STUDY ON THE VEHICLE WEIGHT DISTRIBUTION ON DIFFERENT LOADING CONDITIONS USING IPG CAR MAKER

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Abstract— In Automobile Industry most of the companies looking forward to downsize the vehicle weight in order to increase their performance and range they were decreasing their structural durability, ability and the material properties. For this we have taken A Volvo XC 90 Hybrid model is taken from the GUI (Product Examples) in IPG Car Maker for the weight reduction. First, the theoretical calculation for the model car has been calculated to find the Traction Force for both wheels for the existing model and the optimized models. Later various operation in IPG Car Maker has been done to optimize the vehicle without changing the material properties and analyzing various load acting like Traction Force, Pitch Rate, Roll Rate, Toe FR and FL Rate and Yaw Rate. Then the vehicle load is set and maneuver are applied to run the model car in virtual road. The virtual car demonstration can be done in IPG Movie. Then the results of Traction control, Pitch Rate, Roll Rate, Toe FR and FL Rate and Yaw Rate are taken from the IPG control 2.0.8. The model is subjected to acceleration and deceleration in elevation profiles, tunnels, cornering and in speed bumps and the resultant and the maximum deviation occurred on each optimized model are analysed in IPG control as Graph. Later the simulation results are compared for the best optimized model, best design, cost efficient and its performance range. It should likewise withstand static and dynamic burdens without unnecessary redirection or contortion.

Keywords— **Traction Force, Pitch Rate, Roll Rate, Toe Rate, Yaw Rate.**

I. INTRODUCTION

Virtual testing of automobiles and light-obligation vehicles. We have utilized the reproduction arrangement Carmaker explicitly for testing traveler vehicles and light-obligation vehicles. Utilizing this product, you can precisely show certifiable test situations, including the whole general climate, in the virtual world. At the point when a vehicle speeds up, the power is communicated from its engine through a gearbox to its tires, which then, at that point, applies a longitudinal power to the ground to push the vehicle ahead. If an excessive amount of force is applied to the tires, they will start to slip, which implies that the longitudinal power that powers the vehicle forward will diminish and the speed increase will hence additionally diminish.

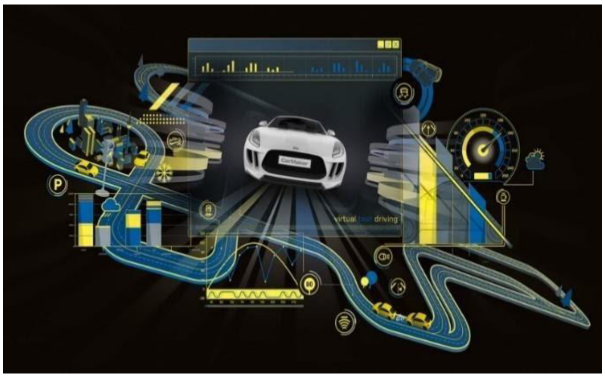

Figure 1.1 Overall view of IPG car maker

To keep away from this, the driver can apply less choke to decrease the applied force on the tires. This should likewise be possible with the assistance of a foothold control framework and is additionally what this degree task will zero in on. The re-enactment arrangement Car Maker was explicitly intended for the turn of events and consistent testing of vehicles and light-obligation vehicles in all advancement stages. The open incorporation and test stage permits to carry out virtual test situations for the application regions Autonomous Vehicles, ADAS, Powertrain and Vehicle Dynamics. The overall car maker software is shown in fig. 1.1. Car Maker offers a superior exhibition, constant proficient vehicle model to assemble virtual models previously during beginning phases of the advancement interaction.

2.LITERATURE SURVEY

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Fenton, J. (1996) - Handbook of vehicle design analysis. England: Mechanical Engineering Publications Limited, 336- 337 Gong, T., Yan, H. & Liu, P. F. (2014). Fontaras, G., Pistikopoulos, P. & Samaras, Z. (2008) - Experimental evaluation of hybrid vehicle fuel economy and pollutant emissions over real-world simulation driving cycles. Atmospheric environment, 42(18), 4023-4035.

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3.ANALYTICAL STUDY

In this project, we had taken Volvo XC90 hybrid model. The weight of the car has been reduced at three different percentages and each of the model has been checked for the traction force, pitch rate, roll rate, yaw rate and rate. In order to know the traction force, the formula is used for calculating the traction force value. The traction force can be calculated by knowing the kerb weight of the car (m) (since the total mass of the car is calculated as kerb weight), co-efficient of friction (μ) (friction between the road and the surface), acceleration due to gravity. Normal kerb weight of the car is taken as 2343 kg, co-efficient of friction is taken as 0.4 (as we had taken dry asphalt surface) and then the acceleration due to gravity is taken as 9.81 m/s^2. The traction force can be calculated using the formula.

$$F = \mu W_t \quad \text{---------} (1)$$

$$F = \mu * m * a \quad \text{---------} (2)$$

Were,

F = Traction Force (N)
μ = co-efficient of friction
m = mass of the car (Kerb weight)
a = Acceleration to due to gravity

3.1 Existing Model

Kerb weight = 2343 kg
F = 0.4 * (2343) * (9.81)/ 4
= 9193/4

Force for one wheel = 2298 N
Force on both wheels = 2(2298)
= 4596 N

3.2 Proposed Model (When 5% Weight Reduced)

Kerb weight = 2248 kg

F = 0.4 * (2248) * (9.81)/ 4
= 8789/4
Force for one wheel = 2197 N
Force on both wheels = 2(2197)
= 4397 N

3.3 Proposed Model (When 10% Weight Reduced)

Kerb weight = 2136 kg
F = 0.4 * (2136) * (9.81)/ 4
= 8381/4
Force for one wheel = 2095 N
Force on both wheels = 2(2095)
= 4190 N

3.4 Proposed Model (When 15% Weight Reduced)

Kerb weight = 2033 kg
F = 0.4 * (2033) * (9.81)/ 4
= 7977/4
Force for one wheel = 1994 N
Force on both wheels = 2(1994)
= 3988 N

4 TESTING AND SIMULATION

In this chapter, a brief view of the Virtual simulation and testing of the proposed models of the car is presented.

The Simulation and testing of the proposed models have been carried out in the IPG car maker 6.0.8 software. The model Volvo XC90 hybrid has been taken from the GUI and the load distributions has been set. The purpose of choosing this type of simulation system is because this project is based on the reducing vehicle loading distribution in different loading conditions.

4.1 GRAPHICAL USER INTERFACE

In this IPG we have select the GUI, in the GUI we have to select car model in the product example. In the product examples there are many varieties of vehicles. Our team selected the Volvo xc90 Hybrid car as shown in Fig. 4.1. Next, we have to give the passengers weight front and back in the box. This is the main graphical user interface which is used to control the actions of the VVE, select the virtual vehicle parameter data, define or select the virtual road, set the virtual driver parameters, define or load maneuver, open other tools that are part of the CIT, and a number of other useful operations.

Figure 4.1 Graphical User Interface of IPG car maker

4.2 MANEUVER

Then we have to set maneuverer for the car. In the maneuverer we have the choice to give the vehicle to move forward, backward or to stop the vehicle as shown in Fig. 4.2. In the maneuverer we have the choice to give vehicle speed, vehicle stop time and vehicle backward speed time.

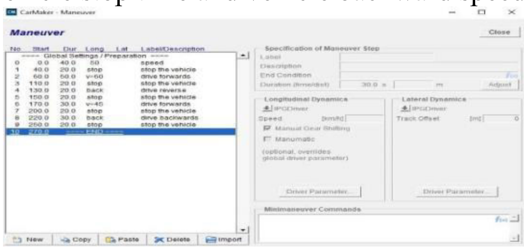

Figure 4.2 Maneuver for the model car

4.3 ROAD/ SCENARIO

In the parameter, using the scenario/road option we are able to draw the road for the vehicle testing. Using the point list, we are able to draw the line for the road. We couldn’t able to join the line using point list, the option for joining the line is connect option as shown in Fig. 4.3. There are many options to insert in the scenario like we have the option to insert the tree, house, tunnel, bridge, signal and bumps etc.

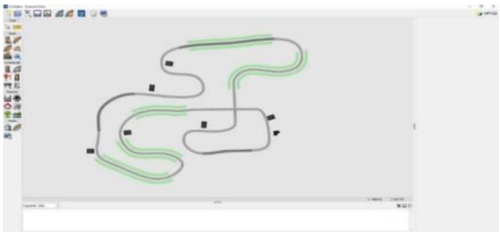

Figure 4.3 Scenario or road on IPG car maker

After finishing the road scenario, we have to specify the route to run the vehicle. In the 3D view we are able to check the road as shown in Fig. 4.4.

Figure 4.4 3D view of the scenario or road

4.4 IPG MOVIE

In the GUI, click the start button to run the simulation. On running the simulation, the video will play in the video player. In the video, settings menu we are able to change the camera view fish view, top view and front view as shown in Fig. 4.5. We have the option to change one frame to four frame and three frame camera view. Real-time 3D-animation of the VVE. The virtual vehicle is shown performing the specified driving maneuver (per- formed by the virtual driver) on the virtual road. For detailed information regarding IPGMovie, have a look at the IPGMovie User's Guide.

Figure 4.5 Different view of our model in IPG Movie

We have to set the coefficient of friction for the road. We had taken the dry asphalt road (the co-efficient of friction is 0.4) as shown in Fig. 4.6.

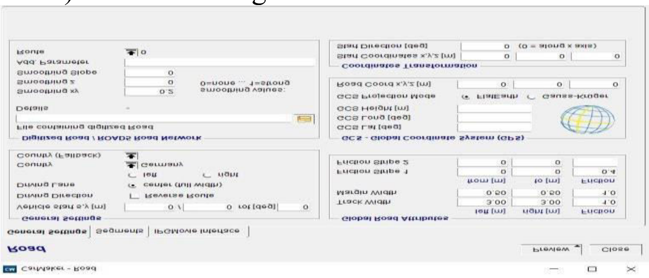

Figure 4.6 co-efficient of friction for the virtual road

4.5 IPG CONTROL

Visualization and analysis tool. IPG-CONTROL can be used to view selected output quantities in real-time, load post-simulation data files, and plot and analyze the results as shown in Fig. 4.7.

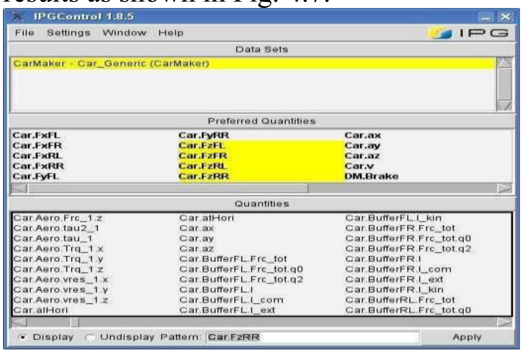

Figure 4.7 IPG control 2.0.8 for the Analyzation

5.6 TEST RUN

A Test Run is a test scenario which collects all the information required to parameterize the virtual vehicle environment and to start a simulation. Depending on complexity of the simulated test case, the Test Run composes of a different number of modules as shown in Fig. 4.8. As minimum requirement to be able to simulate, the following modules have to be parameterized within the Test Run:

• Vehicle:

Definition of the vehicle data set used.

• Road:

Parameterization of the test track.

• Maneuver:

Mainly to specify the driver's task and the vehicle data set to run on the virtual road track.

• Driver:

Set driver behaviour (defensive, normal, aggressive, ...)

Additionally, the following modules can be defined in the Test Run, depending on the field of application.

• Trailer:

To simulate a test car with trailer configuration.

• Tires:

Overwrite the default tire data set referred in the vehicle model and it will be default for most of the cars according to the car specification.

• Traffic:

Add other static or moving traffic objects.

• Environment:

Configuration of the test environment.

All this information is stored within the Test Run. Some information is directly written to the Test Run Info file.

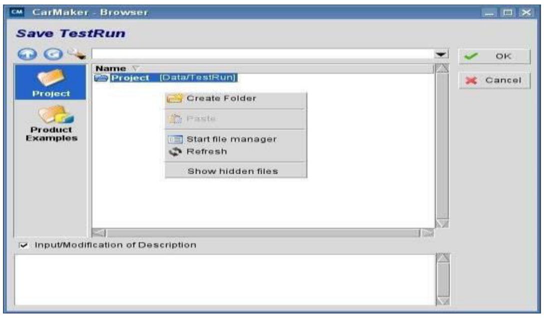

Figure 5.8 Renaming and saving a Test Run

5. RESULTS & DISCUSSION

5.1 TRACTION FORCE

In this section traction force of the vehicle has been calculated. For this IPG control 2.0.8 has been taken for the results. Traction Force is calculated mainly for the friction between the tire and road surface while in cornering, speed bumps, tunnels and bridges. In this virtual simulation the model has been run on the virtual road and the values are obtained. The blue line indicates the Front right tire of the model car and the green line indicated the front left tire of the model car. The values will be varied based on the weight reduction. From the results thus obtained, the comparison of the results is carried out to assert the maximum traction force.

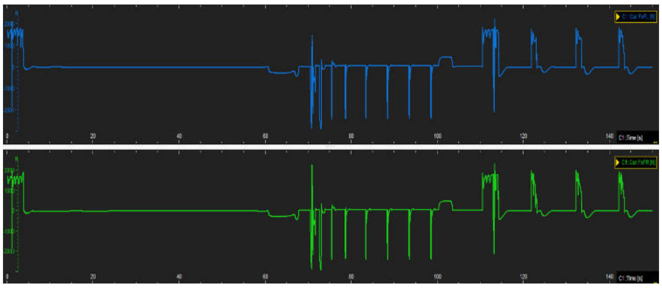

Figure 5.1 Results of the Traction control FR and FL (Existing Model)

Traction Force results in fig. 5.1 and Table 5.1 indicates that the traction force for the model car for the front tires has been shown. The maximum traction is at speed bumps, elevation, cornering and bridges. But its normal in straight roads and the minimum traction is at slopes.

Table 5.1 Traction control (Existing Model)

Parameter	**X - Axis**	**Y - Axis**	**Kerb weight**	**Max. Traction Force**
Traction Force	Time (seconds)	FxFL and FxFR	2343 N	2298 N

Traction Force results in fig. 5.1.2 and Table 5.2 indicates that the traction force for the model car for the front tires has been shown. The maximum traction is at speed bumps, elevation, cornering and bridges. But its normal in straight roads and the minimum traction is at slopes.

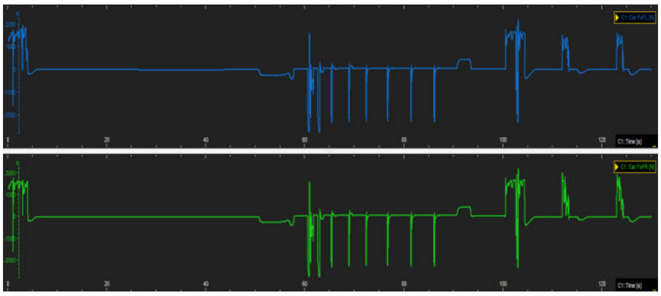

Fig.5.2 Results of the Traction control FR and FL (5% weight reduced model)

From the above graph the blue line indicates the result of Traction force for FxFL and the green indicates the result of Traction force for FxFR.

Table 5.2 Traction control FR and FL (5% weight reduced Model)

Parameter	**X - Axis**	**Y - Axis**	**Kerb weight**	**Max. Traction Force**
Traction Force	Time (seconds)	FxFL and FxFR	2248 N	2197 N

Traction Force results in fig. 5.1.3 and Table 5.3 indicates that the traction force for the model car for the front tires has been shown. The maximum traction is at speed bumps, elevation, cornering and bridges. But its normal in straight roads and the minimum traction is at slopes.

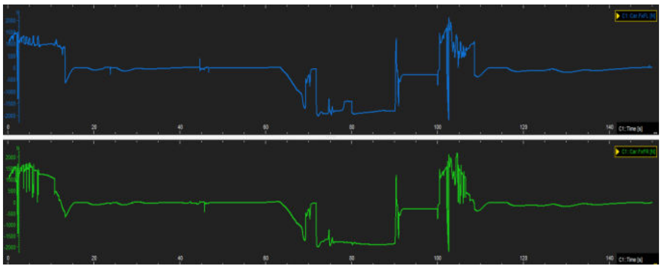

Fig.5.3 Results of the Traction control FR and FL (10% weight reduced model)

From the above graph the blue line indicates the result of Traction force for FxFL and the green indicates the result of Traction force for FxFR.

Table 5.3 Traction control FR and FL (10% weight reduced Model)

Parameter	**X - Axis**	**Y - Axis**	**Kerb weight**	**Max. Traction Force**
Traction Force	Time (seconds)	FxFL and FxFR	2136 N	2095 N

Traction Force results in fig. 5.1.4 and Table 5.4 indicates that the traction force for the model car for the front tires has been shown. The maximum traction is at speed bumps, elevation, cornering and bridges. But its normal in straight roads and the minimum traction is at slopes.

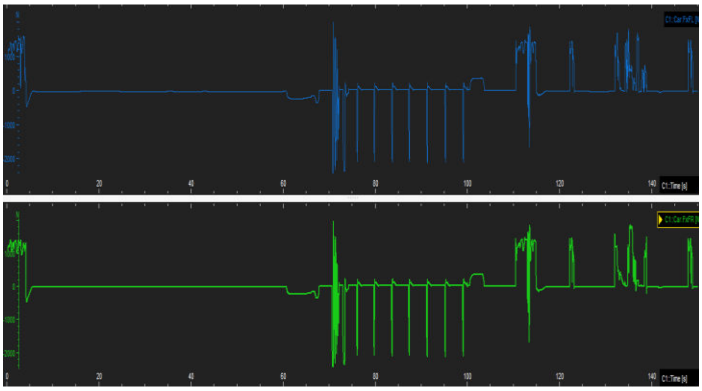

Fig.5.4 Results of the Traction control FR and FL (15% weight reduced model)

From the above graph the blue line indicates the result of Traction force for FxFL and the green indicates the result of Traction force for FxFR.

Table 5.4 Traction control FR and FL (15% weight reduced Model)

Parameter	X - Axis	Y - Axis	Kerb weight	Max. Traction Force
Traction Force	Time (seconds)	FxFL and FxFR	2033 N	1994 N

Thus, from the obtained results of the Traction control it is found that the traction force is increasing while decreasing the kerb weight of the car. The 15% weight reduced shows the maximum traction force.

5.2 Pitch Rate

In this section Pitch Rate of the vehicle has been calculated. For this the same IPG control 2.0.8 has been taken for the results. Pitch Rate is calculated mainly for the vehicle rotation about the transverse axis while in speed bumps and elevation. In this virtual simulation the model has been run on the virtual road and the values are obtained. The values will be varied based on the weight reduction. From the results thus obtained, the comparison of the results is carried out to assert the maximum Pitch rate.

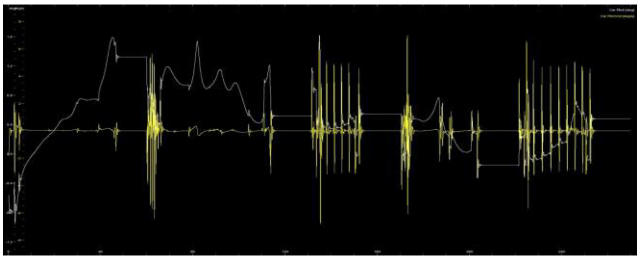

Fig. 5.5 Results of the Pitch control (Existing Model)

From the above Graph the yellow line indicates the result of Pitch velocity (deg/s) of the model car and the white line indicates the result of Pitch (deg) of the model car.

Pitch rate results in fig. 5.5 and Table 5.5 indicates that the pitch rate for the model car for the front tires has been shown. The maximum pitching is at speed bumps and elevation. But its normal in straight roads.

Table 5.5 Pitch control (Existing Model)

Parameter	X - Axis	Y - Axis	Max.Degree
Pitch Rate	Time (seconds)	Pitch Velocity(deg/s) and Pitch (deg)	1.6

Pitch rate results in fig. 5.6 and Table 5.6 indicates that the pitch rate for the model car for the front tires has been shown. The maximum pitching is at speed bumps and elevation. But its normal in straight roads.

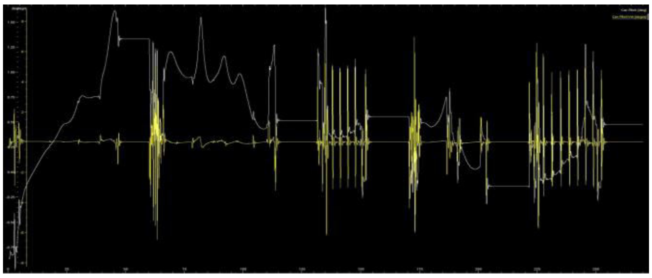

Fig. 5.6 Results of the Pitch control (5% weight reduced model)

From the above Graph the yellow line indicates the result of Pitch velocity (deg/s) of the model car and the white line indicates the result of Pitch (deg) of the model car.

Table 5.6 Pitch control (5% weight reduced Model)

Parameter	X - Axis	Y - Axis	Max.Degree
Pitch Rate	Time (seconds)	Pitch Velocity(deg/s) and Pitch (deg)	1.630

Pitch rate results in fig. 5.7 and Table 5.7 indicates that the pitch rate for the model car for the front tires has been shown.

The maximum pitching is at speed bumps and elevation. But its normal in straight roads.

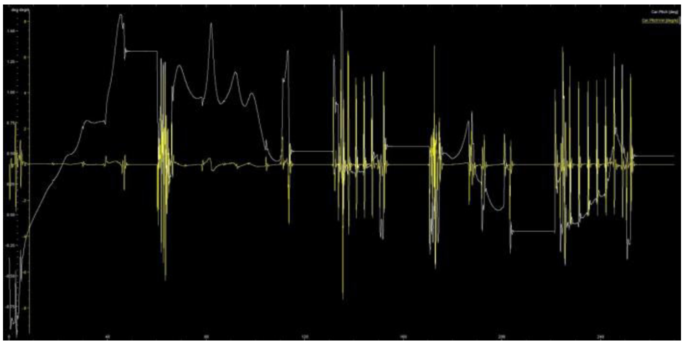

Fig. 5.7 Results of the Pitch control (10% weight reduced model)

From the above Graph the yellow line indicates the result of Pitch velocity (deg/s) of the model car and the white line indicates the result of Pitch (deg) of the model car.

Table 5.7 Pitch control (10% weight reduced Model)

Parameter	X - Axis	Y - Axis	Max.Degree
Pitch Rate	Time (seconds)	Pitch Velocity(deg/s) and Pitch (deg)	1.67

Pitch rate results in fig. 5.8 and Table 5.8 indicates that the pitch rate for the model car for the front tires has been shown. The maximum pitching is at speed bumps and elevation. But its normal in straight roads.

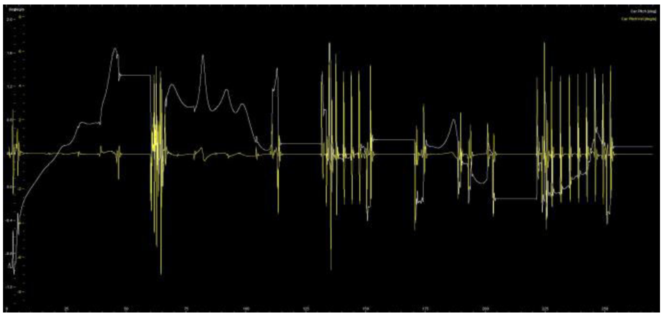

Fig. 5.8 Results of the Pitch control (15% weight reduced model)

From the above Graph the yellow line indicates the result of Pitch velocity (deg/s) of the model car and the white line indicates the result of Pitch (deg) of the model car.

Table 5.8 Pitch control (15% weight reduced Model)

Parameter	X - Axis	Y - Axis	Max.Degree
Pitch Rate	Time (seconds)	Pitch Velocity(deg/s) and Pitch (deg)	1.7

Thus, from the obtained results of the Pitching control it is found that the pitch rate is increasing while decreasing the kerb weight of the car. The 15% weight reduced shows the maximum pitch rate.

5.3 Roll Rate

In this section Roll Rate of the vehicle has been calculated. For this the same IPG control 2.0.8 has been taken for the results. Roll Rate is calculated mainly for the vehicle rotation about the longitudinal axis while in cornering. In this virtual simulation the model has been run on the virtual road and the values are obtained. The values will be varied based on the weight reduction. From the results thus obtained, the comparison of the results is carried out to assert the maximum Roll rate.

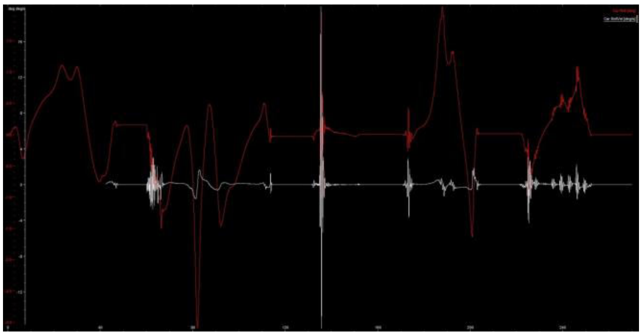

Fig. 5.9 Results of the Roll control (Existing Model)

Roll rate results in fig. 5.3.1 and Table 5.9 indicates that the roll rate for the model car for the front tires has been shown. The maximum rolling is at cornering. But its normal in straight roads.

In the above graph the red line indicates the result of Roll velocity (deg/s) of the model car and the white line indicates the result of Roll (deg) of the model car.

Table 5.9 Roll control (Existing Model)

Parameter	X - Axis	Y - Axis	Max.Degree
Roll Rate	Time (seconds)	Roll Velocity(deg/s) and Roll (deg)	1.6

Roll rate results in fig. 5.3.2 and Table 5.10 indicates that the roll rate for the model car for the front tires has been shown.

The maximum rolling is at cornering. But its normal in straight roads.

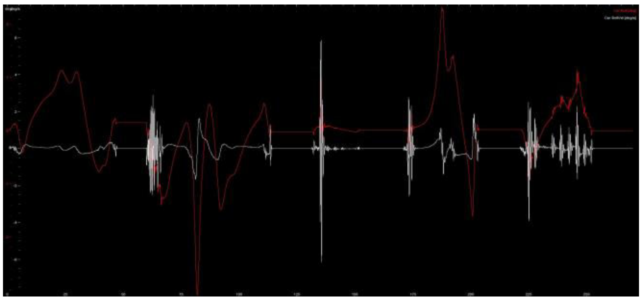

Fig. 5.10 Results of the Roll control (5% weight reduced model)

In the above graph the red line indicates the result of Roll velocity (deg/s) of the model car and the white line indicates the result of Roll (deg) of the model car.

Table 5.10 Roll control (5% weight reduced Model)

Parameter	**X - Axis**	**Y - Axis**	**Max.Degree**
Roll Rate	Time (seconds)	Roll Velocity(deg/s) and Roll (deg)	2.0

Roll rate results in fig. 5.11 and Table 5.11 indicates that the roll rate for the model car for the front tires has been shown. The maximum rolling is at cornering. But its normal in straight roads.

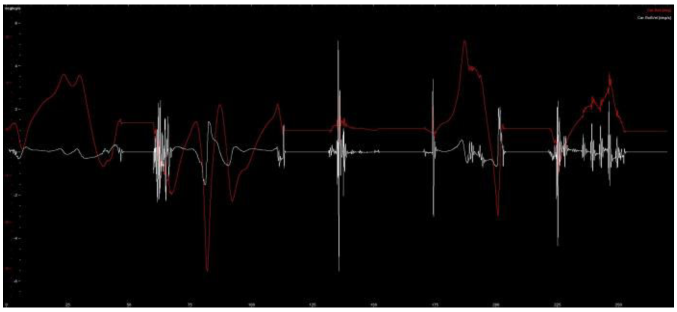

Fig. 5.11 Results of the Roll control (10% weight reduced model)

In the above graph the red line indicates the result of Roll velocity (deg/s) of the model car and the white line indicates the result of Roll (deg) of the model car.

Table 5.11 Roll control (10% weight reduced Model)

Parameter	**X - Axis**	**Y - Axis**	**Max.Degree**
Roll Rate	Time (seconds)	Roll Velocity(deg/s) and Roll (deg)	2.1

Roll rate results in fig. 5.12 and Table 5.12 indicates that the roll rate for the model car for the front tires has been shown.

The maximum rolling is at cornering. But its normal in straight roads.

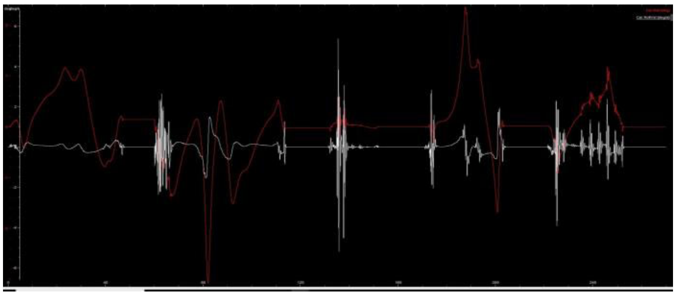

Fig. 5.12 Results of the Roll control (15% weight reduced model)

In the above graph the red line indicates the result of Roll velocity (deg/s) of the model car and the white line indicates the result of Roll (deg) of the model car.

Table 5.12 Roll control (15% weight reduced Model)

Parameter	**X - Axis**	**Y - Axis**	**Max.Degree**
Roll Rate	Time (seconds)	Roll Velocity(deg/s) and Roll (deg)	2.2

Thus, from the obtained results of the Rolling control it is found that the roll rate is increasing while decreasing the kerb weight of the car. The 15% weight reduced shows the maximum roll rate.

5.4 Toe Rate

In this section toe rate of the vehicle has been calculated. For this IPG control 2.0.8 has been taken for the results. Toe Rate is calculated mainly for the symmetric angle that each wheel makes with the longitudinal axis of the vehicle while in speed bumps, elevation, cornering and bridges. In this virtual simulation the model has been run on the virtual road and the values are obtained. The values will be varied based on the weight reduction. From the results thus obtained, the comparison of the results is carried out to assert the maximum toe rate.

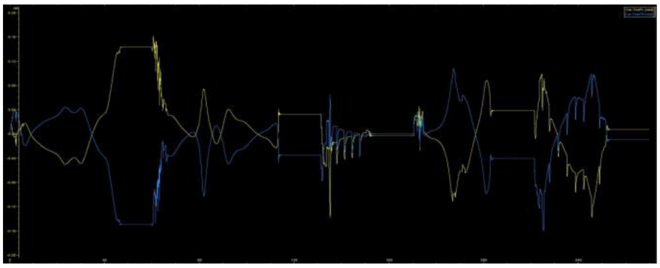

Fig. 5.13 Results of the Toe control FR and FL (Existing Model)

Toe Rate results in fig. 5.13 and Table 5.13 indicates that the toe rate for the model car for the front tires has been shown. The maximum toe rate is at speed bumps, elevation, cornering and bridges. But its normal in straight roads.

Toe angle is used to compensate for the “give” in the suspension bushings. It helps the tires run parallel to each other. A RWD car pushes the front tires. Rolling resistance causes the tires to push back against the suspension. So, RWD vehicles use toe-in settings to offset this movement.

A FWD vehicle has the opposite issue. The front tires pull the car. The weight of the vehicle resists the forward movement. This causes the front wheels to pull forward against the suspension. So, FWD cars use toe-out settings to offset the movement. The toe angle can also affect handling. More toe-in will reduce oversteer and improve stability at speed. More toe-out will reduce understeer. Despite its benefits, the toe angle can have some draw-backs. Excessive toe settings can cause the steering to feel shaky and unstable. It will also cause excessive tire wear.

Table 5.13 Toe control (Existing Model)

Parameter	X - Axis	Y - Axis	Max. Degree Toe FR	Max. Degree Toe FL
Toe Rate	Time (seconds)	Toe FR (rad) and Toe FL (rad)	0.10	0.16

Toe Rate results in fig. 5.14 and Table 5.14 indicates that the toe rate for the model car for the front tires has been shown. The maximum toe rate is at speed bumps, elevation, cornering and bridges. But its normal in straight roads.

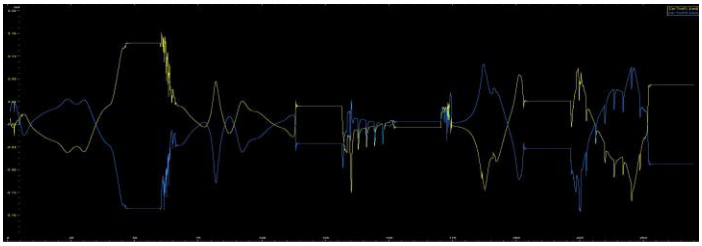

Fig. 5.14 Results of the Toe control FR and FL (5% weight reduced model)

In the above graph the blue line indicates the result of Toe FR (rad) of the model car and the yellow line indicates the result of Toe FL (rad) of the model car.

Table 5.14 Toe control (5% weight reduced Model)

Parameter	X - Axis	Y - Axis	Max. Degree Toe FR	Max. Degree Toe FL
Toe Rate	Time (seconds)	Toe FR (rad) and Toe FL (rad)	0.12	0.163

Toe Rate results in fig. 5.15 and Table 5.15 indicates that the toe rate for the model car for the front tires has been shown. The maximum toe rate is at speed bumps, elevation, cornering and bridges. But its normal in straight roads.

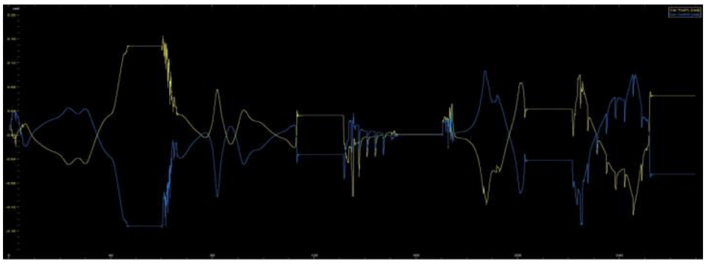

Fig. 5.15 Results of the Toe control FR and FL (10% weight reduced model)

Table 5.15 Toe control (10% weight reduced Model)

Parameter	X - Axis	Y - Axis	Max. Degree Toe FR	Max. Degree Toe FL
Toe Rate	Time (seconds)	Toe FR (rad) and Toe FL (rad)	0.15	0.165

Toe Rate results in fig. 5.16 and Table 5.16 indicates that the toe rate for the model car for the front tires has been shown. The maximum toe rate is at speed bumps, elevation, cornering and bridges. But its normal in straight roads.

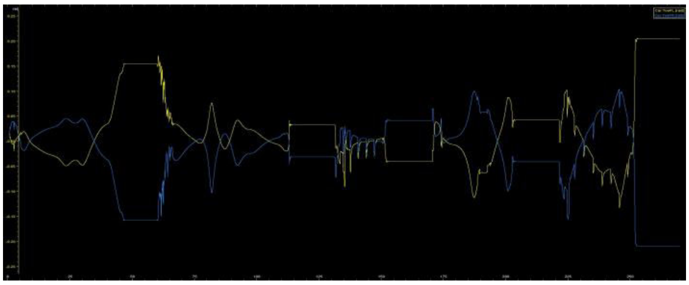

Fig. 5.16 Results of the Toe control FR and FL (15% weight reduced model)

In the above graph the blue line indicates the result of Toe FR (rad) of the model car and the yellow line indicates the result of Toe FL (rad) of the model car.

Table 5.16 Toe control (15% weight reduced Model)

Parameter	X - Axis	Y - Axis	Max. Degree Toe FR	Max. Degree Toe FL
Toe Rate	Time (seconds)	Toe FR (rad) and Toe FL (rad)	0.17	0.166

Thus, from the obtained results of the Toeing control it is found that the toe rate is increasing while decreasing the kerb weight of the car. The 15% weight reduced shows the maximum toe rate.

5.5 Yaw Rate

In this section Yaw Rate of the vehicle has been calculated. For this the same IPG control 2.0.8 has been taken for the results. Yaw Rate is calculated mainly for the vehicle rotation about the vertical axis. In this virtual simulation the model has been run on the virtual road and the values are obtained. The values will be varied based on the weight reduction. From the results thus obtained, the comparison of the results is carried out to assert the maximum Yaw rate.

Fig. 5.17 Results of the Yaw control (Existing Model)

In the above graph the green line indicates the result of Yaw Rate (deg/s) of the model car and the white line indicates the result of Yaw (deg) of the model car.

Yaw rate results in fig. 5.17 and Table 5.17 indicates that the yaw rate for the model car for the front tires has been shown.

A yaw rotation is a movement around the yaw axis of a rigid body that changes the direction it is pointing, to the left or right of its direction of motion. The yaw rate or yaw velocity of a car, aircraft, projectile or other rigid body is the angular velocity of this rotation, or rate of change of the heading angle when the aircraft is horizontal. It is commonly measured in degrees per second or radians per second.

Yaw velocity can be measured by measuring the ground velocity at two geometrically separated points on the body, or by a gyroscope, or it can be synthesized from accelerometers and the like. It is the primary measure of how drivers sense a car's turning visually. It is important in electronic stabilized vehicles. The yaw rate is directly related to the lateral acceleration of the vehicle turning at constant speed around a constant radius, by the relationship tangential speed*yaw velocity = lateral acceleration = tangential speed^2/radius of turn, in appropriate units. The sign convention can be established by rigorous attention to coordinate systems. In a more general manoeuvre where the radius is varying, and/or the speed is varying, the above relationship no longer holds.

Table 5.17 Yaw control (Existing Model)

Parameter	X - Axis	Y - Axis	Max.Degree
Yaw Rate	Time (seconds)	Yaw Velocity (deg/s) and Yaw (deg)	22

Yaw rate results in fig. 5.18 and Table 5.18 indicates that the yaw rate for the model car for the front tires has been shown.

Fig. 5.18 Results of the Yaw control (5% weight reduced model)

In the above graph the green line indicates the result of Yaw Rate (deg/s) of the model car and the white line indicates the result of Yaw (deg) of the model car.

Table 5.18 Yaw control (5% weight reduced Model)

Parameter	X - Axis	Y - Axis	Max.Degree
Yaw Rate	Time (seconds)	Yaw Velocity (deg/s) and Yaw (deg)	24

Yaw rate results in fig. 5.19 and Table 5.19 indicates that the yaw rate for the model car for the front tires has been shown.

Fig. 5.19 Results of the Yaw control (10% weight reduced model)

In the above graph the green line indicates the result of Yaw Rate (deg/s) of the model car and the white line indicates the result of Yaw (deg) of the model car.

Table 5.19 Yaw control (10% weight reduced Model)

Parameter	X - Axis	Y - Axis	Max.Degree
Yaw Rate	Time (seconds)	Yaw Velocity (deg/s) and Yaw (deg)	26

Yaw rate results in fig. 5.20 and Table 5.20 indicates that the yaw rate for the model car for the front tires has been shown.

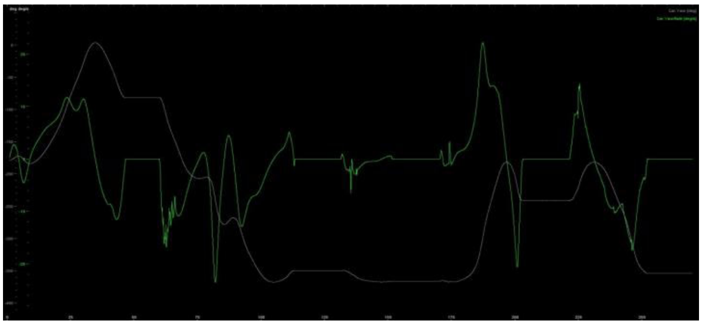

Fig. 5.20 Results of the Yaw control (15% weight reduced model)

In the above graph the green line indicates the result of Yaw Rate (deg/s) of the model car and the white line indicates the result of Yaw (deg) of the model car.

Table 5.20 Yaw control (15% weight reduced Model)

Parameter	X - Axis	Y - Axis	Max.Degree
Yaw Rate	Time (seconds)	Yaw Velocity (deg/s) and Yaw (deg)	24

Thus, from the obtained results of the Yawing control it is found that the yaw rate will be decreased while decreasing the kerb weight of the car. But for the 5% and 10% weight reduction the yaw rate is increasing only for the 15% weight reduction is decreasing. So, the 15% weight reduced shows the maximum yaw rate.

6 CONCLUSIONS

6.1 COMPARISON OF TRACTION FORCE

The Traction Force for existing model and the optimized models has been taken from the IPG control 2.0.8 and compared the results.

Table 6.1 Comparison of Results for the Traction Force

Parameter	Existing Model	5% weight Reduced	10% weight reduced	15% weight reduced
Traction Force	2298 N	2197 N	2095 N	1994 N

Based on the Table 6.1 given above when the weight is reduced the traction force is also decreasing. So, the 15 % weight optimized model is the best Traction Force.

6.2 COMPARISON OF PITCH RATE

The Pitch Rate for existing model and the optimized models has been taken from the IPG control 2.0.8 and compared the results.

Table 6.2. Comparison of Results for the Pitch Rate

Parameter	Existing Model	5% weight Reduced	10% weight reduced	15% weight reduced
Pitch Rate	1.6	1.630	1.67	1.7

Based on the Table 6.2 given above when the weight is reduced the Pitch Rate is also decreasing. So, the 15 % weight optimized model is the best Pitch Rate.

6.3 COMPARISON OF ROLL RATE

The Roll Rate for existing model and the optimized models has been taken from the IPG control 2.0.8 and compared the results.

Table 6.3. Comparison of Results for the Roll Rate

Parameter	Existing Model	5% weight Reduced	10% weight reduced	15% weight reduced
Roll Rate	1.6	2.0	2.1	2.2

Based on the Table 6.3 given above when the weight is reduced the Roll Rate is also decreasing. So, the 15 % weight optimized model is the best Roll Rate.

6.4 COMPARISON OF TOE FR AND FL

The Toe FR and FL for existing model and the optimized models has been taken from the IPG control 2.0.8 and compared the results.

Table 6.4. Comparison of Results for the Toe FR and FL Rate

Parameter	Existing Model	5% weight Reduced	10% weight reduced	15% weight reduced
Toe FR	0.10	0.12	0.15	0.17
Toe FL	0.16	0.163	0.165	0.166

Based on the Table 6.4 given above when the weight is reduced the Toe FR and FL Rate is also decreasing. So, the 15 % weight optimized model is the best Toe FR and FL.

6.5 COMPARISON OF YAW RATE

The Yaw Rate for existing model and the optimized models has been taken from the IPG control 2.0.8 and compared the results.

Table 6.5. Comparison of Results for the Yaw Rate

Parameter	Existing Model	5% weight Reduced	10% weight reduced	15% weight reduced
Yaw Rate	22	24	26	24

Based on the Table 6.5 given above when the weight is reduced the Yaw Rate is increasing. But for the 15% weight reduced model the Yaw rate is Decreasing. So, the 15 % weight optimized model is the best Yaw Rate.

In this project, proposed models of three different weight reductions of the car are simulated and testing has been done. From this study it is found that when the weight has been reduced for the model car the traction force, Pitch Rate, Roll Rate and Toe Rate are increasing and for the Yaw Rate is decreasing.

6.6 COMAPRISON OF RESULTS FOR THE EXISTING MODEL AND THE OPTIMIZED MODELS

The comparison is being made form the vales obtained from the traction force, Pitch rate, Roll Rate, Toe Rate and Yaw Rate. The Traction Force has been calculated using the traction force formula in the theoretical study. The values that were calculated in the theoretical study is within the range of values that is being obtained from the simulation and IPG control 2.0.8.

In this project, we had taken Volvo XC90 hybrid model. The weight of the car has been reduced at three different percentages and each of the model has been checked for the traction force, pitch rate, roll rate, yaw rate and rate. In order to know the traction force, the formula is used for calculating the traction force value. The traction force can be calculated by knowing the kerb weight of the car (m) (since the total mass of the car is calculated as kerb weight), co-efficient of friction (μ) (friction between the road and the surface), acceleration due to gravity.

Table 6.6**.** Comparison of the Results for the Existing Model and the Optimized Models

Volvo XC 90 Hybrid Parameters	Existing Model	5% weight Reduced	10% weight reduced	15% weight reduced
Traction Force	2298 N	2197 N	2095 N	1994 N
Force on Both wheels	4596 N	4394 N	4190 N	3988 N
Pitch Rate	1.6	1.630	1.67	1.7
Roll Rate	1.6	2.0	.2.1	2.2
Toe FR	0.10	0.12	0.15	0.17
Toe FL	0.16	0.163	0.165	0.166
Yaw Rate	22	24	26	24

From these values it is concluded that the 15% weight reduction of the Volvo XC 90 Hybrid is the better optimized model and its performance, efficiency are also better compared to existing model.

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