Wind load effect on train station

by

Mohd Fahmi Abdul Rahim

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

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(Dr. Ahmed Maher Said Ali)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2009

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.

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MOHD FAHMI ABDUL RAHIM

ABSTRACT

This project investigates of the effect of the pressure distribution of a journal bearing by varying the viscosity of the lubricant. This paper mainly consists of two parts which is experimental and theoretical calculation. In the experimental work, the journal bearing system is tested with different viscosity of the lubricant. There are four samples of the lubricant which is tested in this investigation. The data collected from the experiment is plotted in radial plot to give the picture of the behavior of the pressure distribution for a particular lubricant. Whereas, for the theoretical calculation part, a study of the Reynolds', Sommerfeld's and Ochvirk's pressure distribution model is performed and selection of which solution is the most suitable to be used in this project is made. A comparison of the experimental and theoretical result is made and the analysis is performed and discussed. Finally, recommendations are made to the selected model to help to increase the accuracy of the predictions of the pressure distribution of a journal bearing.

ACKNOWLEDGEMENT

I would like to express my full gratitude to all who have helped me directly or indirectly to complete this project. First of all, I would like to thank my supervisor of this project, AP. DR.Ahmed Maher S. Ali, who has been supporting me greatly by offering his knowledge and wisdom in completing this project.

I also would like to thank my family and friends who have been giving me supports, and advice. Their love and care inspires me to work hard for this project and to achieve the expected objectives.

Next, I also would like to thank the laboratory technicians, Mr. Hazri and Mr. Zailan, who have been so supportive and helpful to me since Final Year Project 1 until the end. They had provided me with advices, guidance, ideas and their experiences to help me to attend to any difficulties and problems encountered.

Lastly, I would like to thank my sponsor, PETRONAS, who have been giving me funds for this project. The opportunity given by them to study here in Universiti Teknologi PETRONAS is very priceless and I appreciate their generosity.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

High-speed train is a type of passenger rail transport that operates significantly faster than the normal speed of rail traffic. Specification definition for high-speed train include its speed – 200km/h or faster. Railways were the first mass transportation, and even after the development of motorcar in the early twenty century, this mass transportation still is using and monopoly on land transport. Railway companies in Europe and the United States used streamlined trains since 1933 for high speed services with an average speed of up to 130 km/h (80 mph) and top speed of more than 160 km/h (100 mph).

However, high-speed train has its own effect or known as 'aerodynamic effect' to a surrounding, especially went this transport passing through the train station. By this effect, people standing near the passing through by high-speed train will felt the effect and this effect also could affect the structural of train station itself. Aerodynamic effect will caused the pressure distribution that caused by high-speed train passing through the station, the vibration of station structure (especially windows), and the airflow that induced by a passing train at station.

Aerodynamic effect of high speed train can be investigated by some research. Most researchers used two type of research which are by wind tunnel experiment, and simulation of passing train at station using Computational Fluid Dynamic such as STAR-CD. Wind tunnel experiment is more expensive and need much time to conduct the wind tunnel test. Therefore, many researchers tend to do Computational Fluid Dynamic simulation because it can replace the expense and time spent conducting wind tunnel experiment.

This research is to enhance the safety consideration at every station. Station need to be stable enough to withstand the aerodynamics effect. So, there need a research to conclude the safe design of train station. But, this safety consideration is not only for the station. The passengers also need to be taken into that research to make sure there is no accident in train station that involved the passenger. Thus, there have a few studies to conduct based on these issues.

The first was a computational fluid dynamics analysis result for aerodynamic forces created by high speed train passing high and low level platforms. Secondly, the field measurements using pitot-tubes to determine the airflow induced by high-speed trains and comparing result with computational fluid dynamic result. Thirdly, study used computational fluid dynamic analysis and rail dynamic simulation programs to evaluate the effects of high-speed trains on lightweight freight equipment operating on adjacent track.

1.2PROBLEM STATEMENT

There have a few problems that need to be investigating which are aerodynamic pressures that generated from passing trains, airflow that induced by passing trains, and the structural loading that caused by aerodynamics effect.

- **Aerodynamic Pressures Generated from Passing Trains**
  A moving train creates a pressure distribution from the flow field surrounding it. The pressure is generally near along the length of the train**,** until the rear of the train is reached**,** where the pressure rapidly changes. The differences between maximum pressure and negative pressure and the time interval between those pressures will be the parameter of interest which will act as a force on structure at train station.

- **Airflow Induced by a Passing Trains**

  A moving train will produce viscous effect surrounds it. When the train drags along air, it will produce a boundary layer that grows outward down the length of the train. The effect is, people that near to the track of passing train will feel the wind as a effect from airflow induced by a train.

  Moving train also leave turbulence wake at the rear of train.. This turbulent wake occurred when the moving air along the train mixing with the surrounding air. Turbulent wake occurred when moving air along the train mixing with the surrounding air. The effect of this mixed air in moving train, air will spread rapidly and this mixed air will leave behind and cause a turbulence wake. In energy balance theory, air will dissipates its energy during turbulence wake happened and it will cause a vibrating which at a maximum just after train passes and then it will reduces after passes train proceed on its way. Turbulence wake occurred in a form of circulating motion form with very high turbulent and this will cause an object enveloped in the wake may be feel the great force change that act at any direction.

- **Structural Loading from Aerodynamic Pressures**

  Structures near the railway will withstand the velocity pressure from passing train. Therefore, structures such as buildings which alongside the railway track need to withstand the aerodynamic effect produced by passing train.

1.3 OBJECTIVE AND SCOPE OF STUDY

The main objectives are:-

- To study the aerodynamic effect of train by doing simulation in Computational Fluid Dynamic.
- Analyze the train station model in wind tunnel experiment.
- Comparison of Computational Fluid Dynamic result with experimental result.

Scope of studies in this case is included:-

- To investigate the aerodynamic effect when high-speed train move through the train station.
- To study safety consideration of train station based on velocity pressure of moving train.

Assumptions in this study included;-

- Fluid is in viscous condition
- Atmospheric pressure is always at 101.325 kPa
- The flow of fluid in station is laminar before train passing through station
- Study only about train passing through the station
- The dimension of high speed train is based on the German High-Speed Train
- The temperature is constant at 300K @ 27℃ (room temperature)
- Surface roughness of train is negligible

CHAPTER 2
LITERATURE REVIEW

Wind is a flow of air or other gases that composes in atmosphere. Wind also known as air molecules in motion. Wind is classified based on their velocity and, the type of forces that cause wind. Usually, velocity of air will cause a pressure resulting that people feel it as a wind. This air motion and its effect also can be known as aerodynamic effect.

Previous research, Wind Load Simulation for High-Speed Train by Hur, N. et al. (2008) had done some study about high-speed train aerodynamic effect. They did both experimental analysis and numerical analysis. The numerical analysis actually used Computational Fluid Dynamic software, STAR-CD. That research is more to design a safe station by finding pressure distribution caused by passing train on a few stations. Four stations which are Cheonan-Asan, Daejeon, Gwangmyeong, and Gyeongju had been studied by them to view and analysis the aerodynamic effect of high speed train [1]. The experimental analysis is based on the wind tunnel test, subsonic wind tunnel.

Result of this study, numerical simulations of wind load on high-speed train stations are compared to experimental result. Both analyses showed a good agreement on wind load distribution [1]. From the present study, it shown that CFD can be successfully applied to the prediction and simulation of wind loads on huge and irregularly shaped buildings, whose wind tunnel tests are expensive [1]. Hence a broad application of CFD on wind load is expected in the field of civil and architectural engineering.

In other previous research which is Assessment of Potential Aerodynamics Effect on Personnel and Equipment in Proximity to High-Speed Train Operations by Office of Research and Development Washington D.C (1999), it showed the theories of aerodynamic effect. As the train speed increases, the acceleration of train also increase which resulting the increase of force [2]. These forces can have an adverse effect on adjacent properties and might jeopardize the safety, comfort and possibly endanger people life near the track [2]. These effects consist of pressure variations resulting from the moving train's flow field interacting with another nearby train or structure, and of wind produced by the air being carried along with the train [2]. These effects are consistent with the operation of high-speed trains, and aerodynamics issues is the main criteria that need to be focused to ensure that it is not jeopardize the near people and adjacent structure [2].

A moving train dragged the surrounding air with it, resulting in airflow that people near will felt it as wind [2]. This induced airflow arises at two critical flows which are the boundary layer formed along of moving train and the wake at the rear of the train [2]. Since the air at the surface is moving at the same speed as the train, a train traveling at high speed can induce high airflows near the train [2]. Figure 2.1 showed the mechanism of airflow induced by a passing train. One example of turbulence wake effect, it can stir up the debris near the airflow that induced by a passing train [2]. Therefore, objects or people close to a train passing at high speed can experience high wind forces.

Aerodynamic effect also can affect people surround and equipment too. Based on the explanation above, the pressure distribution that had been produce by an aerodynamic effect can make surround people felt the pressure from moving train. Figure below show the pressure differential that felt by a passenger in 1-meter away from the moving train.

Trains passing through a station at high speed generate a pressure wave that can have a jeopardize effect on the eardrums of people on the platform [2]. The magnitude of the pressure change depends on the design or geometry of the train nose**,** and the person's distance away from the passing train [2]. Figure 2.2 showed that the pressure felt by a people with multiple distances.

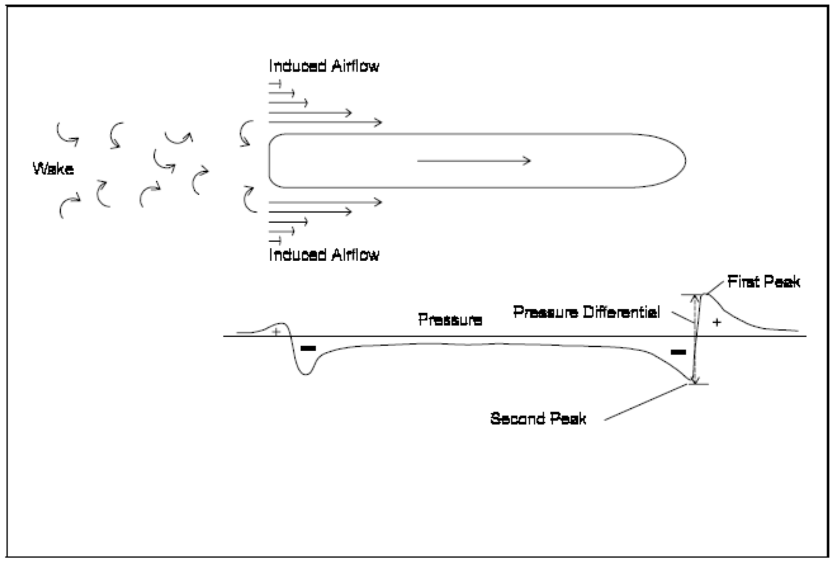

Figure 2.1 Airflow induced in moving train (Office of Research and Development Washington D.C, 1999)

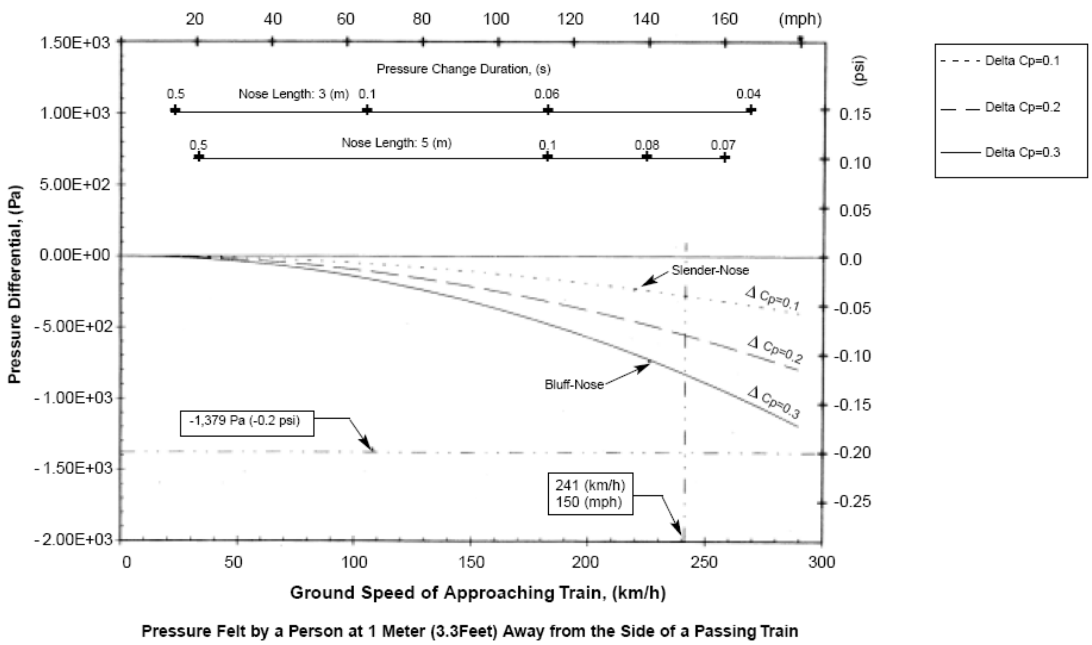

Figure 2.2 Pressure Felt by a Person at 1 Meter (3.3 Feet) Away from the side of passing train (Office of Research and Development Washington D.C,1999)

Carrarini, A. (2006), in Reliability based on analysis of the crosswind stability of railway vehicles, had use the German high-speed train as their sample work to study the stability of railway vehicles during crosswind. This journal also mentioned the approximate dimension of German high-speed train. Carrarini, A. also mentioned that aerodynamic coefficient is absolutely necessary to know the aerodynamic load but aerodynamic loads is only depend on the yaw angle which the angle between longitudinal axis and line of travel [3]. Thus, this coefficient is necessary in crosswind study because of yaw angle between crosswind and line of travel. Below is the table of the basic quantities of train [3].

Basic quantities of the vehicle (approximated)

Basic quantities of the vehicle (approximated)	
Overall height, H	3.8 m
Overall length, L	26 m
Overall width, W	3 m
Gauge	1.4 m
Overall mass	40 t
Vertical stiffness of secondary suspension	170 – 1700kN/m

Table 2.1

Ragunathan, R.S in “Aerodynamic of High-Speed Railway Train” also discuss about the aerodynamic drag and mechanical drag that occur in high-speed train application. Ragunathan, R.S mentioned that the aerodynamic drag is directly proportional to the square of speed and the mechanical drag is directly proportional to the speed [4]. The aerodynamic drag become larger due to velocity increases compared to the portion of mechanical drag [4]. Total drag on train travelling also can be concluding as the sum of aerodynamic drag and mechanical drag [4].

In aerodynamic drag, there can be divided into two contributions which are the dependent of train length and independent of train length. The drag independent of train length is the pressure drag caused by a force and the turbulance wake of train and for the drag dependent, is not easy to assume it because it involve all kind of drags occuring in the connecting parts of between train and strucutre under train [4].

Macneill, R.A. et al. (2002) in Measurement of the Aerodnamics Pressures by a Passing Train discussed about the sensible approach by Computational Fluid Dynamics to studying the aerodynamic loads of passing train. The main difficulties in using a numerical study is about the changing geometry of passing train and unsteady airflow [5]. Those researchers simplified the difficulties by assuming that viscous forces on the passing train are small and the aerodynamic loads are directly proportional to the shape or design of train itself [5].

Macneill, R.A also mentioned the special method such as mesh movement, sliding interfaces or moving boundary conditions is necessary to ensure that numerical method is absloutely in control and it is important to verify those techniques by comparing CFD solution with the experimental analysis [5]. The conclusion of the CFD result is very good agreement as compared to the experimental result.

J.Y Kim and K.Y Kim (2005) in Experimental and Numerical Analyses of Train-Induced Unsteady Tunnel Flow in Subway discussed about the unsteady three-dimensional flow in tunnel subway that cause by a passing train. The experimental analysis is conducted on a 1/20 scale model tunnel and the pressure and air velocity variation with time are presented [6]. The numerical analysis is conducted by using the sharp interface method for the movin boundary of an immersed solid was carried out for some geometry configuration as the experimental analysis [6].

The model was built as $1/20^{th}$ scale of subway tunnel which is a 39 metres long, 250 milimetres high, and 210 milimetres wide [6]. For the train, it is 3 metres long, 225 milimetres high, and 156 milimetres wide [6]. Figure 2.3 showed the schematic diagram of the experimental layout.

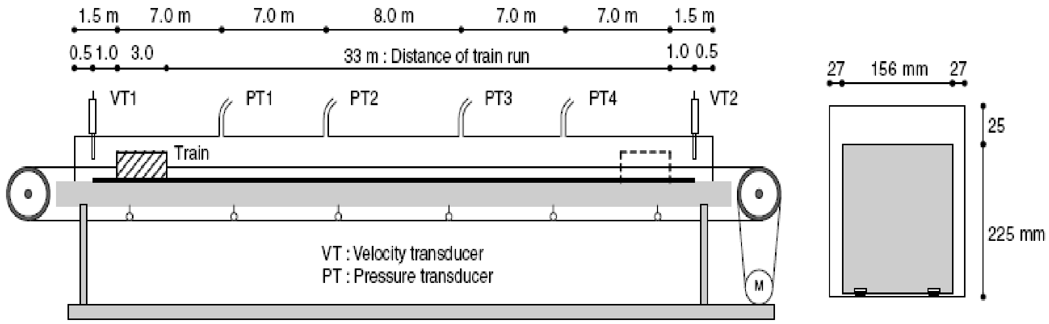

Figure 2.3 Scematic Diagram of Experimental Layout (J.Y Kim and K.Y Kim, 2005)

In numerical analysis, computational model is constructed by using CFX4, commercial CFD software. The equation for unsteady and incompressible flow is mass conservation equation and Reynold Average Navier-Stokes (RANS) equations [6]. Standard k-ε turbulence model is used for turbulence closure [6]. Figure 2.4 showed the diagrammatic representation for numerical model of train moving.

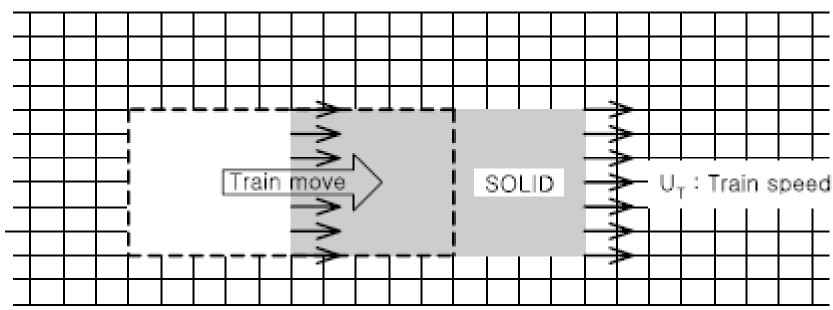

Figure 2.4 Diagrammatic representations for numerical model of train moving (J.Y Kim and K.Y Kim, 2005)

The result for experimental and numerical analyses is both analyses have suitability adoption with the:

1. As the train accelerates, pressure at front of train will rise and pressure at rear of train will drop. As train arrive its maximum velocity, both highest rise and drop pressure will occur. As train moves at constant velocity, the rise and drop

pressure will get smaller and as the train decelerates, re-rise pressure occurs at rear of train [6].

2. On the C_p variation comparison, computational variations such as pressure rise as the train approaches, sudden drop as train passes and the pressure re-rise as train decelerates are in good agreement [6].

In Railway Gazette International, it showed the dimension of high-speed train which is Pendolino Third Generation, ETR 460. This train had been manufactured since 1995 for European tour. The length of a unit is about 28-metres, 3.7-metres height, and 2.8-length. The unit designed for dc voltage 3kV continuous power is 6000 kW and can reach the top speed till 250 km/hr [7]. Figure 2.5 showed the dimension of train. This train has an aerodynamic shape that makes it move faster and based on its shape, the aerodynamics load is quite huge to surrounding.

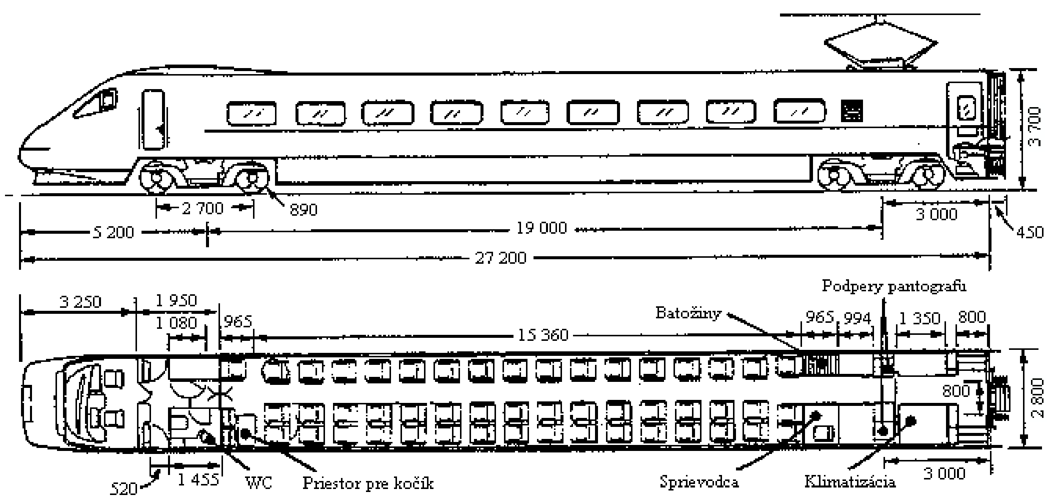

Figure 2.5 Dimension of Pendolino ETR 460 train (Railway Gazette International)

CHAPTER 3

METHODOLOGY / PROCESS FLOW

3.1 PROCESS FLOW

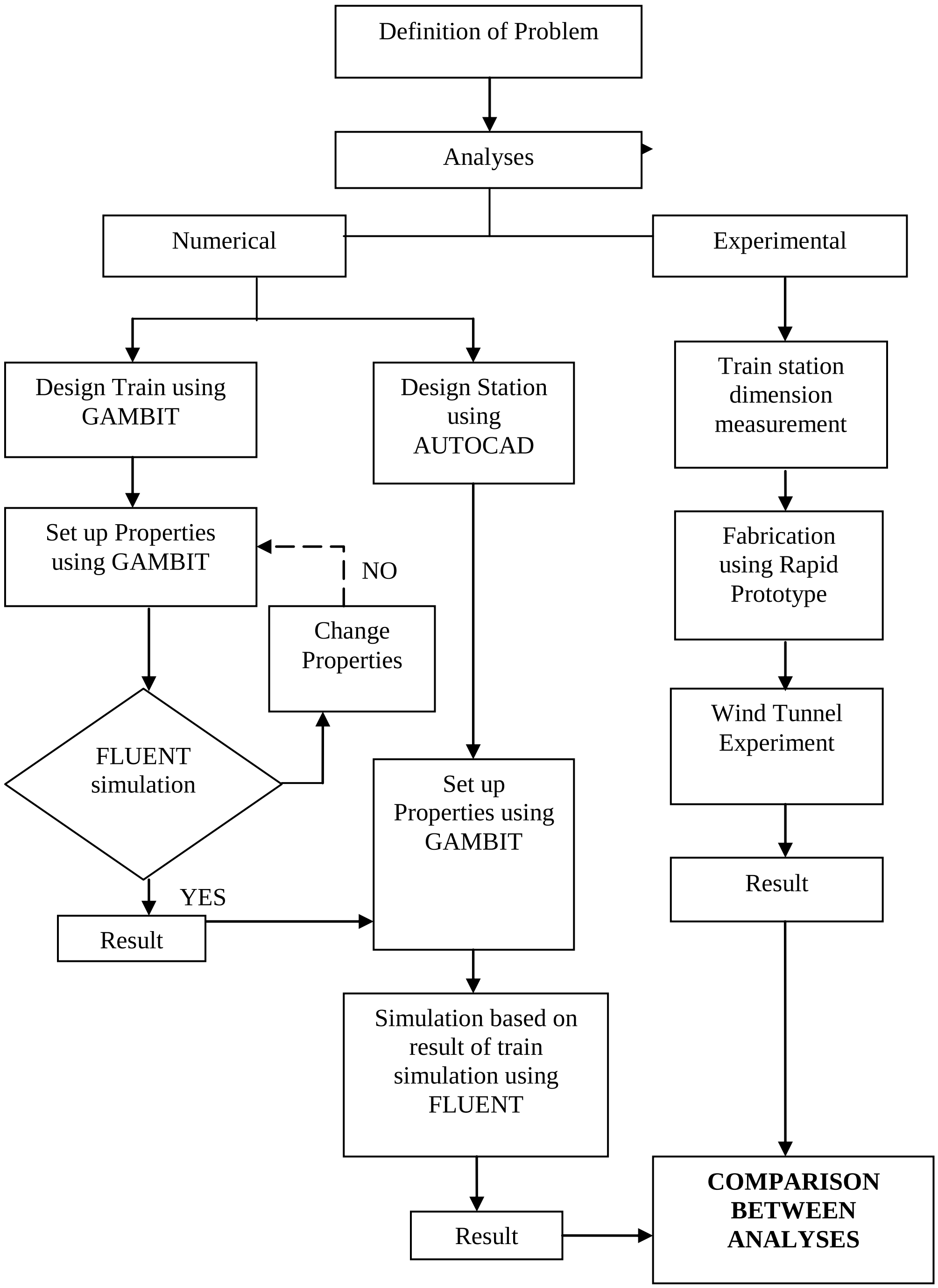

Figure 3.1 Process Flow of the Project

As the process flow chart in figure 3.1 presented, there have many stages need to be completed to achieve the objectives of this project. The objectives in this project are to run a simulation on train, analyze train station based on Computational Fluid Dynamics (CFD) and to compare result of numerical and experiment analyses. These stages have many configurations especially in design the numerical model for computational method and design the prototype or model for experimental analyses. Therefore, a next section will explain the detail of each stage in this project.

3.2 DETAILS OF STAGES

3.2.1 Definition of problem

As discussed in chapter 1 about the problems occurred in this project, we can conclude that the main cause of those problems is the aerodynamic loads and effect to a surrounding area. Therefore, researches have been conducted through journal to journal to study about the behaviors of induced airflow, characteristics of airflow, properties of wind loads, and the analyses that used by a previous research. From those researches, information about procedure and techniques has been decided to analyze this project.

3.2.2 Analyses

Two analyses which are numerical and experimental analyses will be made to achieve the objectives. By these techniques, comparison between to techniques of analyses can be made. Reason of comparison between both analyses is to view and to see either both of analyses have a suitability adoption about the result or not. Therefore, next topic will discuss about the numerical and experimental method.

Numerical Analysis

In numerical analyses, two simulation need to configure which are train simulation and train station simulation. The modeling of train and train station will be use GAMBIT commercial software as the main CFD modeling. For the simulation, FLUENT will be used as the medium to simulate the numerical model that created in GAMBIT.

Objective of simulation of train is to study and investigate aerodynamic loads that created by a moving train. Velocity pressure, airflow induced, and turbulence airflow are examples of effect of aerodynamic loads. In GAMBIT, modeling will be the main process which designing a numerical model which is a train. The train dimension is based on dimension of ETR 460 (Railway Gazette International). Another process is to make a boundary condition of the train. By this boundary condition, area will be defined for the simulation in FLUENT. Figure 3.2 showed the numerical model in GAMBIT.

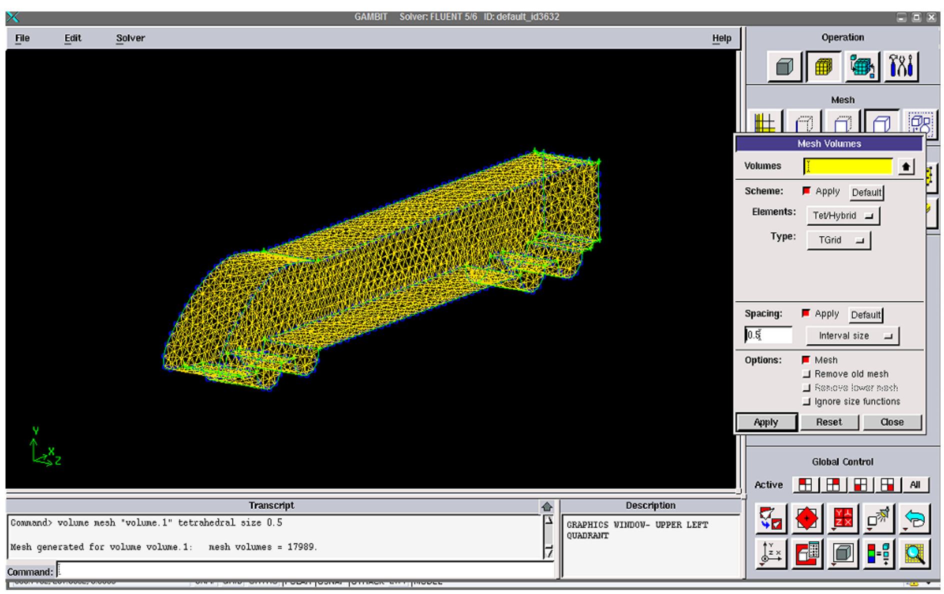

Figure 3.2 Numerical Model

In FLUENT, the main process of this part is to simulate the numerical model. By using Standard k-ε turbulence model, the turbulence airflow of moving train can be study. The velocity pressure also can be found by define the magnitude of velocity of train. The velocity of train in this simulation will be variety which are 10 m/s, 20 m/s, 30 m/s, 40 m/s, and 50 m/s.. Thus, this simulation will obtain the aerodynamic loads and its effect to surrounding during train move at variation of train speed.. Simulation will be started with 1000 iterations till the iteration is converged. By that, the result of simulation will be presented.

In train station simulation, the main objective is to investigate the aerodynamic loads that affect the station. Those aerodynamic loads actually are from the train. In other hand, result that obtains from train simulation will be used as the properties in this simulation. Therefore, from combination of this simulation, there will have a relationship between both numerical analyses. Process in this train station simulation is same with the train simulation which the main process is using GAMBIT and FLUENT but for designing the train station.

Dimension that used in train station is based on the real dimension of train station. Train station that involved in this analysis is Batu Gajah train station which belongs to Keretapi Tanah Melayu Berhad (KTMB). Figure 3.3(a) and figure 3.3(b) showed the dimension of train station in metre.

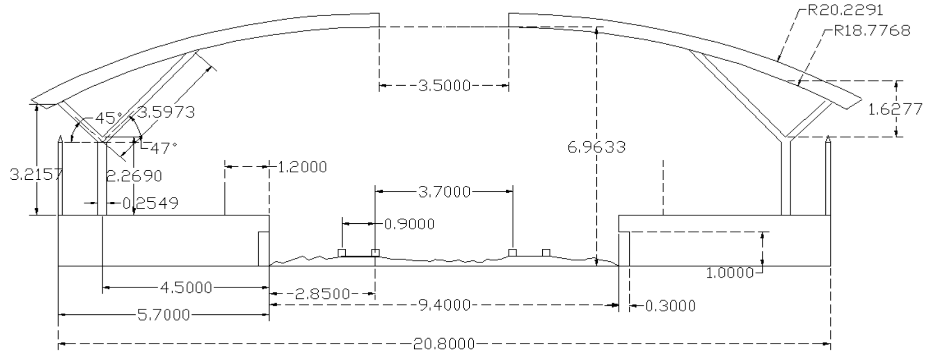

Figure 3.3(a) Dimension of Batu Gajah Train Station (side view)

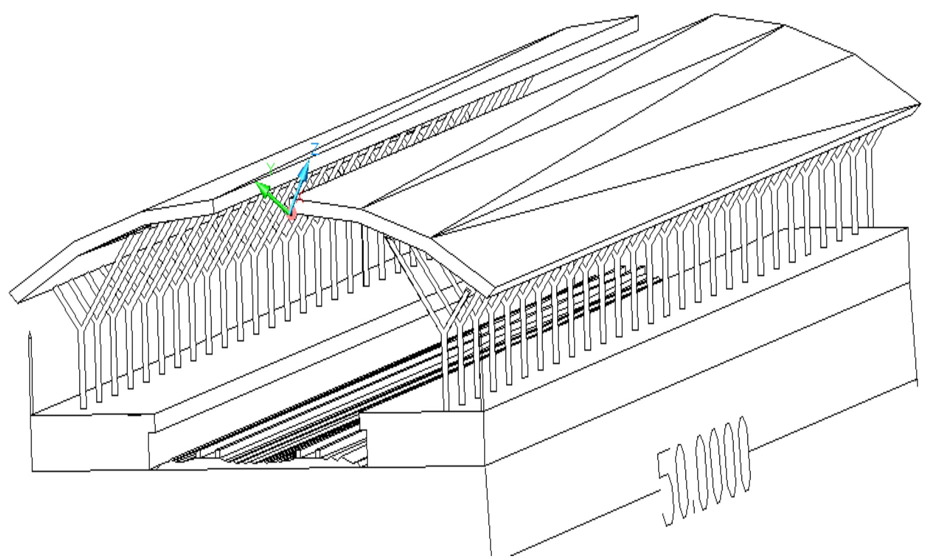

Figure 3.3(b) Dimension of Batu Gajah Train Station (isometric view)

Both figure (a) and (b) is the real dimension, but in Computational Fluid Dynamics (CFD) method, the structure that needs to be created as a numerical model is only the hollow part of the train station which the area that train will be passes through the station. Figure 3.4 showed the numerical model of train station simulation.

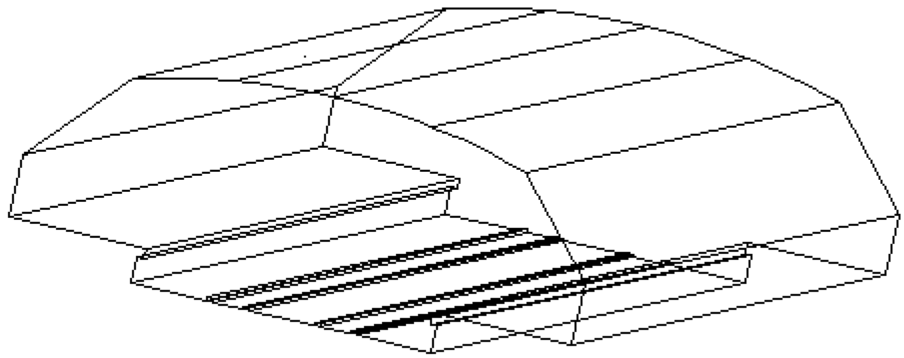

Figure 3.4 Numerical Model of Train Station

By numerical model as shown in figure 3.4, simulation will be developed based on the 1000 iteration till the iteration converged. In this simulation, this model will be monitored the aerodynamic effects such as velocity pressure, pressure distribution, and turbulence airflow as the train passed through the train station.

Experimental Analysis

Main objective of this experimental analysis is to obtain result from the wind tunnel experiment. There have two stages before wind tunnel experiment can be conducts which are dimension measurement of train station and fabrication process on experiment model.

In taking measurement of real dimension, it has been discussed in numerical analyses which Batu Gajah train station as the scope of study. Based on the objectives in the chapter 1 and section 1.3, comparison between both analyses is very important to obtain the suitability adoption of result. So, it is important to use scale down the dimension. For this model, it was be scaled to 1:200.

In fabrication process, method that used to build the prototype is Rapid-prototyping. Rapid-prototyping is an automatic construction of physical objects using addictive manufacturing technology. The use of additive manufacturing technology for rapid prototyping takes virtual designs from computer aided design (CAD), transforms the virtual design into thin, virtual, horizontal cross-sections and creates successive layers until the model is complete. It is process which any design that created is almost identical with the output. The main material that used in this fabrication is wax. Figure 3.5 showed the rapid-prototyping machine and figure 3.6 showed the experiment model of fabrication process.

Figure 3.5 Rapid-Prototyping Machine

Figure 3.6 Experiment model

This experimental model will be test in the wind tunnel equipment to obtain result of aerodynamics loads such as drag force, lift force, and velocity pressure. By this result, comparison between numerical and experimental result will be discuss to justify the suitability between both analyses. Figure 3.7(a), and 3.7(b) showed and wind tunnel picture.

Figure 3.7(a) Wind tunnel equipment (side view)

Figure 3.7(b) Wind tunnel equipment (rear view)

Wind tunnel is a duct through which air is either blown or pulled out to simulate air flow over prototype or experimental model. This model will be placed in the test section of the wind tunnel and the pressures, forces, and moments experienced by the model at various wind speeds. The results of wind tunnel can be utilized to generate the design data for the model.

In this project, the wind tunnel that be used is WT04 Subsonic Wind Tunnel. It is a suction type open circuit win tunnel designed to conduct teaching and basic research experiments related to fluid mechanics and aerodynamics.

CHAPTER 4
RESULTS & DISCUSSIONS

4.1 NUMERICAL ANALYSIS

4.1.1 Train simulation

In this simulation, the result is focused on the three variables which are velocity pressure, turbulence kinetic energy, and turbulence dissipation rate. Those variables are important in next simulation which is train station simulation because train simulations are based on standard k-ε turbulence model. Therefore, turbulence data need to be focused to ensure the result in train station simulation have a good agreement or suitability adoption between both simulation. Table 4.1 showed the result for each variable with different velocity of train.

Results in train simulation

Speed, m/s	Velocity Pressure, Pa	Turbulence Kinetic Energy, m^2 / s^2	Turbulence Dissipation Rate, m^2 / s^3
10	6.52	0.44	6.32
20	23.42	1.58	42.13
30	49.69	3.31	128.34
40	84.72	5.56	285.45
50	129.84	8.50	525.47

Table 4.1

As result showed in table 4.1, it can be concluded that those variables is directly proportional to the speed of train. It proved the theory that an aerodynamic load is increase as the train moving faster. Figure 4.1, 4.2, 4.3, 4.4, and 4.5 will showed the turbulence effects as the train increase its velocity. Figure 4.6 will show the relationship between velocity pressure and train speed.

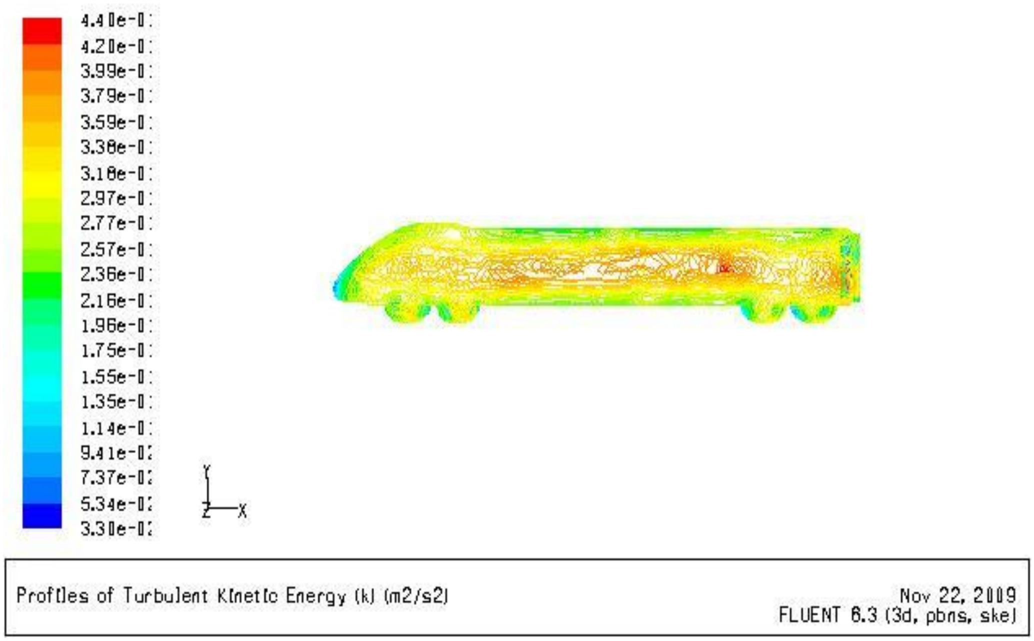

Figure 4.1 Turbulence airflow as train speed is 10 m/s

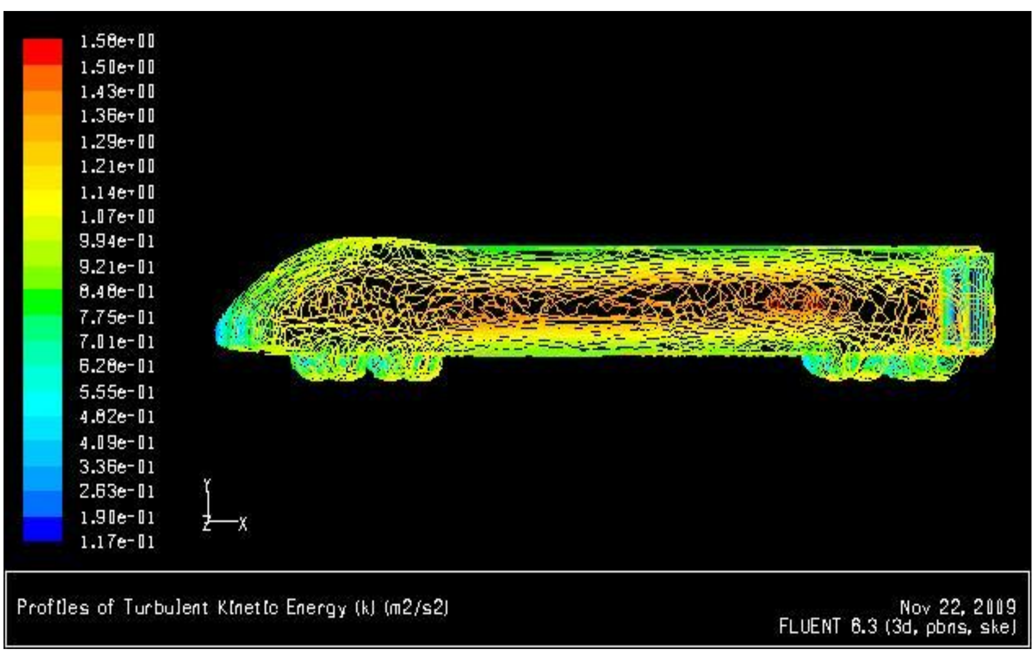

Figure 4.2 Turbulence Airflow as train speed is 20 m/s

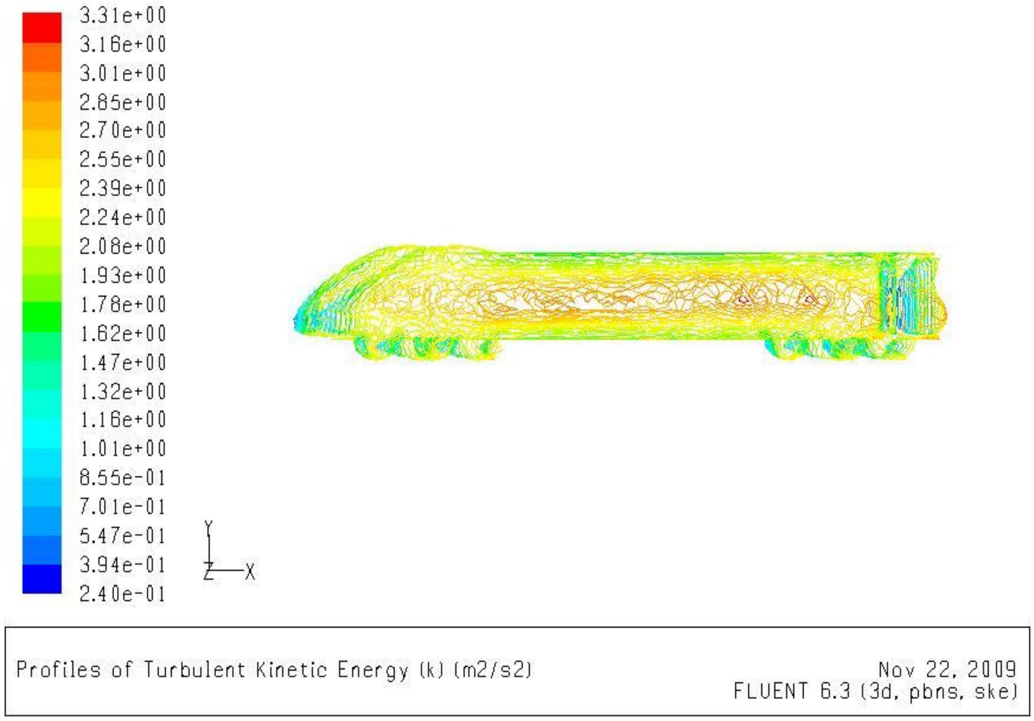

Figure 4.3 Turbulence Airflow as train speed is 30 m/s

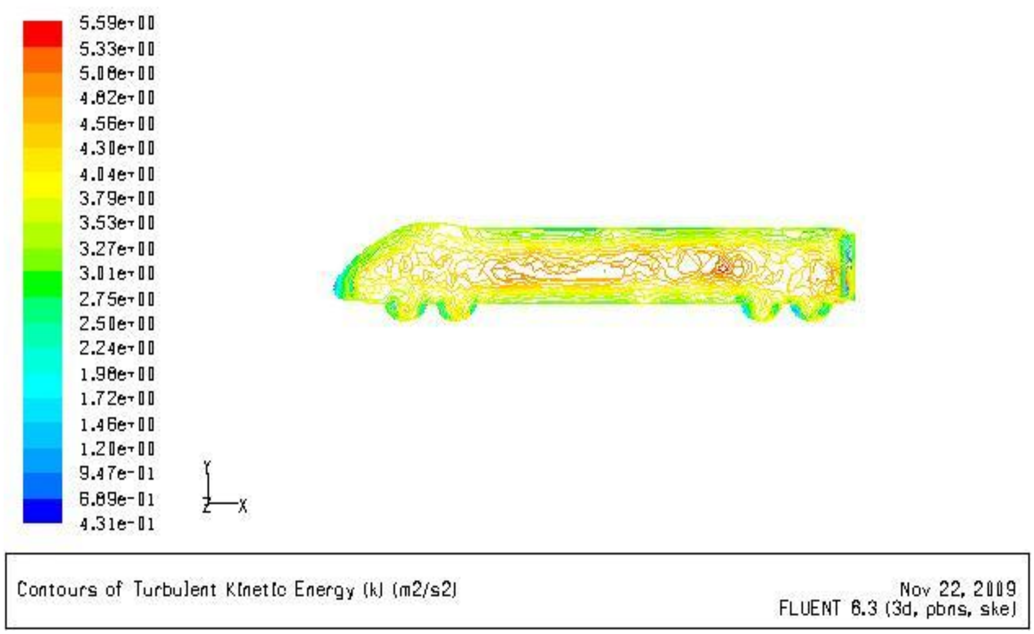

Figure 4.4 Turbulence Airflow as train speed is 40 m/s

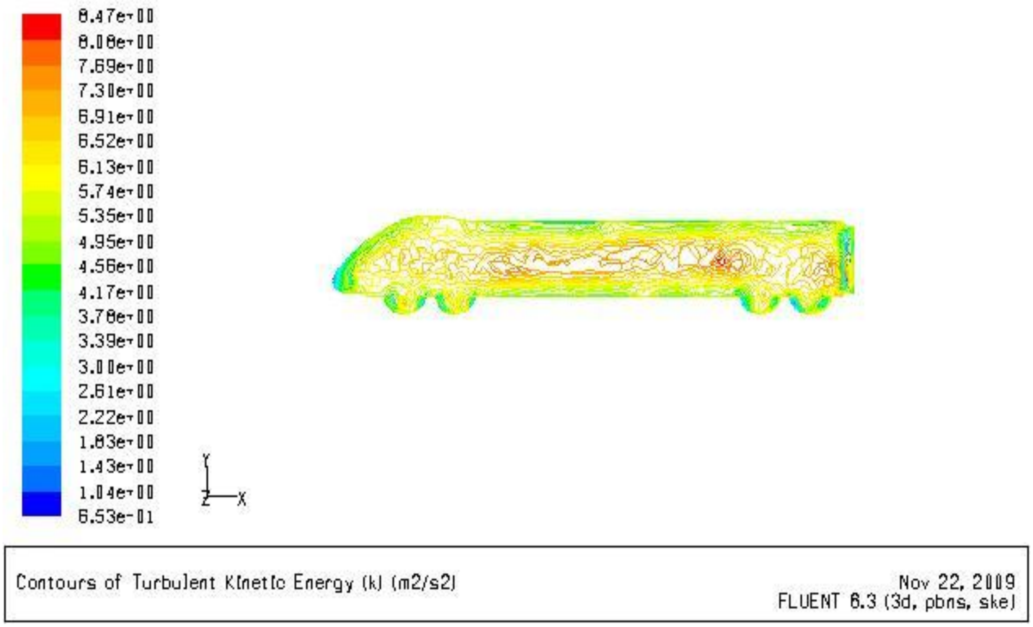

Figure 4.5 Turbulence Airflow as train speed is 50 m/s

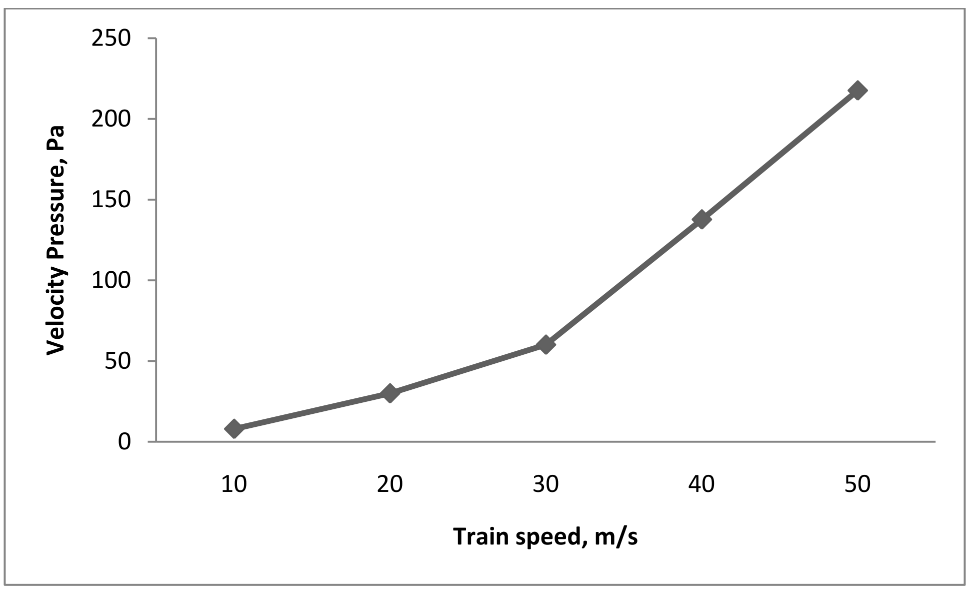

Figure 4.6 Velocity pressure versus Train speed

As a discussion for this simulation, velocity pressure is increase for every increasing of train velocity. In aerodynamics concepts, as a train started to move, the aerodynamic pressure is greater than pressure at the back. After a train achieve its maximum speed, velocity pressure will become greater at the rear of the train compared to the front of the train. This showed that in high speed, velocity pressure will be high, thus for the high velocity pressure, it caused the circulating air flow at surrounding the moving train or in other hand, it known as turbulence airflow. All the figures above proved that the air that drags along the moving train will be induced and becoming more turbulence as train speed increases. Another point that can be discussed based on the figures above, it proves that by numerical analysis, the turbulence airflow at the rear of the train is greater than the front of the train. By this, the turbulence at rear of the train can be known as turbulence wake.

4.1.2 Station Simulation

Station simulation is actually based on the result that obtained from the train simulation. By this way, the aerodynamic effect of moving train can be assumed have an effect to the station. The variables that need to obtain is the pressure on the station during the train passed through the station. Table 4.2 below showed the result of the simulation

Result of station simulation

Train speed, m/s	Pressure on station, Pa
10	7.85
20	29.85
30	60.57
40	137.58
50	217.48

Table 4.2

As a result shown from the simulation, it can be conclude that the increasing of train speed will produce high pressure on station. It can be proved in theory that train speed has a velocity pressure that can be feeling by surroundings as a wind. In this simulation, the circulating air along the train will be spread to surrounding as the train become slow when train near to stop. Figure 4.7, 4.8, 4.9, 4.10, and 4.11 will showed the pressure that experience by a station.

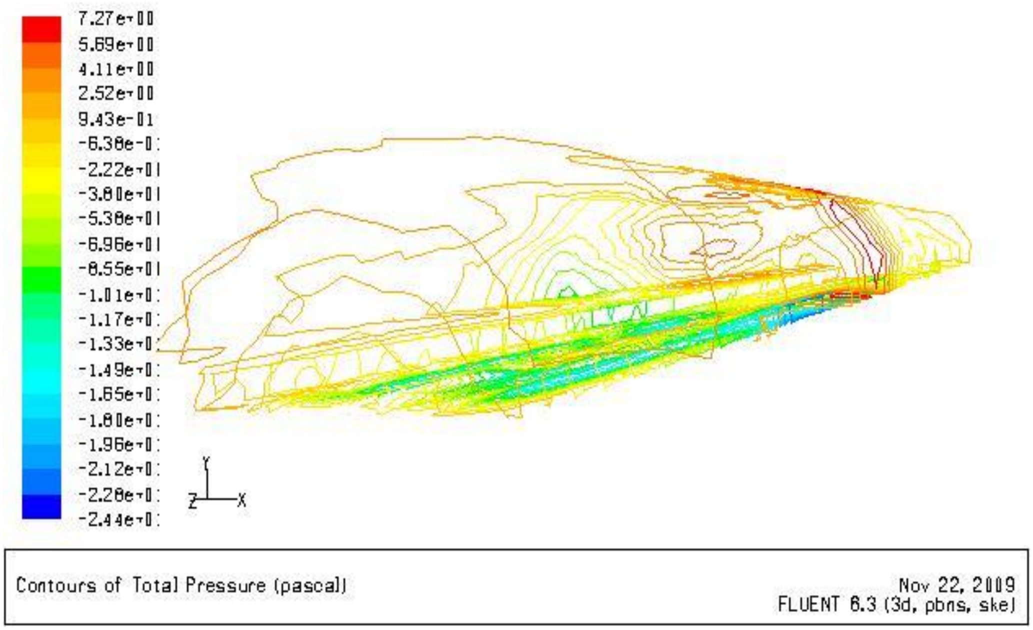

Figure 4.7 Pressure during train passes at 10 m/s

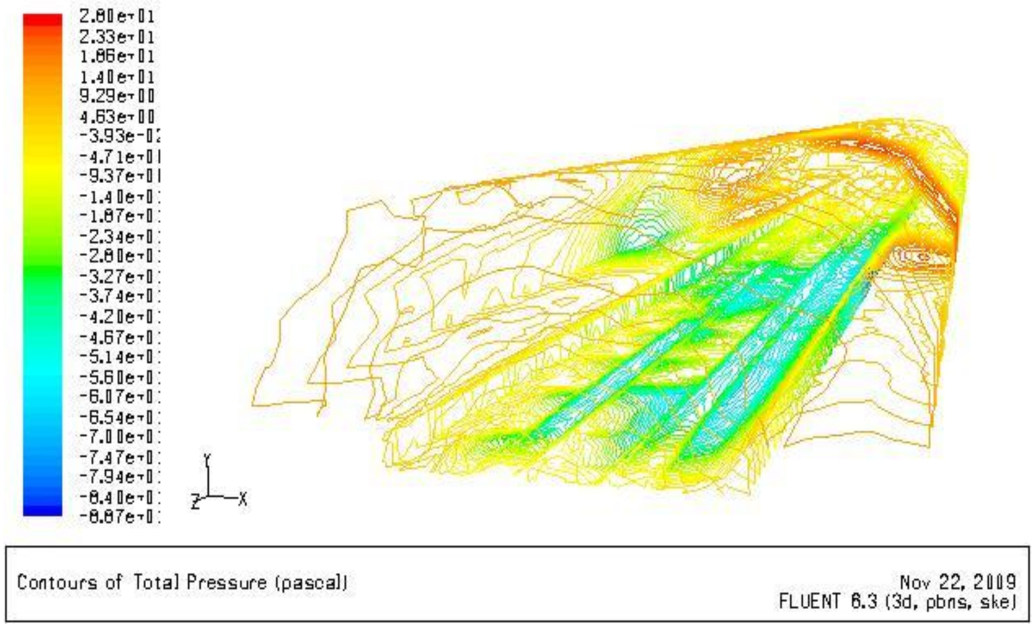

Figure 4.8 Pressure during train passes at 20 m/s

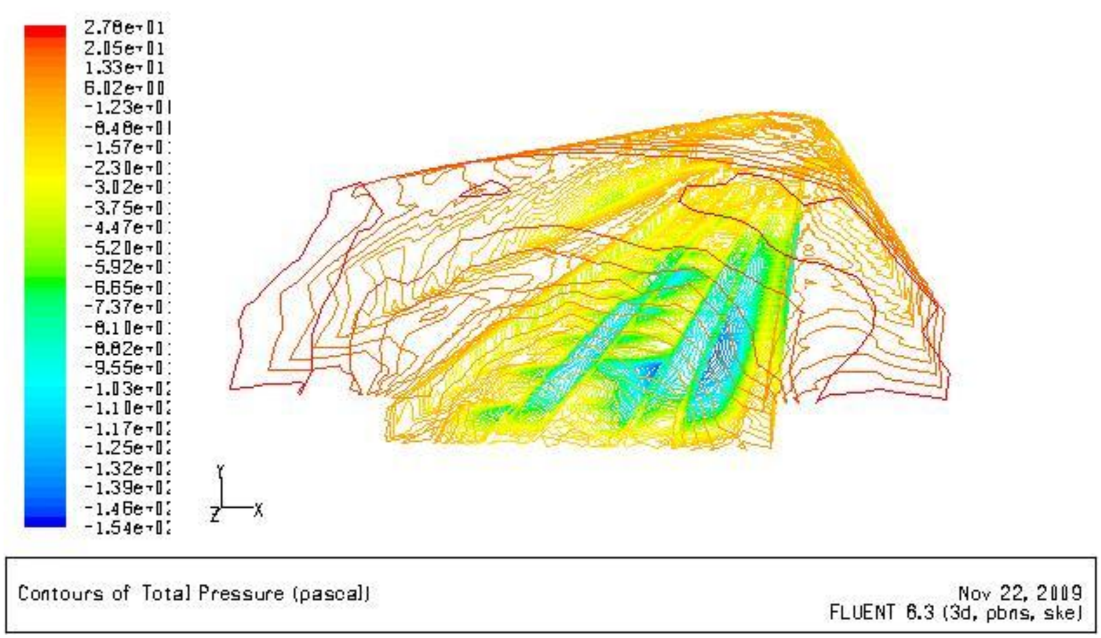

Figure 4.9 Pressure during train passes at 30 m/s

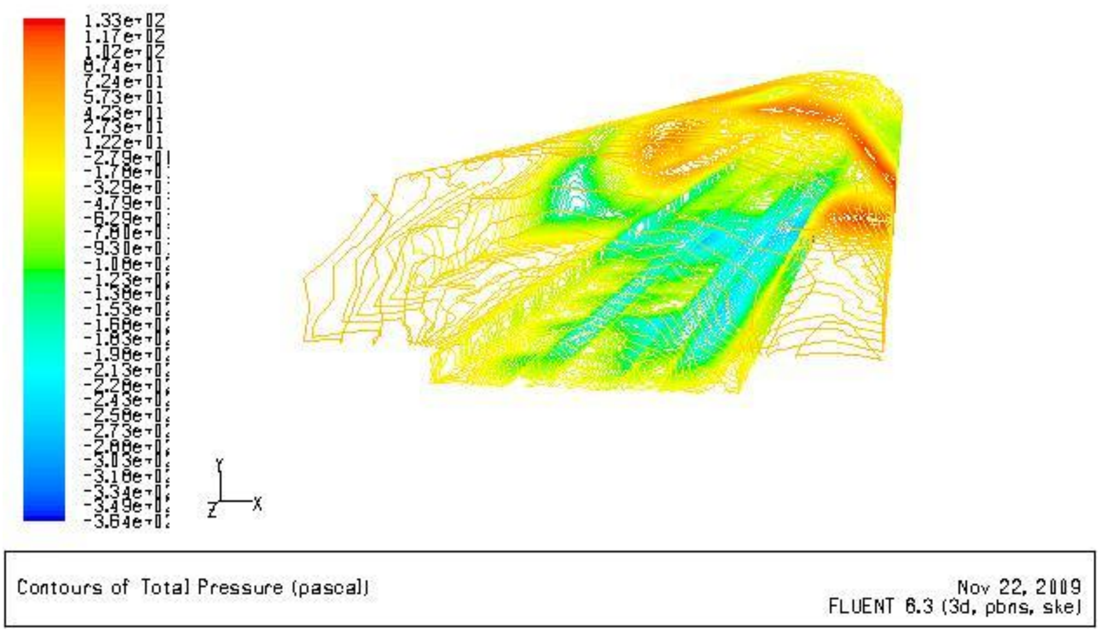

Figure 4.10 Pressure during train passes at 40 m/s

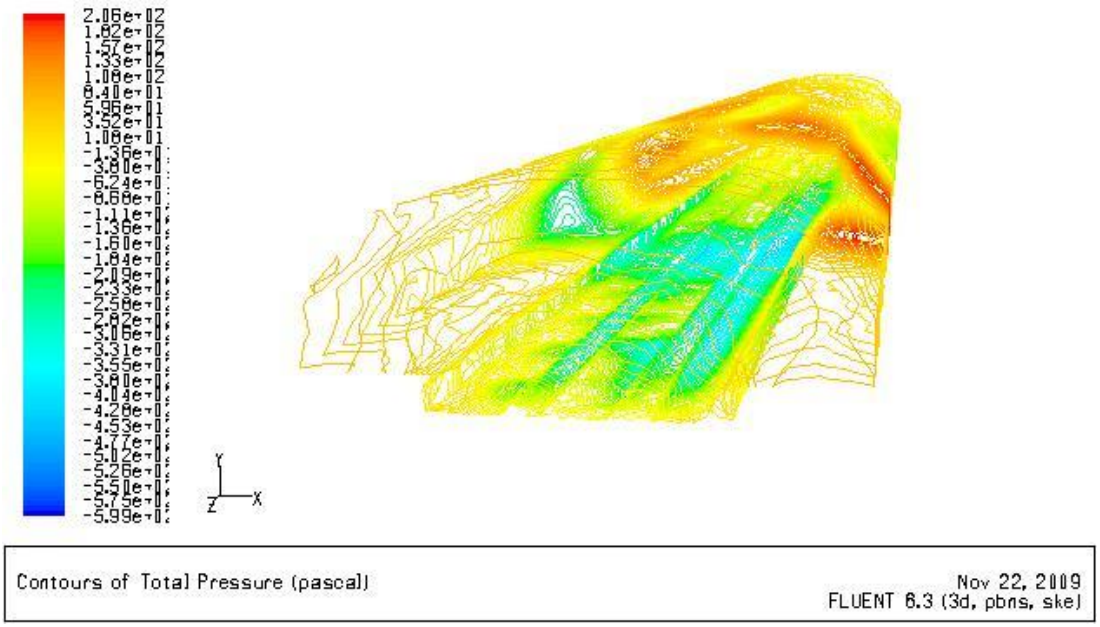

Figure 4.11 Pressure during train passes at 50 m/s

As the figures above, the numerical result showed that the pressure is quite increasing as a train moving faster passes the station. In this situation, station has an aerodynamic effect that produce by a train. In addition, people near the station can feel the pressure as a wind when train passes them but in context of aerodynamic loads, the wind that they feel is actually the velocity pressure that produces by a train. This simulation will be compared to the experimental result as the numerical model is identical with the experimental model. Figure 4.12 will presented the pressure versus train speed for station simulation.

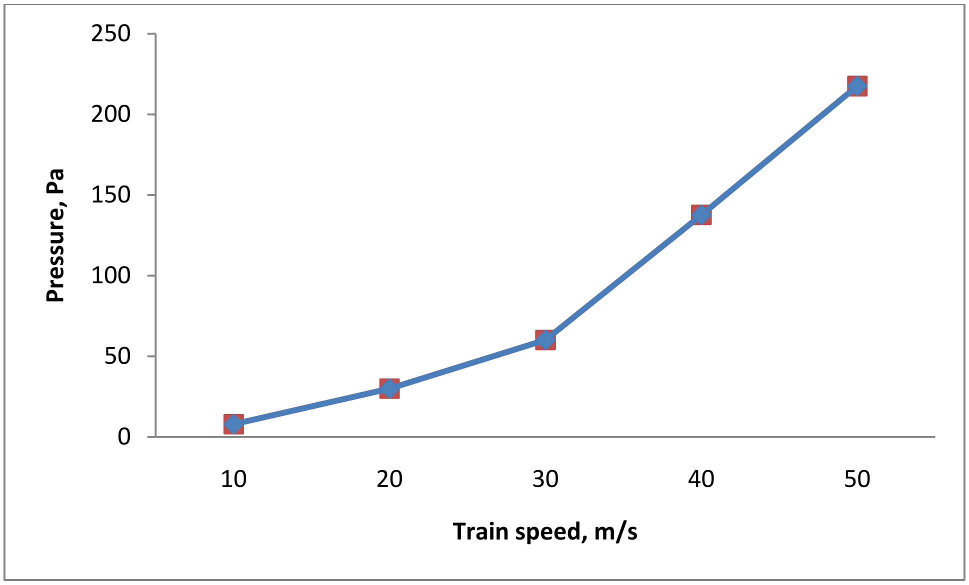

Figure 4.12 Pressure experienced by a station versus train speed

As discussion in this simulation, result obtained is proved the theory that aerodynamics loads have effects to the others such as people and structure. In those figures, it showed that the structure experienced a pressure from the rain, thus it can be conclude that train station have a possibility to have a shock as the pressure effect. Therefore, to increase the safety of train station, it should have a safety system that can withstand the pressure applied on the station. Even though the pressure is not huge, but if the station always experienced the pressure in long term duration, it can jeopardize the people and station itself.

In turbulence airflow, the most area that experience high turbulence flow must be at the entrance of the station. it is proved in the simulation result which attach at the Appendix. Based on the result, we can assume that the circulating airflow at the surroundings of the train become slowly because of train speed decrease. So, entrance of the train station is the high possibility to experience the turbulence effect rather than the middle or the end of the station. Thus, based on the theory, when train decrease its speed, the aerodynamics load become less compared during the train achieve its maximum speed.

4.2 EXPERIMENTAL ANALYSIS

Experimental result had been obtained by conducting the wind tunnel experiment. The main variables that need to obtain is the pressure that applied to a station. Table 4.3 showed the result of the experimental with varies of speed which start at 5 m/s till 50 m/s.

Experimental result

Free stream velocity, m/s	Drag Force, N	Lift force, N	Velocity pressure, mmH_2O	Velocity pressure, Pa	Fan Speed, RPM
5	0.06	- 0.68	1.52	14.91	425
10	1.21	- 0.83	5.69	55.80	897
15	1.06	- 1.09	13.65	133.86	1425
20	1.81	- 1.61	24.07	236.05	1890
25	2.94	- 1.82	37.79	370.59	2371
30	4.62	- 1.77	52.95	519.26	2700
35	4.70	- 2.40	74.71	732.65	3260
40	7.17	- 2.19	96.85	949.77	3838
45	9.30	- 2.03	121.62	1192.68	4294
50	11.92	- 2.29	150.34	1474.33	4764

Table 4.3

As shown in the table above, the wind tunnel experiment obtain many variables such as drag force, lift force, velocity pressure, and speed of fan. Drag and lift force in theoretically should be zero because the orientation of model need to be center straight but in this experiment, because of the mounting problem, the model cannot be center and straight and shifted by an angle of 0 – 5 degree. The velocity pressure is quite large than the expectation because of boundary condition of the model. Experimental model is scale by 1:200. By this huge different between real dimensions and experimental model dimension, it will affect the pressure. Area is absolutely inverse proportional to the pressure, thus, small area of model will cause the pressure become greater. That is why the numerical and experimental result has different value of pressure. But, in graph trend suitability, numerical and experimental have an approximately good agreement because both of analyses shown that the aerodynamics increase as the speed of train increase. Figure below showed the velocity pressure versus velocity of free stream.

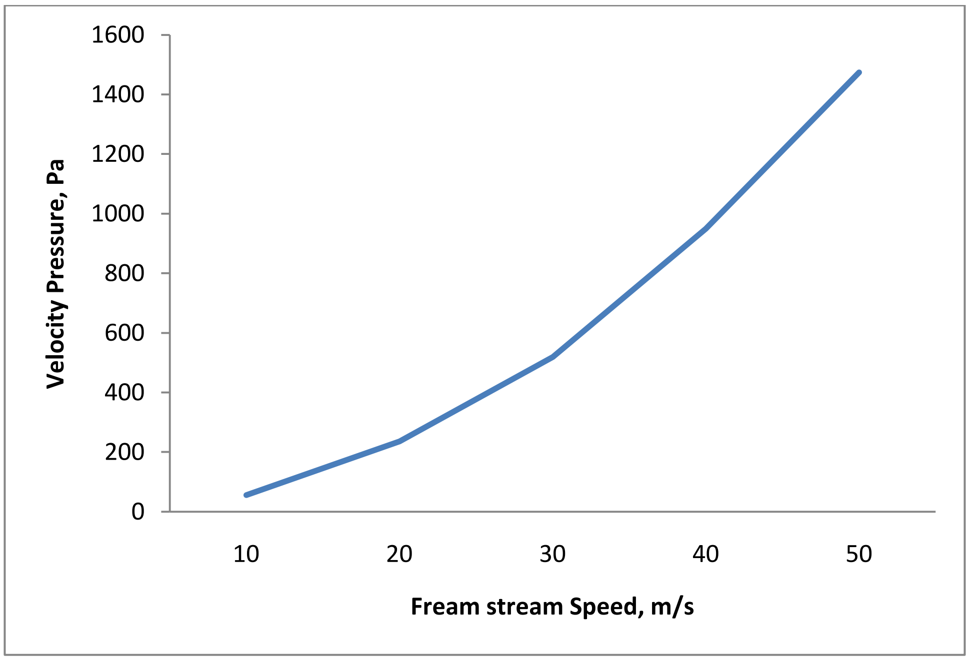

Figure 4.13 Velocity pressure versus velocity of free stream

4.3 COMPARISON BETWEEN ANALYSES

Based on both analyses, is shown that both analyses have different result. But, in context of graph trend, both analyses have an agreement which aerodynamic effects are increasing as train speed increase. As the train speed increase, velocity pressure increase and it make the pressure experienced by a station also increase. Both figure 4.6 and 4.12 trends showed the good agreement about the aerodynamic loads.

For turbulence, as the pressure increase and velocity increase, the air will circulating with high velocity of airflow thus cause a turbulence airflow especially at the rear of the train but the turbulence wake will become small as the train slow its velocity when it comes or near to stops. So, based on good agreement of graph trend, it shows that both analyses have increasing turbulence airflow as velocity of train or wind increase. Thus, in any view, the comparison shows the good agreement and it is right that aerodynamics load become larger as the train velocity increase.

CHAPTER 5
CONCLUSIONS & RECOMMENDATIONS

5.1 CONCLUSIONS

Conclusion of this project is this project meets its objectives which are:

1. To study the aerodynamic effect of train by doing simulation in Computational Fluid Dynamic.
2. Analyze the train station model in wind tunnel experiment.
3. Comparison of Computational Fluid Dynamic result with experimental result.

In the train and station simulation by Computational Fluid Dynamics, aerodynamic effect had been explored and study. Both of analyses have a good agreement that aerodynamic effect become greater as train speed increase. For wind tunnel experiment, the result showed the same pattern with the numerical method. Therefore, comparison of both analyses has met the expectation that both of it will experience greater aerodynamic loads. Both analyses also have good agreement after both analyses had been compared each other.

5.2 RECOMMENDATIONS

There have many recommendations for this project. One of the recommendations is about the experimental analysis. For better analysis, its required bigger wind tunnel, so that the model can be create with bigger size, thus the result of wind tunnel will be more accurate. Another recommendation, students need larger budget for their Final Year Project. Before this, student only get RM 250.00 for their expenses in their project. This creates a limitation for student to do the huge project or better project. With only small budget, it will be an obstacle for student to further their research or investigation to make their project more interesting or better contribution to real life and much more better for university management.

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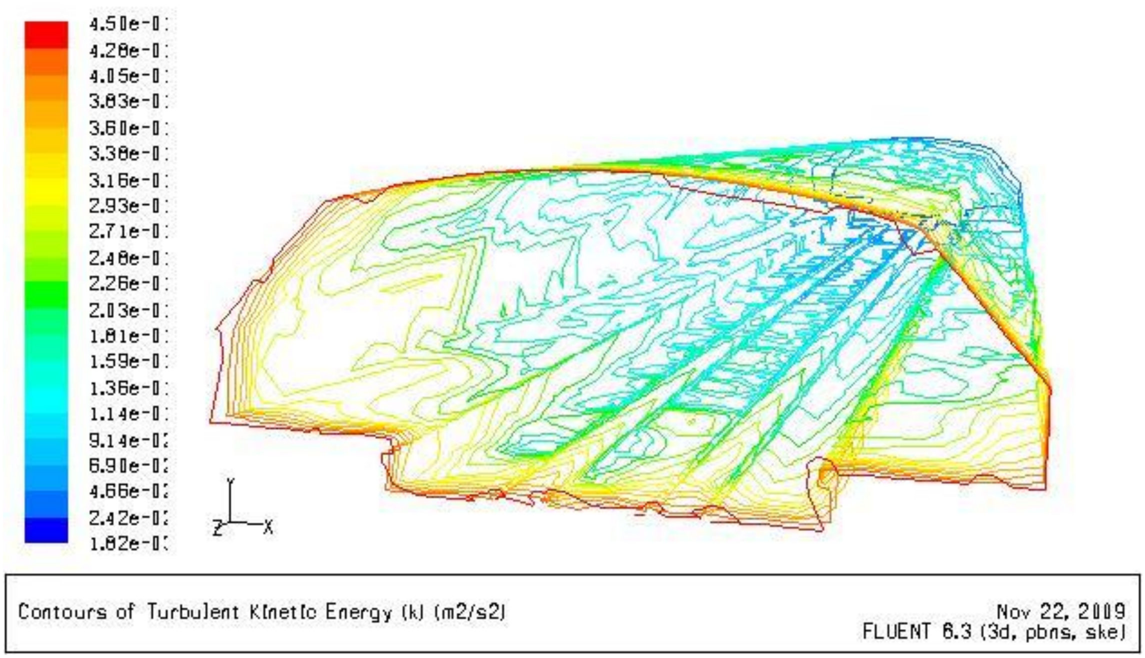
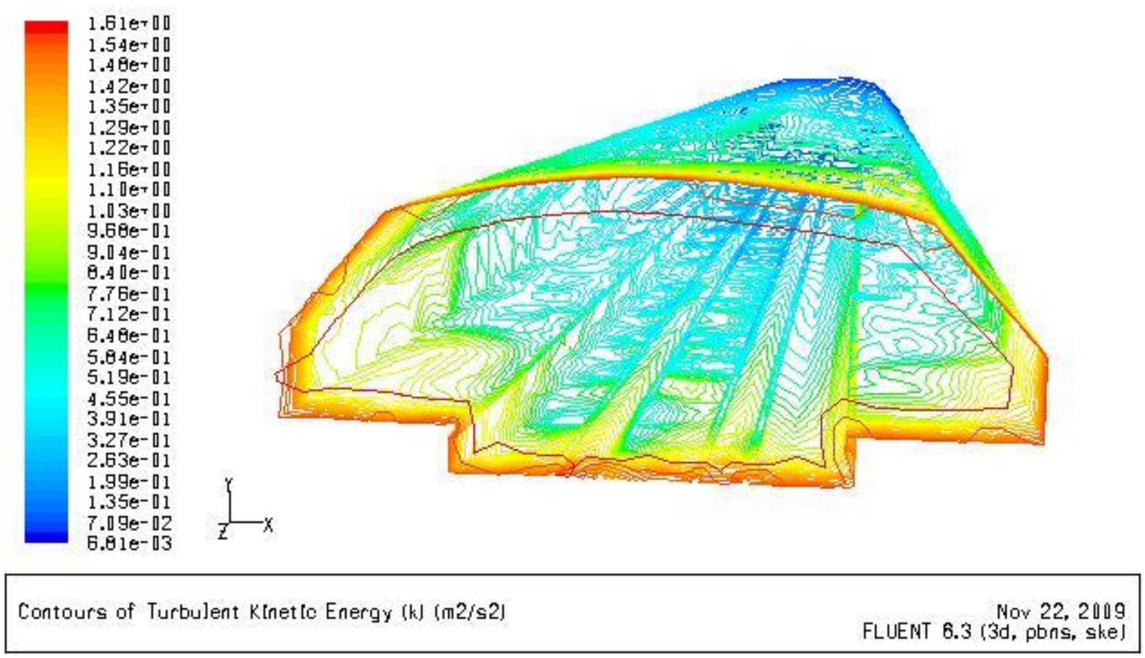
APPENDIX

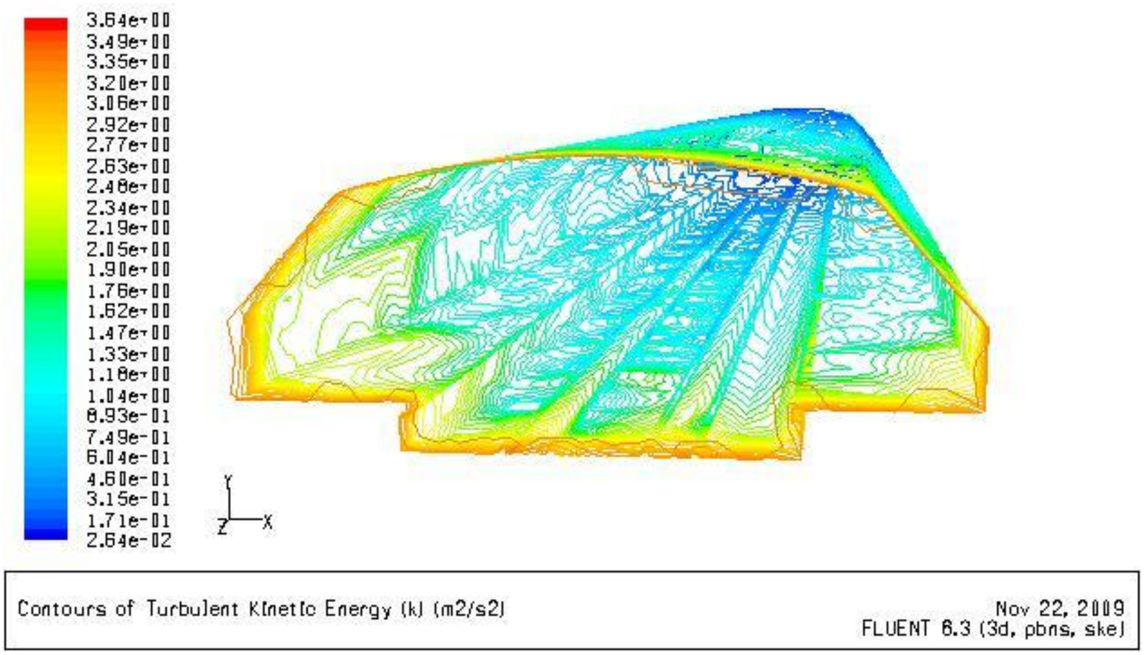
Turbulence airflow at 10 m/s



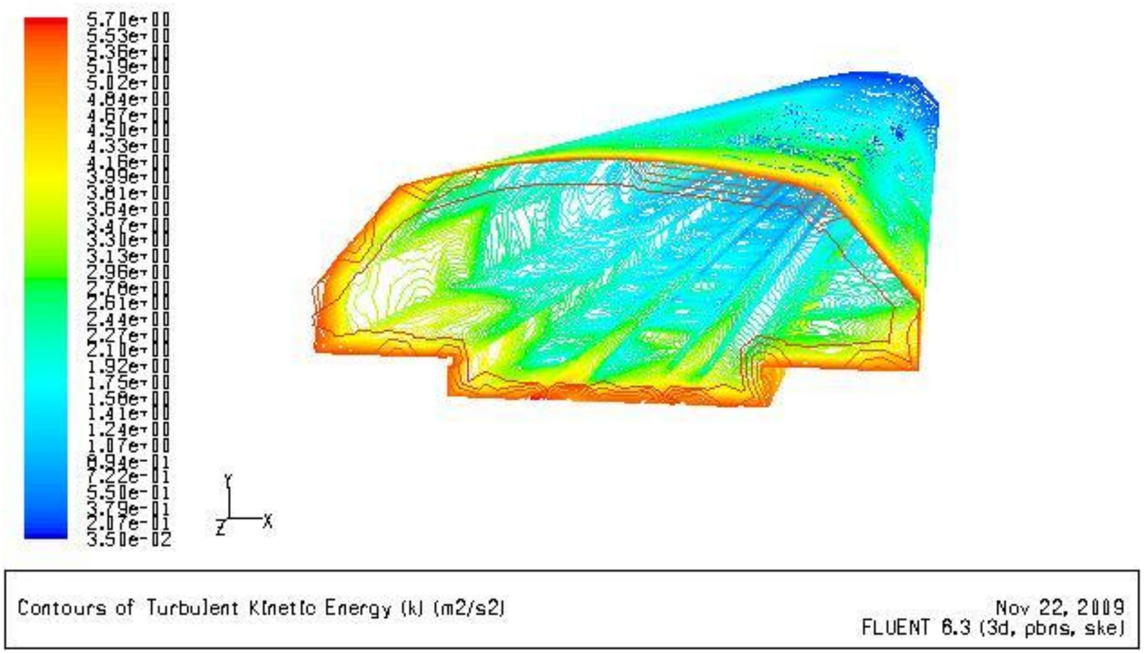
Turbulence airflow at 20 m/s



Turbulence airflow at 30 m/s



Turbulence airflow at 40 m/s



Turbulence airflow at 50 m/s