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Thermo-mechanical analysis of the pressure plate of clutch

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ABSTRACT

High Temperature appears in the contact surfaces of a clutch system (friction surface and pressure plate) due to the relative motion between these parts during the sliding period. These high temperatures are responsible for several failures such as pressure plate crack, pressure plate warpage etc. With the help of Finite element analysis, the sliding friction process of the pressure plate and friction during clutch engagement is simulated to get temperature field characteristics and contact pressure of pressure plate.

1. Introduction

In the engagement process of dry friction clutch, a mass of friction heat is generated due to relative sliding exists in the friction pairs. Thus, the friction surface and pressure plate surface temperature will increase rapidly, it not only affects the friction coefficient, but also the temperature fields in these discs are affected, and then the temperature fields are generated, changing the thermal status in discs. The frictional heat generated at the sliding interface causing an increase in the surface temperature of the contacting surfaces of the clutch elements (flywheel, clutch disc and pressure plate in a single-disc clutch system). The surface temperature and the forces involved are sufficiently to produce non-uniform deformation which affects the temperature field and the pressure distribution. As a result of this situation, the high temperature and contact pressure will focus on a small zone of the contact area and this will lead in some cases to premature failure in the friction clutch surfaces [1, 2]. Changes of temperature fields caused by friction heat is a key factor of the failure of clutch, resulting in the hot cracks, warping of discs, regional burning loss

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and stripping of surface materials as mentioned in figure 1. Therefore, it is necessary to study its frictional heating mechanism and investigate deeply the thermo elastic behavior of the sliding system to know the safe working condition of any application of sliding systems.

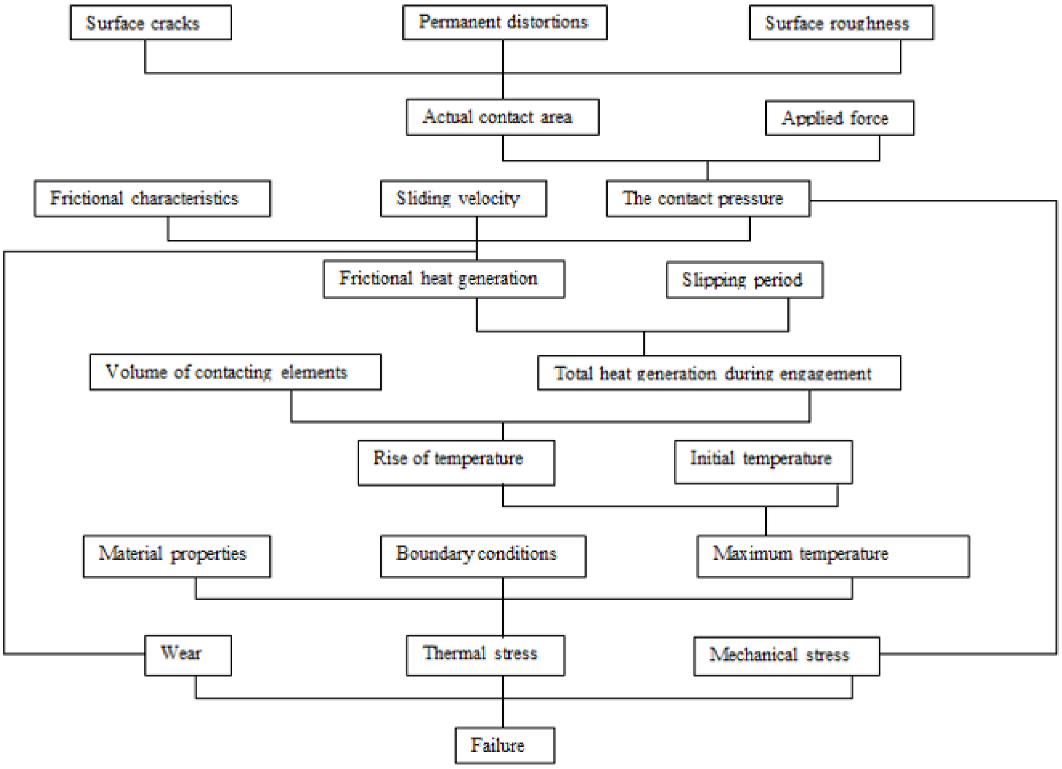

Fig. 1 – Clutch system failure process.

1.1. Literature summary

Abdullah et.al [3] worked on the effect of thermo mechanical stresses on the clutch system. They investigated the effect of boundary conditions on the contact pressure distribution, the temperature field and the heat flux generated along the frictional surfaces in the clutch. Dong-fang et.al [4] worked on the thermal stress effect on tractor clutch pressure plate. Thermal ablation, thermal cracking and other problems often appear in pressure plate of tractor clutch. To solve it φ280 clutch pressure plate was modeled and did necessary improvements to reduce the above problems. Prakash et.al [5] they performed analysis on the clutch and pressure plate using two materials compared the properties of both the materials and suggested the EN15 Steel grade material is better than Grey cast iron. Choon yeol Lee et.al [6] worked on pressure plate, a component of the clutch system, was analyzed by two-dimensional and three-dimensional finite element method under three major load conditions of thermal loading due to temperature distribution, centrifugal force and contact pressure of diaphragm spring. The results show that the effects of thermal loading and contact pressure of diaphragm spring and suggested the direction of design improvement. Guangbiao yang et.al [7] analyzed the influence of pressure plate's thermal deformation to torque transmission ability of clutch and put forward the structure design method of clutch pressure plate. Qi-Tang Wang et.al [8] they notified the problems raised in pressure plate like cracking, erasing, and deformation which results of reduced ability of clutch during the working process. They proposed a method which can be used to calculate the heat flux and the heat transfer coefficient.

2. Methodology

According to the clutch system working principle during the engagement process pressure plate and friction plate rotates with contact together. Due the friction between them the heat is generated between two surfaces. So we are calculating the nodal temperatures and contact pressure on the pressure plate with 0.25MPa, 0.5MPa, 0.75MPa and 1MPa clamping load conditions with different rotational speeds (50 rad/sec and 100 rad/sec) with 0.4 sec of slipping time by keeping friction plate constant as per the methodology shown in figure 2.

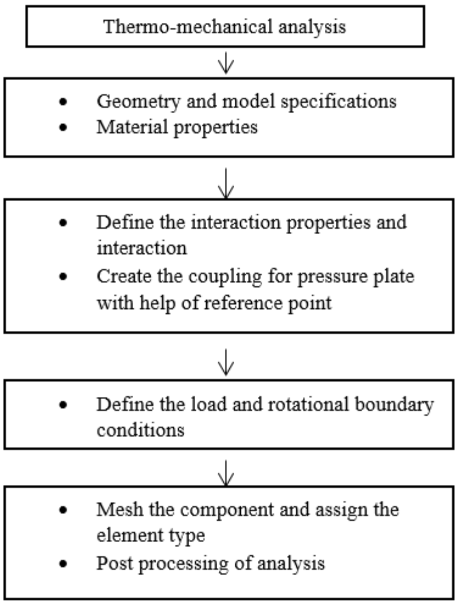

Fig. 2 – Methodology.

According to the clutch working principle when the driver releases the clutch pedal, power can flow through the clutch. Springs in the clutch force the pressure plate against the friction disc combined with clutch plate. This action clamps the friction disk tightly between the flywheel and the pressure plate. Now, the pressure plate and friction disc rotate with the flywheel. But in this process we are considering only pressure plate, friction dis, and clutch plate.

We are combining the clutch plate and friction disc as a single component because we assume that there is no heat loss in the interface between friction disc and clutch plate. So the number of contact pairs also decreased. The heat is generated due to the friction.so the friction coefficient (μ) is considered as 0.2.the friction coefficient is assigned to the contact surfaces for the friction disc and pressure plate.

If there are two three-dimensional elastic bodies in contact with each other, the FEA governing equations for both bodies can be developed in the global coordinate system.

$$[K_A]\{\delta_A\} = \{F_A\} + \{R_A\} \tag{1}$$

$$[K_B]\{\delta_B\} = \{F_B\} + \{R_B\} \tag{2}$$

Where K_A, K_B, δ_A, δ_B, F_A, F_B, R_A and R_B are the global stiffness matrix of two bodies, nodal displacement vectors of two bodies, external load vectors and unknown contact force applied on both bodies. After the assembling, the above two equations can be combined into the global matrix equation as follows.

$$[K'] \{\delta'\} = \{F'\} + \{R'\} \tag{3}$$

The global governing FEA equation cannot be solved directly as the number of unknowns is more than that of the equations. Therefore, additional relations which indicate the contacting conditions are needed to solve the above equations iteratively

3. The finite element model

The engagement, friction, heat of pressure plate and friction discs is a complex process by working principle of clutch to be seen, the model is simplified when the transient temperature field and thermal-structural coupling of friction discs and pressure plate during sliding processes are simulated. The parametric finite element model of pressure plate, friction disc and clutch plate is created using ABAQUS[11] as per the dimensions and material properties given in table 1 and table 2, the parametric input of relevant sizes parameters is implemented in the process of establishment of geometric model and mesh in order to meet the different requirement. The geometric model is obtained by entering the size parameters as shown in figure 2, the mesh is divided using three dimensional thermal analysis unit. The friction discs and pressure plate is divided into 8 node hexahedron element (C3D8RT), the finite element mesh is shown in figure 3.

Table 1 – Dimensions.

	Inner diameter	Outer diameter	thickness
Pressure plate	58mm	92mm	9.69mm
Clutch plate	63mm	87mm	1.5mm
Friction plate	63mm	87mm	3mm

Table 2 – Material properties.

	Grey Cast iron	Friction lining
Density (Kg/m^3)	7800	2000
Young's Modulus (GPa)	125	0.3
Poisson's ratio	0.25	0.25
Thermal expansion (k^{-1})	1.2*10^{-5}	1.2*10^{-5}
Thermal conductivity (W/m. k)	54	1
Specific heat (J/Kg. k)	532	120

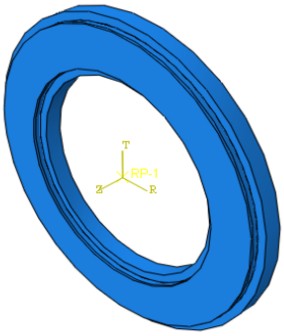

Fig. 3 – Clutch system model.

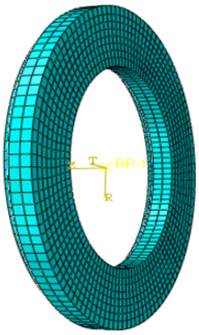

Fig. 4 – Meshing of clutch system.

4. Results and discussion

4.1. Nodal temperature and Contact pressure at 0.25MPa

The figure 5 shows the nodal temperature and contact pressure for 0.25MPa for rotational speeds of 50 and 100 Rad/sec. the results shows the nodal temperatures and contact pressure is increased for the 100 rad/sec when compared to 50 rad/sec

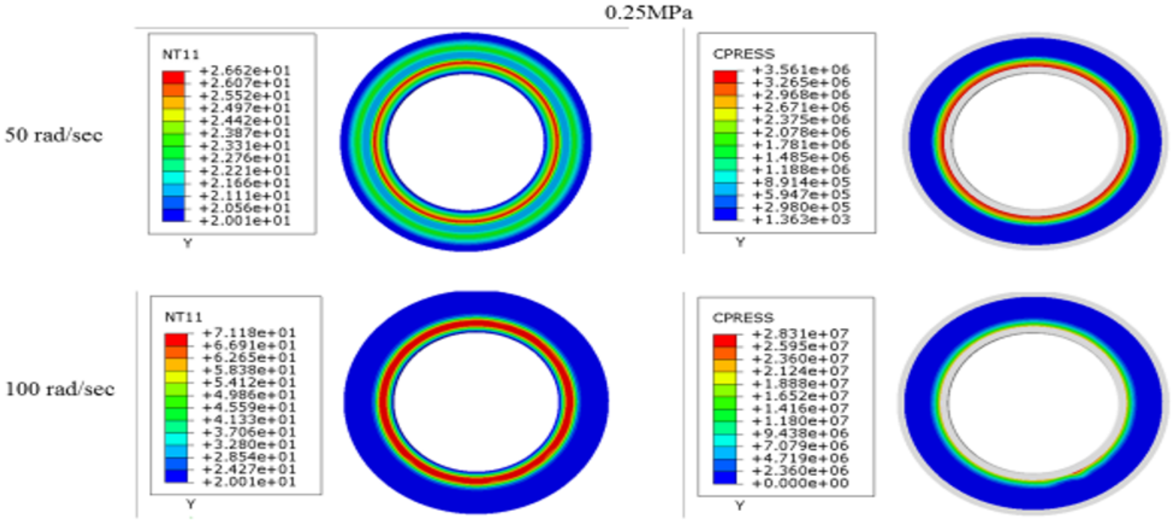

Fig. 5 – Nodal temperature and Contact pressure at 0.25MPa.

4.2. Nodal temperature and Contact pressure at 0.5MPa

The figure 6 shows the nodal temperature and contact pressure for 0.5MPa for rotational speeds of 50 and 100 Rad/sec. the results shows the nodal temperatures and contact pressure is increased for the 100 rad/sec when compared to 50 rad/sec.

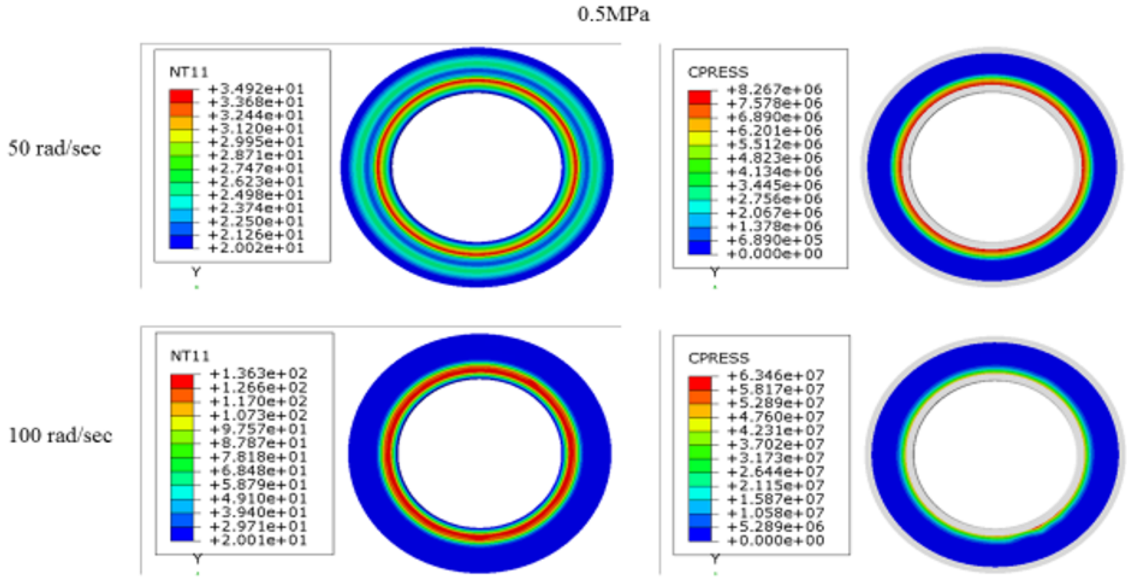

Fig. 6 – Nodal temperature and Contact pressure at 0.5MPa.

4.3. Nodal temperature and Contact pressure at 0.75MPa

The figure 7 shows the nodal temperature and contact pressure for 0.75MPa for rotational speeds of 50 and 100 rad/sec. the results shows the nodal temperatures and contact pressure is increased for the 100 rad/sec when compared to 50 rad/sec

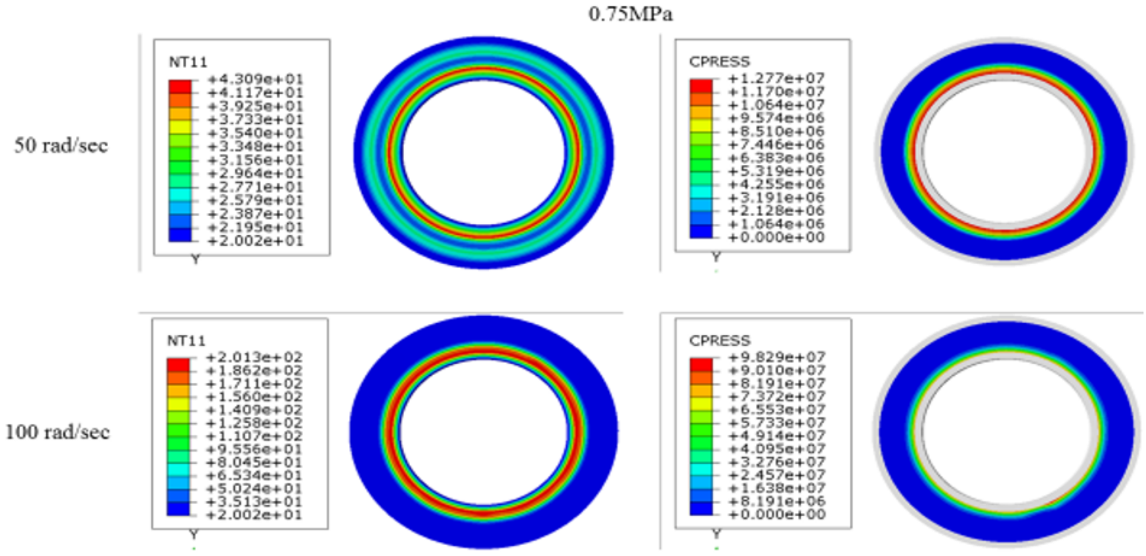

Fig. 7 – Nodal temperature and Contact pressure at 0.75MPa.

4.4. Nodal temperature and Contact pressure at 1MPa

The figure 8 shows the nodal temperature and contact pressure for 1MPa for rotational speeds of 50 and 100 rad/sec. the results shows the nodal temperatures and contact pressure is increased for the 100 rad/sec when compared to 50 rad/sec

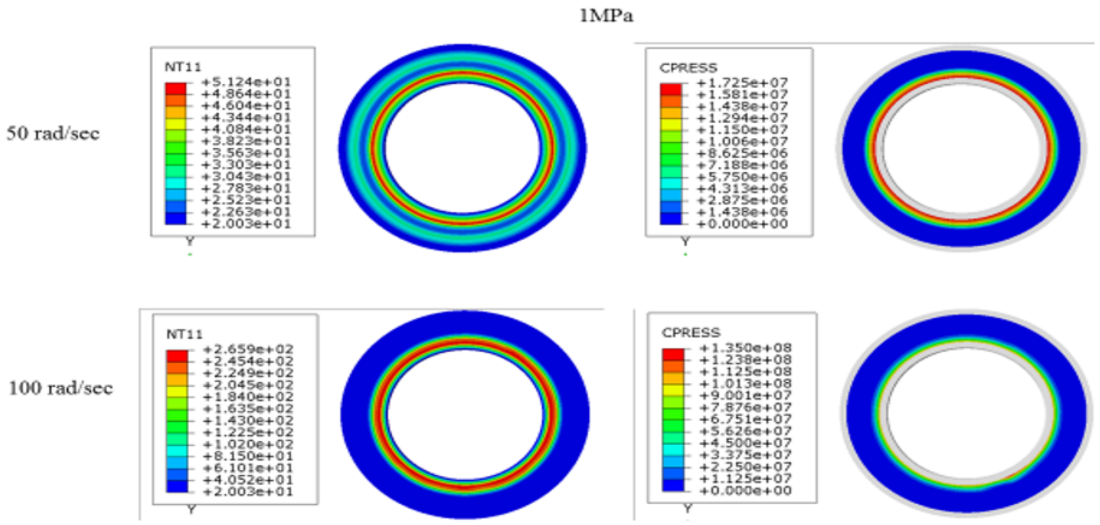

Fig. 8 – Nodal temperature and Contact pressure at 1MPa.

4.5. Comparison between the nodal temperatures and contact pressures with different loading conditions with respect to 50 and 100rad/sec :

Nodal temperatures :

The above figure 9 and 10 shows the temperature difference between the 0.25MPa, 0.5MPa, 0.75MPa and 1MPa loading conditions with respect to 50 and 100 rad/sec rotational speeds.as the load and rotational speed increases the nodal temperature of the pressure plate surface increases.

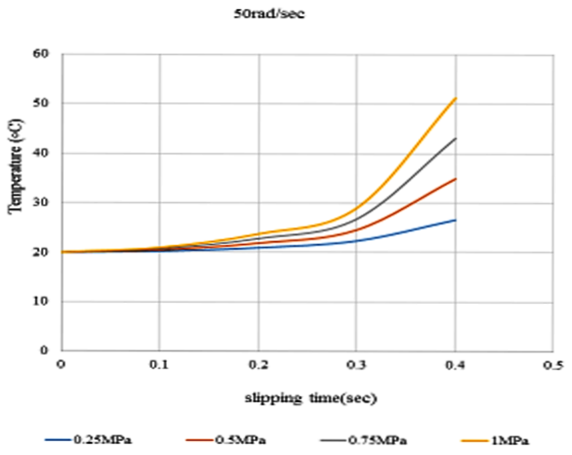

Fig. 9 – Nodal temperatures at 50 rad/sec.

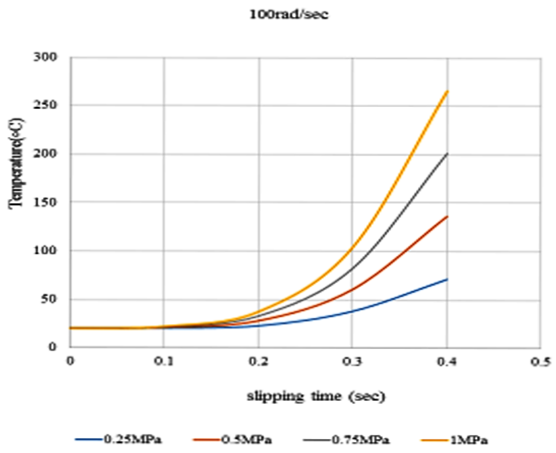

Fig. 10 – Nodal temperatures at 100 rad/sec.

The above figure 11 and 12 shows the temperature difference between the 0.25MPa, 0.5MPa, 0.75MPa and 1MPa loading conditions with respect to 50 and 100 rad/sec rotational speeds.as the load and rotational speed increases the nodal temperature of the pressure plate surface increases.

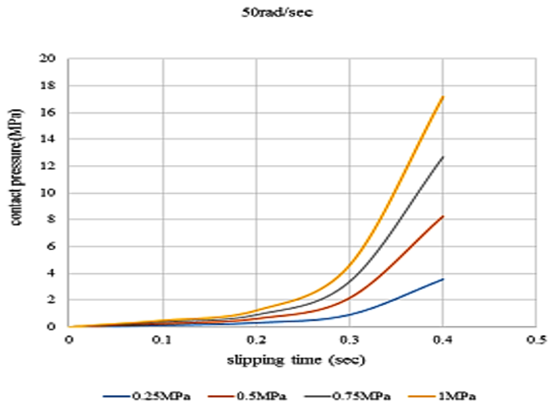

Fig. 11 – Contact pressure at 50 rad/sec.

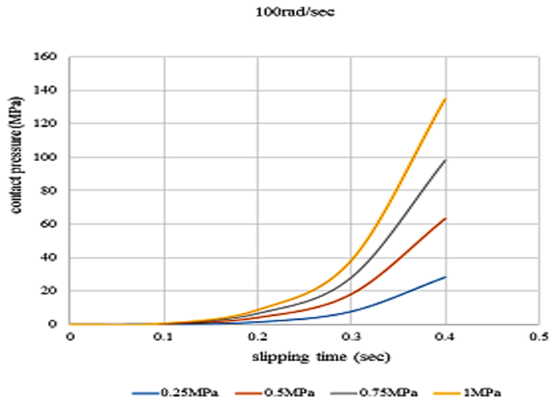

Fig. 12 – Contact pressure at 100 rad/sec.

4.6. Nodal temperatures and contact pressure at 0.25MPa, 0.5MPa, 0.75MPa and 1MPa of pressure plate :

As shown in the table 3 and table 4 the nodal temperature and contact pressure is increased with respect to different loads and with respect to angular velocity

Table 3 – Nodal temperatures.

Loads (MPa)	50 rad/sec (°c)	100 rad/sec (°c)
0.25	26.62	71.18
0.5	34.92	136.3
0.75	43.09	201.3
1	51.24	265.9

Table 4 – Contact pressures.

Loads (MPa)	50 rad/sec (MPa)	100 rad/sec (MPa)
0.25	3.56	28.31
0.5	8.27	63.4
0.75	12.7	98.29
1	17.25	135

5. Conclusion

Pressure plate failure affects the function of clutch system. Following observations are made regarding the better functioning of clutch system.

1. Rotational speed of the pressure plate : As the rotational speed is increased the nodal temperature and contact pressure is increased.so the rotational speed should be according to the capacity of the pressure plate.
2. Loading conditions of the pressure plate : As the clamping load on the pressure plate is increased the nodal temperature and contact pressure is increased.so the rotational speed should be according to the capacity of the pressure plate.
3. Even the material properties also can be changed to get better performance of the pressure plate.

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