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GD&T Assignment

ACHA 4001

Suspension Rocker (Bell-crank) for a Sports 2000

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1. Introduction

This report will be looking at a rocker that is part of a sports 2000 race car. The rockers used are subject to personal preference and are not limited by regulation, allowing for full customisation and development of this component of the car.

The use of a rocker is to adjust the motion ratio and progressiveness to the suspension system through the geometry used. By changing the geometry, not only can you change the behaviour of the car but also have opportunity to shave weight off for performance benefits.

The report will show a potential design for a rocker that would fit to the chosen car and have in-depth analysis on the materials used. As well as listing potential problems and downsides to the design.

2. Component Design Specification

When looking at the rocker used on the MCR this needs to withstand high forces and sudden changes in direction vertically. Along with this, the geometry and weight are key factors in having an effective rocker. The suspension system in a performance car can be expected to see high loads of force; for example, an F1 car accelerating at 3 to 4 g can be expected to have several thousand pounds of force on each tyre.

In comparison, the sports 2000 cars are not as powerful and pull less g force, making the expected load less. In all sports cars, it is important that all parts of the suspension system work to control the forces both when static and especially in a dynamic situation.

The type of suspension being designed, is a push rod set up and should be able to fit front and rear suspension arms.

Due to the design specifications of the car, the rocker can be expected to play a pivotal role in reducing the forces to the chassis.

The material used must be:

- Strong and durable, to withhold pressure in all directional changes, due to the role it plays in the suspension.
- Be able to maintain its strength when heated and under load, this is especially important in the engine bay.
- Should be lightweight to minimise unnecessary additional weight which could potentially hinder the performance.
- Have a finish to it which makes obvious cracks and other signs of wear easily visible.
- Production of the component should be easy.

Other considerations, such as mounting points to the chassis must be taken into account. The type of suspension for example, a push or pull rod set up can affect the required sizes depending on packaging. (Julian Wisnu Wirawan, 2018)

The design of the rocker should allow for development, a basic design as shown in figure (1) can be used and altered as a prototype for proof of concept with an iterative approach. Making gradual steps to improve the performance without compromising reliability. Using simulation software to calculate the stresses on the rocker can also be done to give more accurate

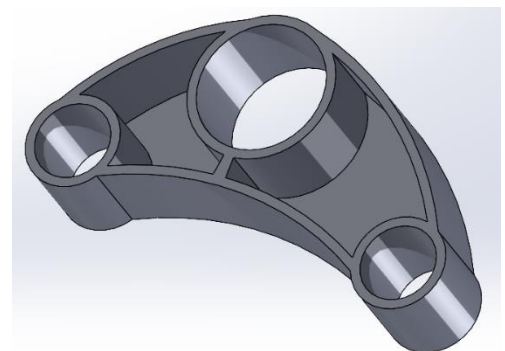


Figure 1- example suspension rocker

feedback and provide additional insight of areas to improve.

Using figure 1 as an example, testing and data analysis might suggest improvements could be made to the areas where the bearings and rods are mounted to. Strengthening these areas might be needed to ensure it doesn't fail when loaded, other areas such as the walls between the bearing housing, may be reduced in size or have holes cut in them to take out more weight. This will need to be tested either on simulation or real world to prove it still structurally sound.

Component	Pushrod	Lower A-arm front	Lower A-arm rear	Upper A-arm front	Upper A-arm rear	Rocker	Control arm	Tab
Axial resultant force (N)	-3.41E+03	-2.57E+03	1.74E+03	2.57E+03	-1.34E+03	-3.41E+03	1.78E+03	-3.41E+03

Table 5 Uniaxial force through components during acceleration.

Component	Pushrod	Lower A-arm: Front	Lower A-arm: Rear	Upper A-arm: Front	Upper A-arm: Rear	Rocker	Control arm	Tab
Axial resultant force (N)	-1.43E+03	3.86E+03	-783.798	-599.012	301.8169	-1.43E+03	-1.00E+03	-1.43E+03

Table 6 Uniaxial force through components during braking.

Component	Pushrod	Lower A-arm: Front	Lower A-arm: Rear	Upper A-arm: Front	Upper A-arm: Rear	Rocker	Control arm	Tab
Axial resultant force (N)	-4.49E+03	5.17E+03	-3.35E+03	508.2514	1.22E+03	-4.49E+03	-8.38E+02	-4.49E+03

Table 7 Uniaxial force through components during left cornering.

Component	Pushrod	Lower A-arm: Front	Lower A-arm: Rear	Upper A-arm: Front	Upper A-arm: Rear	Rocker	Control arm	Tab
Axial resultant force (N)	-915.448	-1.41E+03	3.67E+03	865.0401	-1.95E+03	-915.448	8.38E+02	-915.448

Table 8 Uniaxial force through components during right cornering.

Figure 2- simulation table in 4 axis of movement (Greg Wheatley, 2020)

Simulations carried out in CFD, showed on a push rod system, the forces and loads the suspension system is being subjected to, when in any one of the four states it was being tested in.

From these results, stress maps can be applied to the individual components and give a detailed view of potential stress. Further analysis can predict the number of laps the component is rated to. When looking at the ability of the rocker, the number of laps theoretically would be infinite according to the test results. Showing the component is well within tolerances and could be looked at further to see potential development opportunities. (Greg Wheatley, 2020)

When considering the design of the rocker. The amount of motion ratio wanted by this component can be worked out using the following equation.

$$\text{Motion Ratio} = \frac{\text{Travel of shock absorber/spring}}{\text{Travel of wheel}}$$

The motion ratio shows how much the spring moves when being compressed. For cars using a push or pull rod system, the number is around 0.5 to 0.7, suggesting a softer suspension.

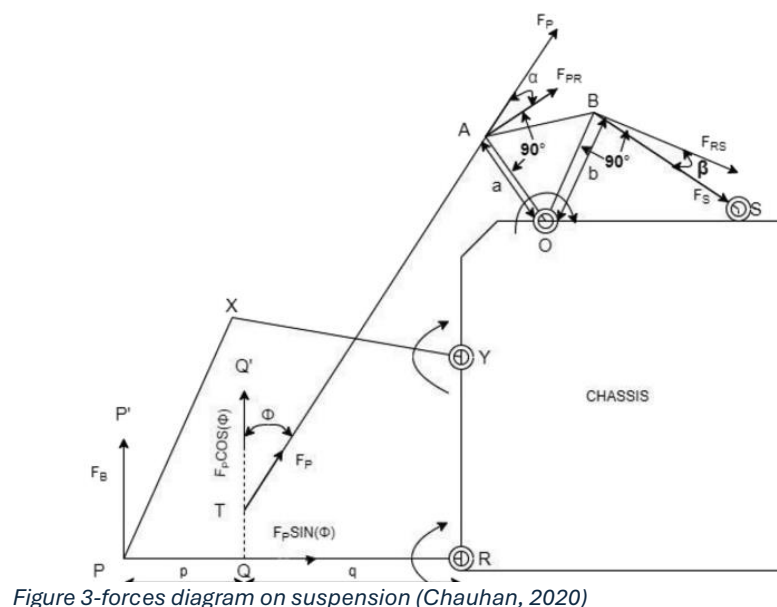


Figure 3 is a diagram showing the angles in a push rod suspension, this can be used to help work out the geometric calculations. Simulation software such as the WinGeo3 software can also do these calculations and give far more data than working out manually. Using these software packages can help with more effective development of the component. “Along with analysis in software, geometry is also checked in CAD software for compliance of all set parameters” (Ajay Kumar, 2017)

3. Material Selection

Material selection is a critical aspect of the component, as this will determine all of the process. From design to manufacturing it is critical that the correct material is selected beforehand to avoid faults and weaknesses in the material.

Ensuring, the materials composition is lightweight, strong and durable will be an essential quality. A homogeneous material such as steel or aluminium will be more appropriate than a composite material.

Materials	Al 7075 T6	Al 6061 T6	Mild Steel
Young's Modulus (GPa)	71.7	68.9	200
Density (g/cc)	2.81	2.7	7.8
Shear Modulus (GPa)	26.9	26	79.3
Poisson's Ratio	0.33	0.33	0.26
Ultimate Tensile Strength	572	310	500
Yield Tensile Strength	503	276	250

Table 1: Material Comparison [3], [4]

Figure 4- (Bhavesh Uprikar, 2022)

Comparing materials with the required qualities and the strength will help select the appropriate metal to maximise the design requisites. In the table above figure (4) 3 metals have been selected that have the desired qualities for the rocker. The AL 7075 T6 is the best candidate due to its higher yield strength and ultimate tensile strength despite not having as high young's modulus, it well within the operating range of the suspension system.

The properties of Al 7075 T6 is desirable in the automotive and aviation industry as a structural component due to its low density and high strength. Also, with other useful qualities such as corrosion resistance and high durability when in operation. Machining AL7075 is also easier than other harder, denser material such as mild steel and titanium helping with the price of manufacturing. (Aishah Najiah Dahnal, 2022)

The use of Al 7075 T6 having a high strength to weight ratio, has a direct effect on overall vehicle performance with weight saving being a priority.

When looking into materials all race teams have to consider “international standards considering all safety features. The important factors which are considered during design are for high performance and safety”. (Ajay Kumar, 2017)

material	Al 7075 T6	Al 6061 T6	Mild steel
Price per KG	£2.50-£3	£1.45-£2.50	£3.40

The price of the material is another consideration for the designer, as mass production of parts will be expensive. The sports 2000 car doesn't require the mass production of parts, but budgeting for good components would be a better more economical aspect for a small team.

Paying a lower cost for quality parts would be of great benefit to the University race team due to limited budgets. However, although the Al 7075 T6 is slightly more expensive per KG than the Al6061 T6, it has better qualities so the additional cost can be justified.

To determine the required strength for the suspension, it is necessary to calculate the forces acting on the components. The process begins after the suspension geometry has been created. By understanding the maximum forces that are subject to the component adjustments, this can be made to fine tune the design before production. The use of FEA (finite element analysis) can also be used to determine the weak and strong points of the component. “To pick the best design, the models are imported in FEA software to more accurately predict stresses and stiffness. (Ajay Kumar, 2017)

4. Manufacturing Process Selection

There are various manufacturing processes available to produce the rocker. Different processes have their pros and cons. Choosing the right process to produce the component is a critical part of the manufacturing process. As the Al 7075 T6 has been picked in the first section, the focus should be around this specific material.

One production approach is using a Die Mould Cast. “Die casting is a manufacturing process that can produce geometrically complex metal parts through the use of reusable moulds, called dies”. (Y. Abdulfatah Abdu, 2016) Using this method accurately, ensures components can be made with consistent results and with minimal material wastage, making it the most effective form of mass production. The downside to this, is the process of making the Die as it is very expensive. If developments are made in design, then a new Die would have to be made, making the process slow and very expensive. This shows the importance of research into the design before going to manufacturing.

Another approach would be a subtractive method such as CNC machining. CNC machining allows for various versions of the design to be made, allowing for development of the component. With a subtractive process, a lot of waste metal is produced but the process is less expensive overall than using a Die Cast. Having enough axis of motion is another limiting factor of CNC, as a Die Cast can create intricate details through moulding. If the design is complicated, then CNC tools might not be able to access the area required.

A suspension rocker doesn't require complex geometry, this is less of an issue with this component design. There is not a need for mass production of the part, due to the limited demand and will only be produced when needed. Therefore, a Die would be impractical and an expensive option for production.

5. Conclusion

In conclusion, when producing a component, creating and following a comprehensive design brief, will benefit the team greatly. As this highlights the requirements of the project and enables engineers to make clear logical selections, based on the data presented.

Being able to check against the design specification helps choose the best fitting material for its purpose. Comparing a range of potential materials as seen in figure (4) allowed a suitable choice to be made based on various factors.

Research into manufacturing and production processes is also important, to work out how viable the material is for production. As well as finding if its scalable to the needs, for example, a production road car would require a big production line with consistent reliable tolerancing with limited amounts of waste. With a bespoke production for a race car, the quantity and waste are not as much of a concern but the ability to develop and prototype rapidly is a desired quality.

Creating a suspension component for a performance car should be a calculated and thought through process as this is a critical part in the driver's handling and feel for the car and it's performance. Control over the set-up of the car is crucial for the engineers when making adjustments to get the maximum performance. It is also important that any adjustments to the suspension are easy to perform when changes need to be made at the circuit in response to driver feedback on the car's performance on the track's conditions.

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