



# DESIGN AND DEVELOPMENT OF CHASSIS FOR FORMULA STUDENT VEHICLE

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## ABSTRACT

*A chassis design involves selecting optimum measures of parts and iterating it to achieve the objectives assumed. Every part of chassis is related to each other; it is necessary to study effects to get an optimum design. This research paper aims at the design, analysis, and manufacturing of a chassis. This paper also covers the pre-designing phase of constructing a human ergonomics for a driver, drafting a chassis to accommodate 95th percentile men and 5th percentile female, and thoroughly analyzing the model to check for safety. This paper also introduces the way to make fixtures for effective and efficient manufacturing.*

**Keywords:** Chassis, Design, Ergonomics, Fixtures, FSAE.

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## 1. INTRODUCTION

This project aims to design and manufacture a new FSAE chassis for the 2020 season. The team has been given the task of iterating on a successful FSAE 2019 car that went to the competition. Major goals include:

- Conform to all FSAE chassis rules
- Improve on previous year designs
- Manufacture the final design

Along with these major goals, the chassis design plays a large role in impacting the car's other systems. It aimed to be as flexible as possible and take into account the needs of the car's subsystems. Designing the chassis is the most crucial part for any team because it supports all the various vehicle departments. The cockpit design is essential, as it has to accommodate the 95<sup>th</sup> percentile male. Also, the design should be made not to compromise driver safety at any condition. The design should not fail at any cost, and it should have the minimum required stiffness, strength, and torsional rigidity, and it should be highly reliable and safe. After the analysis and fabrication of the chassis, during its presentation, the judging is done by the officials by considering results from technical inspection, static event, and dynamic event, and by summing up all the given points in this all events, the final decision is taken.

This paper discusses the method adopted for designing the chassis from design considerations to the final manufacturing of the designed product. It also discusses the development of low-cost fixtures compared to high-cost conventional metal fixtures.

## 2. LITERATURE SURVEY

The research was done about the same subject previously to know how projects can be accomplished and what new things can be implemented, which would help future projects. After going through different researches, discrete information on something that might be implemented in the project was collected.

In “Formula SAE Race Car Cockpit Design and Ergonomics Study for Cockpit” by Eva Mariotti and Badih Jawad, the different ergonomics design and manufacturing of physical ergonomics model is discussed in detail. This paper mainly focuses on the human relationship with the vehicle. It gives specific positioning of the steering wheel, gear shifter, etc. concerning driver's hand. With the use of the physical ergonomics model, it is also possible to check the vehicle's approximate visibility. Also cockpit template and 95<sup>th</sup> male percentile Percy rules can be confirmed by using this physical model. [1]

In Amogh Raut and Aniket Patil's paper, a detailed review of design, testing, and validation is made. This paper discusses different SAE rule regarding the designing of chassis and also considerations of safety while designing. Furthermore, it gives insight into the analysis concepts about loading and boundary conditions. [2]

In the report of “Design and Optimization of FSAE Frame”, the design and manufacturing of chassis and suspension are considered. The report depicts suspension related concepts regarding chassis and also gives a manufacturing view. Managerial ideas, marketing, and financial strategies are also discussed, covering another important static part of the competition.[3]

## 3. METHODOLOGY

Before designing the actual product, iterations on different parameters were done. The problem related to the physical ergonomics setup were identified. These were: Determination of seat inclination, pedal box position, dashboard controls, and shifter location in consideration with

team's drivers and SAE's body dimension for the 95th percentile male. The conclusion was agreed to be made based on jigs set up that acts as a mock-up chassis. An ergonomics setup was created to serve the purpose, as shown below.



**Figure 1** Ergonomics Structure

In this setup, the main hoop can be moved to and fro while the front hoop remains stationary. Series of holes are drilled on the surface of these strips to adjust the height of both. Holes with diameter 10mm and central distance between holes were 25mm, varying the angle by 5 degrees up and down. Also, seat inclination can be changed by the holes made in the main hoop strip, and the pedal box position was adjusted by the SAE rule of min 36in distance from driver's torso. Following are the observations were made from the ergonomics which satisfies all the templates:

**Table 1** Vehicle ergonomics iterations

FRH Height (inch)	Driver Eye Height	FH to MH Distance	MH to Seat	Driver Recline Angle	Visibility (Feet)
22	27	35	11	60	6
21	25	32	11	55	7
22	28	32	11	75	6

The cockpit area and the front compartment of the car were designed in the Creo student version from the above data. Other parameters such as front bulkhead dimensions and ground clearance were selected concerning the anti-intrusion plate and suspension design, respectively. Also, for greater stiffness, all suspension points were brought on nodes. For rear compartment dimensions and position, engine, exhaust bent pipe, battery, and other components were identified and designed to maintain everything in its place to give a required performance. While designing the chassis all constraints provided by SAE were satisfied. The section of bent tubing mounted to the rear; an upper suspension mount is placed to distribute the suspension load and provide a location for mounting of the shocks and chain guard.

All tube sizes that were not explicitly dictated by the SAE SUPRA Rulebook have been analyzed under loading conditions. Also, chassis was made compact, keeping in mind the proper packaging of all components such as engine, differential, springs, steering, etc. These actions were taken to support the weight of the vehicle low simultaneously.

Material selection for steel is limited to 5% carbon. Therefore the available options were AISI 4130, AISI 1018, and AISI 1020. AISI 4130 was selected as it has a high strength to weight ratio amongst the given options. From the literature it is found that Ansys software gives good results [11-31].

**Table 2** Material Properties

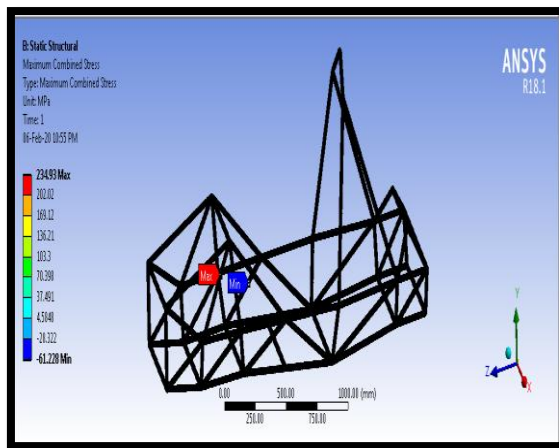
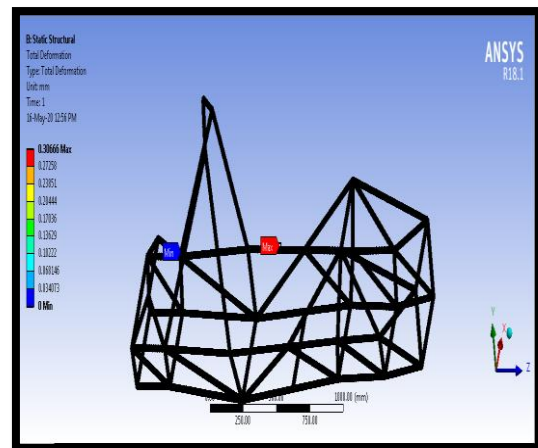
Material $\rightarrow$ Properties $\downarrow$	AISI 1018	AISI 1020	AISI 4130
Carbon %	0.15-0.20	0.18-0.23	0.28-0.33
Density (Kg/m <sup>3</sup> )	7.87×10 <sup>3</sup>	7.7×10 <sup>3</sup>	7.85×10 <sup>3</sup>
Tensile Yield Strenght (MPa)	370	350	435
Tensile Ultimate Strenght (MPa)	440	400	560
Modulus of Elasticity (GPa)	205	200	210
Poisson's Ratio	0.29	0.29	0.29

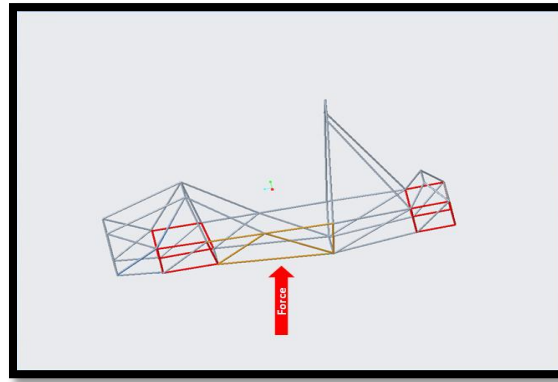
## 4. FINITE ELEMENT ANALYSIS

After completion of the design, the CAD model of chassis was analyzed by using the Ansys student version. Practically there could be four possible failure of a chassis front, side, rear impact, and torsional failure as mentioned below,

### 4.1. Side Impact Test

This test is carried out to ensure a driver's safety in case the vehicle is hit at a side structure. The common cause for side-impact is during a solo crossing at an intersection. In this test, the 3g force is applied to the side impact member. As seen from the fig, the max force generated is 235 MPa, which is less than the selected material's yield tensile strength. Therefore chassis is safe in Side Impact Test.

**Figure 2** Side Impact Stress Analysis**Figure 3** Side Impact Deflection Analysis



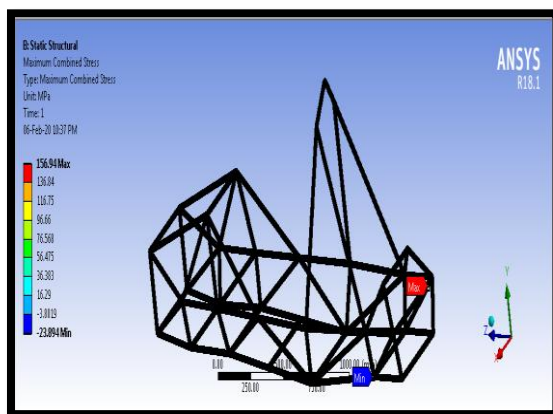
**Figure 4** Side Impact Test Boundary Condition

Figure 4 shows the boundary conditions applied to the side-impact test. Red color indicates the nodal displacement of such points is fixed at the lateral and vertical axis, and the yellow portion shows the area on which force acts. Also, the nodal rotations are made fixed for both front and rear nodal points.

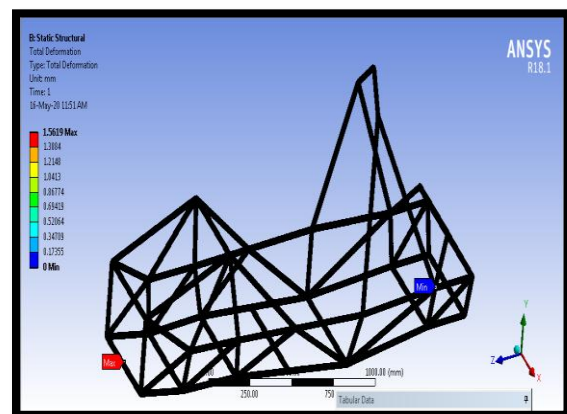
## 4.2. Front Impact Test

This test is carried out to check if the vehicle is safe when it gets impacted by the front. 46% of the total accidents are front impact and have the most influence on the car, so the test is done to check the chassis' safety. For this purpose, a force of 4g is applied to the full-frontal area. Max stress generated in this test is 157 MPa, which is under the safe limit. Therefore it is safe under front impact conditions.

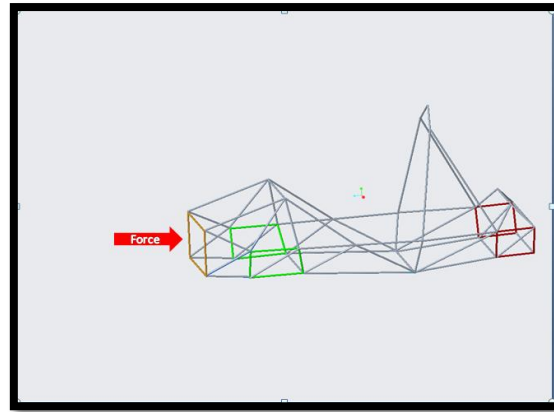
Figure 7 shows the boundary conditions for front impact analysis. In front impact analysis, node points of the rear are made fixed, and the displacement of the front nodes at the longitudinal and vertical axis is made free. Nodal rotations of both ends are made fixed. The yellow portion shows force is applied to the area.



**Figure 5** Front Impact Stress Analysis



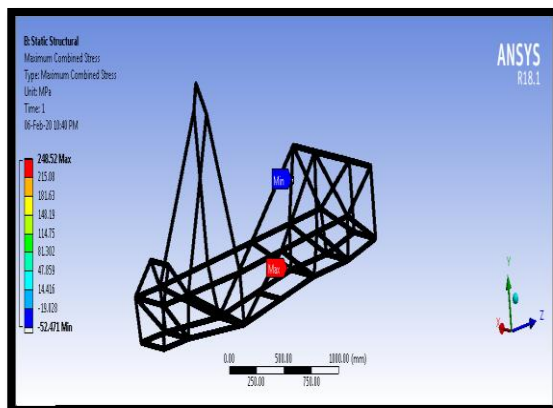
**Figure 6** Front Impact Deflection Analysis



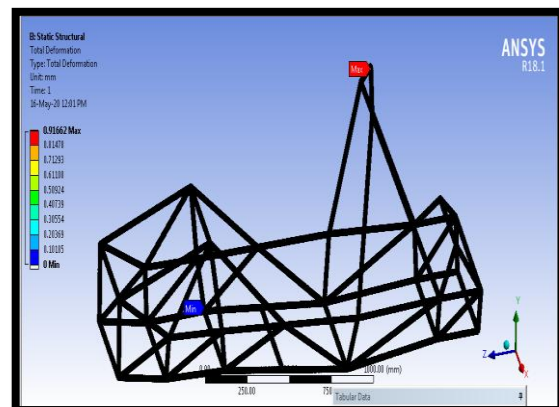
**Figure 7** Front Impact Test Boundary Condition

### 4.3. Rear Impact Test

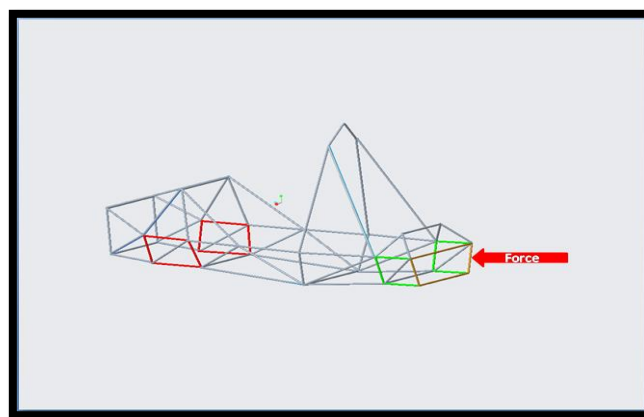
This test is conducted if the vehicle gets hit at the rear portion. These types of accidents are rare, but when it happens, it could be harsh. Generally, 3g forces are applied to the rearmost section of a vehicle that could come in contact during impact. As seen from the figure, max stress generated is 248Mpa, which is less than the selected material's yield strength. Therefore the Chassis is safe in a rear impact test.



**Figure 8** Rear Impact Stress Analysis



**Figure 9** Rear Impact Deflection Analysis



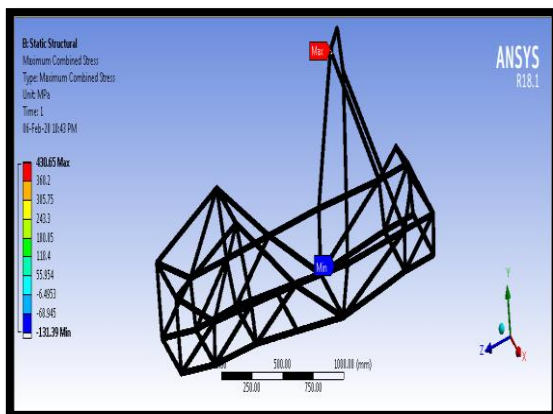
**Figure 10** Rear Impact Test Boundary Condition



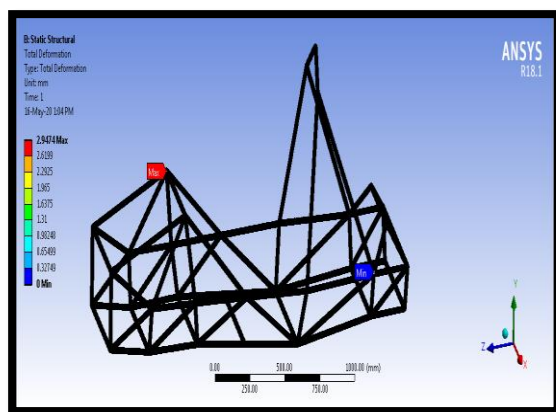
Figure 10 shows the boundary conditions for rear impact analysis. In the rear-impact study, Front suspension nodal points are made fixed while the rear points' displacement is made free in the longitudinal and vertical axis. Nodal rotations of both the ends are set. Force is applied to the yellow portion.

#### 4.4. Torsional Analysis

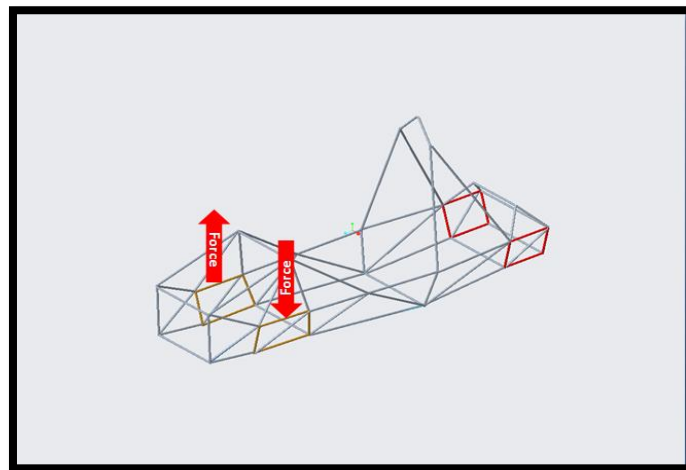
This analysis is critical as the vehicle is subjected to a torsional load every second during its run. These stresses are generated due to the banking of roads. For this particular analysis, loads are applied from both sides of the vehicle to act like a couple at suspension picks up points. Here 3g force is used on both sides. Max stresses produced 430 Mpa, which under the yield strength of a material. Hence the chassis is safe in all the conditions.



**Figure 11** Torsional Stress Analysis



**Figure 12** Torsional Deflection Analysis



**Figure 13** Torsional Analysis Boundary Condition

Figure 13 shows the boundary conditions for torsional analysis. In the torsional analysis, one can make either sides displacement fixed and can apply a force on the other side, as shown by arrows. In the above figure, nodal displacement and rotations are made fixed, and at the frontal nodal points, displacement and rotation are kept free.

#### 5. MANUFACTURING

For manufacturing chassis equivalent to the CAD model, it was necessary to develop accurate fixtures. Before manufacturing, fixtures were designed to give required dimensional accuracy

at a low cost. MDF board is used as a material that provides the necessary strength for holding the chassis tubes and does not catch fire during welding.

Series of slots were made in the main longitudinal plate, and respective strips were sliding in these slots to give proper positioning of the tubes. These fixtures are for one time use. After complete assemblage of tubes, fixtures can be cut by the grinder. Fixtures are shown below:



**Figure 14** Actual Prototype with Fixtures

This type of fixture can accommodate any design of chassis. Slots on the plate are nothing but coordinate with the tubes. With these fixtures, welding of tubes can be done with ease. The fixtures are so accurate that one can start assembling these tubes from both ends.

## 6. RESULTS AND DISCUSSION

As per said objective, the chassis conforms to all the FSAE rules. Because of the change in the design of roll hoops, the new chassis' width is considerably less compared to the previous system. As the height of the front roll hoop is reduced, the driver visibility is also enhanced. It also offers excellent serviceability to other parts of the vehicle because of its neat design.

The chassis was carefully researched by viewing previous designs, past research, and currently manufactured products. The knowledge was then applied and combined to design a chassis to fit formula SAE requirements. The requirements of functions, designs, and rules were met in the final design.

## 7. CONCLUSION

The manufactured design of chassis satisfies all the objectives decided at the beginning. All dimensions of three compartments viz. front, driver, and engine are the same as designed. Because of the kind of fixture developed, it saves a lot of manufacturing and protects the unnecessary investment in steel fixtures. Physical ergonomics gives crucial data about the positioning of different components and visibly aspect to a driver before complete manufacturing and assemblage of vehicle.



## REFERENCES

- [1] Eva Mariotti and Badih Jawad, "Formula SAE Race Car Cockpit Design and Ergonomics Study for Cockpit" 2000 Future Transportation Technology Conference Costa Mesa, California, August 21-23, 2000
- [2] Amogh Raut, Aniket Patil, "Design Analysis of Chassis used in Students' Formula Racing Car using FEA Tool" International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-7 Issue-1, October 2017
- [3] Constantine Scaperdas, Jonathan Ross, Christian Strobel, David Powers, "Design and Optimization of an FSAE Frame, Suspension, and Business Portfolios" Worcester Polytechnic Institute, April 27, 2017
- [4] Surve Aditya, Naik Vishal, Naikar Aditya, Mohd. Raees (March-2018), "ANALYSIS OF FSAE CHASSIS", *International Journal of Scientific & Engineering Research* Volume 9, Issue 3, 40 ISSN 2229-5518
- [5] Corwin Dodd, "MEEG 402-010 Chassis Design Report"
- [6] Sandeep Kumar Pandey, Dr. Vandana Somkuwar(2012), "An Ergonomics Study of Four Wheel Vehicles", *IJRET*, Volume-4, Issue-2
- [7] Khelan Chaudari, Amogh Joshi, Kushal Nair (2013), "design and development of Chassis for all-terrain vehicle", *IJRET*, Volume-2, Issue-4
- [8] Jannis D.G. van Kerkhoven," Design of a Formula Student race car chassis"
- [9] Ryan Buffington," Formula SAE Ergonomics Jig"
- [10] Khizar Ahmed Pathan, Prakash S. Dabeer, and S. A. Khan. Investigation of Base Pressure Variations in Internal and External Suddenly Expanded Flows using CFD analysis, *CFD Letters*, Vol.11, Issue 4, 2019, 32-40.
- [11] Khizar Ahmed Pathan, Prakash S. Dabeer, and S. A. Khan, Effect of Nozzle Pressure Ratio and Control Jets Location to Control Base Pressure in Suddenly Expanded Flows, *Journal of Applied Fluid Mechanics*, vol. 12, no. 4, 2019, 1127-1135. DOI: 10.29252/jafm.12.04.29495
- [12] Khizar Ahmed Pathan, Prakash S. Dabeer, and S. A. Khan, An Investigation of Effect of Control Jets Location and Blowing Pressure Ratio to Control Base Pressure in Suddenly Expanded Flows, *Journal of Thermal Engineering*, Vol. 6, Issue 11, 2020, 15-23. DOI: 10.18186/thermal.726106
- [13] Khizar A. Pathan, P. S. Dabeer, and Sher Afghan Khan, Influence of Expansion Level on Base Pressure and Reattachment Length, *CFD Letters*, Vol. 11, Issue 5, 2019, 22-36.
- [14] Sher Afghan Khan, M. A. Fatepurwala, K. N. Pathan, P. S. Dabeer, Maughal Ahmed Ali Baig, *CFD Analysis of Human Powered Submarine to Minimize Drag*, *International Journal of Mechanical and Production Engineering Research and Development*, Vol. 8, Issue 3, 2019, 1057-1066. DOI: 10.24247/ijmpredjun2018111
- [15] Sher Afghan Khan, Abdul Aabid, Fharukh Ahmed, Mehaboobali Ghazi, Abdulrahman Abdullah Al-Robaian, Ali Sulaiman Alsagri, Analysis of Area Ratio in a CD Nozzle with Suddenly Expanded Duct using CFD Method, *CFD Letters* 11, Issue 5, 2019, 61-71.
- [16] Khizar Ahmed Pathan, Prakash S. Dabeer, and S. A. Khan, Enlarge duct length optimization for suddenly expanded flows, *Advances in Aircraft and Spacecraft Science*, Vol.7, Issue 3, 2020, 203-214.
- [17] Khizar Ahmed Pathan, Syed Ashfaq, Prakash S. Dabeer, and S. A. Khan, Analysis of Parameters Affecting Thrust and Base Pressure in Suddenly Expanded Flow from Nozzle, *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, Vol. 64, Issue 1, 2020, 1-18.
- [18] Pathan Khizar Ahmed, S. A. Khan, and P. S. Dabeer, An Investigation to Control Base Pressure in Suddenly Expanded Flows, *International Review of Aerospace Engineering (I.RE.AS.E)*, Vol. 11, No. 4, 2018, 162-169. <https://doi.org/10.15866/irease.v11i4.14675>

- [19] Khizar Ahmed Pathan, P.S. Dabeer, Sher Afghan Khan, Optimization of area ratio and thrust in suddenly expanded flow at supersonic Mach numbers, *Case Studies in Thermal Engineering*, Vol. 12, 2018, 696-700. <https://doi.org/10.1016/j.csite.2018.09.006>
- [20] Pathan Khizar Ahmed, S. A. Khan, and P. S. Dabeer, CFD analysis of the effect of flow and geometry parameters on thrust force created by flow from nozzle, *2nd International Conference for Convergence in Technology (I2CT)*, 2017, 1121-1125. <https://doi.org/10.1109/I2CT.2017.8226302>
- [21] Pathan Khizar Ahmed, S. A. Khan, and P. S. Dabeer, CFD analysis of the effect of area ratio on suddenly expanded flows, *2nd International Conference for Convergence in Technology (I2CT)*, 2017, 1192-1198. <https://doi.org/10.1109/I2CT.2017.8226315>
- [22] Pathan Khizar Ahmed, P. S. Dabeer, and S. A. Khan, CFD analysis of the effect of Mach number, area ratio, and nozzle pressure ratio on velocity for suddenly expanded flows, *2nd International Conference for Convergence in Technology (I2CT)*, 2017, 1104-1110. <https://doi.org/10.1109/I2CT.2017.8226299>
- [23] Fharukh Ahmed G M, Mohammad Asad Ullah, and S. A. Khan, Experimental Study of Suddenly Expanded Flow from Correctly Expanded Nozzles, *ARPJ Journal of Engineering and Applied Sciences*, Vol. 11, No. 16, 2016, 10041-10047. <https://doi.org/10.35940/ijrte.B1150.0882S819>
- [24] Sajali, M.F.M. Aabid, A. Khan, S.A. Mehaboobali, F.A.G. Sulaeman, E, Numerical investigation of the flow field of a non-circular cylinder, *CFD Letters*, 11(5), (2019): 37-49. [http://www.akademiabaru.com/doc/CFDLV11\\_N5\\_P37\\_49.pdf](http://www.akademiabaru.com/doc/CFDLV11_N5_P37_49.pdf)
- [25] Khan, S.A. Aabid, A. Saleel, C.A, Influence of micro-jets on the flow development in the enlarged duct at supersonic Mach number." *International Journal of Mechanical and Mechatronics Engineering*, 19(1), 2019, 70-82. [http://ijens.org/Vol\\_19\\_I\\_01/191301-2828-IJMME-IJENS.pdf](http://ijens.org/Vol_19_I_01/191301-2828-IJMME-IJENS.pdf)
- [26] Asadullah, M. Khan, S.A. Asrar, W. Sulaeman, E, Low-cost base drag reduction technique, *International Journal of Mechanical Engineering and Robotics Research*, 7, (4), 2018, 428-432. <https://doi.org/10.18178/ijmerr.7.4.428-432>
- [27] Fharukh Ahmed, G.M. Khan, S.A, Active control of base pressure using microjets for area ratio of 7.56, *International Journal of Innovative Technology and Exploring Engineering*, 8 (6), 2019, 491-495.
- [28] Khan, A. Mazlan, N.M. Ismail, M.A. Akhtar, M.N, Experimental and numerical simulations at sonic and supersonic Mach numbers for area ratio 7.84, *CFD Letters*, 11 (5), 2019, 50-60.
- [29] Khan, S.A. Aabid, A. Mokashi, I. Ahmed, Z, Effect of microjet control on the flow field of the duct at Mach 1.5, *International Journal of Recent Technology and Engineering*, 8 (2 Special Issue 8), 2019, 1758-1762. <https://doi.org/10.35940/ijrte.B1148.0882S819>.
- [30] Sohail Khalil Shaikh, Khizar Ahmed Pathan, Zakir Ilahi Chaudhary, B. G. Marlpalle, Sher Afghan Khan, An Investigation of Three-Way Catalytic Converter for Various Inlet Cone Angles Using CFD, *CFD Letters*, 12 (9), 2020, 76-90. <https://doi.org/10.37934/cfdl.12.9.7690>
- [31] Sohail Khalil Shaikh, Khizar Ahmed Pathan, Zakir Ilahi Chaudhary, Sher Afghan Khan, CFD Analysis of an Automobile Catalytic Converter to Obtain Flow Uniformity and to Minimize Pressure Drop Across the Monolith, *CFD Letters*, 12 (9), 2020, 116-128. <https://doi.org/10.37934/cfdl.12.9.116128>
- [32] Miliken's, "Race Car Vehicle Dynamics"
- [33] SAE SUPRA Rule Book 2019