure the validity which involve complex in comparing the general boundary and it also not suitable for certain applications especially in analysing the spatial interferences.

2.3.3 Generating injection mould using CAD

Along with the advancement that have been done in CAD system, designing the injection mould will not be complex anymore. There are many improvements that have been implemented in this field in order to fulfil current industries trend where time is everything. Consuming too much time in designing process will drag down the opportunity in winning the competition and this will affect the profit gained. Aside from geometric modelling function, the add-on software have been added into system in order to facilitate the users. Intelligent mould design (IMOLD) is one of the knowledge-based software that provide information that needed in designing a mould [18]. With that, generating a mould design can be automatically done by inserting the product model.

Focus on generating the mould design automatically, there are some studies have been done determine the geometric features of the mould such as the parting direction, parting lines, parting surface, to recognise undercut features and to generate the core and the cavity [26]. All these features must be recognize carefully since it will contribute to the whole design of the mould. Ravi and Srinivasan [7] have stated nine rules that should be taken care during developing the suitable parting line in the mould. The rules are, the projected area, flatness, draw, draft, undercuts, dimensional stability, flash, machined surfaces and directional solidification.

2.4 Summary

In order to meet the current Industry 4.0 trend, a lot of improvement have been done in existing injection moulding process. One of the crucial part in injection moulding process is in creating the injection mould design. Functionality of the mould and accessibility of the approach in designing process, both should be taken care carefully. Current representation schemes that used to build the solid geometry can play

important role in creating the product since it is the basic requirement in geometric modelling. Hence, integration of basic information might help in improving the injection mould designing system.

Combination of B-rep and CSG have the potential to be improve in the future study. Since hybrid of these two schemes are well known and widely used even in current market, these schemes are chosen for being implemented for generating the injection mould design. The pros and cons for each schemes can be overcome by using hybrid method.

CHAPTER 3

Methodology

3.1 Project Flowchart

This project involved several stages of tasks that need to be performed from the starting until the end of project. The processes was in flow order so that all the tasks will have sufficient information and organized. In the Figure 3.1 below shows the flowchart that representing the tasks performed upon conducting this research study, which includes several phases.

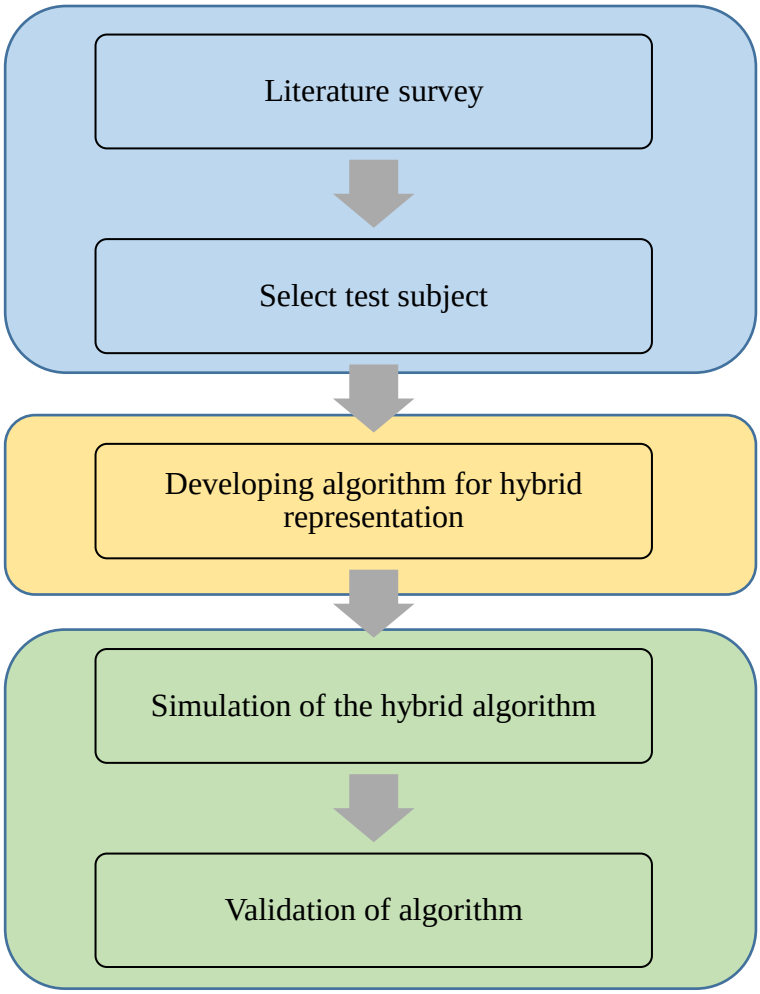

Figure 3. 1: Flowchart of the research procedure

The first phase is about conducting the literature study about the overall scope that related in order to identify information that are used in conducting the project. A test subject (geometric modelling in generating injection mould) is then selected based availability in current study and ease of information obtainment. Then followed by the collection of data for injection moulding process and characteristics of geometric modelling programing. At the end of first phase, representation of schemes are chosen since it is the main criteria in forming the presentation of solid object.

At the second phase, it starts by collecting all the data for the developing the representation scheme as it is the selected subject from the sources that have been recognized. From the information gathered, the algorithm for generating the hybrid representation schemes are developed. Simulation on the developed algorithm is done after that to observe the output if the algorithm.

For the third phase of this project, the validation process for the algorithm is done to ensure the result accuracy. The results from simulation process that have been done are used in this validation step. The verifications are done based on the performance of the hybrid algorithms. Finally, when the finals are obtained after being verified, the results are analysed and discussed.

3.2 Selecting Test Subject

In this hybrid project, the combination of two representation schemes was used for developing the design for injection mould. The first scheme used was Boundary Representation (B-rep) and Construction Solid Geometry (CSG). The B-rep scheme was used as the presenting scheme for the solid geometry for the injection mould. As the method for creating the injection mould, CSG scheme was used in this project. The ability to merge, subtract and intersection operation was used to create pattern on injection mould and splitting injection mould into core and cavity.

3.3 Preparing sat.file

Software SolidWorks was used in preparing the 3D CAD model for the product model. The part option was chosen for creating the product part as shown in the Figure 3.2. The part model was created according to the demand or the form that the product required. As for this project, the product chose was a connecting rod as shown in Figure 3.3. For the file to work in ACIS 3D modeller, the part model had to be saved in format of acis with sat.file extension. The part model in sat.file that opened with software ACIS 3D modeller is shown in Figure 3.4. The sat.file also has been used in the algorithm since the results needed should be opened by using ACIS 3D modeller.

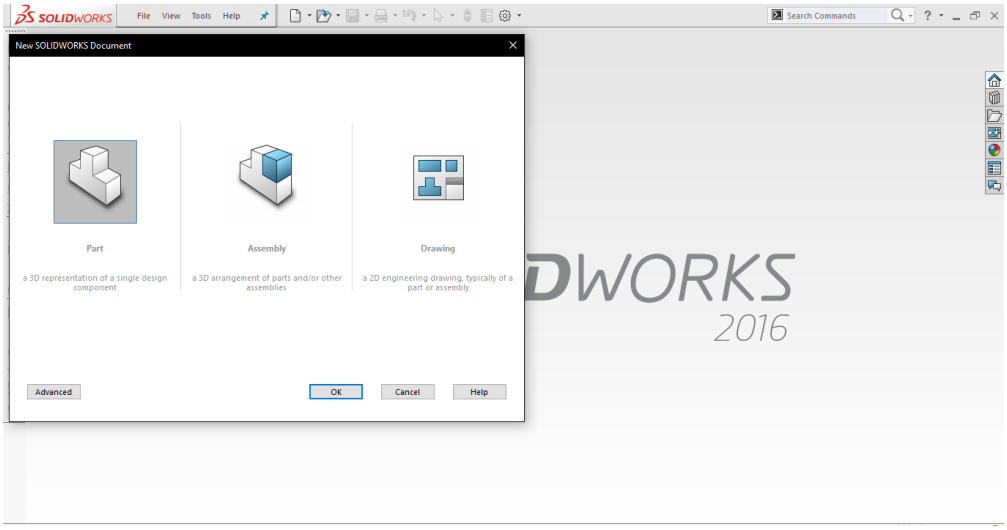

Figure 3. 2: SolidWorks software for creating the part model

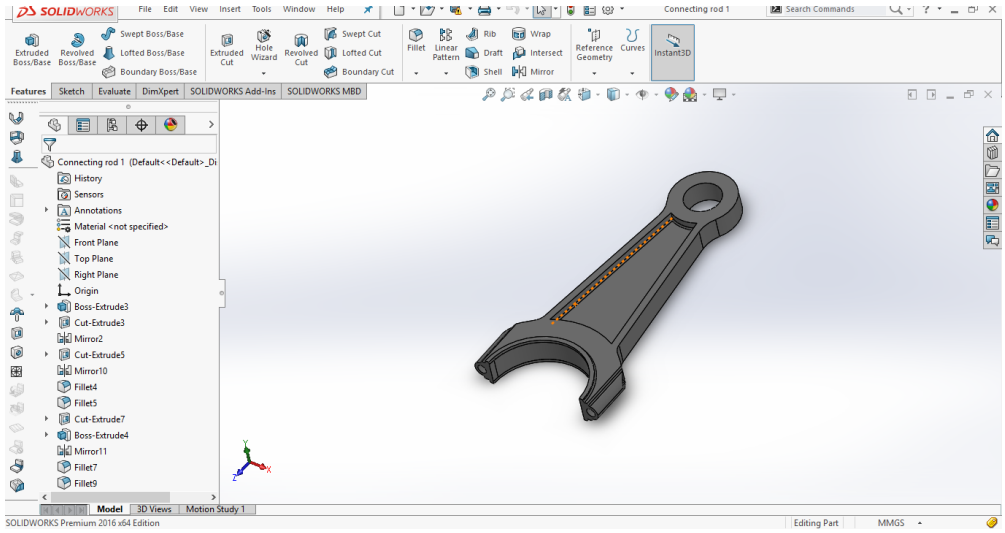

Figure 3. 3: The part model for the project