**Introduction and Metodological approach**

Good morning everyone,

today we are going to show you the analyses of the effects of cross wind on road vehicles, in particular on trucks. We studied the behavior of trucks under different conditions, such as: the metereological conditions, the load fraction, the lane changes, the roll stiffness distribution (front and rear axis) and the entry and exit from a tunnel.

Let’s start illustrating the metodological approach considered.

The first step was to find the aerodynamic coefficients from wind tunnel tests.

We obtained forces and moment coefficients as a function of the wind exposure. The overall and local external wind loads can be studied using static models.

We evaluated, for straight line reference path, the roll over vehicle speed for all wind histories given. There are 6 and they differ from each other by some characteristics: the mean wind speed, the turbolence index and the integral scale lenght.

At this point, we evaluated the aerodynamics loads, with a 3 degrees of fredoom model.

The overall load acting on the model can be directly measured with a force balance: all the perpendicular forces and the three moments should be measured.

After that, we calcaulate the reaction between ground and wheels

The equations of motion are integrated throught ode45 function.

The driver is modelled as a path follower PD control.

When we launch the code, we have to set firstly two parameters: time and vehicle speed. We chose 60s for thew first one and 50 km/h for the vehicle speed.

For each wind history and for each condition (dry, wet and snow) graphs look like these.

We analyzed the behavior of the truck after the change of lane and during the entrance and the exit from a tunnel.

**Different wind speed**

Firstly we compared wind history 1 and 4 in dry conditions: these ones present the same turbulence intensity but different wind speed as can be seen in the table. We decided to focus on aerodynamic forces and moment (on your left) and the trajectory of the vehicle. As can be seen from the plots, the trends of the aerodynamic forces and moment are quite the same and do not change as much as the modulus does. Moreover, as expected the trajectory plot in the second case shows that the vehicle is more unbalanced due to the higher velocity

**Different turbulence intensity**

Now we compared wind history 1 and 4 which have the same wind speed and different turbulence intensity. As can be seen from the wind yaw angle and speed the frequency content is more distributed at high frequencies, which is why the average value of the quantities is similar in the two cases, while the peaks are clearly different. From the plot Loads on the Wheels on right, can be noticed that the peaks are more relevant and the modulus change considerably in the second case over time.

**Different meteorological conditions**

Here we compared different weather conditions taking in account wind history 5. As can be seen the main variations occur when snow condition is considered. In fact the trajectory has a deviation from 0 of 1.2-1.8 compared to 0.2 of dry and wet cases.

The steer angle plot shows that the driver is trying to go against the effect of the wind force and there’s a peak of 27 °.

The vehicle is much faster in the snow case, with a peak speed of 35 km/h, compared to the dry and wet cases

**Load variation**

The vehicle body mass is under 5 tons and the lumped mass we are adding is below 4 tons, therefore lambda=1 equals to a total weight of around 8.5 tons. The wind history we are considering is the most critical one with peaks of 40 m/s (140 km/h) which means that rollover is very likely to happen even on a heavy truck. With such a strong wind we can see that at lambda=0.25 (around 6 tons total) rollover happens after very few seconds. Lambda =0.5 represents instead a sort of limit of an unsafe condition because we can see that the load on the RR wheel is reaching values close to zero but there is always some margin. In a real life case this represents still a dangerous situation. Lambda=0.75 is instead a safe condition. Load on the RR wheel shows a good margin. With wet or snow conditions the situation worsens because even if rollover may not occur the trajectory is still highly affected.

The maximum peaks reached in the trajectory are around 2.2 m for lambda=0.25, 0.4 m for lambda=0.5, 0.25 m for lambda=0.75.

Note that these values are subject to variations due to changes in the tau\_roll which would affect the weight transfer on the two axles. In this case tau\_roll=0.664 was taken as default.

Roll stiffness variation

Tau\_roll corresponds to the ratio between the stiffness of the front axle and the total roll stiffness. A low tau roll therefore indicates a very stiff rear axle and weak front axle which in turn means that we will have a strong weight transfer at the rear and a lower weight transfer at the front. This denotes a critical condition for our truck because we can see that the critical axle for the vertical load is the rear one as the cog is closer to the front. In fact the gap between the RR and RL wheels tends to increase which means that the RR wheel will likely detach from the ground. Moving the roll stiffness to the front we achieve a beneficial effect which increases the safety margin on the rear axle load. In snow conditions an instability was observed also at tau\_roll=0.75 as the driver input reached the lock angle of the steering wheel.

Lane change

In the last part of the presentation we analyzed the behaviour of the truck considering different paths: in the first case, we considered a change of the lane, while in the second and last case an entrance and exiting from a tunnel. For the lane change, we performed the simulation changing the referencepath, which is no more a straight line but the position of the y direction changes. In this slide are reported the trajectory, the steer angle and the load on wheels considering wind history 6 and comparing the results for without the lane change. In the trajectory the change in y direction is highlighted, and the change in the wheels direction is visible also in the steer angle: we recognize the four instants when the driver turns the steering wheel and performs the maneuver. However, differently from the previous analyses, the effect on the vertical load on the wheels is not appreciable.

Tunnel

In the end we considered a different situation: the truck enters and exits from a tunnel. This simulation is performed putting the wind speed equal to 0.4 m/s form 20 to 40 seconds in all positions (it is not strictly equal to 0 to avoid numerical errors). Here are reported the wind speed, the trajectory, the roll angle and the loads on the wheels, for both conditions with and without the tunnel. When the truck gets into the tunnel, the wind stops pushing the truck and the driver starts recovering the desired path, which is a straight line. In the roll angle figure we can appreciate the little transient when the truck still rolls even if there is no more wind. The same effect is visible also in the load on wheels figure. When the truck exits from the tunnel, the condition is similar to the case without the gallery, and after a certain time the diffreence between the two simulations are no more appreciable.