# Design of Gate Valve using SolidWorks and Analyses of Fluid Flow of the Gate Valve using SolidWorks Flow Simulation Software

Wan Hanif Hazwan Bin Wan Suhaimi
Faculty of Electrical Engineering
Universiti Teknologi MARA Malaysia
40450 Shah Alam, Selangor
E-mail: re_wan@yahoo.co.uk

*Abstract* – **This paper presents the design of gate valve using SolidWorks and the analysis of the gate fluid flow using SolidWorks Flow Simulation software. The scope of this project focus on two parts, firstly design of gate valve and secondly on analyze the fluid flow of the gate valve being designed. The gate valve was designed in detail with two and three dimensional model that consists of parts, assembly and drawings. The SolidWorks Flow Simulation was used to test the effectiveness and limitation of the gate valve that has been designed. The gate valve also has been analyzed by using fluid to observe the reaction of the gate valve. This gate valve has the ability to cut through liquids, very durable, and it is mostly used in the petroleum industry.**

***Keywords: Gate Valve, SolidWorks, SolidWorks Flow Simulation***

## I. INTRODUCTION

In recent years, gate valve has increased tremendously and often used in the petroleum industry for on-off service. Gate valves are widely used in the control situation because of the ability to cut through liquids. Gate Valve also known as sluice valve can be defined that closing or modifying the passage through a pipe, outlet, and inlet in order to stop, control or allow the flow of a fluid media [1]. In piping design the valve probably require more engineering effort than any other piping component.

Gate valve are often used when a straight line flow fluid, as it is primary used to prevent the flow of liquids. Therefore, the use of gate valve occurs with high initial cost and requires complex and tedious attachments and fittings, unless they are specifically designed for the purpose of controlling the flow of liquids [1, 2]. Hence, there is need to design a gate valve that require an economical which can be easily implemented and can be observe with primary method of control the flow simulation based on pressure, velocity and density.

Nowadays, there are various type of software that can help engineers and drafters to allow them to design in the shortest time possible at lower cost in their development task. Currently, there are software that enable for the designer and drafter to design and simulate any type of object into three dimensional (3D). Previously, there are several type of software that has been produced that commonly used by the designer and drafter for example arc Pro/ENGINEER, UG, 3D Studio Max, etc that also can produce 3D [3].

This paper presents the design of gate valve using 3D Computer Aided Design (CAD) software that called SolidWorks. SolidWorks software has chosen as it had previously been used by other researchers and was able to help by designing new method of developing models of products, shorten development time, improving product design and increasing product performance in computer [3, 4].

SolidWorks software is a flexible and versatile that helps designer and drafter in term of shorten the development time, increase the speed to design and able to changes the gate valve design easily. The objective of this project is to facilitate the following goals by using the SolidWorks software.

- To design the gate valve which to understand the 3D geometry models.
- To analyze the movement of the gate valve operation by using motion study.
- To analyze the parameter of pressure, density (fluid) and velocity of the liquid inside the valve by using SolidWorks Flow Simulation Software.

## II. METHODOLOGY

Methodology is one of the important sections in the technical paper, it is the way to show all the works and process that have to go through to complete the project. Figure 1 shows the flowchart of SolidWorks for this project that contains four important sections which are parts sketching module, parts module, assembly module and drawing module.

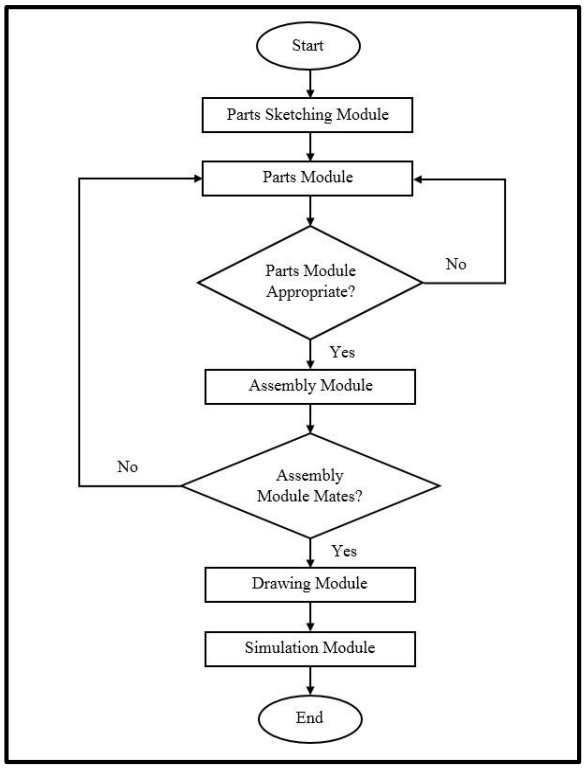


Figure 1: Methodology Flowchart

### A. *Parts Sketching Module*

Sketch drawing is the basis for creating an initial drawing for designers and drafter to come out with the ideas to illustrate the objects to be designed. All the dimension parts in gate valve must be in sketch drawing before it can proceed to design part using the SolidWorks software. In latest SolidWorks, it provide a smart dimension tool where the object can be measured automatically with a desired need and it makes the sketching become faster and easier.

### B. *Parts Module*

The parts module in SolidWorks is to build a simple 2D sketches in advance sketching command manager which consists of geometry such as circle, lines, trims, convert entities, mirror entities, etc and transform it into 3D modelling by using features such as extruded boss, revolved boss, fillets, extruded cut, swept cut, holes, etc.

Besides that, the user interface functions that provided in SolidWorks are user friendly. It offer a wide range of tools that consists of the major elements which is first the Graphics Window where all action take places, second the Feature Manager which the lists of all the features in the part, third the Property Manager where most of the data input activate and last but not least the Command Manager where most of the commands will be access in the software [5].

### C. *Assembly Module*

The assembly module is where all the individual part in parts module are combine together to become a completely 3D object. There are two type of design methods which is Bottom-up and Top-down design or it can be combined with both methods. As for top-down design, the combination of one or more features of a part can be design in the assembly such as resize or correct the model parts. The design intent comes from the assembly and moves into the parts module [5].

In assembly, mates are important in combining one or more parts it creates geometric relationships between assembly components. In SolidWorks, mates property manager provide a various selection that helps to combine the parts such as coincident, concentric, distance, gear, screw, etc. Besides that, the assemble parts can be create a rotation and exploded view by using the interface called motion manager tools. The motion manager enables to create animations showing motion of parts and assemblies based on a timeline and the results of any of the motion capabilities are called motion study [5]. There are three primary methods of creating motion in assemblies which are animation, basic motion and motion analysis.

*D. Drawing Module*

The final section in the flowchart is drawing module that creates either from parts or assemblies in various type of format such as ANSI, ISO, DIN, etc. Views are automatically generated by the each part and dimension can be easily added to the drawing as needed [6].

## III. DESIGN AND SIMULATION OF GATE VALVE

*A. Design And Assembly Of The Parts Of The Gate Valve*

The design and assembly of the gate valve procedure was followed the flowchart in Figure 1. The dimension of each part was defined properly in order to mates together in assembly process to become a complete model [4]. Each part of the gate valve that already mates together could not have any gap between them, as they will face a problem when a simulation study is carried out. All of the parts are given names to make all the procedure neat and orderly. The parts called hand wheel, busher, gasket, lock handle, valve body, bonnet, valve pipe and valve stem.

After part modelling, the individual part was assembled into a single assembly file. The movement and animation are introduced in motion study by using the rotation, key frames and exploded view for a better result. SolidWorks then are used to proceed for the simulation study.

Figure 2 (a) shows the four different views, it display a four view viewport with 1st or 3rd angle projection. Figure 2 (b) shows the exploded view of the complete components that were used to assemble the gate valve.

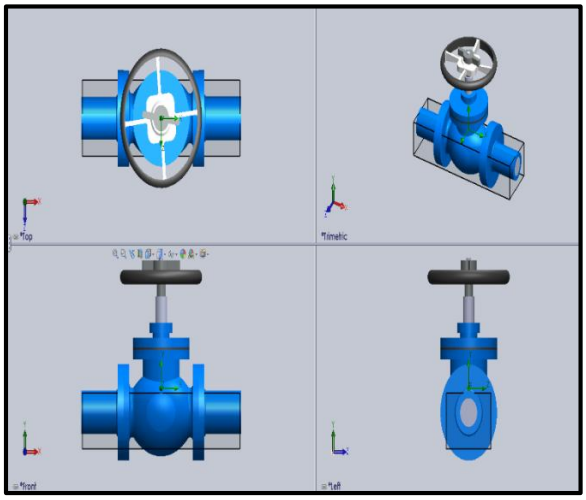

Figure 2 (a): Gate Valve with 4 different views

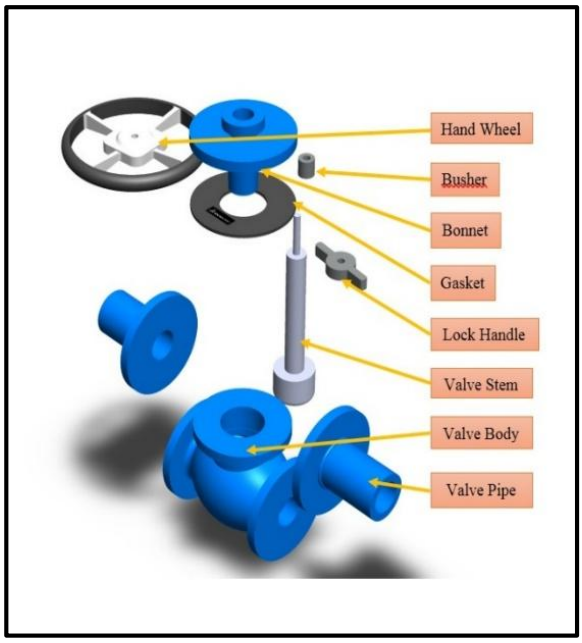


Figure 2 (b): Exploded View of Gate Valve

Figure 3 shows that a complete assembly of the gate valve and a motion was created for each part in this assembly file.

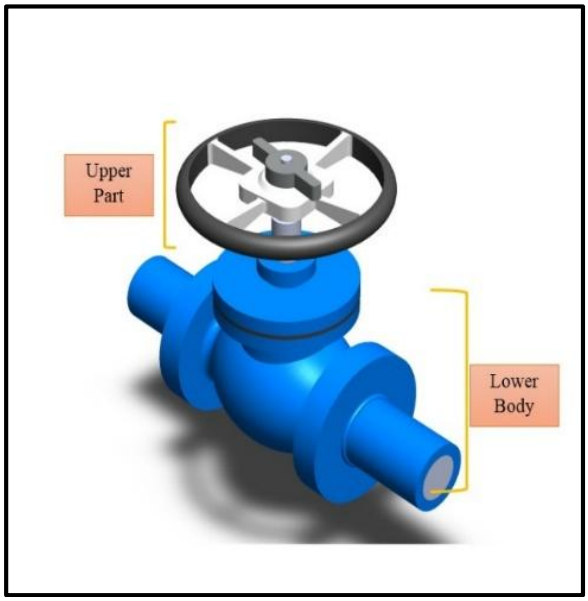


Figure 3: Complete Assembly of Gate Valve

### B. *Simulation Of The Gate Valve*

Simulation study has been introduced in SolidWorks to allow engineer and drafter to perform analysis to solve problems in real world into a simulation in order to reinventing existing methods towards better results. Valve body will be selected at a specific region by the boundary conditions to be analyzed. The analysis will be carried out on pressure, density (fluid) and velocity that give the valve body impact when the liquids flow into gate valve. The selection of the materials of the gate valve model is depends on the fluid properties and details of the specification. The properties of the fluid to be controlled have a major impact on the design and material of construction of the valve. Thus, the valve must be suitable to handle all the factors for example corrosion, erosion and the most important consideration is the internal and external leak tightness when handling explosive fluids.

## IV. RESULT AND DISCUSSION

The complete assembly model of the gate valve was assembled using a combination of the user interface and after that was tested by using the flow simulation study and its operation and movement was analyzed using the motion study [4].

### A. *Flow Simulation Study*

Analysis of the valve body has been conducted on various parameters such as pressure, velocity and density (fluid) that coming out from the valve body during the flow simulation process and the water flow was used as a fluid.

When placing an obstruction in line of flow will have two effect which are pressure on upstream will go up whereas pressure on downstream will go down and flow will be lowered. By referring the formula, the value of flow rate can be obtained. The equation (1) stated as below:

$$Q = k\sqrt{P2 - P1} \text{ ---------- (1)}$$

Where:

Q = flow ($litres/m$)

k = constant that is set by the geometry usually the flow of water through a valve at $20^0$C in $litres/m$ with a pressure drop of ($1Pa$)

P2 = upstream pressure ($Pa$)

P1 = downstream pressure ($Pa$)

Velocity of the fluid can be measured by using the following formula (2):

$$Q = V/A \text{---------- (2)}$$

Where:

Q = Volumetric flow rate in units per units of time

V = velocity of the fluid

A = cross-sectional area of the pipe

#### a. *CASE 1 - Flow Simulation Analysis of the Gate Valve in OPEN CONDITION*

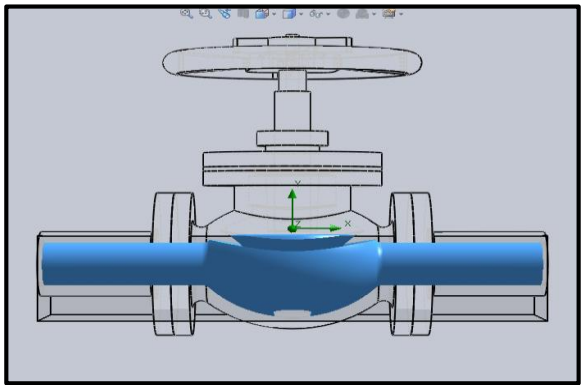

Figure 4: Solid Body Assembly of Gate Valve with the Pipe in Open Condition

Case 1: The analysis of the valve body was carried out on the internal part which is open condition. Figure 4 shows the solid body assembly of gate valve in open condition and the boundary condition. The fluid volume in valve body has been checked and the value was $0.00230381m^3$ and for solid volume the value was $0.00797963m^3$. The mass flow boundary conditions were set on the inlet pipe of the valve body and the flow rate was set to 1kg/s. The environment pressure boundary conditions were set on the outlet pipe of the valve body and the value was set to $101325Pa$ [7-9].

After applying the boundary condition, the result that obtained from the density (fluid), pressure and velocity of the streamline flow through the valve body as shown in Figure 5, 6 and 7.

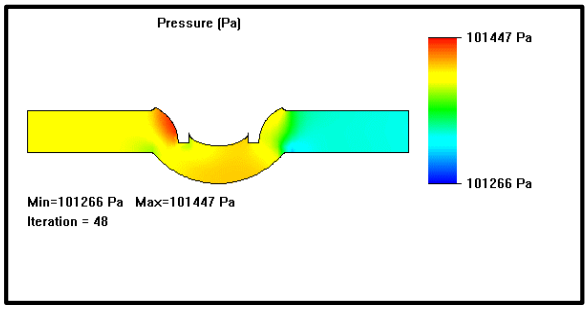


Figure 5: Pressure Streamline Flow in Open Condition

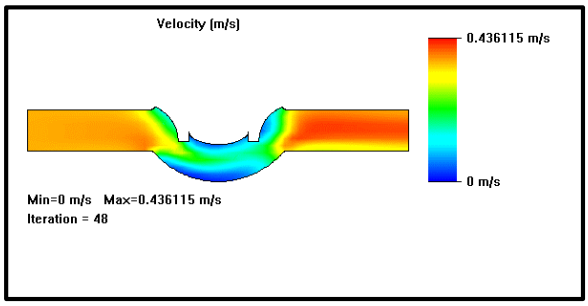


Figure 6: Velocity Streamline Flow in Open Condition

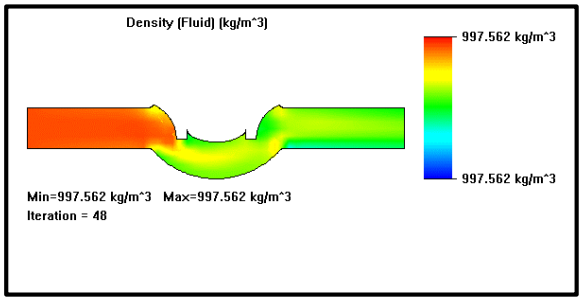


Figure 7: Density (Fluid) Streamline Flow in Open Condition

Figure 5 shows the pressure test results. When liquid is applied, pressure at the valve wall get an impact and the result indicated a maximum value of $101447Pa$ and a minimum value of $101266Pa$. Figure 6 shows the velocity test results. When liquid is applied, the fastest the fluid is flowing the more inertia it have and result indicated a high value of $0.436m/s$ and a low value of $0m/s$.

Figure 7 shows the density test results. When liquid is applied, pressure may effect the density of fluids and can be alter the accuracy of the measurement and result indicated a value of $997.56kg/m^3$. All the test results of the events and list of goals has been calculated using SolidWorks solver with 48 iteration, Figure 8 shows the solver for the test result.

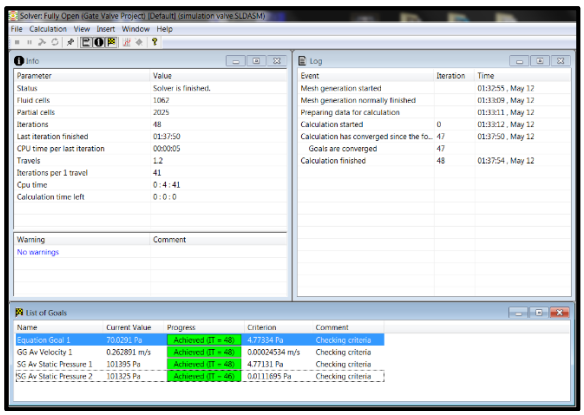

Figure 8: SolidWorks Solver For Open Condition

b. *CASE 2 - Flow Simulation Analysis of the Gate Valve in CLOSE CONDITION*

The analysis of the valve body remains the same as in Case 1, which was on the internal part. The boundary condition for the close condition are the same with the open condition which it shows in Figure 9.

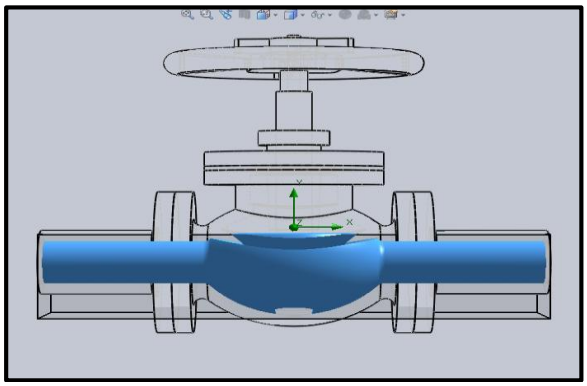

Figure 9: Solid Body Assembly of Gate Valve with the Pipe in Close Condition

All the variables in Figure 9 are remains the same with the case 1, the fluid volume in valve body value was $0.00230381m^3$ and for solid volume value was $0.00797963m^3$. The mass flow boundary conditions were set on the inlet pipe of the valve body and the flow rate was set to 1kg/s. The environment pressure boundary conditions were set on the outlet pipe of the valve body and the value was set to $101325Pa$.

Although, the variables are same but the test results that obtained was slightly difference with the case 1, except density because of the same flow rates that flow into the pipe. The result that obtained from the density (fluid), pressure and velocity of the streamline flow through the valve body as shown in Figure 10, 11 and 12.

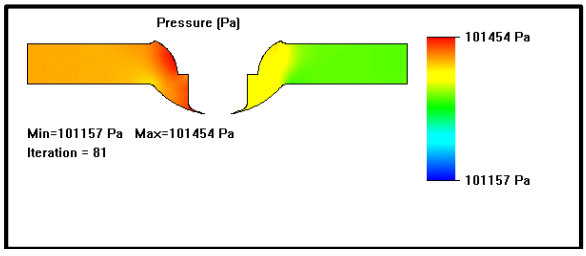


Figure 10: Pressure Streamline Flow in Close Condition

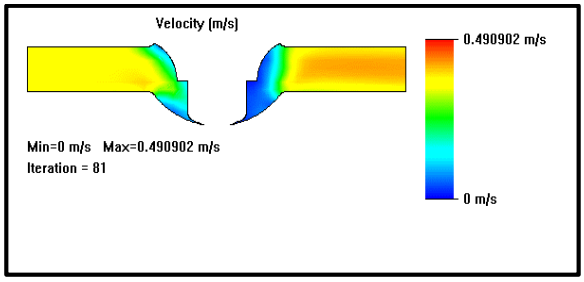


Figure 11: Velocity Streamline Flow in Close Condition

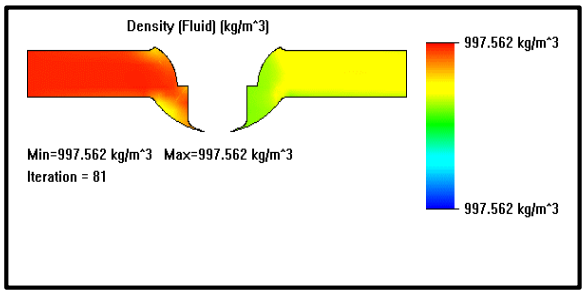


Figure 12: Density (Fluid) Streamline Flow in Close Condition

In close condition, when liquid is applied, pressure at the valve wall and wedge has higher impact due to no space for the liquid to flow. The pressure at the inlet pipe almost at the maximum value and outlet pipe like not having any pressure on it and the result indicated a maximum value of $101454Pa$ and a minimum value of $101157Pa$ as shown in Figure 10. Figure 11 shows the velocity test results. When liquid is applied, it is observed that the fluid flow through the inlet pipe is very fast and the inertia is very high and result indicated a high value of $0.490902m/s$ and a low value of $0m/s$ compared to the open condition in Figure 6.

Figure 12 shows the density test results. The result in case 2 is same with case 1 because of pressure on both cases may effect the density of fluids and since it used the same liquid (water) so the result indicated a value of $997.56kg/m^3$. All the test results of the events and list of goals has been calculated using SolidWorks solver with 81 iteration, this solver take a longer time to solved due to the close condition. Figure 13 shows the solver for the test result.

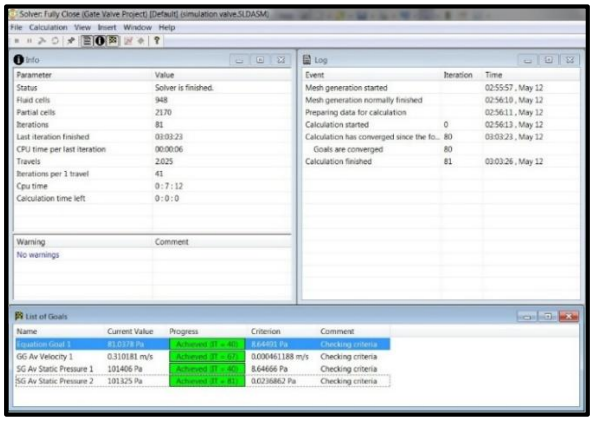

Figure 13: SolidWorks Solver For Close Close Condition

### B. *Motion Study*

The motion analysis was carried out the movement of the gate valve. The timeline for the gate valve is shows at Figure 14 below.

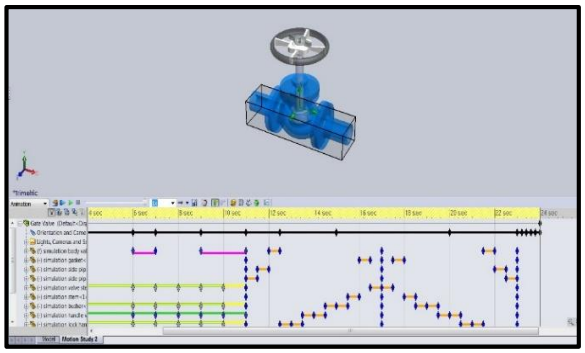

Figure 14: Timeline for the Gate Valve

The timeline that shows in Figure 14, at 0s until 6s time bar was the movement of the gate valve from trimetric to front view. Then, at 6s until 11s time bar was the movement of the hand wheel with the valve stem from open to close valve. Moving on, at 11s until 17s time bar was the exploded view of the gate valve of each parts. Finally, at 17s until 23s time bar was the collapse view of the gate valve of the each parts and the gate valve will rotate 360 degree 2 times to completed the animation.

## V. CONCLUSION

This paper presents the design, modelling and assembly of the gate valve by using the SolidWorks 3DCAD software. The analysis is done using the SolidWorks Motion and SolidWorks Flow Simulation Software. The SolidWorks simulation is easy to use and it able to detect errors quickly in the design of the parts. By applying the boundary condition, it able to test or calculate various type of parameters on the model for the analysis. Flow simulation can determine a value of maximum and minimum of the gate valve and the pipe. A starting point can get more details on the analysis with the actual performance trial of the gate valve. The analysis of the simulation and motion study able to shortened the design period and improve the modeled efficiency. The flow simulation study enabled pressure, density and velocity analysis to ensure the flow rate are safety for the valve body. The motion study helps to develop the movement of the model to be realistic.

## VI. RECOMMENDATION FOR FUTURE DEVELOPMENT

In SolidWorks, there are certain sections that can be improved. Integration of SolidWorks with LabVIEW allow customs to develop their motion control algorithms and use the 3D CAD model created within SolidWorks to evaluate the system behavior and performance. By applying realistic motion control, engineer and drafter able to simulate real-world operating conditions for the design model, check for colliding parts, output numerical and graphical results and use the CAD model for 3D visualization.

## VII. ACKNOWLEDGMENT

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