



# Friction Analysis in Multi-Disc Wet Clutch at Different Temperatures

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## Abstract :

The performance of automotive transmission systems largely depends on the efficiency and reliability of the clutch mechanism. A multi-disc wet clutch is widely used in motorcycles, racing vehicles, and automatic transmission systems due to its high torque-transmission capacity, compact design, and efficient heat dissipation. This research presents a detailed study on friction analysis in a multi-disc wet clutch system using both experimental and numerical approaches.

Experimental analysis involves measuring torque, speed, and thermal characteristics using a controlled test rig, while numerical modelling is performed using fundamental friction and heat transfer equations.

**Keywords:** Friction analysis, Thermal effects, Wear analysis, Tribology.



## Introduction :

Modern automotive transmissions demand smooth gear shifting, high torque capacity, compact design, and. To meet these requirements, wet multi-disc clutches are widely used in automatic transmissions, hybrid drivetrains, and dual-clutch transmission (DCT) systems. As transmission technology advances, the need for a deeper understanding of friction behaviour in wet clutches has become increasingly important. Unlike dry clutches, wet which results in vibration, noise, and reduced driving comfort. Therefore,

## Literature Review:

Li et al. – Numerical Analysis of Dynamic Characteristics of Wet Friction Temperature Fields  
Li et al. (2017) investigated the temperature distribution and thermo-mechanical behaviour of wet clutch friction pairs using a combined numerical and experimental approach. The study revealed that the maximum temperature occurs at the outer radius of the friction disc and that temperature initially increases and then decreases with sliding time. The authors also reported that radial temperature differences are significantly higher than circumferential variations and are a major cause of clutch failure due to thermal stresses and hot-spot formation. It mainly focuses on temperature behaviour and does not consider the interaction between lubrication, friction coefficient variation, and wear mechanisms, indicating the need for coupled thermo-tribological studies.

Lubricants – Tribological Behaviour of Wet Clutch Systems  
The authors analysed tribochemical reactions, friction-speed characteristics, and the influence of additives on friction stability and on friction stability and torque transmission. The results showed that carbon-based friction materials

conventional materials, while lubricant additives significantly influence clutch behaviour. The research highlights the importance of experimental testing for realistic performance evaluation but provides limited numerical modelling, suggesting the need for combining experimental data with simulation techniques for better prediction of clutch performance.

multi-disc clutches operate under continuously changing lubrication conditions.

One of the most important tools used to describe friction behaviour in lubricated contacts is the Stribeck curve, which relates the coefficient of friction to sliding speed, lubricant viscosity, and contact pressure understanding and controlling the Stribeck behaviour is a key objective in wet clutch research.

durability. The study highlighted that lubricant additives form protective friction films that significantly affect friction coefficient behaviour and wear resistance. It also emphasised the importance of temperature and surface interactions in determining clutch performance. However, the work primarily addresses tribological aspects and does not incorporate detailed thermal modelling, indicating a research gap in integrating thermal and tribological behaviour in wet clutch systems.

Zhang et al., -The authors combined the modified Reynolds equation, elastic contact theory, and heat transfer models to build a two-dimensional transient thermal model solved using the Runge–Kutta method. The study analysed the effects of applied pressure, initial speed, surface roughness, elastic modulus, permeability of friction lining, and ATF flow rate on temperature evolution. Although the work provides detailed insight into parameter sensitivity, it relies mainly on numerical modelling and lacks experimental validation and friction-wear analysis, suggesting the need for integrated experimental–numerical approaches. Composition, operating conditions, and running-in behaviour

offer superior friction stability and durability compared to

Strobl et al. investigated the influence of steel plate surface finishing on the friction behaviour of automotive wet clutch systems. The results demonstrated that steel plate surface finish significantly affects the coefficient of friction and overall clutch performance, highlighting the importance of surface topography in clutch design. The study also emphasized the strong influence of



temperature, lubrication, and measurement methods on friction behaviour. While the research provides valuable experimental insights, it does not develop advanced numerical models, indicating a gap in integrating surface engineering with thermo-mechanical modelling.

**4. Forschung im Ingenieurwesen– Experimental Evaluation of Wet Clutch Friction Materials.** This study investigated the performance of various wet clutch friction materials, particularly carbon-based and paper-based linings, using experimental test rigs. The authors examined the influence of lubricant composition, operating conditions, and running-in behaviour on friction stability and torque transmission. The research highlights the importance of experimental testing for realistic

result, the lubrication regime shifts from hydrodynamic lubrication toward

mixed and boundary lubrication, where surface asperity contact becomes more dominant, leading to increased wear and unstable friction behaviour.

Theoretical Analysis :

To analyse the friction accurately, we utilise the modified Stribeck equation.

The torque balance equation for a multi-disc pack is generally

expressed as:

$$T_c = n \cdot \int_{R_i}^{R_o} 2\pi \cdot r^2 \cdot P(r) \cdot \mu(r) \cdot dr$$

...1]

Where:

- $T_c$  = Transmitted torque

Basic Assumptions Used in Analysis

- Uniform pressure distribution OR uniform wear theory
- Oil film exists between the plates
- Axial force is constant

performance evaluation but provides limited numerical modelling, suggesting the need for combining experimental data with simulation techniques for better prediction of clutch performance.

#### Problem Statement :

Accurate friction behaviour in wet multi-disc clutches remains a significant challenge due to strong thermo-mechanical coupling during clutch engagement. When the clutch plates slide against each other, mechanical energy is converted into heat, causing a rapid rise in the interface temperature. This temperature increase strongly influences the properties of the automatic transmission fluid (ATF), particularly its viscosity, which decreases as temperature rises. As a

- $n$  = Number of friction surfaces
- $R_i$  = Inner radii of the discs
- $R_o$  = Outer radii of the discs
- $P(r)$  = Pressure distribution
- $\mu$  = Local friction coefficient

Numerical Analysis :

Understand What You Are Calculating

Calculate friction coefficient, torque, temperature effect, slip speed, etc., using equations.

Main outputs:

- Friction coefficient ( $\mu$ )
- Torque capacity (T)
- Heat generation (Q)
- Temperature rise ( $\Delta T$ )
- Heat generated = friction work



Input Parameters

Symbol	Meaning
N	No of friction plates
R <sub>i</sub>	Inner radius of plate
R <sub>o</sub>	Outer radius of plate
F	Axial force applied(N)
μ	Coefficient of friction
ω	Angular speed difference (rad/sec)
ρ	Oil density
C <sub>p</sub>	Specific heat

h	Heat transfer coefficient
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Choose Friction Model

1. Uniform Pressure Model (New clutch)  
Pressure constant across plate.
2. Uniform Wear Model (Used clutch)

We use uniform wear theory in numerical analysis.

$$R_m = (R_o + R_i)/2.....3]$$

Mean Friction Radius Calculation

This gives effective radius where friction acts.

$$T = n \cdot \mu \cdot F \cdot R_m.....4]$$

Friction Torque Calculation

Where,

T = Torque capacity (Nm)

This is the most important equation

Sliding Velocity Calculation

Relative sliding speed between plates:

$$V = R_m \cdot \omega.....1]$$

Where

ω = slip speed (rad/s)

$$\omega = \frac{2\pi(N_1 - N_2)}{60}.....2]$$

N<sub>1</sub> = engine speed

N<sub>2</sub> = gearbox speed

Frictional Heat Generation

Friction Coefficient vs Temperature Model

In a wet clutch, μ decreases with temperature.

Simple numerical model used in research:

$$\mu(T) = \mu_0(1 - kT)..6]$$

Where:

- μ<sub>0</sub> = friction at room temp
- k = temperature constant
- T = temperature rise

This gives a realistic simulation.

When the clutch slips, heat is produced.

$$Q = T \cdot \omega.....$$

Temperature Rise Calculation

$$\Delta T = \frac{Q}{mC_p}.....5]$$

Where

m = mass of clutch plates

C<sub>p</sub> = specific heat

This tells how much the temperature increases during slipping.

Iterative Numerical Method

Numerical analysis means solving repeatedly:

1. Assume μ
2. Calculate torque T
3. Calculate heat Q
4. Calculate temperature ΔT
5. Update μ(T)
6. Repeat until stable

Example Calculation

- n = 6 plates
- F = 4000 N
- μ = 0.08



- $R_i = 0.06$  m
- $R_o = 0.09$  m
- Mean radius:
- $R_m = \frac{0.09+0.06}{2}$ ...eq 3  
 $= 0.075$  m
- Torque:
- $T = 6 \times 0.08 \times 4000 \times 0.075$ ...eq 4
- $T = 144$  Nm
- This is clutch torque capacity.

Now you want the friction force acting between the clutch plates.

We use the basic friction relation:

$$T = n F_f R_m$$

Where,

$T =$  Torque (Nm)

$n =$  number of friction pairs = 6

$F_f =$  friction force between one pair (N)

$R_m =$  mean radius = 0.075 m

Rearrange the formula to find the friction force

$$F_f = \frac{T}{nR_m}$$

Substitute values

$$F_f = \frac{144}{6 \times 0.075}$$

$$F_f = \frac{144}{0.45}$$

$$F_f = 320 \text{ N.}$$

Friction force per friction pair

$$F_f = 320 \text{ N.}$$

Total friction force in the clutch

Since there are 6 friction pairs:

$$F_{\text{total}} = n \times F_f.$$

$$F_{\text{total}} = 6 \times 320.$$

$$F_{\text{total}} = 1920 \text{ N}$$

Objectives –

This research focuses on understanding friction behaviour, heat generation, and torque transmission in multi-disc wet clutches. These clutches are essential for smooth power transmission in modern machines. Since friction and heat during engagement affect performance and lifespan, the study analyses these factors using theoretical calculations, numerical modelling, and experimental data.

1. This study examines the friction behaviour of wet clutch plates, where torque is transmitted through friction between plates. It focuses on how the coefficient of friction ( $\mu$ ) changes during engagement and sliding, particularly with sliding speed ( $\mu$ - $v$  curve), which affects shift smoothness and vibrations. The research also analyses transitions between hydrodynamic, mixed, and boundary lubrication regimes, as these significantly influence friction behaviour.

2. The study focuses on the thermal behaviour of clutch plates during engagement. Friction between sliding plates generates significant heat, which must be dissipated to prevent failure. It analyses temperature distribution in friction and separator plates, heat flow in radial and circumferential directions, and the formation of hot spots. Understanding these factors is crucial, as excessive heat leads to wear, material degradation, and reduced clutch life.

3. This study examines how operating parameters affect wet clutch performance. It focuses on factors such as applied pressure, sliding speed, lubrication and cooling, surface roughness, and material properties, and their impact on friction and temperature rise. Understanding these effects helps improve clutch design and performance.

4. To develop a numerical model of a wet clutch system using equations for friction, lubrication, and heat transfer. The model will predict temperature



distribution, estimate friction behaviour, and analyse performance under various conditions. It helps improve clutch design while reducing the need for costly experiments.

5. Objective focuses on validating the numerical model by comparing simulation results with experimental data from research papers and test rigs. This ensures the model accurately predicts real wet clutch behaviour.

6. This study compares theoretical calculations, numerical simulations, and experimental results to identify differences and improve the accuracy and reliability of the model.

7. Objective aims to improve the durability, efficiency, and smooth operation of multi-disc wet clutches. The findings can support better cooling methods and enhance overall vehicle transmission performance.

### Methodology :

1. System Selection and Geometry Definition A multi-disc wet clutch system is selected for analysis. Parameters defined: Inner radius of plate ( $R_i$ ), Outer radius of plate ( $R_o$ ) Number of friction surfaces ( $n$ ), Friction lining thickness, Steel plate thickness. These dimensions are required to calculate contact area and sliding velocity.

#### a. Contact Pressure Calculation:

When a multi-disc wet clutch engages, hydraulic force pushes the friction plates and steel plates together. This force creates **normal pressure** on the contact surfaces.

Contact pressure is very important because it directly affects:

- Friction force
- Torque transmission
- Heat generation
- Wear of clutch plates

Therefore, determining the contact pressure is the first step in friction analysis.

#### Contact Area of Clutch Plate

b. The contact area is calculated using:

$$A = \pi(R_o^2 - R_i^2)$$

c. Contact Pressure Formula :

$$P = \frac{W}{A}$$

d. Role in Friction and Heat Generation

Higher contact pressure leads to:

- Higher friction force
- Higher torque transmission
- Higher heat generation

e. Sliding Velocity Determination :

Sliding velocity at mean radius:

$$V_s = \omega R_m$$

Mean radius:

$$R_m = \frac{R_o + R_i}{2}$$

f. Friction Force Determination :

$$F_f = \mu W \dots$$

g. Torque Measurement Method

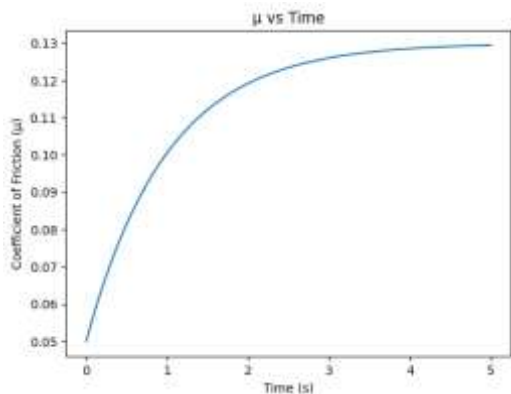
Torque transmitted by clutch:

$$T = n\mu W R_m.$$

h. Time-Dependent Friction Behaviour

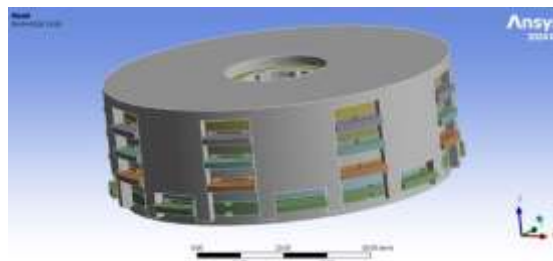
Friction changes during engagement

Therefore,  $\mu$  is calculated at small time intervals.



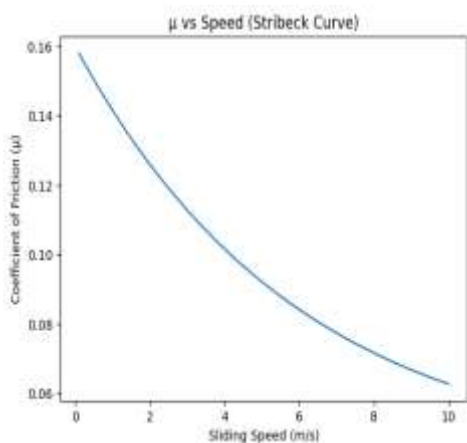
Result-

Model :-

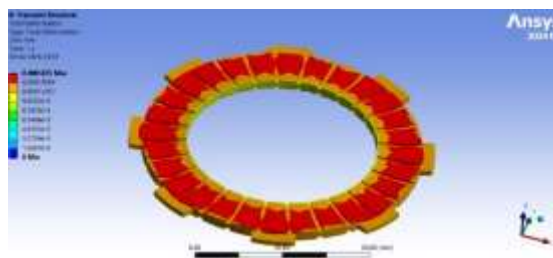


i. Friction-Speed ( $\mu-v$ ) Analysis

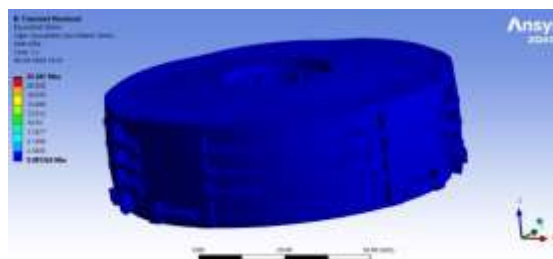
In a wet clutch, the coefficient of friction ( $\mu$ ) is not constant. It changes continuously with sliding speed during clutch engagement. The relationship between the friction coefficient and sliding speed is called the  $\mu-v$  curve or Stribeck curve.



Transient Structural:-



1] Total Deformation (Friction Plate)

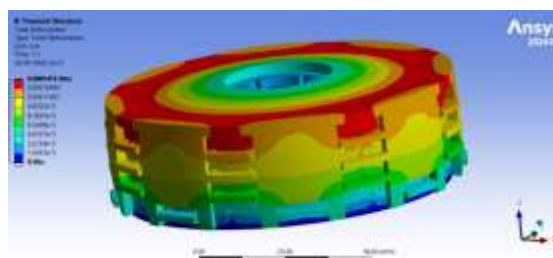
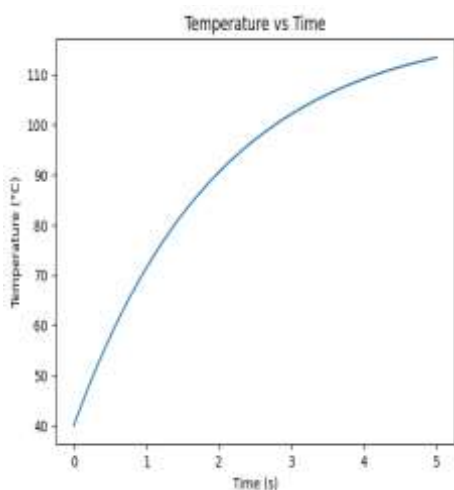


2] Safety Factor

j. Heat Generation Due to Friction :

Friction work converts into heat.

$$Q = \mu W V_s.$$



3] Total Deformation



conclusion –

This research studies friction behaviour in a multi-disc wet clutch using experiments and numerical modelling. It shows that friction varies with speed, temperature, load, and number of plates. Higher speeds and temperatures reduce friction due to lubrication effects, while more plates increase torque but also heat. Wet clutches provide better cooling and smoother operation than dry clutches. The results validate the model and highlight the need to balance friction and lubrication for better performance, durability, and efficiency. explores how friction behaves in a multi-disc wet clutch by combining experimental results with numerical modelling. It shows that friction is not constant it changes

with factors like speed, temperature, applied load, and the number of plates. For example, higher speeds and temperatures tend to reduce friction because of improved lubrication, while increasing the number of plates helps transmit more torque but also leads to greater heat generation. It also highlights that wet clutches offer better cooling and smoother operation compared to dry clutches. Overall, the results confirm that the model accurately represents real behaviour and emphasise the importance of maintaining the right balance between friction and lubrication to achieve better performance, durability, and efficiency.

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