DESIGN AND FABRICATION OF PEDAL BOX

[1]Mr.B. Praveen Kumar, [2]C.V. Pranay, [3]L. Shiva Kumar, [4]K.Ramanjaneyulu

[1]Assistant Professor, Department of Mechanical Engineering, Guru Nanak Institute of Technology, Hyderabad, India

[2,3,4]Btech. Student, Department of Mechanical Engineering, Guru Nanak Institute of Technology, Ibrahimpatnam, Hyderabad, India

Abstract—The main objective of this project is to Design and Fabricate the Pedal box for formulastudent vehicle. The purpose of making pedal setup as a box assembly is to reduce space consumption by mounting pedals in a box. The main advantage of pedal box is, it can be adjusted according to ergonomics of the vehicle as well as driver's comfort. To complete this project, several designs were made considering various parameters from given rules in formula student rule book. Best suitable design was selected basedon required ergonomics among all designs. Materials were selected, machined, and assembled. ANSYS software was used to verify the design. The final step was manufacturing and assembling all the components together and placing them in the racecar.

This assembly allows for the actuation of three pedals. One pedal applies force to the master cylinders used in the hydraulic braking system. A balance bar is used to allow for the calibration of the hydraulic braking system.

The final assembly improves upon the previous year's design as well as alleviating several concerns from the previous year. It has successfully integrated with the hydraulic braking systems as well as other subsystems, particularly the frame. This report documents the design process and describes the manufacturing process. The finaldesign is tested and proved to be reliable in all possible working conditions.

Keywords—Pedal Box, Design, Assembly, Solids Works,

I. INTRODUCTION

Formula Bharat is a collegiate design competition that encompasses more than 70 teamsaround all over the world that compete in eight different competitions located across the globe. The purpose of the competition is to design and manufacture a small formula- style race car. The competition contains two events namely static and dynamics events. The static event consists of cost analysis, engineering design and presentation while thedynamic event consists of acceleration, skip-pad, auto cross, fuel economy and endurance. Of particular importance to the design of pedal box are the cost, design and overall dynamic events. There is a total of 1000 points in the competition, of which 100 pointsrelated to the cost, 150 points to the design, and 675 points are directly related to the performance of the vehicle in the dynamic events. Due to the tremendous pointdifferentials, the focus of the design of the pedal box relies heavily on performance, then design, with cost being a major consideration.

The performance of the pedal box fundamentally can be measured by the effectivenessof the brake pedal, throttle pedal and possibly the clutch pedal to send a signal to the system for immediate activation. While performance is the top priority, the ergonomicsof the pedal box together with the driver's feel must also be taken into consideration indesigning the system as the driver is the only person that controls the car in a race. In recent year, the material competes with each other for existing and new market. Over aperiod of time many factors that make it possible for one material replace to another forcertain application. The main factors affecting the properties of the materials are strength, cost and weight. In automobile industries it is mandatory to look for cheap and lightweight materials and which should be easily accessible. The constituents of a composite are generally arranged so that one or more discontinuous phases are embedded in a continuous phase. The discontinuous phase is termed the reinforcement and the continuous phase is the matrix. A brake pedal in motor vehicles has the task ofproviding the driver's command through foot leg on master cylinder of the brake system

II. DESIGN

A. Design constraints

The main design constraints imposed on the pedal box are the weight and cost limitations provided by the budget. A theoretical design is not always plausible to makedue to budget constraints and the benefits of the design should be weighted with the cost of constructing the design. Due to a limited budget, the cost of the parts required to make the pedal box must not be exceedingly high. This restricts buying the pedal box configuration from a supplier as any sturdy pedal box with the necessary requirements tends to call for a high price. The cost budget also points to the fact that machining the parts individual would be the best price option. The weight budget is required to gain points in the design competition. A lower weight car would also allow for increased acceleration and speed of the vehicle and increased maneuverability, which would all be beneficial in the dynamic events of the Competition.

Two major constraints are imposed by the mass and cost budgets of the entire car. Before the design begins on every component, the team management assigns a weightand cost goal to each component. The overall weight of the vehicle gives benefit in the design judging and performance. The frame and human body are the major constraintsthat determine the size and location of pedal box. The pedal box may not extend beyondthe bulkhead plane of the car. It must fit between the lower frame rails that extend from the lower suspension point to the bulkhead. It must move along these rails as to accommodate different drivers.

The size and position of the driver's feet determines the height and angle of the pedals.The average length of a human foot from the heel to the ball is 7.5 in. The pedal pad must be located at the ball of the foot. The pedals need to travel about 2.5 inches in order to accommodate foot movement while maximizing the pedal feel.

The brake pedal places the largest forces on the pedal box frame. The master cylindersfeed brake fluid to the brake calipers. The pressure in the system needs to reach 851 psifor the front and 496 psi for the rear in order to lock all four wheels. The forces created by displacing the fluid in the master cylinder go onto the pedal box frame.

B. The Constraints of the Pedal Box Design are as follows:

The pedal box needed to be designed around the geometry constraints set in the results from the braking system calculations.

The master cylinder mount height and the distance between the master cylinderpivot and the brake pedal are fixed.

The team's frame engineer insisted that the total width be not more than 10inchThe length of the brake pedal needs to be approximately the length of a humanfoot (~ 8.5inches).

The SAE rules designate that the brake pedal must be able to withstand a forceof minimum 2000N due to this constraint the material selection of the brake pedal and the overall pedal box must be strong, stiff and have high toughness.

The objective of the pedal box design was to satisfy all of the constraints mentioned above and optimize for a minimal weight.

To design a brake system comprising of an adjustable pedal box which should be able to lock all four wheels at the same time.

The Acceleration and Clutch pedals are also designed using the required pedal ratios with respect to the ergonomics of

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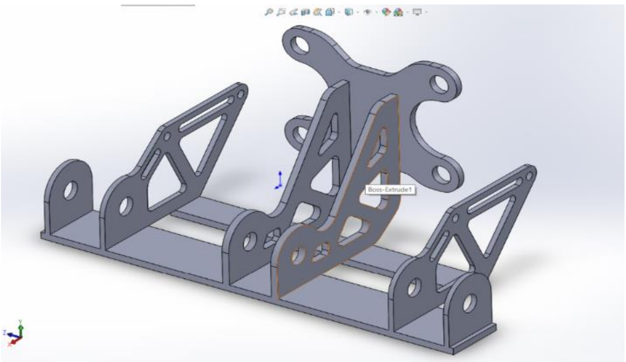
the driver.

If the braking force distribution is need for the vehicle then we can able to use connecting rod (BIAS BAR) or we can able to use proportionating valve For theforce distribution for the locking of the vehicle.

The brake pedal is connected to a balancing rod which is divided to both the master cylinders to generate the required braking force.

The front braking force should be higher than that of the rear braking force hence the balance was made not as equal amount but as for rear 45% and for front is 55%.

C. Force input and calculation:



The input force required by driver's foot depends on the total force entering the pedal box frame from the master cylinders and the pedal ratio. The typical adult male can exert roughly 154 lb ("'1335 N) of force (maximum) with one leg. For the race application, it is important to keep the required input force below 120 lb ("'534 N) and 80 lb ("'356 N) is the ideal most race application.

The average manual (non-power boosted) master cylinder requires between 600-1,000PSI (~137-6895 kPa) to be totally effective. Thus, 80-120 lb ("'356-534 N) of leg forcehas to be translated into 600-1,000 PSI (~137-6895 kPa). The way it is accomplished isby adjusting the pedal ratio. The effectiveness of the force applied is dependent on the pedal ratio of the brake.The effective force can be calculated using the following equation:

FORCE × PEDAL RATIO = MOMENT

Therefore, by increasing the pedal ratio, the actual force applied to the cylinders and therefore the braking system would increase. For typical manual brake systems, the pedal ratio is between 5:1 and 6.5:1, but for power systems a typical ratio of 4:1 to 5:1is more likely to be seen due to the force conversion relationship.

D. Design Software: Solid Works

Design intent is how the creator of the part wants it to respond to changes and updates.For example, you would want the hole at the top of a beverage can to stay at the top surface, regardless of the height or size of the can. Solidworks allows the user to specify that the hole is a feature on the top surface, and will then honor their design intent no matter what height they later assign to the car

In designing the brake, the pedal itself requires important analysis due to the requirement of stability under a large impact load. Because of the high strength requirement, the design of the whole pedal box then must revolve around the design ofthe brake pedal and its accessories.

In addition to the high structural strength, there is the necessity to be able to function under normal braking loads, which plays into the pedal ratio of the brake, which shouldalso be adjustable to meet the needs of the driver. With the requirements in mind, the brake can be positioned relative to the hydraulic cylinders in a couple of orientations todecrease the weight and size of the pedal box.

The brake pedal which is mentioned in the above Fig. is provided with 3 holes. In generally the holes used for the purpose of the mating, and also for lacing of bias bar since we had provided slot in order to reduce its weight. The thickness of the brake pedal is 10mm and it is weighing with 0.895kg of weight, with a height of 8.5-10 inches depending upon the comfort of the driver. The material used for the brake pedal is

1023.

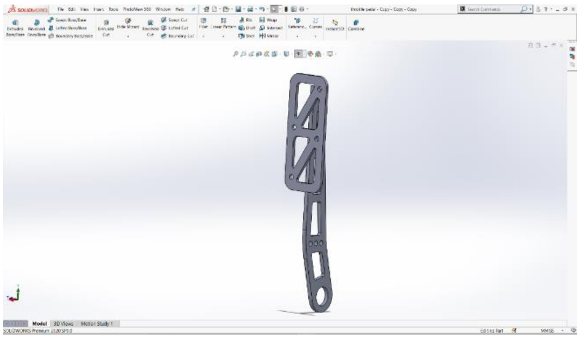


Figure 11: Design of Acceleration Pedal

Clutch lever operation is performed by pushing the lever towards forward. Champ-Caris at the high end of commercially available formula car. Champ car, clutch operationis performed by left ankle motion on a foot pedal. Formula 1 is the ultimate of formulacar competition.

The material used for the pedal is 1023 i.e., MILD STEEL but most of the racing vehicle will use the polymer or aluminium alloys because the clutch pedal doesn't need as much force required when we compare with brake pedal. So that's the reason most the vehiclewill have low weight clutch pedal in terms of fabrication purpose.

We have provided an extension for the clutch pedal which is used to for purpose of passage of clutch wire through it, because if we doesn't provide Any extension for thewire, by placing the wire with in the pedal side face due to the application of force on it there may chance of shearing in the pedal and it may leads to damage of pedal.

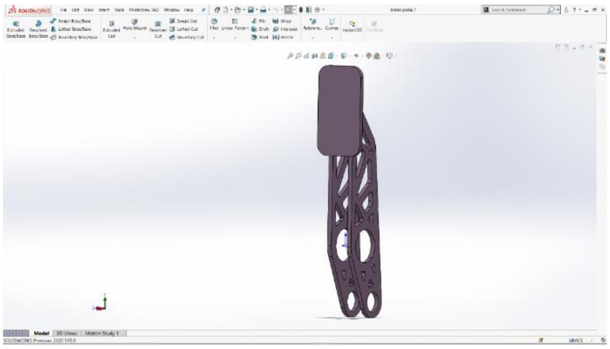


Figure 12: Design of Acceleration Pedal

COMPONENTS IN PEDAL BOX

PEDALS

MASTER CYLINDERS

NUT & BOLTS

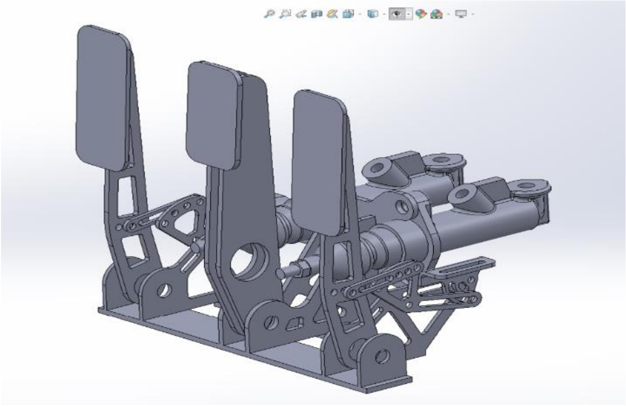
BRASS PLATE

BIAS BAR

BALL BEARING

EXTENSION ROD

PEDAL MOUNTS



E. BRAKING CALCULATIONS

i. Braking Force (B.F):

The braking force is essential in determining the rate of deceleration of the vehicle. In order to determine the braking force, we initially have to determine the force on the pedal. The force applied on the pedal we need to know the max force that can be appliedby the driver's foot. We determined this by placing a weighing machine in front of thedriver's feet instead of the pedal box. We got a value of 50 kgs max.

Force on the pedal Force applied = 50×9.81= 490.5N

After getting the value for the force applied on the pedal, we now have to calculate theforce at the master cylinders. For our design we used a pedal ratio of 1.45 in order to get the required force.

Force at master cylinders = Force at pedal × Mechanical advantage (Pedal ratio) = 490.5 ×1.45 = 711.225N

Next, the pressure inside the master cylinders is determined by dividing force at mastercylinder / area of master cylinder. The diameter of the master cylinder is 15.75mm.

Pressure inside master cylinders = Force at master cylinder / Area ofMaster cylinder= 711.225 / 0.785× $(15.75\times10^{-3})^2$ = 3650530.794N/m^2

The total braking force is determined to find the deceleration rate. The diameter of thecalliper's piston is 35mm.

Total braking force (Ff) = 2× 2×4×μd × Pressure at master cylinder ×Area of calliper piston = 22478.22N

μd =coefficient of friction Finally, the total braking torque is determined. The disc diameter is 200mm

Total braking torque = Total braking force × Disc radius

S No	Forces	Values
1	Force applied	490.5N
2	Force at master cylinder	711.252N
3	Total braking force	22478.22N
4	Total braking torque	2247.822N
5	Deceleration	19.5 m/s^2
6	Rolling	64.746N

= 22478.22 × 0.1 = 2247.822Nm

***i.Rolling Resistance**:*

The rolling resistance is the resistive force generated by the tyres that obstruct free acceleration. The rolling resistance is vital as it helps improving the stopping distance.If the rolling resistance is too high, the vehicle will have to generate a lot more power in order to push the vehicle, but the amount of grip generated will be enough to preventunnecessary wheel rotation. Higher rolling resistance generates a lot of heat in the tyresand also reduces tyre life on the track. Hence, a balanced rolling resistance value is required for propelling the vehicle and also stopping it at the right time. Frw = Fr × wcosϴ

Fr = Rolling resistance coefficient = 0.02 × 330 ×9.81 = 64.746N

Table:

III. CONCLUSION

We have gone through the design and analysis of the pedal box and its components which have been contained in the pedal box are designed and analysed for the racing vehicles but not for the SUV, SEDAN, TRUCKS etc. I.e. depending upon the sitting position of the driver in the cockpit which is far different when compare with normal vehicle and racing vehicle. The component pedal box should be rigid when we are goingto mount in any racing vehicle. The material which we preferred according to the cost that had been allotted to the individual department. The material we used is mild steel rather than any steel alloys, aluminium alloys, polymers, etc.., we had more than two iteration on the pedal box to understand behaviour of the pedal in all circumstances. Sothat by all consideration we can able say that the pedal box was design and fabricated by our team members suitable for "**FORMULA STUDENT VEHICLE".**

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