Comprehensive Review on Design, Development and Testing of Full Face and Staggered Geometry of Friction Lining in Automated Single Plate Clutch

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Abstract— *Clutch system is among the main systems inside a vehicle. Clutch is a mechanical device located between a vehicle engine and its transmission and provides mechanical coupling between the engine and transmission input shaft. Clutch system comprise of flywheel, clutch disc plate and friction material, pressure plate, clutch cover, diaphragm spring and the linkage necessary to operate the clutch. The clutch engages the transmission gradually by allowing a certain amount of slippage between the flywheel and the transmission input shaft. However, the slipping mechanism of the clutch generates heat energy due to friction between the clutch disc and the flywheel. At high sliding velocity, excessive frictional heat is generated which lead to high temperature rise at the clutch disc surface, and this causes thermo-mechanical problems such as thermal deformations and thermo-elastic instability which can lead to thermal cracking, wear and other mode of failure of the clutch disc component. This paper gives a brief review on Different design approach and structural analysis using ANSYS.*

Keywords— Design, Clutch Plate, Friction Lining, FEA, ANSYS

I. INTRODUCTION

A clutch is a mechanical device for quickly and easily connecting or disconnecting a pair of rotating coaxial shafts. It is usually placed between the driving motor and the input shaft to a machine, permitting the engine to be started in an unloaded state. Single plate, dry clutch is among the popular type of clutches in use. A clutch is a mechanism designed to disconnect and reconnect driving and driven members. It is a device, which enables one rotary drive shaft to be coupled to another shaft, either when both the shafts are stationary or when there is relative motion between them. The need for the clutch seems mainly from the characteristics of the turning-effort developed by the engine over its lower speed range. When idling, the engine develops insufficient torque for the transmission to be positively engaged. To obtain a smooth engagement, the clutch has to be progressively engaged to take up the drive until the torque transmitted from the engine equals that required to propel the vehicle. Also the clutch disconnects the engine from the transmission to change the gear. The clutch, thus, takes up the drive smoothly and also disengages the drive whenever necessary.

II. DESIGN OF CLUTCH

A conventional clutch is design analytically to determine torque transmitting capacity and compliant clutch is designed graphically to determine torque transmitting capacity.

2.1 *Calculated values for Conventional Clutch*

A conventional clutch is design analytically to determine torque transmitting capacity from given power and speed for particular application. Mass of shoe is calculated from centrifugal force and spring force. The table shows calculated values of required parameters for clutch as given below [1].

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Sr. No.	Application	Transmitted Torque (Nm)	Mass of shoe (Kg)	Centrifugal force (N)	Spring force (N)
1.	Lawn mover	3.81	0.076	241.75	137.81
2.	Chain saw	2.675	0.0150	25.38	181.51
3.	String Trimmer	1.011	0.00498	118.54	66.78
4.	TVS Moped	4.96	0.0306	328.64	798

Fig. 2.1: Required parameters of Conventional clutch

2.2 *Calculated Values for Compliant Clutch*

A compliant clutch is designed graphically to determine torque transmitting capacity from force analysis on arm of clutch for particular application. The transmitted torque is calculated from centrifugal force and normal force acting on a contact point of drum and rotating arm. The table shows calculated values of required parameters for clutch as given below [1].

Sr. No.	Application	Transmitted Torque(Nm)	Centrifugal force (N)	Spring force(N)
1.	Lawn mover	2	277.7	53.77
2.	Chain saw	9	739.47	134.83
3.	String Trimmer	0.856	137.75	29.130
4.	TVS Moped	3.36	377.125	88.79

Fig. 2.2: Required parameters of Conventional clutch

III. Clutch Materials

3.1 *Design Fabrication of Spring Operated Material Handling Equipment*

The clutch disc is generally made from grey cast iron. This is because grey cast iron has a good wear resistance with high thermal conductivity and the production cost is low compare to other clutch disc materials such as A1-MMC (aluminum-metal matrix composite), carbon composites and ceramic based composites. High thermal conductivity of diffusivity of the material is considered advantageous because heat is then allowed to dissipate at higher rate. In this project, BS200 or ASTM G2500 grade grey cast iron is selected as the material for the commercial clutch disc. [3]

3.2 *Sintered Friction Materials*

Friction pads are manufactured by sintering blend of powders consisting of heat absorption material along with friction generating & lubricating materials. The powders are blended in optimized proportions & compacted to form a solid flat button of predetermined shape. They are highly durable with harsher engagement characteristics compared to organic linings. The quality of materials used along with the sintering parameter play an important role in providing the required performance. Particulate reinforcement gives the necessary WEAR resistant for the sintered matrix. [3]

3.3 *SF-BU*

SF-BU is a high performance, high friction, non-metallic composite material containing a high percentage of aramid fibre. It can be considered an alternative to sintered metallic materials and offers many advantages, it will with stand high energy inputs, is suitable for both dry and oil-immersed applications. It is not abrasive to the counter material, is silent in operation, it will with stand high pressures. The wear rate is low even at high temperatures, is available in thicknesses from 0.6mm to 5mm. Similar to SF001 but even higher Kevlar composition, in order to enhance friction properties[8].

3.4 *LO31*

LO31 is a rigid moulded friction material, whose main characteristics are the low dynamic friction coefficient having the lowest friction. It is composed basically of resins as a link system with frictional modifier agents. This material has good mechanical properties [8].

3.4 *Materials used in multi-plate clutch:*

S. N.	Materials	Density (Kg/ m^3)	Young's modulus (Mpa)	Poisson ratio	Tensile strength (Mpa)
1.	LO31	1940	11925	0.23	37
2.	SFBU	1250	7260	0.5	70
3.	Al6061	2700	68900	0.33	276

Table 3.1: Materials used in multi-plate clutch

Material Combination	Coefficient of friction	Temp. (Max) °C
LO31/Aluminium	0.23	150
SFBU/Aluminium	0.50	325

Table 3.2: Material Properties

IV. Method of Analysis

The torque that can be transmitted by a clutch is a function of its geometry & the magnitude of the actuating force applied as well the condition of contact prevailing between the members. The applied force can keep the members together with a uniform pressure all over its contact area & the consequent analysis is based on uniform pressure condition [3]. However as the time progresses some wear takes place between the contacting members & this may alter or vary the contact pressure appropriately and uniform pressure condition may no longer prevail. Hence the analysis here is based on uniform wear condition [3].

V. Structural Analysis

Structural analysis comprises the set of physical laws and mathematics required to study and predicts the behavior of structures. The subjects of structural analysis are engineering artifacts whose integrity is judged largely based upon their ability to withstand loads; they commonly include buildings, bridges, aircraft, and ships. Structural analysis incorporates the fields of mechanics and dynamics as well as the many failure theories. From a theoretical perspective the primary goal of structural analysis is the computation of deformations, internal forces, and stresses. In practice, structural analysis can be viewed more abstractly as a method to drive the engineering design process or prove the soundness of a design without a dependence on directly testing it. It consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation.

It includes the following methods,

- Analytical Methods.
- Strength of materials methods (classical methods).
- Finite element methods (FEM) [2].

VI. Finite Element Analysis

After designing clutch assembly its modeling is done in appropriate CAD software. Then it is imported in analysis software like ANSYS. This CAD model is converted in FEA model. Boundary conditions are applied to the FEA model and then it is solved. In post processer final results are plotted.

The cast iron material was applied to the model followed by meshing the model. Boundary condition was set by clamping at the static region. The applied moment was set in axial direction with magnitude 59.43 Nm. The result in finite element analysis was determined and the total deformation. The maximum total deformation is 1.0377×10^{-5}mm.Since the gap between clutch disc and pad lining is greater than maximum total deformation. Thus, it is acceptable. The maximum von misses stress is 0.034286 MPa and the minimum von misses stress is 5.24×10^{-6}MPa. It shows that the maximum stress will be exert on the four hole that mounted to the wheel hub. Since the result maximum Von-mises stress from finite element analysis is greater than the yield strength of the cast iron, there will be a wear and tear in long period [5].

Structural analysis was done on the clutch for different materials, the structural analysis results were given in the following table [6].

Materials	Theoretical	Without crack	With crack
Aluminum 7475	46.961	0.345338	0.355466
Aluminum 6061	11.263	0.307968	0.355561
S2 Glass	444.184	1.932	18.12
Kevlar	328.819	0.300531	51.897

Table 6.1: Comparison of Static Stress Values without Crack and with Crack

VII. Determine Parameter

The capabilities of braking system performance were depend on its design. The design process of clutch disc includes several of steps before the product was fabricated. Some of the parameter needs to be determine in the design process of clutch disc such as diameter of clutch disc, axial force acting on the clutch, translational displacement deformation of clutch and the maximum load that clutch can withstand. There are also several criteria need to be considering in designing a clutch disc such as:

- Material selection
- Sizing
- Ventilation system
- Configuration

Material selection and sizing criteria are main parameter need to be considered. Other than that assumption has been made:

- The applied pressure to the disc is uniform.
- Disc is completely been contact.

This assumption is made to determine the maximum stress can be applied to the selection material clutch disc. In addition it helps to determine the parameter of clutch disc such as optimum diameter in finite element analysis [5].

VIII. Conclusion

From exhaustive literature survey following conclusions are made;

- From the comparison of conventional and compliant clutch they conclude that compliant clutch is more efficient if we used in chain saw and in other applications, it gives nearly same value of torque than conventional clutch. The main advantage of compliant clutch is cost benefitted and having no movable component in its design. The problem of backlash and wear is eliminated by using this type of clutch.
- After completion of the analysis in CAE software i.e. ANSYS 9.0 based on the values of Equivalent stresses for material loading conditions it is clearly seen that these are less than the allowable stresses for that particular material under applied conditions the part not going to yield and hence the design is safe.The stresses as well as deformation clear the idea about what parameter should have been taken into account while defining the single plate friction clutch.
- Torque transmission capacity of sintered-iron friction material is 350 to 400N which is more than Kevlar. Total deformation in Kevlar material is less than sintered-iron friction material. Sintered-iron material can sustain higher temperature. By applying the maximum force i.e, 220 N of the friction plate of single plate clutch, after analytical calculations & software analysis.
- The present design analysis was done to find the failure region and reasons for failure only by considering the structural analysis. In future this project can be extended to thermal analysis by considering frictional effects during the operation.
- So it is conclude that if the crack propagates in the composite materials, they tend to fail faster than aluminium alloys thereby reducing their life. So care should be taken for composite materials not to get the crack.
- Alternative modification of the side plate is done by increasing the fillet radius. The maximum stress obtained by this modification is lesser when compared to the previous modification. Factor of safety is increased to 1.52.In order to reduce the maximum stress further, both the above said modifications are combined. The maximum stress is reduced further.
- By observing the analysis results, the maximum shear stress, Von -Mises stress and total deformation values for hybrid SF-BU are less than LO31 respective values. So we expected that for multi plate clutches using as hybrid SF-BU friction material is advantageous than using LO31 as friction material.
- The temperature will increase rapidly when the number of engagements increase and in some cases the temperature exceeds the maximum limit of temperature, this situation lead to friction clutch failure before the expected lifetime, therefore the study of the temperature field of contact surfaces during repeated engagements operation is necessary to give an indication about the maximum temperature during the engagements.

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