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To cite this article: Rishi Kanth Choppa *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **691** 012035

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Aero dynamic cross wind analysis of locomotive

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Abstract. Aerodynamic cross wind has become most vital part in the approving process in locomotives. From last few decades, many of the incidents took place on the cross wind stability of locomotives during high speed. Even though a lot of research work is going on the cross wind analysis of locomotive by using computational fluid dynamics (CFD). In this paper Computational fluid dynamics simulation was used to carry out the study on WAP5 locomotive (Wide gauge AC Passenger, class 5 model) and the simulations were utilized to study the impact of the motion (relative) among locomotive and infrastructure, also the variance which happen in WT (wind tunnel). After an inception approval against test data, the numerical model was utilized to consider relative motion impacts among locomotive and infrastructure (STBR i.e. single track with ballast and rail). The variance, regarding coefficient of aerodynamics obtained with active and static model simulations, was investigated: the both rolling moment coefficient and lateral force were brought down with the static model of around 5% and the variance of around 12% for the coefficient vertical force. The other variations like CWC (characteristics wind curve), presents the limitation for overturning of locomotive was in the sequence of 1.5% for direction of locomotive that is perpendicular to wind. In the conclusion, regardless of whether stationary test is not conventional, the distinctions as far as characteristics wind curve are significantly less in the single track with ballast and rail situation and these outcomes carry assumptions of stationary model tests on single track with ballast and train situation as illustrative of aerodynamics of locomotive.

Keywords: Aerodynamics, Cross wind, Locomotive, Computational fluid dynamics, Wind tunnel, Wind curve, STBR, CWC.

1. Introduction

This paper shows and examines the after effects of CFD investigation of the impacts of both locomotive and infrastructure relative motion on locomotive aero dynamic coefficients. The enthusiasm for such an investigation is identified with the basic practice, received in locomotive optimal design investigations of performing WT tests on static models, re-delivering the relative cross wind-locomotive approach on the plane (horizontal) by revolving infrastructure and locomotive models to vertical axis. On other side the real one is having different situation where relative wind speed results on the cross wind absolute velocity and train velocity when the infrastructure remains constant and is subjected to absolute wind speed. Forces of crosswind following up on the running locomotive are typically assessed embracing a quasi-steady that depends on the learning of aero dynamics coefficients estimated through WT tests on static models. The standard WT rehearse is to perform tests on static models situated on static scaled infrastructure models. The aero dynamic coefficients at various angles are estimated by concurrently turning the infrastructure and locomotive models by a similar amount regarding the approach in direction of wind. It is obvious that this circumstance is not quite the same as what really occurs at full scale working running conditions. Actually an escalate presentation of aero dynamics phenomenon requires the WT tests with cross



wind facility on active locomotive model. From the previous papers it's very hard for moving model to have required amount of wind to pass, the inertial forces require an in-depth comprehension on locomotive dynamics at that stage it requires a pressure reference for pressure systems and results are made at the end.

It is significant that locomotive speed is considered as 160 km/h and has higher wind speed of 16 m/s, the relative yaw angle in the CW locomotive connection are somewhere in the range of 0° and 30° , and velocity vector of locomotive presents the significant commitment to relative wind speed magnitude. This implies active model tests ought to be performed with a vehicle speed that which is more than speed of wind, additionally expanding the multifaceted nature of the test. Because of the constrained measurements of WT, thus the length of the way on which the locomotive [1-12] might be subjected to cross wind, just a couple of moments might be recorded on each test and an outfit normal strategy must be received to gauge aero dynamic forces. Transient powerful conditions amid speeding up and deceleration may likewise initiate dynamic impacts that may affect aerodynamic and should be considered in data post processing.

2. Device Structure

In between the years 1995 to 1998 researchers conducted a project test named TRANSAERO that which was performed in wind tunnel with the active locomotive model. After conducting the test researchers have concluded that from the tests, aero dynamic coefficient force of active locomotive test is possible in wind tunnel. In this paper we are studying locomotive aero dynamics on infrastructure that which is in motion. Our aim is to study and investigate the infrastructure contribution by changing the locomotive aero dynamics, is recorded by means of stationary model in WT, or the relative motion among infrastructure and locomotive should be produced in WT. For this computational fluid dynamics are utilized on stationary and active models to simulate and WT test by changing boundary conditions. Comparison tests are performed for both models in terms of pressure distribution and aerodynamic coefficient. Here WAP5 (wide gauge AC passenger class 5 model) model locomotive geometry (Figure 1a) is used for numerical study to validate CFD analysis against WT in small scale model under the testing conditions. At the same time STBR (Figure 1b) is also considered for this paper because how infrastructure can modify the flow. The same mesh and set-up simulations are used for both the stationary and active models to carry out the consistent results.

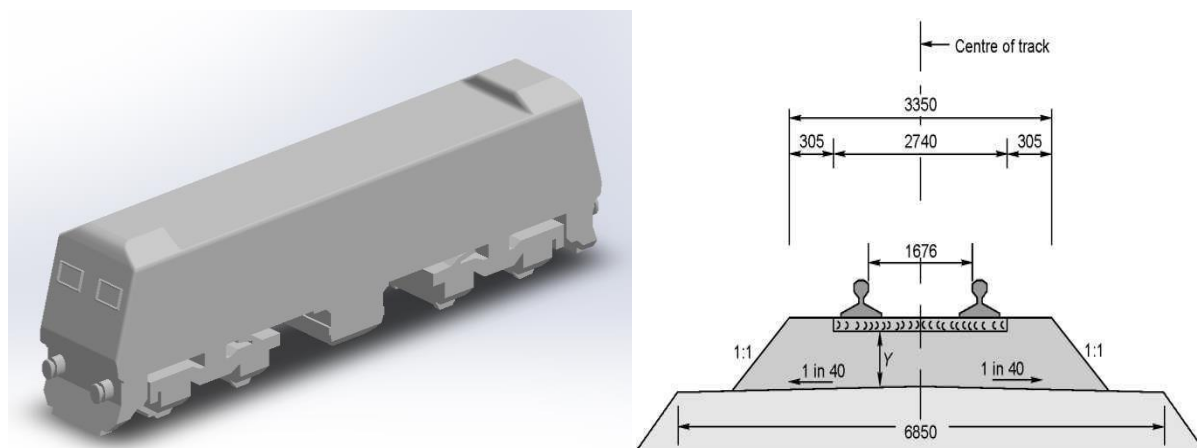


Figure 1. (a) CAD geometric model of WAP5 locomotive (b) STBR infrastructure section

3. CAD modeling of locomotive

The modeling of locomotive was designed in solid works software by using the blue prints of WAP5 (Wide gauge AC Passenger, class 5 model) with same dimensions as shown in figure 2 [13-25].

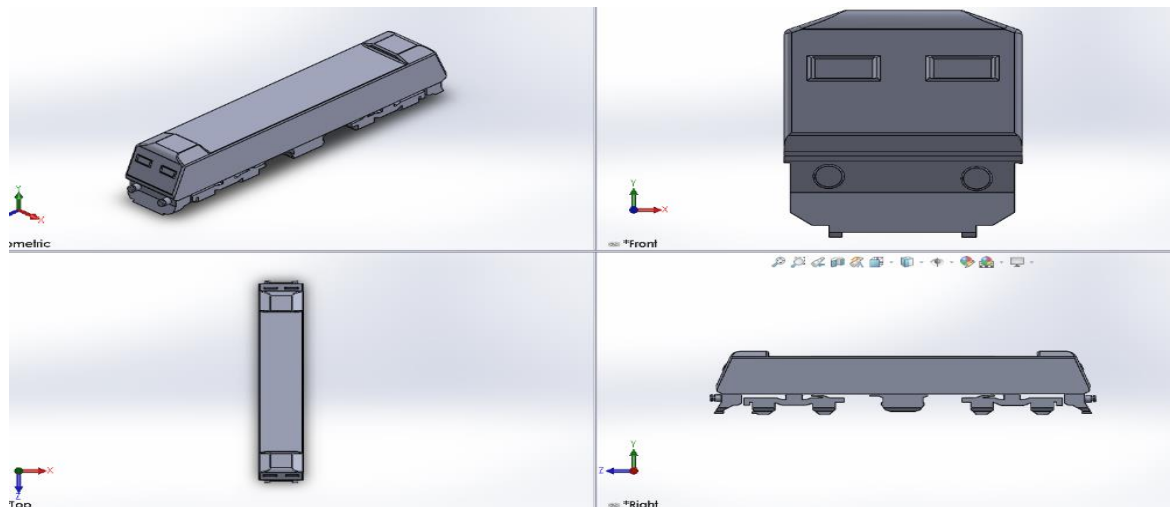


Figure 2. WAP5 locomotive model

3.1. CFD simulation process

The main objective of this simulation is to find the major dissimilarities of both stationary and active model aero dynamic coefficients and analysis is done by comparing the wind tunnel model test and numerical model. It is considered that simulations are done in 1:15 geometric scale of WAP5 and STBR, after that the meshing and analysis was performed by using Ansys fluent package for the post processing and solution and processor as gambit. For the rectangle domain (figure 3) a 100-meter geometric dimensions are taken into considerations to create the domain.

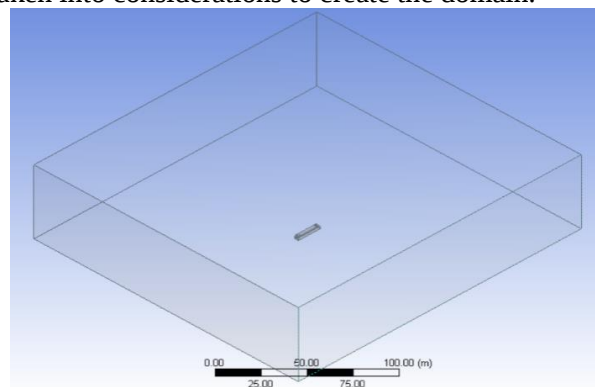


Figure 3. CFD simulations domain

3.2 Meshing

The dimensions are considered according to the locomotive dimensions and meshing is performed in sub-domain to maintain the better quality that which is created by selecting fine mesh for tetrahedral meshing on the locomotive model as shown in figure 4.

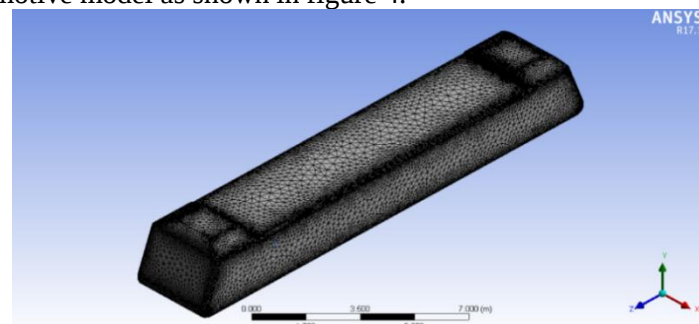


Figure 4. Meshing on locomotive model

3.3 Boundary condition

Basically the aerodynamic coefficients of stationary model are done in wind tunnel by placing infrastructure and locomotive at various yaw angles β_w (figure 5a) which faces coming wind and also to measure the aerodynamic moments and forces. The relative yaw angle β (figure 5b) is acquired by changing the locomotive angle according to the flow of air. Here two reference systems were used to define steady state simulation where absolute is fixed to ground and moving reference frame is attached to locomotive. For solving absolute reference system Navier Stokes equations are used. From absolute wind speed and train speed both relative wind speed and yaw angle are resulted in active locomotive simulation by fixing 90° wind incident angle and wind velocity is indicated then by considering the relative wind speed, Reynolds number is computed in wind tunnel to attain required angle for crosswind.



Figure 5. Yaw angle of wind (a) stationary model (b) active or moving model

4. Layout of wind tunnel testing

The WAP5 model (Wide gauge AC Passenger, class 5) is made of polymer material by using 3D printing model (figure 6) that which makes the model lift weight [26-45]. The wind tunnel is already contains an average pressure and force values when it is in stationary condition. The moments and forces are measured by the components that are fixed below the infrastructure. It maintains $I_u=0.2\%$ of turbulence intensity level for the mean wind speed of blocked vertical profile.



Figure 6. Locomotive testing on wind tunnel

5. Results

The outcomes acquired in re-enactments with a still model in a STBR situation are contrasted and the outcomes got in wind burrow tests with the end goal to decide the precision of the numerical structure. The examination is performed both as far as worldwide forces (aerodynamics) and minutes following up on the main vehicle and regarding weight dispersion around specific segments along the

locomotive. The examination centres around yaw angle 0° - 30° , since they are the most basic for rapid speed locomotives and are the well on the way to be experienced by fast locomotives amid regular working conditions

The coefficients like pressure, force and moments are considered under the non-dimensional forms and are calculated follows

$$c_p = \frac{p}{V_{rel}^2 \rho \frac{1}{2}}; c_{f_i} = \frac{f_i}{V_{rel}^2 \rho A \frac{1}{2}}; c_{M_i} = \frac{M_i}{V_{rel}^2 \rho h A \frac{1}{2}}$$

Where p – static pressure, $A=10 \text{ m}^2$, $h=3\text{m}$

M_i -moment along I direction, f_i -force along I direction, ρ -air density, V_{rel} -relative wind speed

The relative error for both numerical and experimental data are evaluated as “err”

$$err = \frac{C_{CFD} - C_{EXP}}{C_{EXP}}$$

C_{CFD} -Numerically computed aerodynamics coefficient, C_{EXP} -experimentally measured coefficient

It is possible for numerical and experimental results that are good by considering lateral force coefficient with 8% lesser than relative error for yaw angles. The numerical and experimental methods that which is done in wind tunnel have made by changing the yaw angle to various angles from $0 - 15^\circ$ (figure 7) , $0 - 30^\circ$ (figure 8) and $0 - 45^\circ$ (figure 9). The numerical and experiment concurrence on both pressure and force distribution exhibits that the CFD approach received can recreate the fundamental flow highlights features for locomotive aerodynamics the yaw angle researched, and can accordingly be utilized to investigate the impacts of the relating locomotive and infrastructure movement for definition of coefficients of aerodynamics.

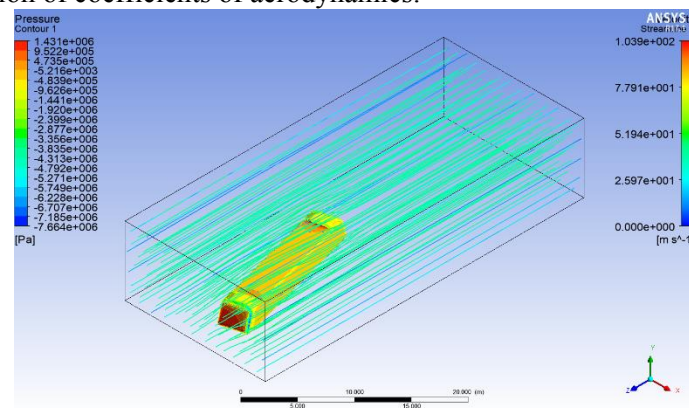


Figure 7. CFD analysis on locomotive yaw angle (0-15°)

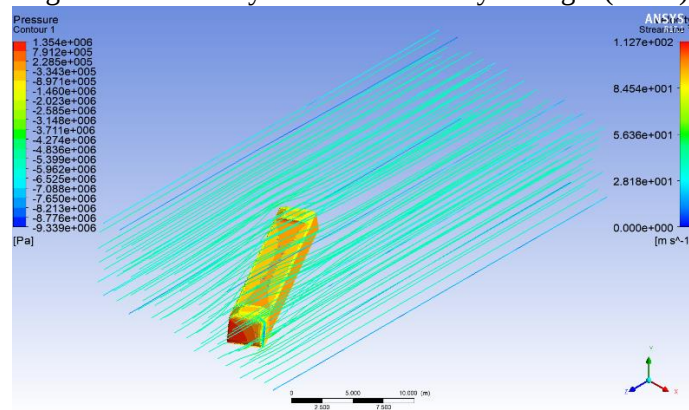


Figure 8. CFD analysis on locomotive yaw angle (0-30°)

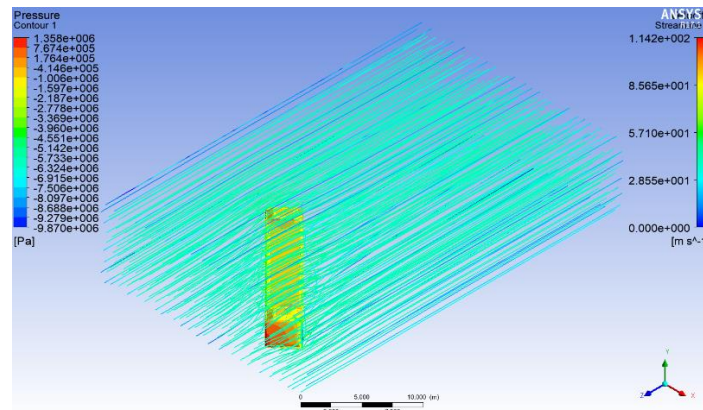


Figure 9. CFD analysis on locomotive yaw angle (0-45°)

5.1 Pressure distribution of locomotive at different yaw angles

The numerical and experimental study is done and the outcome of the both models are compared, and it continued to find the pressure distribution on surface of locomotive. At various yaw angles from 15°, 30°, 45° as shown in the figure 10a.

5.2 Pressure distribution on infrastructure and locomotive for stationary and active model

The pressure distribution on both locomotive and infrastructure are done by comparing the experimental and numerical results of the respective models at various yaw angles in between 15°, 30°, 45° and the pressure distribution results are carried out. The results are shown in the pictorial representation as shown in figure 10b.

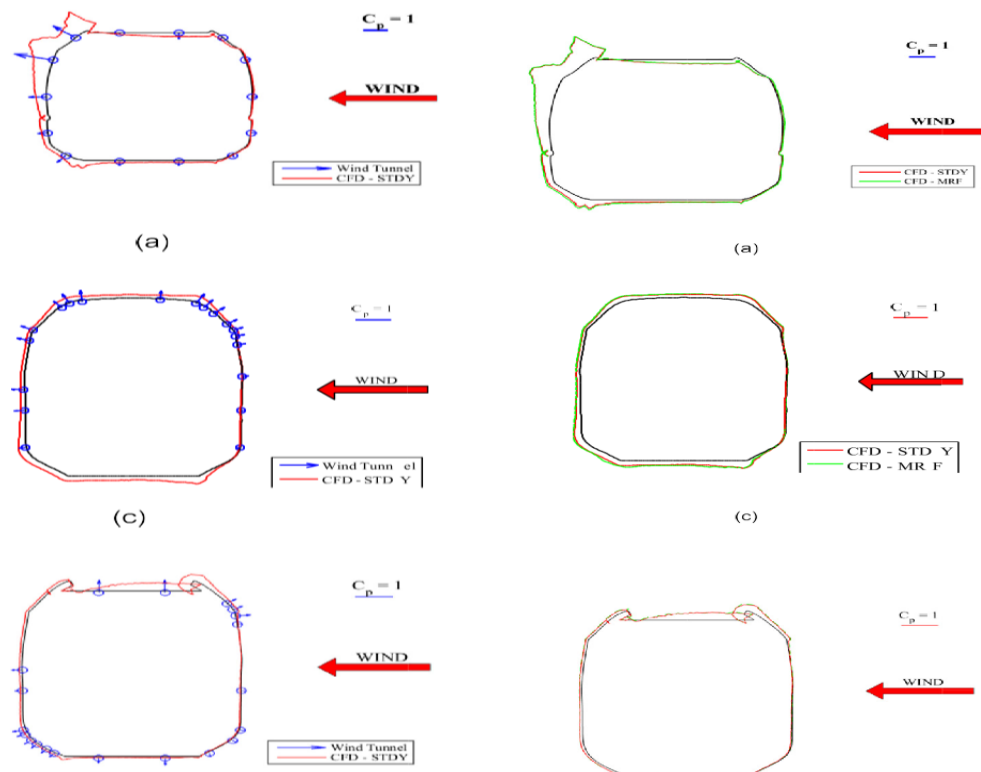


Figure10. (a) Pressure distribution of locomotive at various yaw angles (0-45°) (b) Pressure distribution for STBR and locomotive for stationary and active models

6. Conclusion

Correlation of the consequences of reproductions led with still and moving models featured that thought of the relative movement between the infrastructure and the locomotive prompts bigger aerodynamic coefficients. The variance is less (<5%) for rolling moment coefficient and lateral forces somewhat higher for the coefficient of vertical forces. very little contrasts show up in pressure distribution of surface, only among infrastructure and locomotive that principally influences the coefficient of vertical forces. Since the impact is restricted to a little piece of the entire locomotive, the effect on aerodynamic coefficient isn't exceptionally articulated. Underestimation of the aerodynamic coefficients, when considering a stationary locomotive, prompts underestimation of the CWC as far as possible conditions for the locomotive over turning. Then again, this underestimation is in the order of 1.5% for wind point $\beta_w \frac{1}{4} 90^\circ$. As a result, regardless of whether stationary tests are not conservative, the distinctions as far as CWC are significantly low in the STBR situation. The magnitude of variation in coefficient when locomotive is moving is of indistinguishable from the estimation vulnerabilities that would be presented if more intricate test fix set-up and estimation frameworks were utilized for moving model WT tests. Taking everything into account, the consequences of this investigation adoption of stationary model tests in the STBR situation as illustrative of locomotive aerodynamics features. These outcomes could be unique if greater infrastructure scenarios were mulled over, and a specific study will be performed on this case.

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