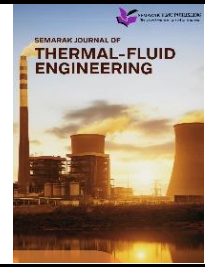




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Mechanical Design Analysis and Manufacturing Process of Hollow Carbon Steel of Double-Wishbone Front Suspension for Go-Karts

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ABSTRACT

One of the main mechanical connections between a vehicle and its wheels is the suspension system. The suspension system serves to distribute vehicle loads, absorb road-induced vibrations, and maintain continuous tyre road contact, thereby improving handling, stability, and ride comfort. Most go-karts lack front suspension, which means a stiff chassis, a rough ride and a tendency to oversteer through corners because the tyres are not all in a consistent contact. Hence, the aim of this research is to design, evaluate, and fabricate a reliable front double-wishbone suspension system for a go-kart to improve its handling, stability, and driver comfort. A morphological evaluation was carried out comparing wishbone, MacPherson strut, and multilink designs, and the double wishbone was selected. Suspension components were designed and analysed for static stress, strain, and displacement using Finite Element Analysis (FEA). The physical prototype was fabricated from hollow cast carbon steel by cutting, grinding, drilling, and metal welding. In the computational static stress analysis, the maximum stress in the lower control arm was 8.88 MPa which was well below the yield strength of the material. This is a minimum factor of safety of 27.9. The physical load tests show that the produced suspension system can withstand a maximum load of 833.85 Newtons and a maximum vertical displacement of 7.5 centimetres. In summary, the use of hollow cast carbon steel in a double wishbone layout provides a very robust and effective front suspension. The system effectively absorbs physical shocks and improves the vehicle's alignment. The system is validated in terms of structural safety and performance advantages for kart applications.

1. Introduction

A suspension system is an important mechanical part that connects a vehicle's frame to its wheels, allowing relative movement between them [1,2]. It is primarily engineered to carry the combined weight of the vehicle and its passenger, evenly distributing it across all wheels. Suspension systems are also important for damping shocks and vibrations caused by irregular road surfaces, thereby increasing ride comfort by isolating the driver from external road noise and impacts [1-3]. A

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suspension does more than just make the ride comfortable. They are crucial to the vehicle's dynamics. They control body roll, pitch, and yaw, keeping the tires planted on the road as much as possible for better handling and stability [4].

Despite these mechanical advantages, most go-karts on the market lack a front suspension. This structural rigidity reduces the tires' constant contact with the road surface, resulting in poor ride quality and difficulty oversteering in corners. Moreover, a stiff front axle can impose additional physical stress on related steering components, leading to misalignment, uneven tire wear, and poor handling. Thus, the absence of a suitable front suspension is a fundamental limitation regarding the dynamic performance, cornering ability, and overall reliability of standard go-karts [5].

To overcome these mechanical disadvantages, the design, analysis, and manufacture of a functional front suspension system for go-kart applications were carried out in the previous study [3]. Several studies selected the double-wishbone suspension as the most appropriate solution for the suspension system [6]. The selection is due to its superior kinematic performance and camber control during vertical wheel travel. Besides that, there are also other alternatives for the suspension, such as MacPherson strut and multilink systems.

The study follows a holistic engineering approach that combines the conceptual design, computational analysis, and physical manufacturing. The linkages (top control arm, bottom control arm, wheel mount) were modelled in 3D through computer-aided design software. The computational static stress analysis was then performed to obtain the bending moments, the resultant displacement, and the overall factor of safety under simulated physical loads. Lastly, the physical prototype was manufactured using standardized manufacturing processes such as cutting, grinding, drilling, and metal inert gas (MIG) welding. This was then assessed through practical load-bearing tests to verify structural integrity and functional damping capabilities.

The main objective of this study is to develop a reliable prototype using hollow cast carbon steel, which offers high yield strength, tensile strength, and structural rigidity. It is expected that the engineered suspension system will provide a significant competitive advantage in terms of lap times, traction, and ride comfort.

2. Methodology

2.1 Design Selection and 3D Model

Generally, three primary suspension systems are considered for go-kart applications. These systems are the MacPherson strut, multilink, and wishbone [7-10]. Each system has its own specialty. MacPherson Strut is lightweight, easy to make, and space-efficient. However, it has a high roll center and is not for heavy loads. Multilink suspension is a system that provides greater rear-wheel stability and reduced unsprung weight [9]. Disadvantages of this system are a very complicated design, improper steering action, and high manufacturing costs. Wishbone Suspension is a system that has kinematics that can be easily controlled, good camber compensation during vertical movement, and balanced pitching [10]. It is, however, structurally more complex and has poor kingpin geometry [11].

From the assessment, it was decided that the double-wishbone setup would be the best design for the go-kart [12]. It adds the required rigidity, greatly improves handling, and allows the wheel alignment to be largely adjusted as in Figure 1. The most suitable design, which is the double-wishbone system, was then selected, and the engineering analysis and 3D modelling were done in SolidWorks, as shown in Figure 1 [4,13,14]. The double-wishbone system is made up of three components, which are the upper wishbone arm, the lower wishbone arms, and the steering knuckle. The double wishbone is the wheel mount and the entire go-kart chassis. The component was

fabricated using hollow Carbon Steel, which features a yield strength of $2.48 \times 10^8 \text{ N/m}^2$, density of 7800 kg/m^3 , an elastic modulus of $2.0 \times 10^{11} \text{ N/m}^2$, and a Poisson ratio of 0.32 [15,16].

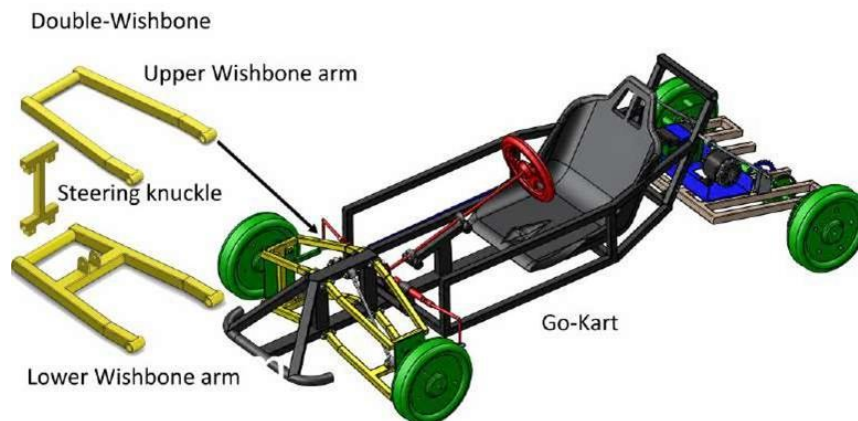


Fig. 1. Go-kart and double wishbone model

2.2 Design and Material Analysis

It is estimated that the driver's weight is 70kg and is distributed evenly across all the tyres. Thus, each tyre supports a force of 171N. This force is absorbed by the absorber, which is fixed at the middle of the lower wishbone arm, as in Figure 2. The engineering analysis was performed using by 171 N, assuming C_y and A_y are reaction forces to maintain static equilibrium [17]. Thus, the equations of static equilibrium are used to essentially determine the new reaction forces [17]. The total length of the arm is assumed to be 300 mm (0.3 m) based on the 100 mm (0.1 m) and 200 mm (0.2 m) segments in the diagram. Sum of moments about point A, which taking counterclockwise as positive as in Eq. (1):

$$\sum M_A = 0 \quad (1)$$

$$-(171 \times 0.1) + 0.3 C_y = 0$$

$$C_y = 57 \text{ N}$$

The sum of forces in the y-direction was as in Eq. (2). Whereas, bending moment as shown in Eq. (3).

$$\sum F_y = 0 \quad (2)$$

$$A_y - 171 + 57 = 0$$

$$A_y = 114 \text{ N}$$

$$\sum M = 0, \text{ at } x = 0.1 \text{ m} \quad (3)$$

$$M - 114x + 171(x - 0.1) = 0$$

$$M = 11.4 \text{ Nm}$$

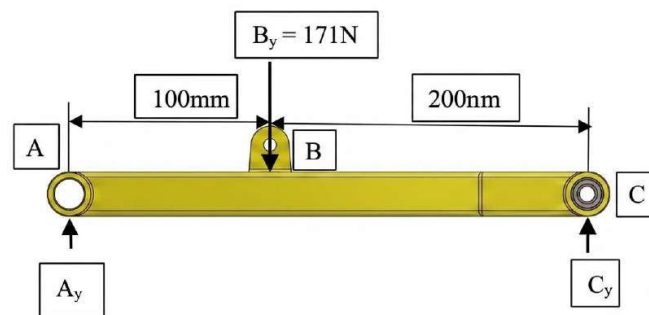


Fig. 2. Free body diagram of the lower wishbone arm

The lower control arm model is generated with a 3D solid tetrahedral mesh, as in Figure 3 [18]. This can be considered as a triangular network on the square hollow tube and cylindrical joints. This mesh structure enables the finite element analysis (FEA) software to accurately determine the structural stresses at all points in the geometry [19]. The system's downward loads from outside are shown as purple arrows on the central dual-tab mounting bracket, matching the free-body diagram in Figure 2. For the go-kart suspension, these arrows represent the downward force the shock exerts by compressing the shock.

The green arrows in the simulation represent fixtures and boundary constraints that anchor the model in space. On the right, the green arrows within the two rear cylinders indicate the fixed hinge connection where the control arm attaches to the go-kart frame, preventing translation at "Point A" as in theoretical calculations. The green arrows pointing up on the left side of the front cylindrical tube are the physical connection to the wheel knuckle. The boundary constraint prevents the arm from pushing down through the wheel assembly and stabilizes the model. On the other side, which was denoted to Point C, the hinge boundary condition was assigned to represent the part's condition, allowing rotation but fixing it in the other directions.

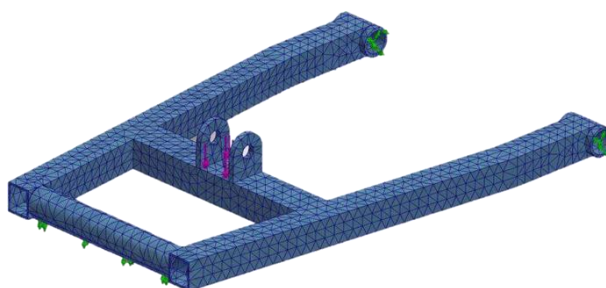


Fig. 3. Meshed part of the lower wishbone used in the simulation study

2.3 Fabrication Process

The prototype of the front suspension was physically made in the workshop of the Faculty of Mechanical Engineering. The hollow cast carbon steel beams of 18.7 mm × 18.7 mm were used [1,20]. Accurate measurement and marking of the raw steel were done using a conventional measuring tape to initiate the manufacturing process. The steel was cut to the following dimensions: 300 mm, 173 mm, 155 mm and 88 mm [1,16]. Once marked, a cut-off machine was used to precisely cut the metal beams to the required lengths [21]. The cut ends were finished with a stone grinder to remove any sharp burrs or rough edges, ensuring safe handling and proper fitment during subsequent assembly steps [21-23]. Then, using a bench drill, accurate mounting holes were drilled in the metal beams for

the M6 and M10 hex bolts required for the suspension's hardware connections [24].

3. Results

This section presents the results of computational simulations and physical tests conducted on the fabricated double-wishbone front suspension system. The assessment studies the structural integrity of the prototype and the general mechanical feasibility for go-kart use. Before production, the suspension parts were statically analysed using computer-aided design software to predict their structural behaviour under load [25].

3.1 Stress Distribution

As shown in Figure 4, the simulation results shows that the maximum von Mises stress on the lower control arm to be $3.073 \times 10^7 \text{ N/m}^2$. This maximum stress value is still well below the material's defined yield strength, which is $2.482 \times 10^8 \text{ N/m}^2$. With a factor of safety exceeding 8.0, the design provides an exceptional margin against mechanical yielding under peak operating loads. So, the component will not fail under the applied loads.

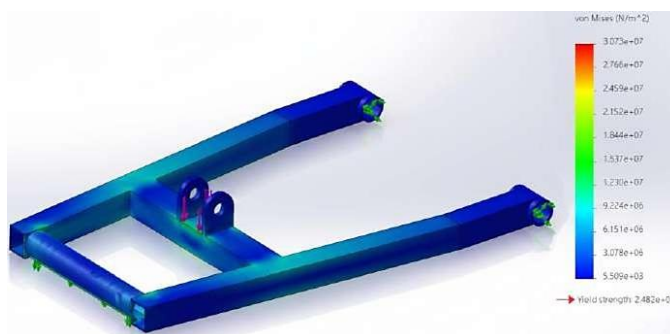


Fig. 4. Stress distributed on the lower wishbone arm due to the applied load

3.2 Strain Distribution

The structural strain analysis shows a maximum equivalent strain (ESTRN) of 8.478×10^{-5} over the control arm. Minimum equivalent strain in the component is 4.354×10^{-8} as shown in Figure 5. These minimal values align with the linear elastic behavior expected under the given loading conditions, verifying that no severe local deformation occurs.

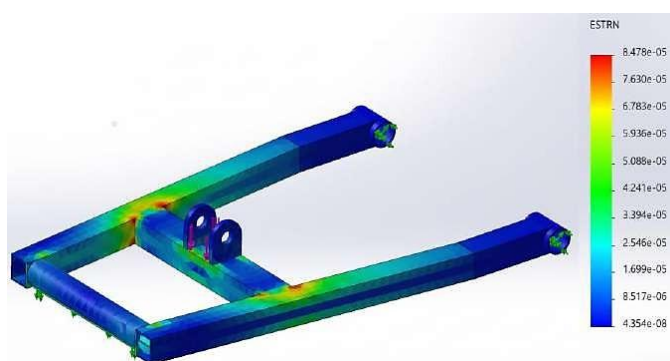


Fig. 5. Strain distributed on the lower wishbone arm due to the applied load

3.3 Structure Displacement

Figure 6 shows the visual contour model that highlights deformation on the lower wishbone arm. It can be seen that the maximum deformation is localized at the center of the cross-member, specifically concentrated around the shock absorber mounting brackets. This sub-millimeter deflection confirms that the assembly maintains high global rigidity and meets strict dimensional stability constraints. The maximum resultant displacement of the (URES) under the simulated load is noted as 8.95×10^{-1} mm.

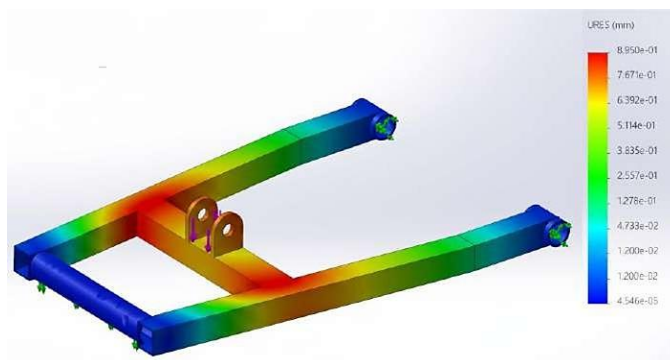


Fig. 6. Structural bending on the lower wishbone arm due to the applied load

3.4 Fabricated Prototype

Figure 7 shows the manufactured part of the double wishbone. The implementation of the double wishbone suspension provides distinct mechanical advantages alongside structural trade-offs. With the double-control-arm design, the chassis was made quite rigid, resulting in direct improvements in both handling and stability. The shock absorbers did a good job of isolating road vibrations, thereby increasing ride comfort. The geometry also allowed for accurate calibration of the wheel alignment, optimising tyre contact.

However, the system introduced a highly complex design that required complex fabrication methods. The spatial footprint of the double-wishbone setup occupied a large portion of the go-kart's front frame. Finally, the more moving parts, the more things can wear out, and therefore the more frequent maintenance checks for issues like fluid leaks or bushing wear.



Fig. 7. Fabricated double-wishbone based on the design and analysis using hollow carbon steel

4. Conclusions

The present work has successfully designed, analysed and fabricated a functional front suspension system for a go-kart application. Three preliminary conceptual designs were evaluated for superior handling and wheel alignment, and a double-wishbone configuration was chosen and modelled in SolidWorks. The physical prototype was cast in carbon steel over 10 weeks. The structural safety of the lower control arm was confirmed by computational analysis, and the reliability was proved by physical load testing. Based on the test, the suspension system can dampen the applied loads of 50 kg (833.85 N) and has a maximum vertical travel of 7.5 cm. Finally, the main objective of this project, the development of a reliable system for the improvement of the vehicle stability and ride comfort, has been achieved.

Some improvements to the dynamic behavior of future versions of this go-kart suspension system are proposed. For starters, some high-performance shock absorbers would greatly improve overall damping and control over rough surfaces. Secondly, the inclusion of improved performance springs would decrease the height of the vehicle for better aerodynamics. Finally, the structural control arms could be enhanced by the use of advanced and lightweight materials to minimise the overall vehicle mass and further optimising efficiency.

References

- [1] Mohd Bakeri, Muhammad Syafiq, and Ab Aziz Mohd Yusof. "Design and fabricate back suspension system for go-kart." *Prototype Design and Research Collection Series 1* (2025): 71-75.
- [2] Syahriza, Muhammad Irfan, and Ab Aziz Mohd Yusof. "Design and fabrication of go-kart front suspension system." *Prototype Design Collection Series 4* (2025): 97-98.
- [3] Piquet, Boris, Clayton A. Maas, and Florent Capou. "Next generation of suspension bushings: review of current technologies and expansion upon new 3rd generation product data." In *2007 World Congress*. 2007. <https://doi.org/10.4271/2007-01-0850>
- [4] Mohamed Samud, Nur Adlin Farhana, Ab Aziz Mohd Yusof, and Ainaa Maya Munira Ismail. "Development and manufacturing fixing holder and gearing mechanism for a electrical go-kart." *Prototype Design and Research Collection Series 1* (2025): 76-79.
- [5] Bastow, Donald, Geoffrey Howard, and John P. Whitehead. *Car suspension and handling*. Warrendale: SAE international, 2004.
- [6] Liu, Yucheng. "Recent innovations in vehicle suspension systems." *Recent Patents on Mechanical Engineering* 1, no. 3 (2008): 206-210. <https://doi.org/10.2174/2212797610801030206>
- [7] Cronin, D. L. "MacPherson strut kinematics." *Mechanism and Machine Theory* 16, no. 6 (1981): 631-644. [https://doi.org/10.1016/0094-114X\(81\)90069-0](https://doi.org/10.1016/0094-114X(81)90069-0)
- [8] Koide, Reo, Yoshihiro Kawabe, Keiichi Nakajima, and Kiriya Kazuhiro. "Development of a new multi-link rear suspension." *SAE International Journal of Passenger Cars-Mechanical Systems* 192355 5, no. 2 (2012): 974-980. <https://doi.org/10.4271/2012-01-0978>
- [9] Lee, D. M. A., D. M. Pascoe, and W. H. ElMaraghy. "An analysis of the multi-link independent suspension system." *International Journal of Vehicle Design* 14, no. 1 (1993): 44-58. <https://doi.org/10.1504/IJVD.1993.061824>
- [10] Güler, Duygu. *Dynamic analysis of double wishbone suspension*. Izmir Institute of Technology (Turkey), 2006.
- [11] Tanik, Engin, and Volkan Parlaktaş. "On the analysis of double wishbone suspension." *Journal of Advanced Mechanical Design, Systems, and Manufacturing* 9, no. 3 (2015): JAMDSM0037-JAMDSM0037. <https://doi.org/10.1299/jamdsm.2015jamdsm0037>
- [12] Hazim Sharudin, Ab Aziz Mohd Yusof and Nurul Anis Farhanah Faizal, "Design and fabrication of chassis with structural system for student formula racing car." *Journal of Engineering Technology and Applied Physics* 8, no. 1 (2026): 50-55. <https://doi.org/10.33093/jetap.2026.8.1.8>
- [13] Rudrakanth Thota Sadashiva, Rudrakanth, and Gowtham Gowtham Ramaswamy. "Development and Simulation of Suspension system for L7e European car." *Master Programme in Mechanical Engineering*, (2016).
- [14] Patil, N. R., Ravichandra R. Kulkarni, Bhushan R. Mane, and Suhil H. Malve. "Static analysis of go-kart chassis frame by analytical and SolidWorks simulation." *International Journal of Scientific Engineering and Technology* 3, no. 5 (2014): 661-663.

- [15] Kadir, RA Abdul, S. Abdullah, AA Mohd Yusuf, K. Md Isa, and AW Mohd Arhafudin. "Comparative analysis of aluminum and steel mechanical properties." *Marine Frontier* 14, no. 2 (2023): 27-31.
- [16] İpek, Mümtaz, İhsan H. Selvi, Fehim Findik, Orhan Torkul, and I. H. Cedimoğlu. "An expert system-based material selection approach to manufacturing." *Materials & Design* 47 (2013): 331-340. <https://doi.org/10.1016/j.matdes.2012.11.060>
- [17] Mahmoodi-k, Mehdi, Iraj Davoodabadi, Vinko Višnjić, and Amir Afkar. "Stress and dynamic analysis of optimized trailer chassis." *Technical Gazette/Tehnički Vjesnik* 21, no. 3 (2014): 599.
- [18] Nudehi, Shahin, and John R. Steffen. "Analysis of machine elements using SolidWorks simulation 2016." *Engineering Faculty Publications & Patents* (2016).
- [19] Zamri, Aidil Azlan Ahamd, and Chin Jia Xin. "Finite element analysis for solar car chassis." *MAHSA International Journal of Engineering and Technology* 3, no. 2 (2023): 30-34.
- [20] Mohd Ishak, Alya Amanina. "Design and fabrication of glass bottle cutter." *Diploma in Mechanical Engineering Thesis*, (2021).
- [21] Merchant, M. Eugene. "Basic mechanics of the metal-cutting process." *Journal of Applied Mechanics* (1944): A168-A175. <https://doi.org/10.1115/1.4009380>
- [22] Klocke, Fritz, and Aaron Kuchle. *Manufacturing processes*. Vol. 2. Berlin: Springer, 2009. <https://doi.org/10.1007/978-3-642-36772-4>
- [23] Bakhit, M. B. M. "Mini sander machine for small-volume production." *Journal of Engineering and Technology (JET)* 15, no. 2 (2024): 83-96. <https://doi.org/10.54554/jet.2024.15.02.005>
- [24] Mohd Din, Yusuff Badrisyah, Kamariah Md Isa, Ros Atikah Abdul Kadir, Ainaa Maya Munira Ismail, Hazriel Faizal Pahraraji, and Ab Aziz Mohd Yusof. "Fabrication of rechargeable screwdriver for small-volume assembly process." *Marine Frontier* 15, no. 1 (2024): 39-46.
- [25] Serrano-Rincón, C. A., L. Navarro Torrado, and E. Florez-Solano. "Failure study as a physical component in mechanical suspensions of two automobile models of an automotive company." In *Journal of Physics: Conference Series*, vol. 1587, no. 1, p. 012029. IOP Publishing, 2020. <https://doi.org/10.1088/1742-6596/1587/1/012029>