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Evaluation the Aerodynamic Drag Force of CC201 and CC203 Locomotives by CFD Simulation

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***Abstract* - Trains are a very important mode of transportation for freight and passengers in Indonesia. This encourages PT KAI, which is a train operator in Indonesia, to improve its performance. Currently PT KAI uses several types of locomotives. CC201 locomotives made in 1977-1978 and CC203 made in 1995 are locomotives that are still widely operated. Fuel consumption is one of the components of train operating costs, the percentage of which reaches more than 30%. Railroad fuel consumption is strongly influenced by various factors, one of which is the aerodynamic performance of the locomotive. This study presents an evaluation of the aerodynamic performance of CC201 and CC203 locomotives. The research stages include direct measurement of locomotive geometry and dimensions, CAD drawing creation using SoildWorks and aerodynamic evaluation using ANSYS software. The simulation results show that the flat front design of the CC201 locomotive has greater aerodynamic resistance. This can be seen from the pressure contours and turbulence around the locomotive body. This causes the drag force of the CC201 locomotive to be 44% greater than that of the CC203 locomotive.**

Keywords: Aerodynamic, CFD, Locomotive.

I. INTRODUCTION

The railway is a very important mass transportation for the distribution of goods and passengers. The use of trains is getting higher every year. The increase is driven by economic growth and the increasing population. This requires a better and more efficient locomotive to drive the train carriages. [1, 2]

Locomotive fuel consumption is very important to consider. Saving fuel consumption can reduce train operating costs by more than 30%. Fuel efficiency can be achieved by reducing the aerodynamics drag force. Various studies on train aerodynamic performance have been conducted using CFD simulations. [3, 4, 5, 6, 7]

PT KAI, which is a train operator in Indonesia, has several types of locomotives. These locomotives have different designs despite having the same engine type. Therefore, it is necessary to evaluate the locomotives owned by PT KAI so that it can be known which type of locomotive is more efficient in using fuel.

CC201 and CC203 are 2 types of locomotives owned and operated by PT KAI. The CC201 locomotive with the GE U18C model series is the oldest diesel electric locomotive. This locomotive was first imported to Indonesia in 1977-1978. This locomotive has a slim design with a weight of 84 tons and engine power of 1950 hp. The CC203 locomotive with the GE U20C series model is the improved of CC201 electric diesel locomotive model. CC203 has 84 tons weight and operated since 1995. The CC201 and CC203 are manufactured by General Electric. Both locomotives have very different designs. Therefore, their aerodynamic performance is also different.

This research presents the aerodynamic evaluation of CC201 and CC203 locomotives. The evaluation uses Computational Fluid Dynamics/CFD. With the CFD simulation, the amount of aerodynamic drag can be determined.

II. MATERIALS AND RESEARCH METHOD

The research phase begins with measuring the dimensions of CC201 and CC203 locomotives. Figure 1 shows photos of CC201 and CC203 locomotives. After the measurements were completed, CAD drawings were made using SolidWorks software. When CAD drawing, some simplification of the geometry and shape of the locomotive. The consideration is that detailed geometry and shape do not significantly affect aerodynamic performance. The CAD drawings were then exported to ANSYS software for simulation. Figure 2 shows the CAD drawings of the two locomotives.

Figure 1: CC201 and CC203 Locomotives

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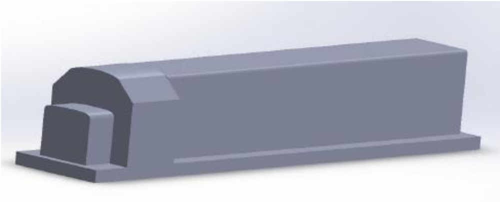
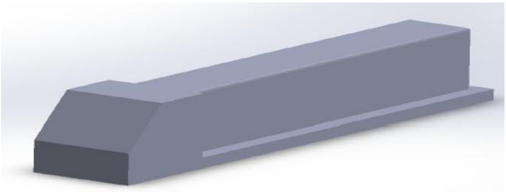


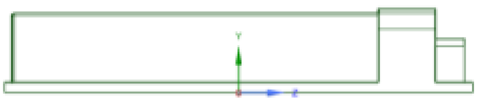
(a)



(b)

Figure 2: CAD Drawing of a) CC210 and b) CC203 Locomotives

The geometric shape of the locomotive body to be analyzed can be obtained by creating a simulation domain and body of influence (BOI) using Space Claim software. The shape of the locomotive geometry to be analyzed is shown in Figure 3. The boundary conditions used during the simulation process are shown in Table 1. The meshing with poly-hexcoreis shown in Figure 4.



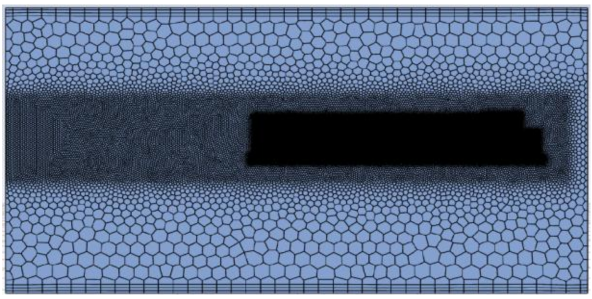
(a) CC201 Locomotives

(b) CC203 Locomotives

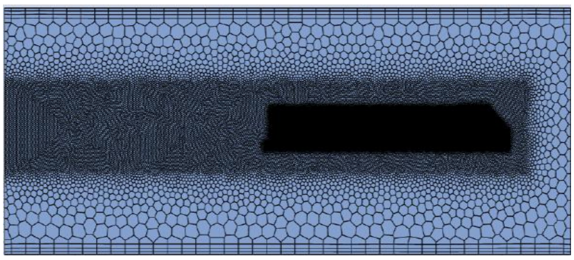
Figure 3: Locomotive Geometry

Table 1: Boundary Condition

	Inlet	Outlet	Bottom Wall	Far & Top Wall
Velocity	25m/s; 29,17m/s; 33,33m/s			
Initial Gauge Pressure	1 atm	1 atm		
Turbulent Intensity	5%	5%		
Turbulent Viscosity Ratio	10	10		
Shear Condition			No Slip	Specified Shear



(a) CC201 Locomotives

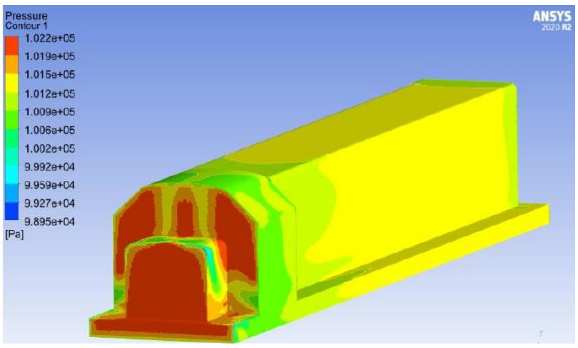


(b) CC203 Locomotives

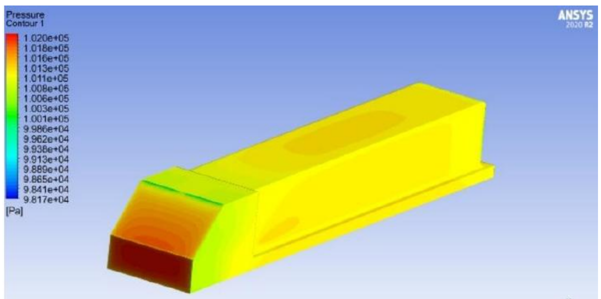
Figure 4: Mesh of Model

III. RESULTS AND DISCUSSIONS

Figure 5 shows the contour pressure of the simulation model. The pressure contour shows that the red-colored part is the most highly stressed. It can be seen that the area of the red CC201 locomotive is larger than that of the CC203 locomotive.



(a) CC201 Locomotives



(b) CC203 Locomotives

Figure 5: Contour Pressure Plots

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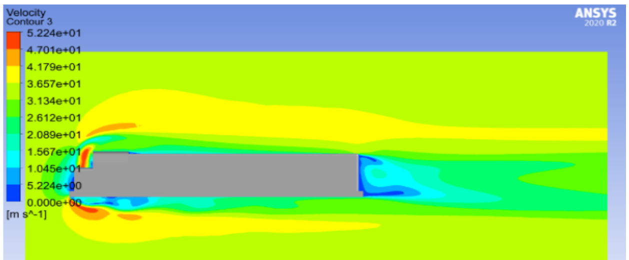
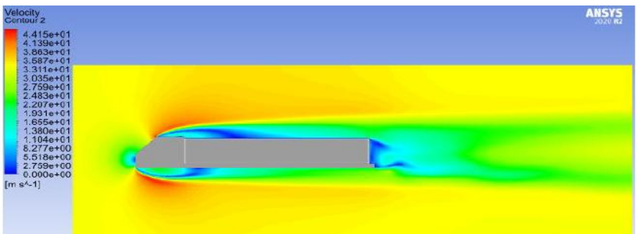
CFD simulations produce data visualizing the distribution of airflow velocity passing through the body surface of both types of locomotives, displayed through contour color gradations. The purpose of the airflow velocity distribution contour is to see which part of the locomotive body has the highest and lowest air velocity when traveling.

The following explanation discusses the analysis of the airflow velocity distribution contours passing through the design surface of the CC201 and CC203 locomotive bodies. In the figure above, it is found that the highest airflow velocity on the locomotive body design. CC201 and CC203 locomotive body designs occur at the top of the cab and under the body, as evidenced by the orange to red color on the contours in both parts. The airflow that hits the front of the locomotive then separates and is pushed towards the top and bottom of the locomotive, resulting in a significant increase in energy as well as speed. [8, 9]

In addition, it is found that the lowest airflow velocity in both locomotive body designs (0 km/h) occurs in the area around the body with blue contours, namely the front, top, bottom, and rear of the locomotive. At the front end of the body, there is no airflow rate because that part is the initial meeting point of the airflow with the body surface, where there is wind resistance due to the shape of the front of the body which tends to be perpendicular so that it inhibits airflow. Meanwhile, at the top, bottom, and rear areas of the body, there are vortices formed due to turbulence, which has the effect of increasing the drag force in these areas. The high drag force causes the air flow rate to decrease or even disappear altogether. Figure 6 shown the velocity contour of model for the speed 33,33m/s.



(a) CC201 Locomotives

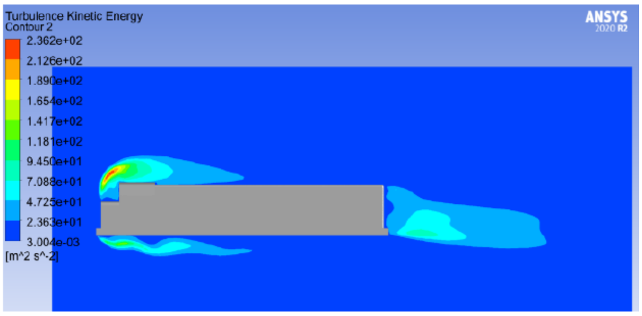


(b) CC203 Locomotives

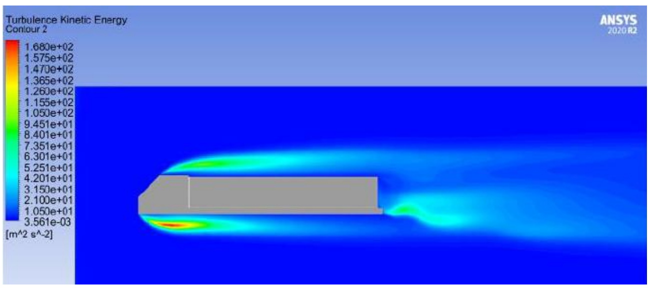
Figure 6: Contour Pressure Plots

The air drag that occurs when a vehicle is moving is strongly influenced by the turbulent flow that forms around the locomotive body. When the locomotive is moving, the airflow passing behind the body is distorted and irregular in nature, creating turbulence. The main contributing factor to the amount of drag generated due to turbulence is the body design.

In the Figure 7, there is a difference in the turbulent flow formed between the CC 201 and CC 203 locomotive body designs in speed 33,33m/s. In general, both types of locomotives experience turbulence in the same parts, namely the top, bottom, and rear of the body. However, there are differences in the shape and distribution of turbulent flow between the two locomotive designs. In the CC 203 locomotive, the turbulent flow that occurs at the top and bottom of the body is not as strong as that in the CC 201 locomotive. In addition, the turbulence area at the rear of the CC 201 locomotive body is more evenly distributed on both the upper and lower sides, while in the CC 203 locomotive the turbulence at the rear tends to occur only from the lower side with minimal turbulence on the upper side. [10, 11]



(a) CC201 Locomotives



(b) CC203 Locomotives

Figure 7: Kinetics Energy Contour

Aerodynamic drag is not only influenced by the shape of the locomotive, but also depends on the speed of the train. Figure 8 and Figure 9 show the results of the drag calculation. Both figures show that the calculation of the drag force reaches a constant value after 6000 iterations. Table 2 shows the magnitude of the drag. It can be seen that the drag of locomotive CC203 is 44% lower than that of locomotive

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CC201. The decrease in drag is due to the more aerodynamic front shape of the CC203 locomotive. The reduction in drag contributes to fuel savings.

Table 2: Drag Force of CC201 and CC203 Locomotives

Speed (mm/s)	Drag Force (N)	
	CC201	CC203
25	1.666	929
29.17	2271	1261
33.33	2968	1635

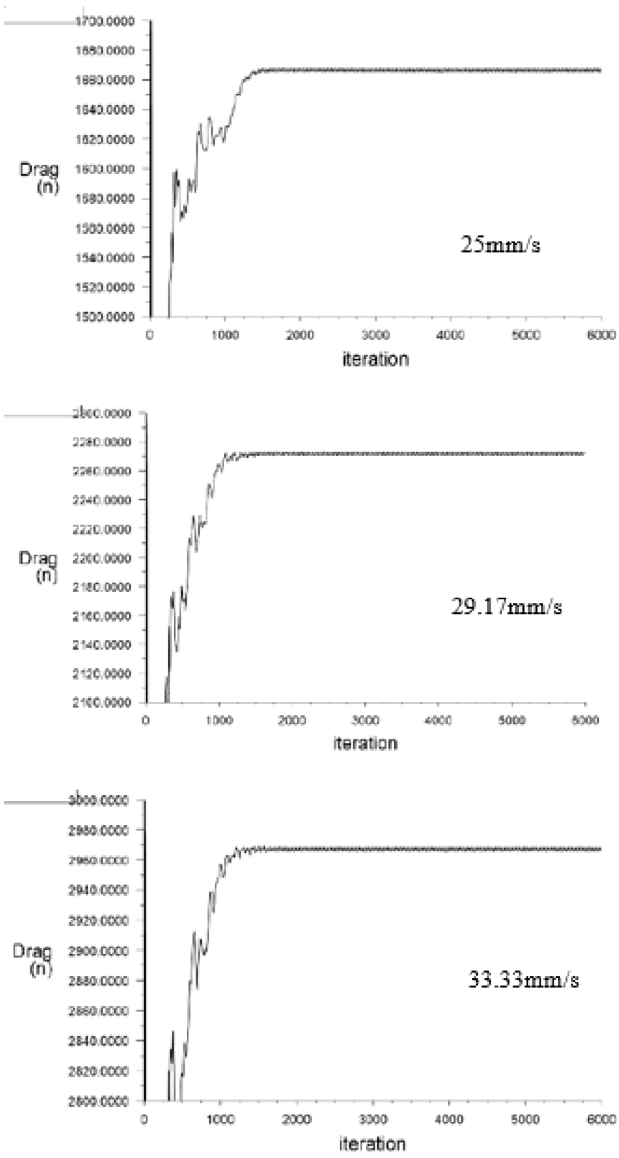

Figure 8: Drag Force for CC201 Locomotives

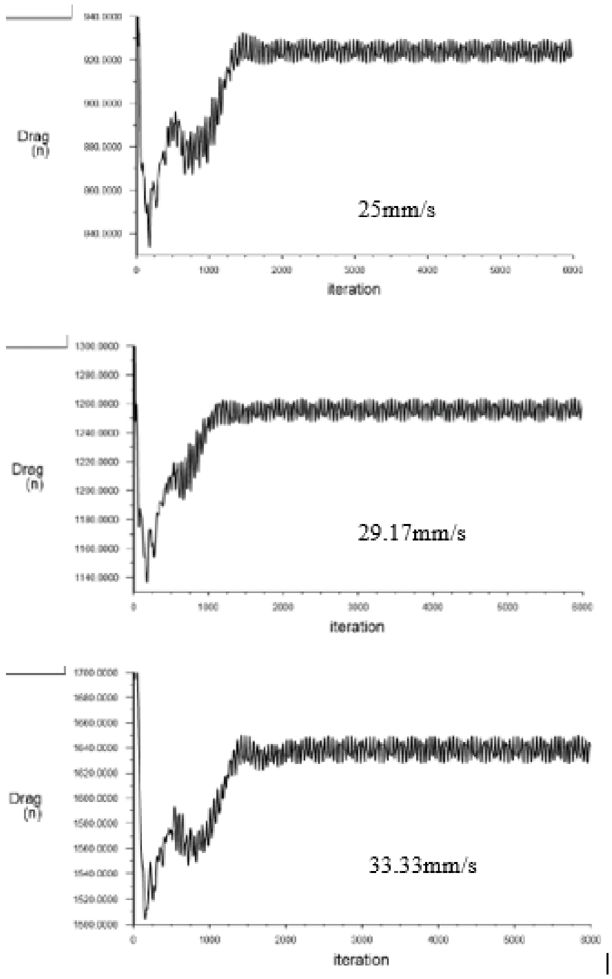

Figure 9: Drag Force for CC203 Locomotives

IV. CONCLUSION

CC203 locomotives have an aerodynamically better design than CC201 locomotives. The amount of drag on the CC203 locomotive is 44% lower than that of the CC201 locomotive. The reduction in drag contributes to fuel consumption reduction.

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