

University of Wales Trinity St David – School of Engineering

ACHA5010 – DYNAMICS ANALYSIS AND SIMULATION OF A
CENTRIFUGAL CLUTCH

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Task A

Mechanical clutches are an essential component in allowing numerous mechanical systems to function, serving as a dynamic link between a motor or an engine connected to a driving shaft and the shaft desired to be driven, allowing for controlled engagement and disengagement and the transmission of power. There are numerous different types and variations of clutches, such as the frictional clutch, hydraulic clutch, vacuum clutch and the dog clutch. However, the centrifugal clutch has been a particularly successful design throughout the 20th and into the 21st century, particularly in applications that use a small displacement motor and require a smooth power engagement. This is because they engage the output of the engine to the driven shaft gradually, meaning that the engine can reach near to its maximum torque output before the clutch has engaged and a load has been applied.

A centrifugal clutch is a form of automatic clutch that uses centrifugal force to engage frictional shoes on a rotating assembly connected to the driving shaft with a drum that is connected to an output shaft. When the torque is low, and the input shaft is at low rpm's the centrifugal force is not strong enough to overcome the resistance of springs that are attached to the shoes. This means at that speed there is no contact between the input and output shaft, so no power transferred. As the rotational speed of the input shaft increases, the centrifugal force increases to a point where it overcomes the resistance of the spring causing the frictional shoes to move outward towards the drum. Once the input shaft reaches a certain speed, the centrifugal force overcomes the spring resistance and the shoes come into contact with the drum. As the shoes have a lining that is high in friction, they come into the contact with the drum and allows it to spin the drum. This engagement connects the input shaft from the engine or motor to the output shaft, connected to the transmission or driveshaft, depending on the application used, allowing torque to be transmitted. When the engine or motor slows down, the centrifugal force decreases, therefore the process happens in reverse and springs force overcomes the centrifugal force and the shoes are pulled back in towards the centre, and the clutch disengages, stopping the transmission of torque.

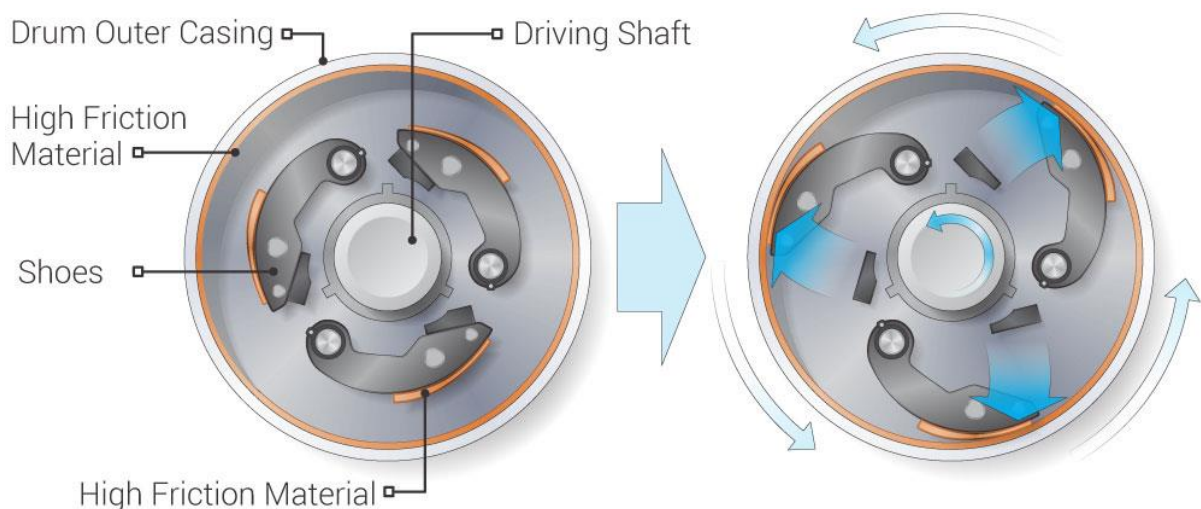
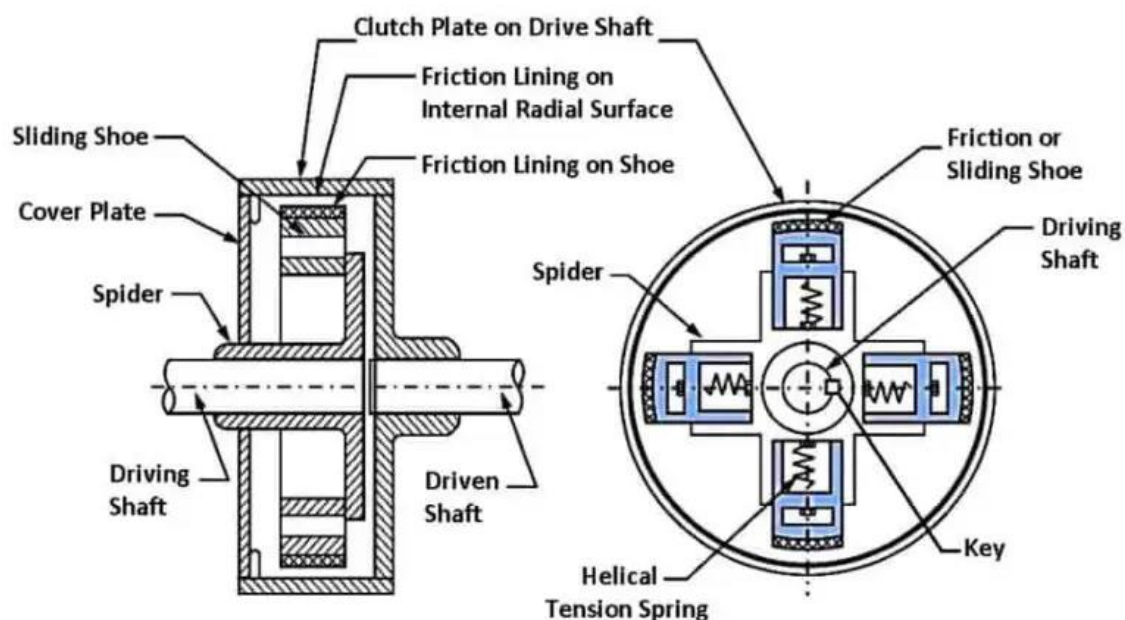


Figure 1: Centrifugal clutch operation (Source: Engineeringclicks, 2023:online)

The centrifugal clutch is believed to have been first used in the late 19th and early 20th century for use in steam and early electric and diesel locomotives and was first implemented in an automotive use case by Armstrong Siddeley in 1936, although Thomas Fogarty was believed to be implementing centrifugal clutches into small motor applications around the same time. Early examples of centrifugal clutches were extremely rudimentary in design and were comprised of very basic

components. However through years of studies, analysis and use, the design of centrifugal clutches has been changed to improve the balancing of the rotating assembly and also the materials used to create them have improved considerably, allowing for a more controlled engagement speed, a faster response time between engine acceleration and when the shoes make contact with the drum, an increase in the efficiency and therefore decrease in power lost as forms such as heat and allows them to be used in a much wider amount of applications.

Even though all centrifugal clutches operate on the same principle, using centrifugal force to push shoes to the inside edge of a drum, and where the shoes use friction to transfer torque from one shaft to another, there are several different designs for how this is achieved. These include: Drum/shoe Type clutches, which are the most common type of centrifugal clutch. The drum-type centrifugal clutch consists of a housing that is shaped like a drum and houses the clutch shoes, and it is attached to the shaft that receives the input from the motor; Cone Type clutches, where the input and output shafts are connected to two cones that serve as the input and output, with one cone being slightly smaller than the other. When the motor accelerates and starts spinning the input shaft, the centrifugal force causes the smaller cone to come into contact with the larger cone, utilising the friction between the two to transfer torque to the output shaft; Roller Type clutches, which are very similar to the traditional drum or shoe type, however instead of shoes, rollers are used to transfer torque to the outer drum from the input shaft and Diaphragm Type clutches, which are another variation of the traditional drum/shoe type clutch however instead of using springs to hold the frictional shoes, a diaphragm is used. The material used for these components is a key design consideration. The shoes are fitted with a material with a high friction coefficient, which is often made from composite materials that offer a balance between durability and effective friction. The drum is usually constructed from metals capable of withstanding high operational temperatures and stresses. The development of material selection and the understanding of material properties has significantly improved the performance and durability of these clutches.



Parts of Centrifugal Clutch

Figure 2:Centrifugal clutch labelled diagram (Source: The engineers post, 2023:online)

Centrifugal clutches are often found in various small displacement engine-powered applications, such as lawn mowers, chainsaws, go-karts, as well as certain industrial machinery. Their automatic engagement and disengagement based on engine RPM make them suitable for applications where manual clutch operation is not easy to implement, would not be beneficial to its operation or would be dangerous. An example of this is in petrol powered chainsaws, using a centrifugal clutch allows the engine to idle without driving the chain, and only engaging when there is sufficient rotational speed. They are also used in industrial applications such as conveyor belt systems, where torque is smoothly introduced so that the conveyor starts smoothly, allowing for no sudden loads which could damage products on the conveyor and, are also used in equipment such as pumps and compressors, mixers and agitators, generators and fans and blowers, allowing for the engine or motor to reach an optimal speed before a load is placed upon it, reducing unnecessary initial loads and stresses on the motor, meaning that wear is reduced and therefore longevity is increased, and also makes the operation more efficient. The operating conditions for these clutches encompass a wide range of mechanical loads, rotational speeds, and environmental conditions. When designing centrifugal clutches, factors such as operational temperature ranges, potential causes for corrosion, and the different loads and speeds that will be transferred through the clutch must be considered to ensure that it is both reliable and also efficient.

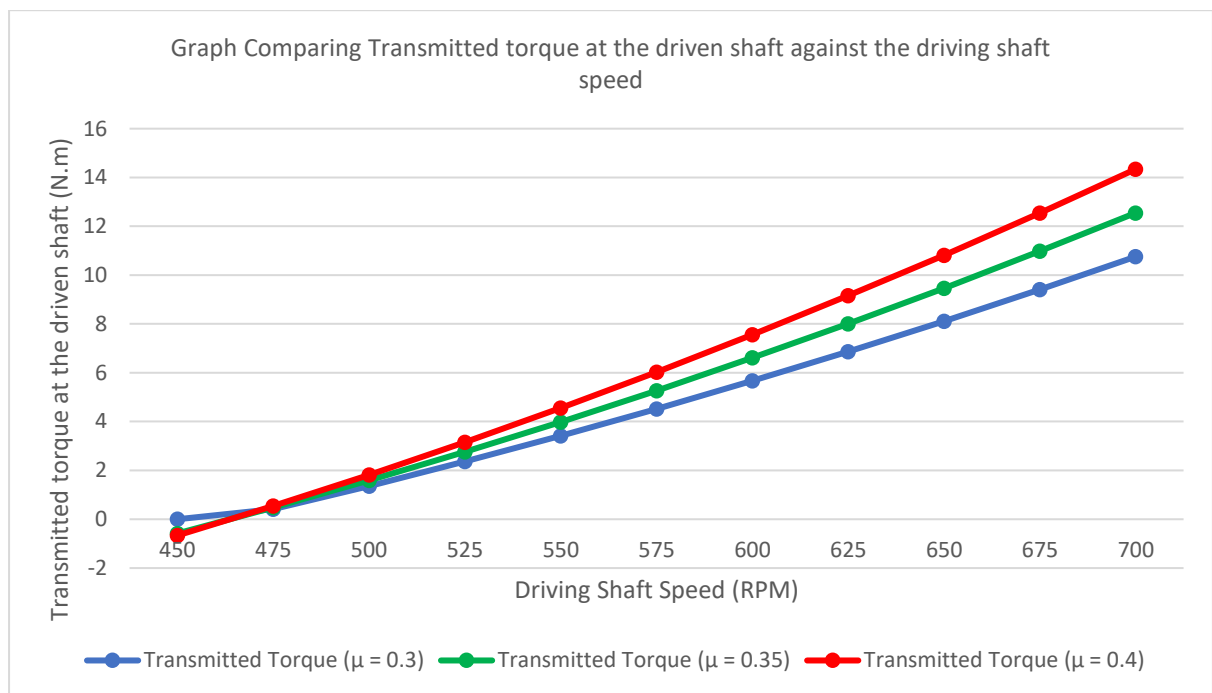
There are numerous advantages when it comes to centrifugal clutches, however this only applies to very certain applications and operating conditions. Their automatic engagement means that there is no manual actuation, resulting in easier operation. The simple design means that they require less maintenance at a reduced cost as there are fewer mechanical components that can wear down or would require adjustment, therefore making them more reliable. Centrifugal clutches are also advantageous as they are able to handle variable loads, smoothly introducing the torque into the system, reducing the sudden initiation of torque, which is commonly experienced with manually operated clutches, and protecting them from overloading the output side of the system as if the torque was to reach excessive levels, then the shoes would spin inside of the drum, preventing failure. This, as well as the fact that at engine idle speeds, the drive system is not engaged, means that it is safer than other types of clutches.

The introduction of electromagnetic clutches has created a significant shift in clutch technology. Opposite to centrifugal clutches, electromagnetic clutches allow for sudden, precise engagement and disengagement through electromagnetic engagement. This advancement is one of the most visible areas in which displays the shift in automation and control engineering from mechanical to electromechanical systems.

Electromagnetic clutches play a key role in modern manufacturing automation. These clutches are integral to modern complex machinery, allowing for rapid changes in operation without mechanical adjustments. The ability to combine them with the ever-increasing amount of digital control systems allows for precise operational control, meaning that they are easily able to meet the advanced requirements of automated manufacturing processes. Not only does this increase efficiency, but it also allows for further improvement in automated manufacturing and advancements in robotic assembly lines, CNC machinery, and other automated systems.

Task B

- 1) 0.216m
 - 2) 464rpm
 - 3) 9.58N
 - 4) 3.986N.m
- 5+6)



At 450 rpm there is no torque transmitted between the driving shaft and the driven shaft as the clutch has not engaged with the outer drum, this engagement happens at a speed of 464rpm as calculated previously.

When the shoe coefficient of friction increases the torque also increases in a linear pattern. This can be shown as when increasing the coefficient of friction from 0.3 to 0.35 and 0.35 to 0.4, the difference in the torque values at between the 3 coefficients of friction at a specific rpm value are the same. For example, at the maximum speed considered of 700rpm, the difference between the torque transmitted with a value of $\mu = 0.3$ and $\mu = 0.35$ is 1.793, and between $\mu = 0.35$ and $\mu = 0.4$ the value is also 1.793.

- 7) 354.074 rad/s²

Dynamics Assignment Calculations

1) Radius of drum = Radius_{cam} + Clearance + wall thickness
 $= 95 + 9 + 4 = 108$

Diameter of drum = 2×108

$= 216 \text{ mm}$

$= 0.216 \text{ m}$

2) Spring force = Centrifugal force

$m \cdot r \cdot \omega^2 = k \cdot x + \mu \cdot m \cdot g$

$\omega = \sqrt{\frac{k \cdot x + \mu \cdot m \cdot g}{m \cdot r}}$

$\mu = 0$ as calculating engagement speed
 So no friction

$\omega^2 = \frac{7.5 \times 10^3 \times 0.009 + 0 \times 0.275 \times 9.81}{0.275 \times 0.104}$

$\omega = 48.581 \text{ rad/s}$

$\therefore 48.581 \times (60/2\pi)$

$= 463.91$

$\approx 464 \text{ rpm}$

Spring force =
 $7.5 \times 10^3 \times 0.009$
 $= 67.5 \text{ N}$

3) Centrifugal force = $m \times \omega^2 \times r$

$\omega = \left(\frac{550 \times 2\pi}{60} \right)$

$\omega = 57.5959 \text{ rad/s}$

$= \mu (m \cdot \omega^2 \cdot r - k \cdot x)$

$= 0.35 (0.275 \times 57.5959^2 \times 0.104 - 7.5 \times 10^3 \times 0.009)$

Force $= 9.58 \text{ N}$

Centrifugal force - Spring force
 $= 96.65 - 67.5 \times 0.009$

4) Torque = friction force $\times$ radius $\times$ 4 Shoes

Friction force = Coefficient of friction $\times$ Normal force

Normal force = Centrifugal force - Spring force

$\therefore$ Torque = $(0.35 \times (94.874 - 67.5)) \times 0.104 \times 4$

$(4 \times 9.581 \times 0.104) \times 4$
 0.996×4

Torque = 3.986 N.m

7) Torque = Moment of inertia $\times$ angular acceleration

$I = \frac{1}{2}mr^2$

$= \frac{1}{2} \times 0.75 \times 0.108$

$I = 0.0405 \text{ kgm}^2$

Max Torque = 14.34 N.m

$\frac{14.34}{0.0405} = \frac{0.0405 \alpha}{0.0405}$

$\alpha = 354.074 \text{ rad/s}^2$

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