DESIGN & ANALYSIS OF DISC FOR HYDRAULIC BRAKING SYSTEM OF A SOLAR CAR

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Abstract

The present research work aims to design of a disc for the braking system of the Solar Car. The disc of grey cast iron is modelled in Autodesk Inventor and Analysis of same was done in the FEA module of the Autodesk Inventor. Structural analysis of disc is carried out to study stress distribution, strain, deformation, etc for real world implementation. It is designed in a manner that the disc will support different loading condition without failure. Basic approach is to reduce the mass of disc which directly leads to reduce unsprang mass of the vehicle. As the friction between the disc pads and disc causes wheel to slow or stop where kinetic energy is converted to heat energy. In order to dissipate maximum heat, several vents are designed in the disc which may leads in reduction of mass of the disc. At the same time there should be enough strength to sustain under the dynamic conditions.

Introduction

A brake is a device which is used to retard or to stop the motion of vehicle. The purpose of the brakes is to stop the car safely and effectively without skidding in minimum possible time. In order to achieve maximum performance from the braking system, the brakes have been designed to lock up all four wheels. A disc brake is a wheel brake which slows rotation of the wheel by the friction caused by pushing brake pads against a brake disc with a set of calipers. To stop the wheel, friction material in the form of brake pads, mounted on a device called a brake caliper, on which the force is applied mechanically, hydraulically, pneumatically or electromagnetic ally against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. After the removal of force from disc pads, the pads retain its original position and the wheel can rotate freely again. Disc brakes have proven to be the most reliable and stable working, so they are widely used in modern automobiles. In a hydraulically actuated system, master cylinder and brake lines are used for transferring the motion of driver's pedal. The fluid filled in lines. The brake pedal linkage operates a piston in a master cylinder to pressurize the fluid inside the lines. Fluid pressure in each wheel cylinder or caliper forces the friction material against the drum or rotor. Hydraulic brakes work on the principle of pascal law.

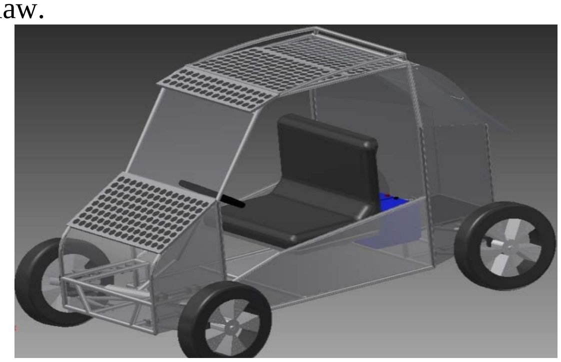

Fig.1, 3D model of Solar Car

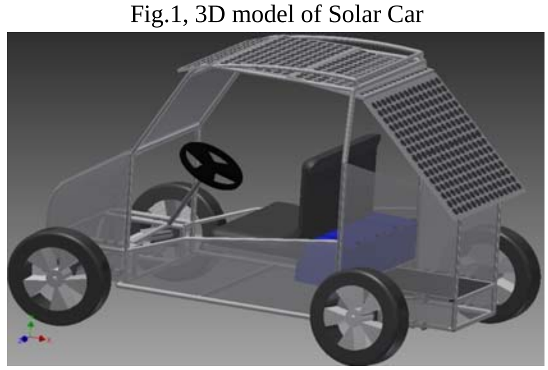

Fig.2, 3D model of Solar Car

Design

Gross Weight of Vehicle, W = 3500 N
Weight on Front axle with no braking,
W_1 = 1400 N
Weight on rear axle with no braking,
W_2 = 2100 N
Height of cg, h= 547 mm
Wheel base, l= 1550 mm
Coefficient of friction b/w road & tyre,
μ =0.6
Tire radius= 240 mm
Dynamic weight transfer
On front wheels =2254 N
On rear wheels = 1246 N
Brake force
Front wheel, f =1352.4 N
Rear wheels, f =747.6 N
Braking torque required
For front wheels = 162.288 Nm
For rear wheels = 89.712 Nm
Brake line pressure = 1.403 MPa
Clamping force = 971 N on each face
Brake Torque Actual =100 Nm
Stopping distance = 5.75 m
Braking efficiency = 80 %

Material

The material should have enough strength to withstand all the loads acting on it in dynamic conditions. The material selection also depends on number of factors such as material properties, availability and the most important parameter is the cost. Grey Cast Iron is selected for the material of disc. Properties of Grey Cast Iron are as under:

1.	Mass Density	7.15 g/cm^3
2.	Yield Strength	758 MPa
3.	Ultimate Tensile Strength	884 MPa
4.	Young's Modulus	120.5 GPa
5.	Poisson's Ratio	0.3 ul
6.	Shear Modulus	46.3462
7.	Coefficient of Thermal Expansion (m/°C)	46 W/m-K

Table.1, Properties of material for the Disc

Modelling

The design of a disc for a solar car is modelled in Autodesk Inventor software. It involves creating of sketch in the two dimensional sketch module and then transferring it to three dimensional sketch module and by using extrude command, the two dimensional sketch is converted to solid model or part. Disc for a braking system of the solar car is modelled. The assumptions which are made while modeling the process are given below.

- The disc material is considered as homogenous and isotropic.
- The problem domain is considered as axis- symmetric.
- Inertia & body force effects are negligible during the analysis.

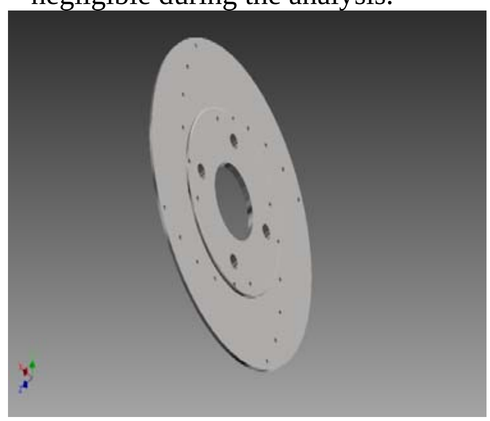

Fig.3, 3D model of Disc

Meshing

Meshing involves division of the entire of model into small pieces called elements. It is convenient to select the free mesh because the disc is circular in shape, so that shape of the object will not alter. To mesh the disc element type must be decided first. The numbers of elements after mesh are 5692 and the total numbers of nodes are 11285. Here, the description of element type is follows as:

1.	Avg. Element Size (fraction of model diameter)	0.1
2.	Min. Element Size (fraction of avg. size)	0.2
3.	Grading Factor	1.5
4.	Max. Turn Angle	60 deg
5.	Create Curved Mesh Elements	Yes

Table.2, Mesh Properties for the Disc

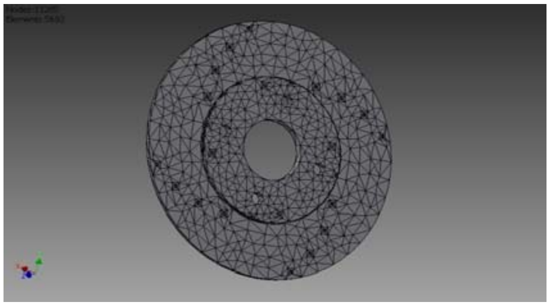

Fig.4, Meshed view of Disc

ANALYSIS

A structural analysis is performed over the disc when the loads & boundary conditions remain stationary & do not change over with the time. It is assumed that the load or field conditions are applied gradually, not suddenly. The system under analysis can be linear or nonlinear. Inertia and damping effects are ignored in structural analysis. Static analysis is used to determine displacements, stresses, etc. In structural analysis following matrices are solved [K][X]=[F],Where K is stiffness matrix, X is displacement matrix, & F is the force matrix.

Pressure Applied

A pressure is applied to the both faces the disc. Area of disc on which pressure is applied is shown by shaded region. Pressure of magnitude 1.5mpa is applied on the both side of disc.

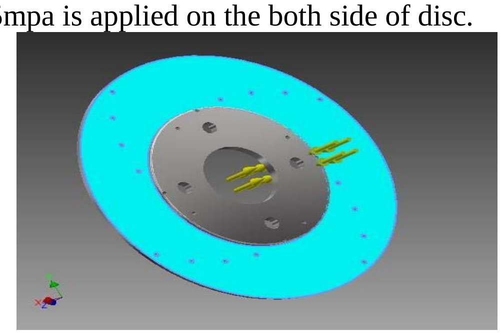

Fig.5, Pressure applied to the Disc

Von Mises Stress

The equivalent Von Mises Stress induced in the disc under the action of applied force. The maximum stress induced in the disc is 498.6 mpa.

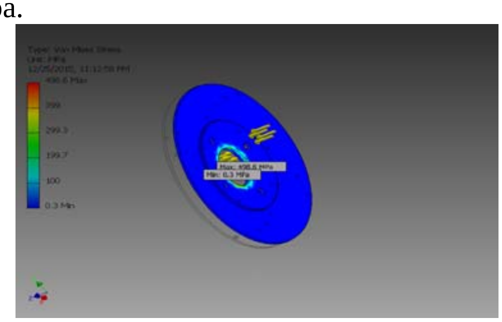

Fig.6 Von Mises Stress in the Disc

1st Principal Stress

The Principal Stress induced in the disc under the action of applied force. The maximum stress induced in the disc is 292.9 mpa.

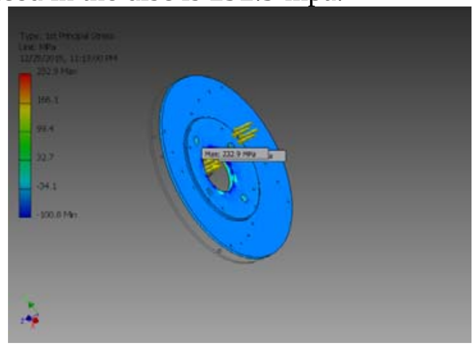

Fig.7 Principal Stress in the Disc

Displacement

The Deformation induced in the disc under the action of applied force. The maximum deformation induced in the disc is 0.308 mm.

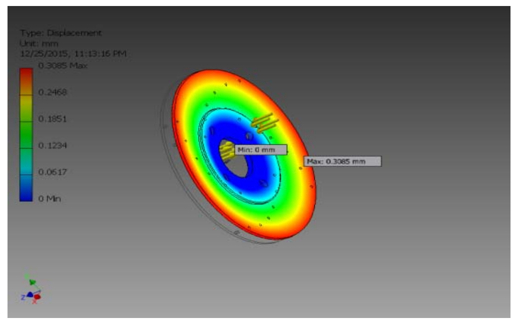

Fig.8 Deformation in the Disc

Safety Factor

The Factor of Safety in the disc under the action of applied force. The maximum Factor of Safety is 15 and the minimum Factor of safety recorded in the disc is 1.5 at orange zone.

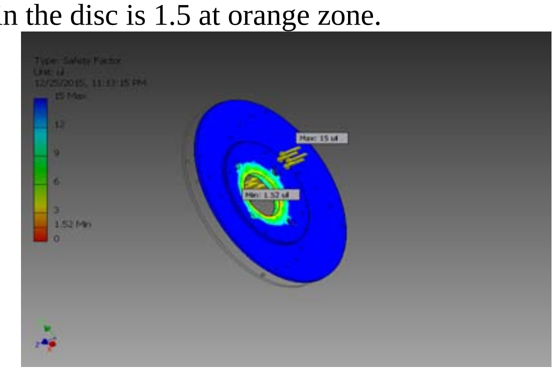

Fig.9 FOS in the Disc

Equivalent Strain

The Equivalent Strain in the disc under the action of applied force. The maximum Equivalent Strain is 0.0037 and the minimum Equivalent Strain recorded in the disc is 0.000004.

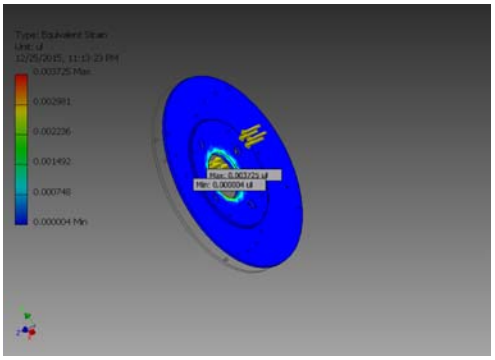

Fig.10 Strain in the Disc

Conclusion

The Disc is designed for the solar car in which brakes are applied by hydraulic mechanism. It is made up of Grey Cast Iron which has enough strength to sustain under variable loading condition. The thickness of designed disc is 3 mm which is validated by the results of Von mises stress, Principal stress, Strain, Deformation and FOS (Factor of Safety). Hence the designed disc is safe and would be suitable for implementation.

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