Suspensionless Soapbox Car

Sanket T. Tekade[1]

[1]*Student, Department of Mechanical Engineering, SOET, Sandip University, Nashik, India*

Abstract - This paper presents to introduce the factors influencing and the corresponding derivation of a mathematical model for the suspensionless vehicle which runs without any motor engine. Vehicle is design such a way that both axles of car acts like a suspension at the time of performance. It may be applied to actual model designs and full size vehicles as it's typically used in "Soapbox Car" racing events. By studying the model should clarify the design parameters as well as main aspects that forces the vehicle on slope, and reduce the speed on the level. Increasing the forward acceleration, particularly at a initial stage with all bumps and hurdles, it is a key performance characteristic to reduce the elapsed time of running. This suspensionless model was used successfully in the design and construction of actual competition vehicle and offers a potentially useful design tool and helps in teaching aid for studies in car dynamics.

Keywords – Suspensionless, Soapbox, vehicle, car.

1. INTRODUCTION

This study concerns the acceleration of a gravity powered suspensionless "soapbox" type vehicle as used in fun and college contests, and scale model versions for events such as the Sinhgad Institutes Soapbox Car Competition. An expression for acceleration in such type of vehicle is derived taking account of the various resistances like speed brakers to the motion. The analysis is based on a vehicle dynamics teaching model used successfully in University [1]. In the University, students works in small groups to design, anlayse, build and test actual model dragsters each powered by a given spring like axle as the energy source. The tests are runs along a 15 m test track with a time limit. So it helps to understand the dynamics of the vehicle, it clearly shows the importance of reducing losses due to aerodynamic drag, friction and rolling resistances.

Also taken into account that we examine various parameters such as wheel diameters, masses and second moments of mass, position of the centre of mass, etc. Without using actual suspension components, there is a modified structure of both front and rear axle which itself acts like a suspension on road. It is important to minimize elapsed time but at the same time to maximize performance in the sense of acceleration. This is profitable to increase forward acceleration initially of the run, even to the extent of coasting unpowered in the latter stages. A higher initial acceleration can be mean as higher average speed and hence reduced elapsed time over the given distance. Acceleration is the key or important performance factor, as in most forms of motorsport events including gravity powered "soapbox" type vehicles.

Energy approach to derive mathematical expressions for elapsed time and instantaneous speed for model vehicles which are travelling downwards a track as in used for the Sinhgad Institutes Soapbox Car event in the India, making the point that Derby or Soapbox car races are often won by no more than one or two hundredths part of a second [2]. By extending this approach to include a sensitivity analysis of the various parameters which are identified and made the point that race time and not displacement and velocity is the typical quantity of interest [3]. They also make the point that increasing the vehicle mass results in reduced time of race but at a certain limit the increased friction neglates this. Hence "the most efficient parameter to manipulate is the friction between the wheel and axle".

The Stallion Motorsports has tabled a simple model for the acceleration, further extended to include an expression for terminal velocity and makes the slightly surprising observation that "the diameter and mass of your wheels has no effect on your car's terminal velocity" based on an interpretation that the extra inertia of a larger wheel is cancelled out by the larger torque applied to rotate it [4]. This observation is clarified by observing about wheels that " the moment of inertia does not affect car's top speed while it only affects the time it take you to get there" [5].

Our team build a record vehicle with a weight of 120kg including driver in the competition.

In terms of the practical physics involved, Gale has published a 52 page document containing many recommendations and tips on design, construction and indeed driving of gravity powered vehicles [6].

1.1 SETTING THE SCENE

The Sinhgad Institute Soapbox event has been run since 2013 and literally thousands of pupils and students have benefitted in terms of understanding dynamics of the vehicle and in the practical issues associated with applying theory to real/actual working models or products.

Events for full size real vehicles have become popular too in this period and continue to introduce youngsters to the fun, trials and tribulations of motorsport including preparation, dealing with entries and officials, passing through technical inspection or scrutineering etc. Fig.1 shows a typical paddock scene from a recent college level event in the Uk, reminiscent of a European Formula 2 race meeting.

Fig.1. A typical paddock scene getting ready for thecompetition

Generally events are run fairly informally, but having issues associated with or which parallel "actual" motorsport events. Vehicles can be run in pairs (as with drag racing), sigly, in groups, or at staged intervals, it is completely depending on the track, starting ramp or hill. Usually there are several elimination heats culminating in a final. Vehicles are released from the top of the special starting ramp, and to ensure consistency and fairness push or running starts are often forbidden. Thus gravity is the only power source to the vehicle at intial stage. As mentioned above, performances can be remarkably close at the finish line, as shown in Fig. 2 below.

Therefore such closeness implies that it is important to pay attention to the details that may affect the performance, however small. Key to this is the initial acceleration and any final deceleration if the track goes levels out, thus it is very much important to consider all the factors of influence during event.

Fig. 2. A close finish. Typical "soap box" cars in action (Courtesy Wikimedia Foundation [7])

1.2 FREE BODY DIAGRAMS AND ANALYSIS MODEL

There are normally 4 wheels but for the purposes of analysis the two front wheels, with axles and other rotating parts are considered as one rotating mass and the two rear wheel assemblies. Fig. 3 shows the free body diagrams of the chassis or body (including driver) and the front and rear wheel assemblies. The vehicle is rolling down on the slope and it is assumed that there is no slip at the both wheels to the road contact.

The only force providing a positive acceleration in the x direction is the component having weight, mg sinq, which may be why some teams opt for heavier constructions. Some of the resistance forces and other issues are also directly or indirectly a function of the mass, however so it is not as clearly solved. For example, QF and QR are the resistance torques due to the and any friction in the rotating parts as bearings. These torques will almost certainly increases as the mass increases. The torques also do negative work of sapping energy from the car. The friction forces FF and FR at the tyres to the road contact patches are generated in response to QF and QR *and* to provide the rotational acceleration of the wheel assemblies for both tyres. Thus during the acceleration stages FF rF ¹ QF and FR rR ¹ QR but they do no work on the vehicle unless there is slipping or skidding between the wheels and road surface.

The forces RF and RR are separates rolling resistance forces due to the tyre distortion and possible scrub effects at the contact patch to the surface. They are generally difficult to relate and quantify to the normal reactions by a rolling resistance coefficient such that RF = mRNF and RR = mRNR where mR takes values typically in the region 0.01 to 0.02 for pneumatic tyres on asphalt. It should be noted that NF and NR both are in turn functions of the vehicle mass and also that RF and RR do negative work on the vehicle but they have no moment about the wheel axes of the vehicle. In this respect these rolling resistance forces are sometimes modelled as acting at wheel centre height, sometimes as to bring forward movement slightly the both normal reactions NF and NR so that the resultants pass through the both wheel centres of the vehicle.

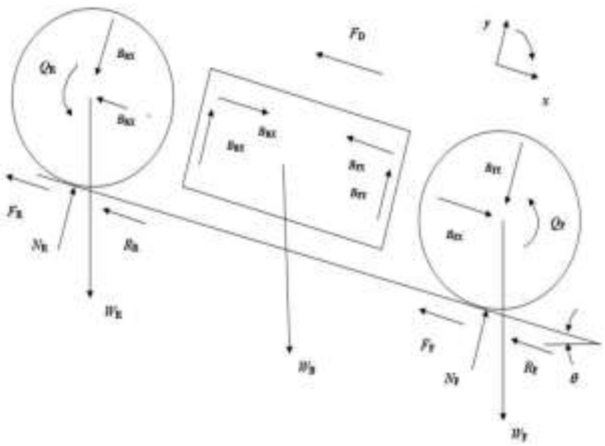

Fig. 3. Free body diagram of a Soapbox vehicle

It is important to distinguish between the two types of rolling resistance forces. It is particularly for “soapbox” type vehicles where they may be significant enough to warrant attention.

2. COMPUTER MODEL AND STUDY

A computer model of vehicle in was designed in CATIA V5R20 software. It is tested and verified and used to study the effects on predicted forward acceleration and various design parameters. Fig.4 indicates the computer design of actual soapbox vehicle which was used in the Institute Competition.

Fig.4 Computer model for SoapBox Car

From the initial studies, specification was chosen and the main parameters studied in turn.

The base vehicle data were used: total mass 60 kg. Mass per wheel is 2 kg, diameter of wheels 1.2m, height of centre of mass 0.5m. Position of centre of mass ahead of rear axle is 0.7m and wheelbase of 2.0m.

As expected, decreasing the bearing resistance torques including the number of wheels had a small positive linear effect on the forward acceleration. Initial acceleration was not affected by drag coefficient or frontal cross sectional area as the aerodynamic drag is of course velocity dependent. For the base specification vehicle the aerodynamic drag force at a speed of 22 km/h was of the order 7.0 N. The wheelbase and position of the centre of mass had very little effect on overall acceleration.

3. RESULT

In Fig.5 it shows the built in vehicle after analysis or testing on different parameters of computer model in software. As per design axles of vehicles were built such a way that they can works like suspension.

Fig.5 Built in vehicle after analysis

After satisfying all the criterias Fig.6 shows the real model of Suspensionless Soap Box Car which was ready to participate in Sinhgad Institutes Soapbox Car Competition.

Fig.6 Suspensionless Soap Box Car

4. CONCLUSION

A mathematical and computerised model has been formulated to express the acceleration of a gravity powered suspensionless vehicle. Observations are given regarding the factors which influence the acceleration in the soap box vehicle. These factors can be evaluated or analysed and applied to the vehicle systematically to arrive at an optimum real design. The model or vehicle was considered in the design of a successfully event winning vehicle. Observations on the factors which improve acceleration and thereby overall performance generally agree with the suspensionless and energy based approaches [2] [3]. Therefore it is hoped that this paper will add to the understanding of working of axle itself as a suspension in Soap box vehicle, such factors provide useful guidelines for the design of future SoapBox Car (gravity propelled vehicles).

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BIOGRAPHIES

"**Sanket T. Tekade** – Pursuing B.Tech in Mechanical Engg., SOET, Sandip University, Nashik. "