

# Analysis and Simulation of a Centrifugal Clutch

Stress Analysis

ACMA5010

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16/12/2024

Word count: 2500 or equivalent

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## [1] Introduction

The following report is an assignment for the module: Stress Analysis and Dynamics, ACMA5010. This assignment is broken up into two tasks, 'Task A' and 'Task B', both centred around topic of centrifugal clutches. 'Task A' covers an analysis of centrifugal clutches, the development and applications of centrifugal clutches. 'Task B' is a mathematical simulation of a clutch with varying calculated mechanical aspects of the clutch when certain conditions are met, or aspects of the mechanical system are changed. This report will have a word count of 2500 or equivalent and should show high academic understanding of the topic discussed.

## [2] Task A

### [2.1] What is a centrifugal clutch

A clutch is a mechanical device that connects and disconnects two rotating shafts, allowing for the transfer of power between them. A centrifugal clutch is a clutch automatically engages and disengages a connection between shafts depending on the speed of the input shaft. It works by using centrifugal forces automatically engage mechanisms within to remove the need for manual operation.

The key components of a centrifugal clutch are springs, clutch drum and clutch feet, they are all connected to the drive shaft by component referred to as the spider. At low rotational speed, the springs will keep the feet retracted within the device, however as the speed increases, the centrifugal force increases and overwhelms the force from the springs and are then pushed outward from the device, pressing against the clutch drum, engaging the clutch and allowing for the transfer of power between the two shafts. As seen in 'Figure 1' it is common for shoes to be equipped with some form of friction lining for better performance which will be discussed later. Once the speed decreases again, the clutch will automatically be disengaged by the force of the springs being stronger than the centrifugal force, retracting the shoes back in.

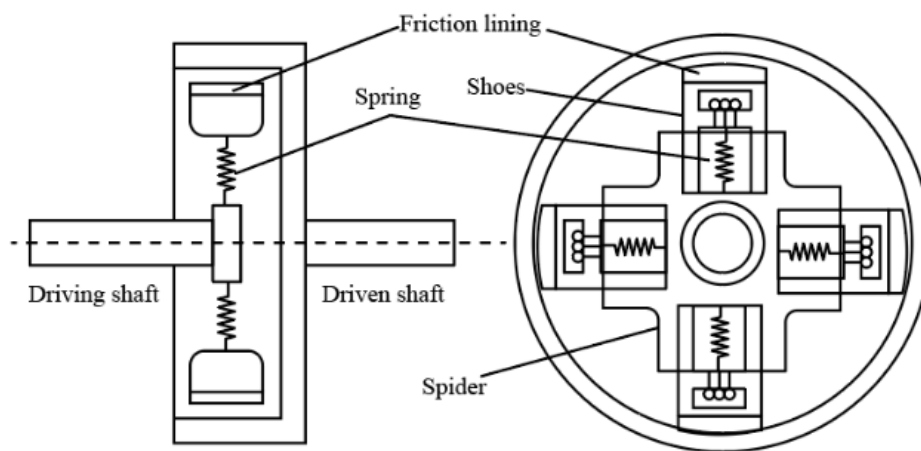


*Figure 1: Centrifugal Clutch Diagram.*

Centrifugal clutches can operate in wet and dry conditions within a preferred temperature range of -20 to 100 degrees Celsius, operation outside this can lead to reduced efficiency or failure, so many have built in cooling systems. Depending on design, centrifugal clutches operate and engage within a 2000 to 4000 RPM range.

## [2.2] Centrifugal clutch development

The development of the centrifugal friction clutch has evolved over time to enhance performance and efficiency in various applications. Centrifugal clutches have supposedly been used since at least 1858, appearing in railway locomotives. There is also a patent application from 1899 featuring a centrifugal clutch design, but it wasn't until the 20<sup>th</sup> century that they began seeing use in areas such as motor vehicles and machinery. In 1936, Armstrong Siddeley cars began to feature automatic centrifugal clutches, but it was credited to anyone until 1940, to the inventor of the balloon catheter, Thomas Fogarty.

Early centrifugal clutches were relatively simple, made up using very simple mechanical components. Over time, designs began to become refined to include better materials and more efficient mechanisms, this included the introduction of friction materials for the clutch feet, which improved grip and durability. Then as technology advanced, centrifugal clutches found applications beyond small engines, finding a popular place in motorcycles and most importantly, varying industrial machinery where automatic engagement was beneficial. More modern innovations to the centrifugal clutch have come from being designed with precision engineering, incorporating advanced materials and computer aided design. This has led to improvements in responsiveness, reliability and performance, making them highly suitable for high performance applications.

More recent developments of the centrifugal clutch focus on weight optimisation, reducing wear and improving thermal management to better handle higher power outputs. Engineers continue to explore new technologies like electronic controls to enhance the functionality of centrifugal clutches. Over the last century of development, the centrifugal clutch has become an essential component in many vehicles, machinery and equipment we use, despite now being generally superseded by fluid mechanical clutches.

## [2.3] Centrifugal clutch applications

Centrifugal clutches have many applications due their ability to engage and disengage based on rotational speed. The following are some of the most common applications:

**Motorcycles:** many motorcycles use centrifugal clutches to simplify the riding experience, allowing riders to focus on acceleration with the worry of manual clutch operation.

**Go-Karts:** these commonly use centrifugal clutches to provide smooth acceleration to allow for young and inexperienced drivers operate and learn without the complexity of manually operating a clutch.

**Small engines:** centrifugal clutches are commonly found in small engines, such as those found in chainsaws, lawnmowers and other power equipment, allowing for an easy startup and simple operation.

**Automated machinery:** in industrial settings, centrifugal clutches used in conveyor systems and other machinery to efficiently control power transmission.

**Dune buggies and ATVs:** these vehicles typically use centrifugal clutches for better performance in offroad conditions, providing smoother power delivery.

## [2.4] Centrifugal clutch advantages

Centrifugal clutches have several advantages that make them popular amongst engineers. The following are some of the most impactful advantages:

**Automatic engagement:** the ability to automatically engage and disengage without manual user input, simplifies the operation and enhances the user experience by not having the operation be difficult or require training.

**Smooth operation:** they provide smooth power transfer between shafts, reduced shock loads on the drive train and improve overall performance.

**Reduced wear:** centrifugal friction clutches tend to have longer lifespans due to less wear and tear since the clutch gradually engages as the speed increases.

**Compact design:** centrifugal clutches are typically smaller and more compact than other options, making them highly suitable for very applications with limited space.

**Versatility:** they can be used in a wide variety of applications ranging from small engines to large machinery.

## [2.5] Common material choices

Centrifugal clutches are typically made from a combination of materials to ensure durability and efficiency. The most common material choices for each component are as follows:

Housing: often made from aluminium or steel, which provides strength and can withstand the forces generated during the operation.

Clutch shoes: these are usually made from a composite material or rubber that can provide good friction properties to engage and disengage the clutch efficiently.

Springs: typically made from high carbon steel, which are strong enough to help keep the clutch shoes retracted at low speeds.

Drum: similar to the housing, this is often made from steel or aluminium to handle high rotational speeds and wear.

## [2.6] Electromagnetic clutch applications in automated manufacturing

Electromagnetic clutches are increasingly being used in modern automated manufacturing due to their precision and reliability. In robotics systems, electromagnetic clutches allow for precise control of movements and gripping mechanisms, enabling robots to engage and disengage tools or components quickly and efficiently, increasing productivity. Electromagnetic clutches are also used in conveyor systems, being able to start and stop conveyor belts without the need for mechanical linkages, allowing for smoother operation and reducing wear and tear. In CNC machines, they provide precise control over spindle engagement and disengagement, allowing for better machining accuracy and improved cycle times. Automated assembly lines are facilitated by the use of electromagnetic clutches by controlling the timing and movement of components and tools. They greatly help in synchronising different parts of an assembly process, crucial for efficiency and productivity. These clutches also serve a similar role in packaging machinery as they do in an assembly line, controlling the timing and movement of components, allowing for items to be packaged quickly and accurately. Across all these applications, it is clear they play a vital role in automated manufacturing, enhancing efficiency, precision and providing flexibility to the manufacturing process.

## [3]Task B

### [3.1] System specifications

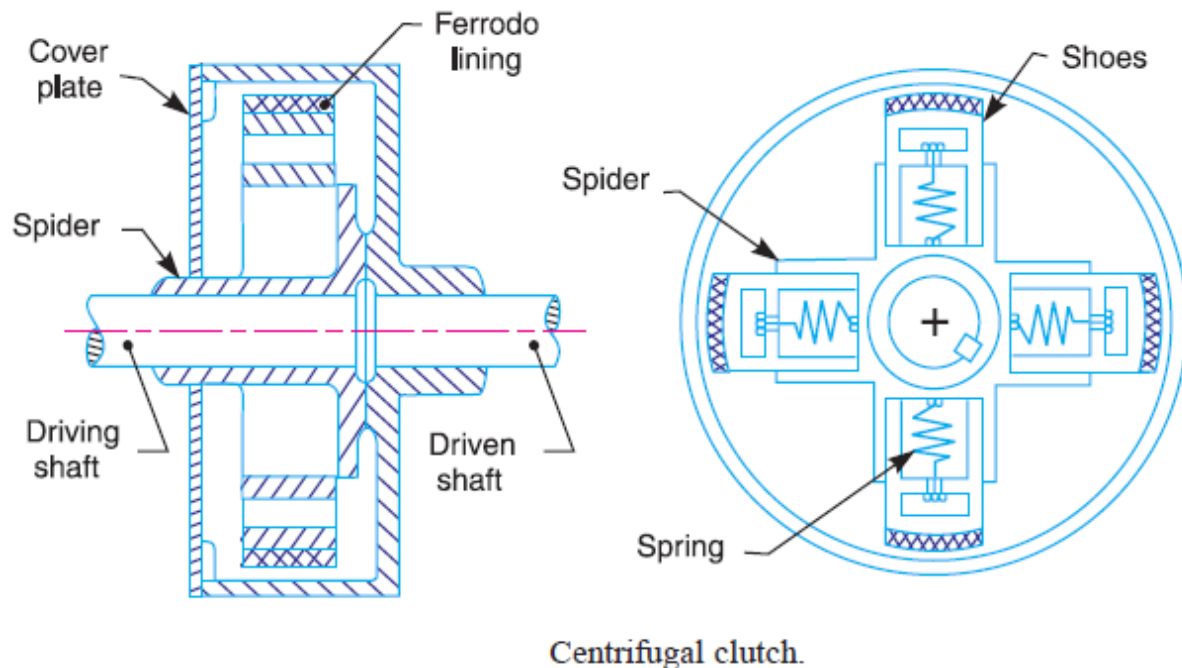


Figure 2: ACMA5010 Assessment Specification Centrifugal Clutch Diagram.

‘Consider the centrifugal clutch above that comprises of four ‘shoes’ symmetrically attached to the ‘spider’. Each shoe with its friction lining has a mass of 275 grams and is attached by means of a linear mechanical spring with a stiffness value of 7.5 kN/m. The coefficient of friction of the material attached to the shoes is 0.35. The centre of mass of each of the shoes is at a radius of 95 mm from the shaft centres in the rest position shown above, i.e. can be considered as the distance to ‘edge’ of shoes and have a clearance distance of 9 mm to the outer drum. The outer drum has a wall thickness of 4 mm.’

ACMA5010 Level 5 Assessment Specification Task B.

### [3.2] Diameter of the outer drum

$$\text{Outer drum diameter} = 95 + 9 + 4 \times 2 = 112\text{mm}$$

### [3.3] Centrifugal clutch engagement speed

A linear mechanical spring's stiffness is the same as its spring constant.

$$\text{Force required for clutch engage} = 7.5 \times 10^3 \times 9 \times 10^{-3} = 67.5N$$

$$\text{Velocity} = \sqrt{\frac{67.5 \times 104 \times 10^{-3}}{275 \times 10^{-3}}} = 5.05245m/s$$

$$\text{Clutch engagement speed} = \frac{5.05245}{\pi} \times 60 = 96.4947RPM$$

### [3.4] Radial force acting on the clutch face

$$\text{Centrifugal force at 550RPM} = 275 \times 10^{-3} \times \frac{(\frac{550 \times \pi}{60})^2}{104 \times 10^{-3}} = 2.1929kN$$

$$\text{Radial force at 550RPM} = 2.1929 \times 10^3 \times 0.35 = 767.515N$$

### [3.5] Torque transmitted to the driven shaft

$$\text{Torque at 550RPM} = 767.515 \times 104 \times 10^{-3} = 79.822Nm$$

### [3.6] Transmitted torque against driving shaft speed graph

| Friction Coefficient |                       |                  | 0.35        |
|----------------------|-----------------------|------------------|-------------|
| RPM                  | Centrifugal Force (N) | Radial Force (N) | Torque (Nm) |
| 450                  | 1467.98503            | 513.7947605      | 53.43465509 |
| 475                  | 1635.625296           | 572.4688535      | 59.53676077 |
| 500                  | 1812.327198           | 634.3145191      | 65.96870999 |
| 525                  | 1998.090735           | 699.3317573      | 72.73050276 |
| 550                  | 2192.915909           | 767.5205682      | 79.82213909 |
| 575                  | 2396.802719           | 838.8809516      | 87.24361896 |
| 600                  | 2609.751164           | 913.4129076      | 94.99494239 |
| 625                  | 2831.761246           | 991.1164361      | 103.0761094 |
| 650                  | 3062.832964           | 1071.991537      | 111.4871199 |
| 675                  | 3302.966317           | 1156.038211      | 120.227974  |
| 700                  | 3552.161307           | 1243.256457      | 129.2986716 |

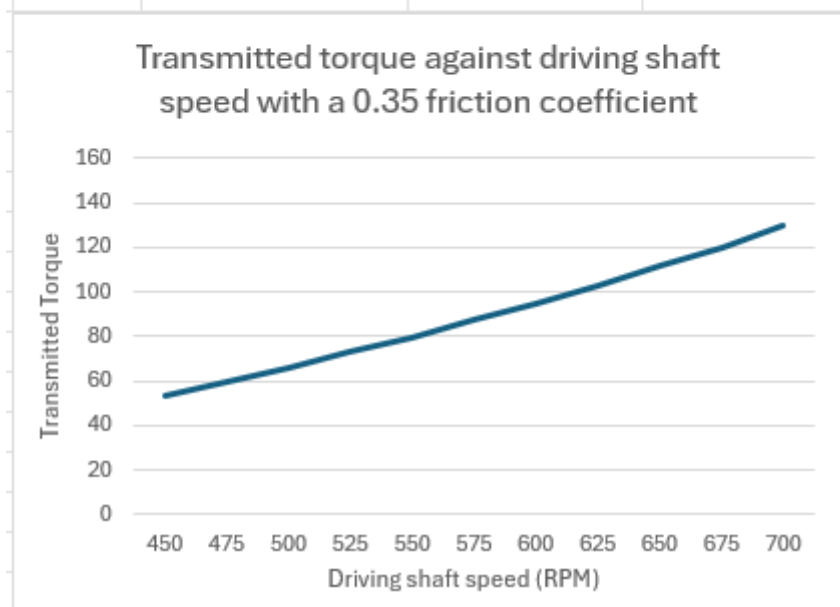


Figure 3: Graphed results showing the change in torque as the speed increases.

### [3.7] Analysis of torque against speed with varying friction coefficients

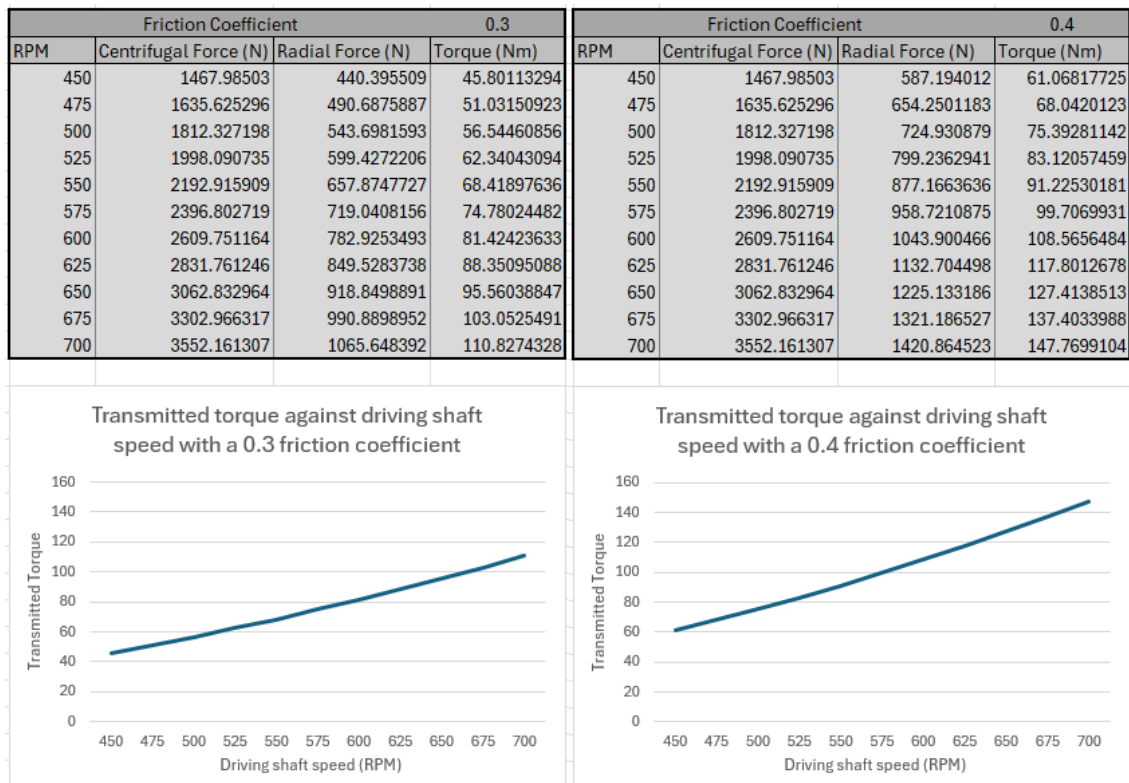


Figure 4 and 5: Graphed results showing the change in torque as the speed increases with different values for the friction coefficient.

As expected, the increase in friction directly results in an increase to the torque. This shows the importance and the benefits of having a high friction material at the contact points of the clutch feet, allowing the clutch to have a larger power transfer output and overall increased efficiency.

### [3.8] Angular acceleration of the drum to achieve maximum torque

Maximum torque calculated was 147.7699Nm.

Drum mass of 750g.

$$\text{Moment of inertia} = \frac{1}{2} \times 0.75 \times (112 \times 10^{-3})^2 = 0.037932 \text{kgm}^2$$

$$\text{Angular acceleration for maximum torque} = \frac{147.7699}{0.037932} = 3895.6527 \text{rad/s}$$

### [3.9] Maximum angular acceleration with breaking force

If the driven shaft has a diameter of 17.5mm and a breaking force of 500N was applied, then:

$$\text{Breaking torque} = 500 \times 17.5 \times 10^{-3} = 8.75Nm$$

$$\text{Maximum torque} = 147.7699 - 8.75 = 139.0199Nm$$

$$\text{Maximum angular acceleration of the drum} = \frac{139.0199}{0.037932} = 3664.9768rad/s$$

## [4] Bibliography

Figure 1 Source: [[Clutches, Brakes, Couplings, and Flywheels | bartleby](#)]