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Design, Analysis and Manufacturing of Integrated Hub and Rotor for an All Terrain Vehicle

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ABSTRACT
Now-a-days commercial All Terrain Vehicles (ATV'S) use separate hub and rotor. In this research paper we design, analyze, manufacture INTEGATED HUB AND ROTOR (Brake Disc) for all ATV'S. Design and analysis of components is done on CATIA V5 and ANSYS WORKBENCH 16.0 respectively. At first, we designed integrated hub and rotor for ATV in SAE BAJA 2017 competition which turned out to be very reliable. In this paper we are designing integrated hub and rotor (IHR) considering different materials to further reduce weight, overall size and manufacturing cost.
KEYWORDS *- Al 7076-T6, Baja vehicle, En 8, En 24, Integrated hub and rotor, Static analysis, SG cast iron, Thermal analysis.*

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I. INTRODUCTION

Conventional ATV'S which use separate wheel hub and rotor are normally made as two separate parts which are bolted together to facilitate a replacement of worn out brake rotors. The life span of the disc is relatively short as compared to the hub, which normally do not need any replacement. This design results in increasing number of machining operations and misalignment during assembling. It also has long overall length and is heavier in weight [1]. For our ATV we designed an integrated hub and rotor (IHR) in which they are manufactured as one piece. The material used for manufacturing IHR in our ATV in BAJA SAE was En 8. The induction hardening process was done only on rotor part to increase its wear resistance and hardness required for braking purpose.

II. DESIGN OF INTEGRATED HUB AND ROTOR

As shown in fig. 2, radial outward flanges of hub on which rotor is mounted are removed and rotor is directly attached to cylindrical part of hub. Due to removal of flanges and joining parts like nuts and bolts, weight of wheel assembly reduces substantially and also helps to optimize performance of ATV with integrated hub and rotor [1].

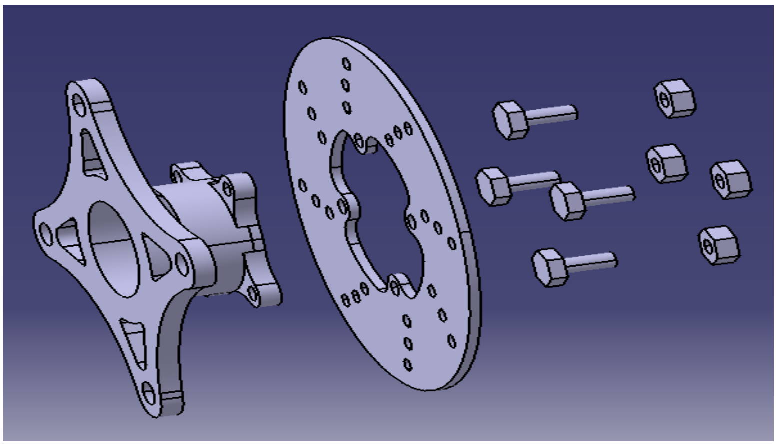

Fig 1: Bolted hub and rotor

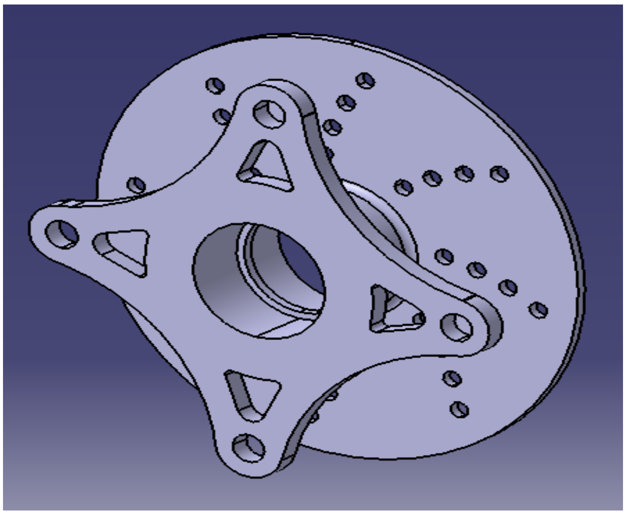

Fig 2: Integrated Hub and Rotor

As the functions of hub and rotor are different, where hub goes through severe loading during operation therefore it requires high strength and ductility. On the other hand, rotor requires high hardness, wear resistance, compressive strength. Also, higher thermal storage capacity to prevent distortion and cracking from thermal stresses which is crucial in the case of repeated stops from high speeds. Therefore, we have to select a material which fulfills properties required for both hub and rotor.

III. MATERIALS FOR INTEGRATED HUB AND ROTOR

The materials which are selected for integrated hub and rotor are EN 8, EN 24, Spheroidal Graphite Cast Iron (SG CI) and Al 7076-T6. En 8 and En 24 have high strength which is required for hub but have low wear resistance as well as low hardness. To overcome this problem, selective hardening process like induction hardening is done on the surface of rotor only. In this process, hardness of rotor is increased from 20HRC (Rockwell Hardness) to 40HRC. During induction hardening, only rotor part is heated at high temperature and then quenched in oil due to which only the hardness of rotor increases and other part (hub) remain unaffected.

Table 1: Mechanical properties of materials

MATERIALS / PROPERTIES	EN8	EN24	Al 7076-T6	SG CAST IRON
DENSITY (g/cm^3)	7.8	7.8	3	7.5
YOUNG'S MODULUS (GPa)	190	190	70	180
POISSION RATIO	0.29	0.29	0.32	0.29
UTS (MPa)	650	850	560	460
YTS (MPa)	350	654	480	310

IV. ANALYSIS

4.1 STATIC ANALYSIS

Static structural analysis has been performed on the Integrated Hub and Rotor to find out deformation and factor of safety of the component during severe loading conditions. An ATV of mass 250 Kg with driver is considered for analysis with maximum speed of 60 km/hr.

Loading conditions [2]:

1. Braking torque = 300 Nm
2. Bump force = 3g = 3 x 9.81x 250 = 7357.5 N
3. Cornering force = 1.5g = 1.5 x 9.81 x 250
   = 3678.75 N
4. Longitudinal Force = 1g = 1x 9.81x250
   = 2452.5 N

4.1.1 STRESS

As design is same therefore stress generated in component is also same for all materials as shown in fig. 3.

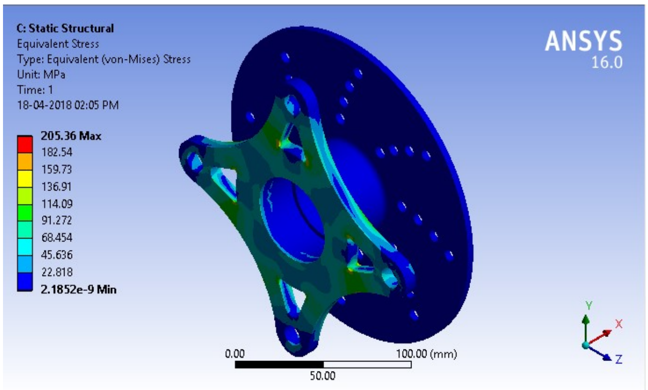

Fig 3: Stress generated for all materials

4.1.2 DEFORMATION

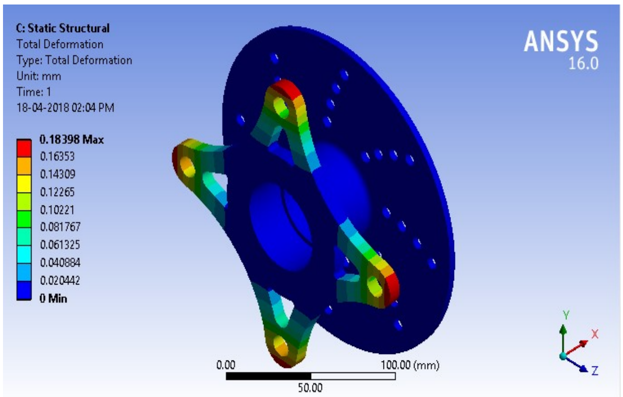

Fig 4. Deformation for En 8

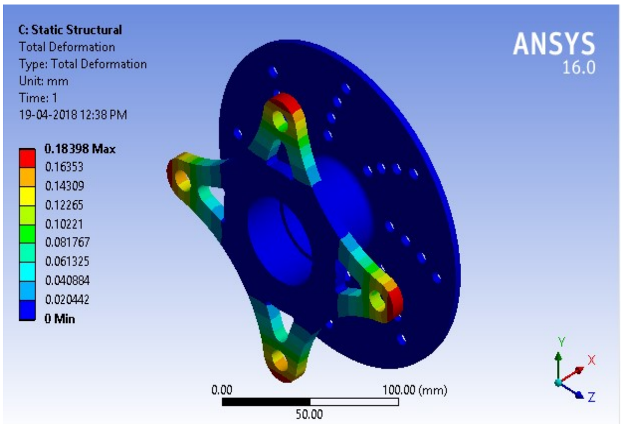

Fig 5. Deformation for En 24

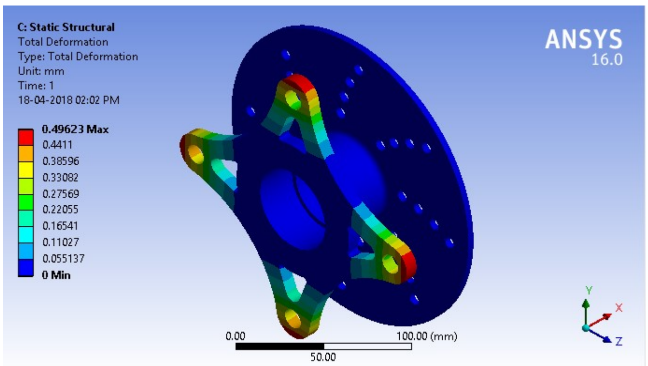

Fig 6. Deformation for Al 7075-T6

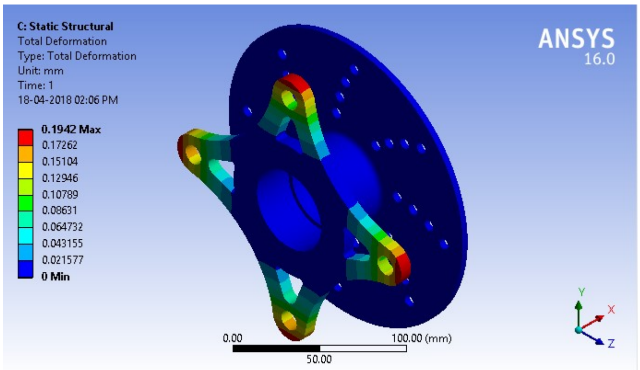

Fig 7. Deformation for SG CI

4.1.3 FACTOR OF SAFETY

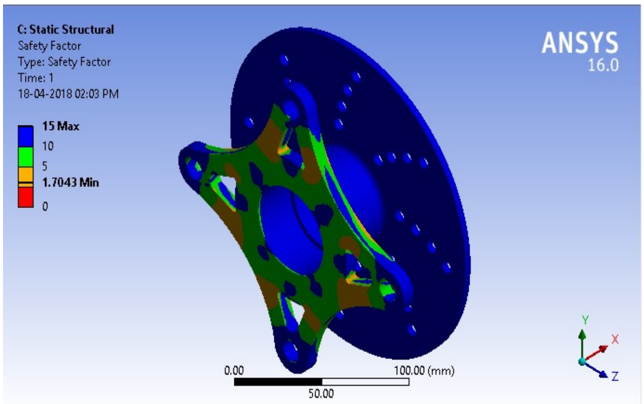

Fig 8: Factor of safety for En 8

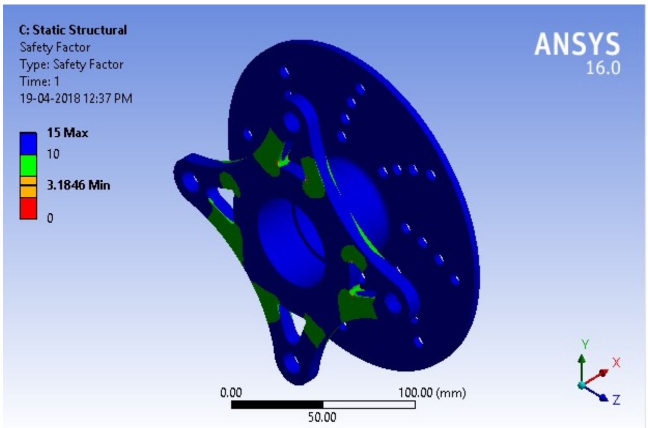

Fig 9: Factor of safety for En 24

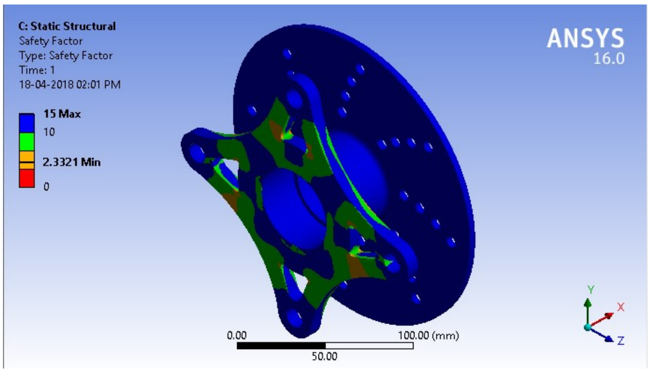

Fig 10: Factor of safety for Al 7075-T6

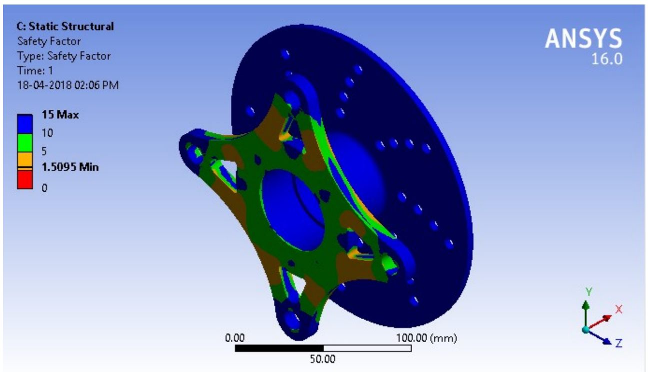

Fig 11: Factor of safety for SG CI

4.1.4 COMPARISON OF STRUCTURAL ANALYSIS RESULTS BETWEEN MATERIALS

Table 2. Static analysis table

MATERIAL / ANALYSIS	EN8	EN24	Al 7076-T6	SG CAST IRON
STRESS	205.36	205.36	205.36	205.36
DEFORMATION	0.1839	0.1839	0.4962	0.1942
FACTOR OF SAFETY	1.704	3.1846	2.33	1.509

4.2 THERMAL ANALYSIS

The transient thermal analysis has been performed on brake rotor to find out temperature during braking. We have calculated heat flux for 2.5 seconds of braking. As temperature reached after braking is low therefore thermal properties varying over period of time can be neglected. Thermal analysis is also used to study temperature distribution during braking, as temperature of wheel hub should not rise above specific temperature.

For analysis, we have considered maximum vehicle speed as 60 km/hr therefore vehicle which is supposed to stop in 2.5 sec with deceleration of 0.8g. Weight distribution in the ratio of 70:30 is considered as standard during braking period.

Thermal calculation [4]:

For front,

1. KE = $\frac{1}{2} \times (m.v^2) = \frac{1}{2} \times (250 \times 16.60^2)$

For front tyre (considering 70:30 weight distribution),

2. Heat generated = 34694.45 x .7 x .5 = 12143.057 J

Area of rubbing surface,

3. Area = $\pi/4 \times (0.19^2 - 0.14^2) \times 2 = 0.0259\ mm^2$

Heat flux,

4. Total Heat flux = Heat generated/Second/Rubbing Area

= 12143.057 / (2.5 x 0.0259)

= 187537.55 W/m^2

= 0.1875375 W/mm^2

Table 3: Thermal properties of materials

MATERIALS / PROPERTIES	EN8	EN24	Al 7076-T6	SG CAST IRON
Thermal conductivity (w/m-k)	51.9	51.9	130	35
Thermal expansion (µm/m-k)	12	13	23	11
Specific heat capacity (J/kg-k)	470	470	870	460

Overall heat transfer coefficient (w/m^2k)	7.9	7.9	25	5.7
Melting Point (^oC)	1420	1420	480	1120

4.2.1 TEMPERATURE

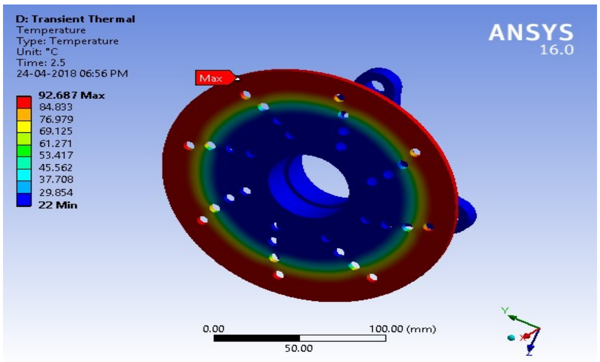

Fig 12: Temperature distribution for En 8 & En 24

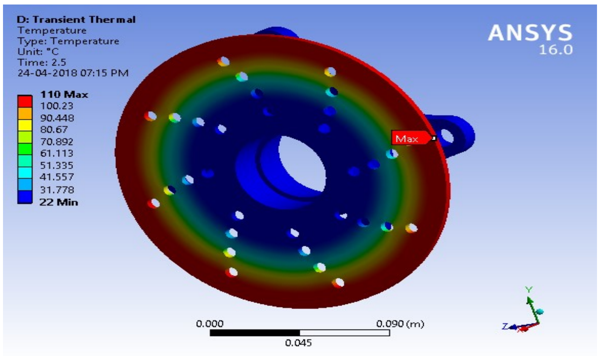

Fig 13: Temperature distribution for Al 7075-T6

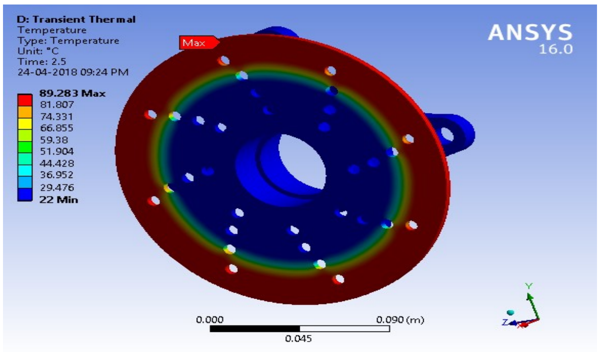

Fig 14: Temperature distribution for SG CI

4.2.2 COMPARISON OF THERMAL ANALYSIS RESULTS BETWEEN MATERIALS

Table 4. Thermal analysis result table

Material	EN8	EN 24	Al 7076-T6	SG CAST IRON
Temp (^oC)	92.68	92.68	110	89.283

V. CONCLUSION

After evaluating structural analysis results of different materials, it can be concluded that factors of safety of IHR with En 8 & SG CI are almost same but of Al 7075 T6 & En 24 are comparatively higher. Therefore, both Al 7075 T6 & En 24 are more suitable for IHR on the basis of strength and rigidity.

Maximum temperature reached during braking is same for En 8 & En 24 as both materials have same thermal properties. Temperature of Al 7075-T6 rotor is comparatively higher. Temperature of the rotor can also reach up to 300ºC during excessive driving; as melting point of Aluminum is 480ºC therefore Al 7075-T6 is not suitable for IHR.

Temperature distribution of En 8, En 24 & SG CI is almost same but in En 8 & En 24 during excessive driving more heat is transferred to wheel hub part which is not suitable for performance. Also, we have to perform induction hardening on rotor of En 8 & En 24 which increases machining time as well as manufacturing cost of the component.

As SG CI contains graphite flakes it gives better thermal diffusivity at higher temperature [5]. Hardness and wear resistance of SG CI is also high therefore there is no need of any specific hardening process for rotor part.

After considering both, thermal behavior and stress analysis of four materials it can be concluded that SG Cast Iron is most suitable for IHR whereas, En 24 & En 8 are second and third alternatives for IHR respectively.

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