Design Analysis and Fabrication of M-BAJA ATV 2020

Sandeep Chaudhary, Ganesh Kumar Kantak, Priyanka Sharma, Harshita Mathur

Abstract - ***This report gives a brief of process to finalize the design of ATV by team Vivekananda conjurers. This report mentions specifications of roll cage, suspension system, steering system, braking system and transmission system. The objective of the design team was to obtain best output of manufacturing, cost, weight and overall aesthetics and performance by meeting the guidelines and rules by SAE.***

***Key Words*: Roll cage, ATV, Suspension system, Steering system, Braking system, Transmission system, analysis, FEA.**

1. INTRODUCTION

The paper includes steps taken by team "Vivekananda Conjurers" to design and fabricate the All-terrain vehicle for SAE Baja 2020. To design and test the vehicle 3D modeling and analysis tools like Solidworks 2019, Ansys workbench 15.0 and Lotus shark suspension were used. Tube miter was also used to print the profile of pipes for welding purposes.

2. VEHICLE DESIGN

The main design of the vehicle focuses on meeting the guidelines and rules by SAE Baja and designing a light weighted, reliable, economical, rigid, easily operable vehicle for all terrain conditions. Vehicle designing involves the following major systems-

Roll cage, Suspension system, steering system, Braking system, Transmission system.

3. ROLL CAGE

The roll cage is designed in such a way that it can pack the assembly of vehicle, can bear all forces and its shape must resist the roll over conditions with a small center of gravity height.

Material Selection

By proper selection of material, the strength, safety, reliability can be maximized and weight, cost can be minimized. Hence, the overall performance of the vehicle can be optimized. For that we first chose three best recommended materials and then compared their physical, mechanical properties and cost. Here is a table of four type carbon steels comparing their properties.

Table1. Material comparison for roll cage

Properties	AISI 1018	AISI 1026	AISI 4130
Density(g/cc)	7.87	7.858	7.80
Ultimat e Strength (MPa)	440	490	560
Yield Strength (MPa)	370	415	460
Elongation at break in 50mm	15	15	21.50
Cost (Rs/Kg)	65	55	65

By the table it was observed that AISI 4130 carbon steel is most suitable for roll cage of the ATV. By simulation and analysis, we opted the best inner and outer diameter for primary and secondary members i.e. shown in following table.

Table2. Roll cage primary and secondary member specification

Diameter(mm)	Primary member	Secondary member
Outer	25.4	25.4
Inner	22.4	23.4

Welding

In the very first the prototype is made through PVC pipes and then design is modified further then the fabrication of roll cage is started by using appropriate welding method for AISI 4130 carbon steel. We have selected TIG welding for joining the metal because of its good weldability and they obtain safer medium for welded zone by the use of inert gases (argon gas). The strength of welded joint is achieved by using a filler rod ER70S-6. This filler rod is also widely used, cost effective and easily available. To check the compressive strength of welding joint, the test is performed on UTM and the results are following-

Table.3 Welding compression test results

Ultimate load & peak displacement	134.8 KN & 15.93 mm

Break load & max displacement	84.70 KN & 25.38 mm
Ultimate compression strength	266.17 N/ Sq.mm
Yield load & breaking stress	10.17 & 167.24 N/Sq.mm

Finite Element Analysis

Solidworks simulation and Ansys workbench 15.0 were used for testing the roll cage because of its ease, accuracy and frequent changing in the model. The tests are- Front impact, Rear impact, Side impact, torsional impact and roll-over tests. The results are shown from figure-1 to figure-5.

4. SUSPENSION SYSTEM

Objective

The aim is to design a suspension system which keep the vehicle and wheel alignment stable. It has less fluctuation of roll center during steering, rolling and bumping. All the aspects are keeping; to prevent the wear and tear of vehicle, to absorb the shocks, to make the driver comfortably operate vehicle, better performance to sustain the jounce and rebound.

Design

A double wishbone A-arm suspension system is chosen because of its high FOS, best riding quality, flexible and easy design. The other reason for choosing double wishbone system is that it is consist horizontal and vertical structure which makes is a system with small center of gravity (near to the ground). Due to the high cost and unavailability in the market we created our own kind of suspension system which is combination of hydraulic and inbuild spring. The material and diameter for A-arms is same as primary member of roll cage since it reduces the cost. The ground clearance of vehicle is kept at 8inch to prevent roll over condition. The center of gravity is calculated at the minimum height i.e. 20.62inch. The other information is given in the innovation abstract. The designing software for this system used is Lotus Shark by which the least movement of roll center is made by varying the x, y, z coordinates. After that the 3D model was designed on Solidworks 2019 and made to simulate that model. The specifications chosen for front and rear suspensions are as follow-

Table.4 Suspension specifications

Specifications	Front Suspension	Rear Suspension
Coil Diameter	90 mm	90 mm
No of active coils	8	8
Total no of coils	9	9
Solid length	290mm	268mm
Free length	360mm	360mm
Pitch of coil	36.25 mm	38.28mm
Stiffness (Ks)	19.46 N/mm	25.74 N/mm

After taking the above specifications for suspension we successfully created 8inch of travel for shock absorber. The stiffness of front shock absorber is chosen lesser than rear because it reduces the chances of roll over at uneven terrain. Also, the Dampers are created in such a way so that we can change the ground clearance with the help of nut and bolts.

The analysis of wishbone using Ansys workbench 15.0 is shown in figure-8 and figure-9.

Additional Parts used

1. Bushes
2. Bushes mounting and casing
3. Ball joint
4. Ball joint casing

5. STEERING SYSTEM

Objective

BAJA track consists of different terrain conditions with sharp turns and hilly section, at this condition vehicle’s smooth run depends upon the stability of system. The purpose of this system is to get directional control, stability and smooth ride of the vehicle, in all terrain conditions, with less steering effort and to achieve least turning radius.

Design

We have chosen rack and pinion steering system because of its easy design and construction, lighter in wight and cost effectiveness over other steering systems. We choose the centralized rack and pinion which travels from one end to another end (6.27") in 3 turns of pinion. Steering ratio of 7:1 is achieved which means for every 7degree rotation of steering wheel, then tires will be turned by 1 degree. We preferred Ackerman type steering geometry because of its better stability and smooth ride during cornering. Steering is designed after deciding track width through suspension system.

Adjustable steering column

We made our steering system with adjustable column through which driver can change the steering wheel angle according to comfortability and height. A plunger type mechanism through universal joint connect between pinion and steering column helps it to adjust accordingly.

Tie rods

Tie rods are used to transmit the motion of steering wheel by steering arm to steering knuckle and sustain the vibration due to uneven terrain. We have chosen mild steel over aluminum because of weldability, stress and cost consideration. Tie roads also used to adjust toe by the application of ball joints.

Correct steering angle

While taking turn the outer wheel covers more radius then the inner wheel i.e. inner wheel makes greater angle then outer wheel with a maximum angle of 34.16^0. Higher steering angle gives smaller turning radius.

The simulation of knuckle is shown in figure-6 & figure-7.

Table.5 Steering specification

Steering parameters	Specifications
Steering geometry	Ackermann
Steering ratio	7:1
Rack travel	6.27"
Front track width	52''(1320.8mm)
Wheel base	62"(1575 mm)
Steering angle inner	34.16º
Steering angle outer	23.84º
Caster angle	0.10 degrees, adjustable
Turn of lock to lock rev.	3
IBJ Centre distance	197.8mm
OBJ Centre distance	590.5mm
Steering wheel diameter	304.8mm
Length of tie rod	423.44mm
Ackermann percentage	74.37%
Turning radius	2.59m
Tie rod length	112.66mm

6. BRAKING SYSTEM

Objective

The main purpose of braking system is to bring a vehicle at rest safely when the vehicle is in motion by locking all the four wheels at the same time and to increase driver's safety in off terrain conditions.

Design

We preferred hydraulically actuated disc brake system on all four wheels instead of drum brakes because of its heat dissipation ability, cost effectiveness, better stopping distance and to avoid brake fade. We designed a couple foe wheel assembly and simulated the same by using solidworks and achieved optimum results. We use X split braking circuit with 2 port TMC (tandem master cylinder) because in case one system fails, then another will still operate and perform appropriate task. We use DOT 4 brake fluid because of its high boiling point then DOT 3 and DOT 5 brake fluid. Brake bleeding is achieved by setting the calipers at 3 and 9'o clock position.

The analysis of couple with mild steel is shown from figure- 10 to 12.

Table.6 Braking specification

Rotor diameter	200 mm	170 mm
Caliper piston diameter (floating)	DP 28mm	SP 32mm
TMC diameter (M800) & stroke	20mm & 33mm	
Caliper pad area and Coefficient of friction	1428.73 mm^2 & 0.4	
Coefficient of friction for road	0.65	
Weight transfer	59.42%	40.57%
Stopping distance	2.76m	
Deceleration	6.967 m/s^2	
Pedal ratio	4:1	
Pedal force	300N	

Braking calculation-

By applying the newton's low of motion, we get the stopping distance

S= 13.82 m

From the equation

$1/2\ mv^2 = \mu\ mgx$

Considering only 20% of energy is utilized while braking, stopping distance comes out as

S=0.2*13.67

S= 2.76m

7. TRANSMISSION SYSTEM

Objective

The purpose of drive train is to transfer power from engine to wheel by the application of CVT and appropriate gear reduction of FNR gear box which needed for consistent running of vehicle in competition. We have chosen CVT over transaxle because of following reason-

1. It provides constant torque change automatically at harsh condition.
2. Reduce wear & tear of gear teeth.
3. It provides infinite gear ratio.
4. It is lighter and economical.

Engine

Engine is provided by BAJA SAE 2020 i.e.19 vanguard series Briggs & Stratton 305cc engine and model type is 19L232-0054G1. The torque is generated by this engine is 18.98 Nm. According to the SAE BAJA guidelines the governor setting not exceed to 3800 rpm.

Design Methodology

The engine is placed with 52'' track width at the rear side of the vehicle. The output shaft of the engine is connected to primary pully of CVT through the coupler. The coupler is designed and simulate using the solidworks software. The primary pully is then connected to secondary pully through belt which is connected to input of gear box. Through gear mechanism inside the FNR gear box we get power at output shaft of gear box. From the output of gear box power is transmitted to drive shaft and then at tires. This power is used to accelerate the vehicle.

We customize the differential and modified gear box according to our need in the competition.

Table.6 Transmission system specification

Engine displacement	305cc
Max power	10HP @ 3800 rpm
Max torque	18.98 Nm @ 2500 rpm
Gear ratio	12:1
Acceleration	5.9607(max) & 0.0098 (min)
Gradeability	62.32%(max) & 6.67% (min)
Tire size	24*8*12(front & rear wheel)
Starting CVT ratio	3
Fina CVT ratio	0.43
Max Speed	53.985 Km/h

8. ELECTRICAL SYSTEM

The vehicle consists of certain electrical components to ensure the safety of vehicle and driver. It is also used to prevent the critical accidental cases on the track 12V, 7 Amp battery is used to supply the power to all electrical components. Brake light, reverse light and reverse alarm is used for vehicle safety at the track according to the SAE BAJA guidelines. A transponder is being used to relay number of laps with the help of timing system on the track.

9. CONCLUSION

The objective of designing a single seater off road vehicle by the team Vivekananda Conjurers for the competition SAE BAJA 2020 has to be accomplished with consideration of driver's safety, cost effectiveness and durability of vehicle. The team has selected material as their priority to reduce the vehicle overall weight, cost and to maintain strength of every components. Before the actual fabrication of the vehicle, engineering design and their application is used to design and simulate the vehicle with real time condition on the software like Solidworks, lotus shark etc.

If one is doing anything for the first time then for sure there are some difficulty in their path. The team faced all the problems and solve by them self like managing time with study and project, market scenario etc. With design and manufacturing, the team has also focused on fund management, project management, marketing and research, working of vehicle within available funds and complete all the tasks before deadline successfully. Apart from that the team members developed all the qualities so that they can works with industries.

REFERENCES

[1] Ball, R. S. (2004). *Automotive Engineering Fundamentals.* United States of America: SAE - International.

[2] Debidutta Mishra, N. (2014). *TEAM JAABAZ BAJA SAE (UTEP 2014) DESIGN REPORT.* 2014 SAE International.

[3] Dr. V. K. Saini, P. K. (2017). *Design Methodology of Steering System for All-Terrain Vehicle.* Ghaziabad (U.P.) India: IRJET.

[4] J.K. Gupta, R. K. (2005). *Machine Design.*
S. Chand.

[5] Shrivastava, D. (2014). *Designing of All Terrain Vehicle (ATV).* Bhopal: International Journal of Scientific and Research Publications.

[6] Yamsani, A. (2014). *Gradeability for automobile*
. Automobile engineering M.V.S.R. Engineering College, India: IOSR-JMCE.

Analysis Results

Roll Cage Analysis Results

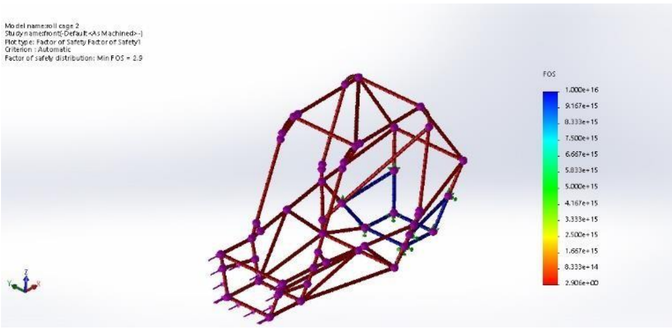

Figure 1. Front impact test result for FOS.

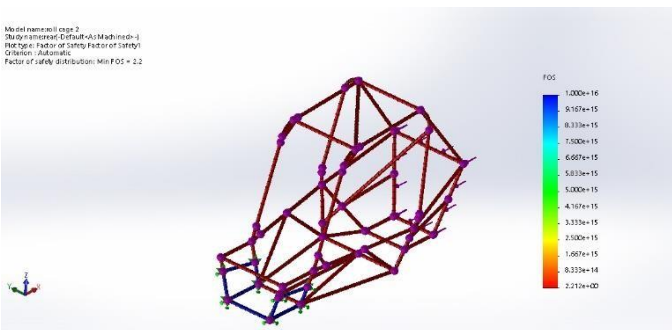

Figure 2. Rear impact test result (FOS).

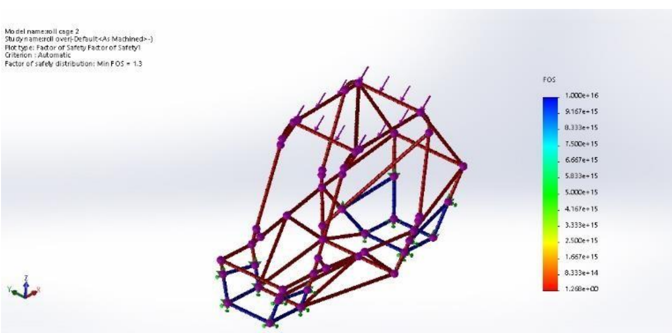

Figure 3. Roll over test result (FOS).

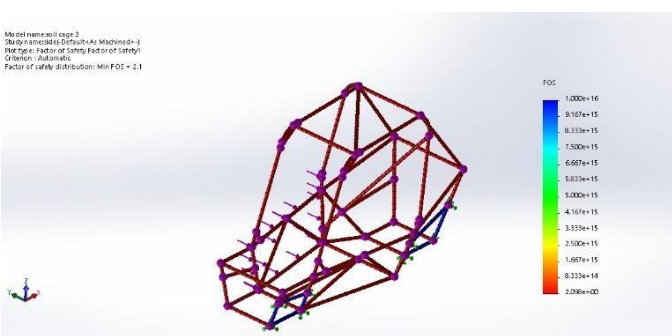

Figure 4. Side impact test result (FOS).

Table7. Static test results for roll cage analysis

Test Name	FOS	Max. Deformation	Force Applied per member	Boundary Conditions
Front Impact	2.9	2.85mm	1827.6N	Fixed at rear suspension mountings
Rear Impact	2.2	4.4mm	1827.6N	Fixed at front suspension mountings
Roll Over	1.3	6.125mm	1780.64N	Fixed at front & rear suspension mountings
Side Impact	2.1	8.5mm	1218.4N	Fixed at opposite suspension mountings
Torsional	1.32	5.8mm	1666.5N @front 1213N @rear	In front, right-side suspension mountings fixed and in rear, left- side suspension mountings are fixed

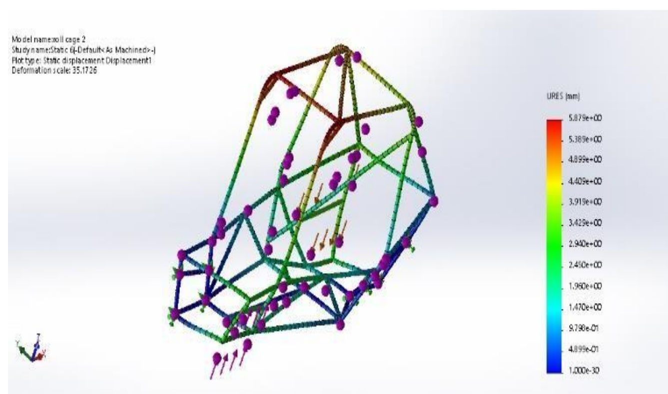

Figure 5. Torsional test result (Deformation)

Knuckle Simulation Result

FOS comes out to be 1.2 when an equivalent force due to braking, Steering and due to sprung mass. The deformation is 0.15mm for this part.

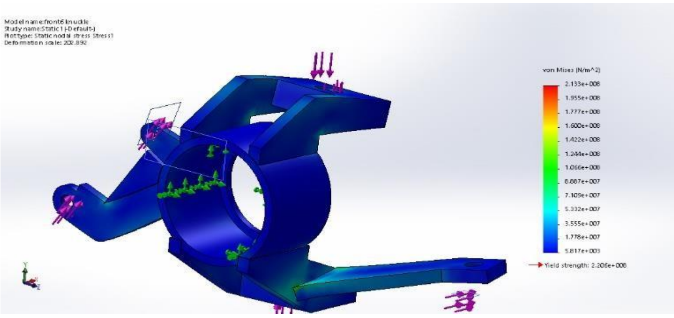

Figure 6. Knuckle simulation result (Stress).

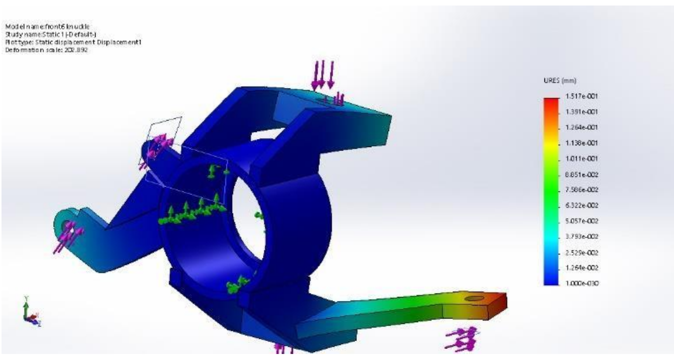

Figure 7. Knuckle simulation deformation result.

Suspension Wishbone simulation Results

Table8. Suspension Wishbone simulation Results

Part Name	FOS
Front Wishbone	1.6
Rear Wishbone	1.8

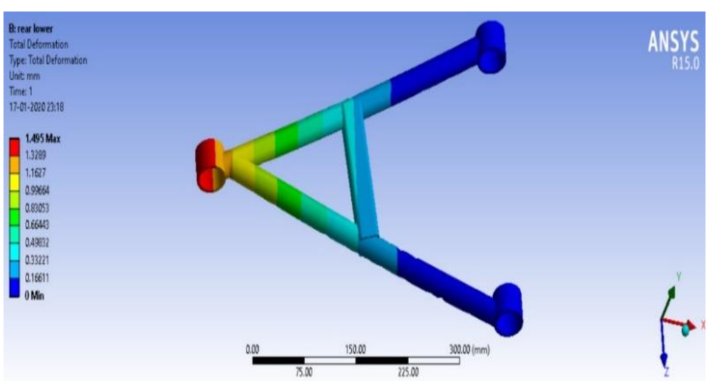

Figure 8. Rear lower wishbone simulation total deformation result

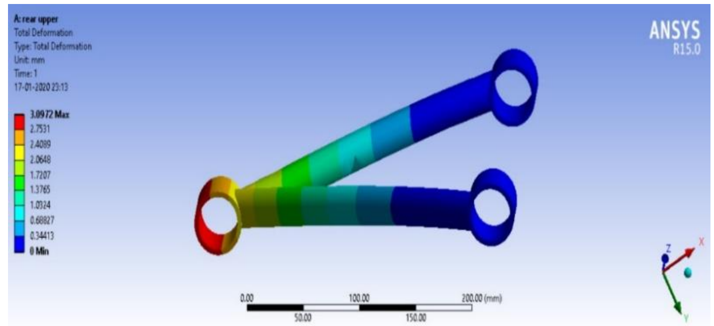

Figure 9. Rear upper wishbone simulation total deformation

Disc couple Analysis Results

FOS comes out to be 7.4 when an equivalent force due to braking is applied on the disc couple surfaces in opposite direction. The deformation is 0.0187mm for this part.

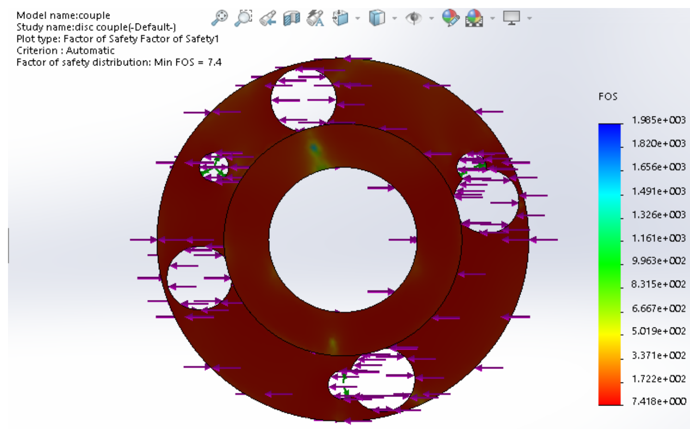

Figure 10. Disc couple simulation (FOS).

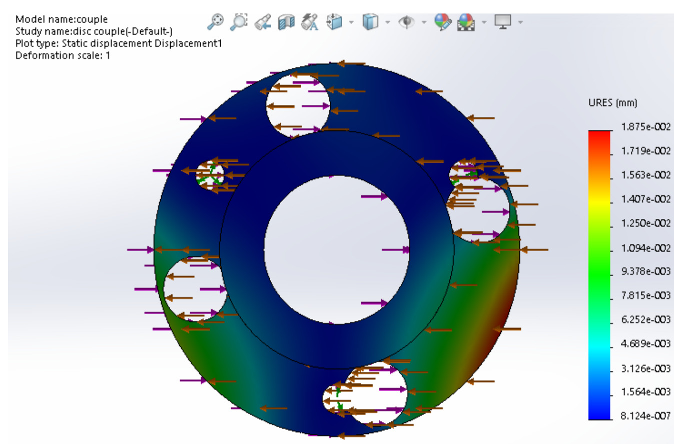

Figure 11. Disc couple simulation deformation result.

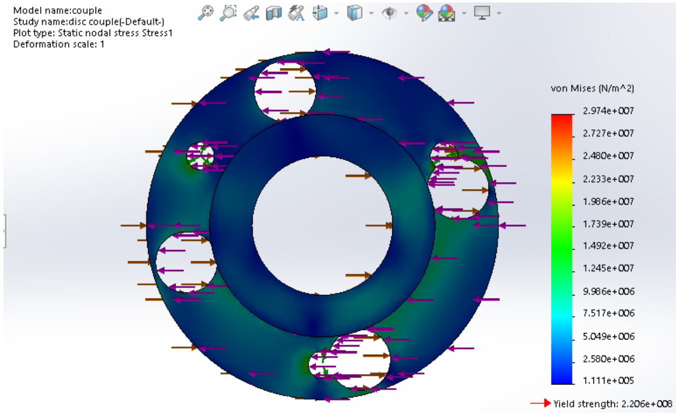

Figure 12. Disc couple simulation result (Stress).

AUTHOR'S PROFILE

Ms. Priyanka Sharma is a student of in Department of Mechanical Engineering at VIVEKANANDA INSTITUTE OF TECHNOLOGY, JAIPUR.

Mr. Sandeep Chaudhary is a student of in Department of Mechanical Engineering at VIVEKANANDA INSTITUTE OF TECHNOLOGY, JAIPUR.

Mr. Ganesh Kantak is working as an Associate Professor in Mechanical Engineering Department of Vivekananda Institute of Technology, Jaipur. He has total 9 years' experience of teaching. He has completed M. tech from NIT, Trichy and

B. tech from M.B.M. Jodhpur. His area of research includes inventory management, operation research and quality management etc.

Ms. Harshita Mathur is a student of in Department of Mechanical Engineering at VIVEKANANDA INSTITUTE OF TECHNOLOGY, JAIPUR.