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EMPIRICAL STUDY AND ANALYSIS OF A SINGLE LOADED CLUTCH DISC.

By

[1]. Ndubuisi, Paul-Darlington Ibemezie, ndudarla@gmail.com [2]. Eneh, Innocent Ifeanyi [3]. Nnaji, Anthony Chidolue.

1. Department of Electrical/Electronics Engineering, Akanu Ibiam Federal Polytechnic, Unwana. 2. 3.4. Department of Electrical/Electronics Engineering, Enugu State University of Science and Technology, Enugu

Abstract

A Clutch is a control mechanism used in drive systems to couple torque and power between an engine shaft and a load shaft. The effect of the load on the speed of rotation, the resultant torque, and the power on a drive system is presented. These parameters are important in the study of the actuation control process of an electro-pneumatic clutch system in heavy-duty vehicles. An empirical research method and analysis were adopted. The study revolves around a single loaded clutch plate of radius 30.325mm which was attached through a pulley system to rotate with the speed of an a. c. motor or dynamometer. A tachometer is used for measuring the speed. The consequential analysis of the load and speed yielded torque and power. The result showed that load on a clutch plate is inversely proportional to speed, while proportional relationships exist with torque and power.

Key Words: Clutch, Control, Drive, Rotation, Shaft, Transmission.

1.0 Introduction

Clutching is a mechanism that provides a means of control in machines, in such a manner that the machine can be given instruction to operate. Clutch is therefore an essential control element to actualise effective control and smooth transmission of drive torque, power and speed in many rotating drive systems. The transfer of torque to an output shaft from an input shaft is the function of a clutching system. A clutch is a mechanical device applied to engage and disengage transmission of power particularly from a driving shaft (usually attached to the engine) to a driven shaft (usually attached to the load). It can also be said that a clutch ensures that the transmission link between the engine and the load establishes a releasable torque (Hidehito, 2016). Clutch disc is constructed with steel. The steel plate is treated with some materials to enhance friction. The treatment is similar to that applied in brake system. The assembling of the clutch system is such that both the flywheel and pressure plate sandwich the clutch disc which is centrally located between them. The hub is at the centre of the clutch disc and is fitted on the spline of the drive shaft ready for transmission. Under clutch engagement mode, the disc is pressed tightly from both sides by the flywheel and the pressure plate respectively. In this manner, the power from the engine is coupled through the hub onto the drive shaft for transmission (Johnston and Johnson 2012). Principally, two rotating shafts are connected and disconnected using clutches. For their operation, majority of clutches rely on frictional forces between the clutch plates. The friction forces on the clutches ensure that a moving member is connected to another, usually at a different speed, or at a stationary condition, the purpose being to synchronize their speeds and/or to effect power transmission. Usually, a need exists for difference in speed between the two members. In order to study the effects of loads and speeds on a clutch plate necessitated this experiment. The analysis will also lead us to establish the relationships between speed, torque and power in a rotating machine. These parameters are important in the study of actuation process in an electro-pneumatic clutch system of heavy-duty vehicles.

Fig.1: Shafts Shapes and sizes (Mishra, 2014)

Fig.2: Clutch plate of an Actross Truck**.**

2.0: Methods.

Empirical research design method was adopted. Experiment was done with the following;

1.The driver shaft was attached to rotate with the speed of an a. c. motor or dynamometer.

2. The driven shaft of clutch disc or flywheel of radius 30.325mm is loaded via a pulley system. 3. Loads or weight of 200 grams up to 1000grams were added at intervals on the pulley base pan and loading speed observed.

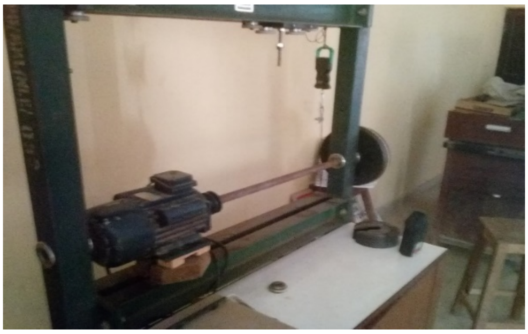
4. Loads were gradually reduced from 1000gram to 200 grams in the similar manner it was increased and unloading speed were also recorded.

5. The tachometer was used for measuring the speed of the driver shaft via a led sensor monitor positioned on top of the plate.

6. The resultant speeds were read from the monitor accordingly.

3. 0: Experimental Design, Analysis and Results.

The setup of the experiment is shown pictorially in figure 3.



(a)

(b)

(c)

(d)

Fig. 3 (a) to (d): Features of the experimental set up of a single loaded clutch disc.

The results of the experiment are shown in table 1.

Table 1: Load (Weight), Loading speed and Unloading speed of a clutch system

S/n	**Load (Weight) (gm)**	**Loading Speed (RPM)**	**Unloading Speed (RPM)**
1	0	∞	∞
2	**200**	**1300**	1310
3	**400**	**1140**	1150
4	**600**	**990**	1020
5	**800**	**860**	960
6	**1000**	**735**	800

The data in table 1 is used to derive the torque and power of the system. The loading speed is used to establish the output torque while the unloading speed is applied for the input torque. It is noteworthy that when the load is zero, the speed assumes a dangerous value defined as infinite value.

The rotation of the disc is brought about by a turning force or output Torque and is defined by Spolsky and Atwood (2019) as

$$\boldsymbol{Torque}\ (\phi) = \boldsymbol{Force}(\boldsymbol{F})\boldsymbol{x}\ \boldsymbol{Distance}(\boldsymbol{s}) \quad (1)$$

$$\boldsymbol{Force}(\boldsymbol{F}) = \boldsymbol{Weight}\ (\boldsymbol{w})\ \boldsymbol{x}\ \boldsymbol{gravity}\ (\boldsymbol{g}) \quad (2)$$

$$\boldsymbol{Distance}(\boldsymbol{s}) = \boldsymbol{radius\ of\ brake\ pully}\ (\boldsymbol{r})$$

(3)

$$\boldsymbol{Weight}\ (\boldsymbol{w})\ \boldsymbol{x}\ \boldsymbol{gravity}\ (\boldsymbol{g})\ \boldsymbol{x}\ \boldsymbol{radius\ of\ brake\ pully}\ (\boldsymbol{r}))$$

Thus for $Weight\ (w) = 200g, 400g, 600g, 800g, 100g, Radius =$ 30.25mm and gravity =9.81.

By substitution we have;

$Torque\ \phi_{1=}$ 0.2 x 9.81 x 30.325 = 59.498 Nmm $= \frac{59.498}{1000}$ Nm = 0.059498Nm

$Torque\ \phi_{2=}$ 0.4 x 9.81 x 30.325 = 118.995 Nmm $= \frac{118.995}{1000}$ Nm =0.1189952Nm

$Torque\ \phi_{3=}$ 0.6 x 9.81 x 30.325 = 179.239 Nmm $= \frac{179.239}{1000}$ Nm = 0.179239Nm

$Torque\ \phi_{4=}$ 0.8 x 9.81 x 30.325 = 237.991 Nmm $= \frac{237.991}{1000}$ Nm = 0.237991Nm

$Torque\ \phi_{5=}$ 1 x 9.81 x 30.325 = 297.488 Nmm $= \frac{297.488}{1000}$ Nm = 0.297488Nm

Note that torque defined in equation (1) is the twisting torque of the shaft and can as well be defined as

$$Torque\ (\phi) = force(F)\ x\ radius\ of\ shaft(r) = Fr\ \ or\ \phi = Fr \quad (4)$$

But Energy dissipated or work done by shaft in one revolution can be defined as

Energy(E) = $force(F) x\ linear\ distance\ or\ perimeter\ of\ the\ shaft(d) = Fd$ (5)

But $d = 2\Pi r$ (6)

Thus, work or energy $E = F\ x\ 2\Pi r = 2\Pi\phi$ (7)

Power (P) is defined as the rate of dissipation of energy or Energy per second,

$$\mathrm{P} = \frac{\mathrm{E}}{S}\ (Watts) = \frac{2\Pi\phi}{S}\ \text{(watts)} \quad (8)$$

But rotational power of shaft is defined as energy dissipated per a revolution in watts while the rotational speed (S) is defined as the number of revolutions per a minute.

Thus

$$\text{Power P} = \frac{\text{Energy}}{rev}\ x\ \frac{\text{rev}}{min}\ \text{(rpm)} = \frac{\text{Energy}}{time}\ \text{or}$$

$$P = 2\Pi\phi \text{ x S x } \frac{1\text{min}}{60s} = \frac{2\Pi\phi S}{60} = 0.10472\phi S = \frac{\phi S}{9.5488} \quad (9)$$

Hence, the power developed in the clutch is defined as

$$Power\ (P) = \frac{\textbf{Torque}(\phi)\textbf{x Spead}\ (\textbf{s})}{\textbf{9.5488}} \quad (10)$$

The power developed in the clutch as defined in equation (10) agrees with that of Spolsky and Atwood 2019.

hence, by substituting the values for torques ($\phi_{1,}\ \phi_2, \phi_3, \phi_4\ \ and\ \ \phi_5$) and loading speeds from table 1, in equation (10), we have;

$$Power\ (P_1) = \frac{0.059498 \text{ x } 1300}{9.5488} = 8.100\text{kw}$$

$$Power\ (P_2) = \frac{0.1189952 \text{ x } 1140}{9.5488} = 14.207\text{kw}$$

$$Power\ (P_3) = \frac{0.179239 \text{ x } 990}{9.5488} = 18.583\text{kw}$$

$$Power\ (P_4) = \frac{0.237991\text{x } 860}{9.5488} = 21.434 \text{ kw}$$

$$Power\ (P_5) = \frac{0.297488 \text{ x } 735}{9.5488} = 22.899\text{kw.}$$

The results obtained from these calculations are summarised in table 2.

Table 2: Loading or output Torque and output power of a clutch system

S/n	Load (Weight) (gm)	Loading or output Torque (Nm)	Output Power (kw)
1	200	0.059498	8.100
2	400	0.1189952	14.207
3	600	0.179239	18.583
4	800	0.237991	21.434
5	1000	0.297488	22.899

It is noteworthy too from the analysis above, that if load of zero gram is applied, the torque will be zero and similarly, the power derived will be zero too. Consequently, the speed will become infinity. This is a dangerous situation; hence precaution should be taken to avoid running the clutch under no load conditions. Table 3 below illustrates this scenario.

Table 3: Comparison of speed, torque and power of a loaded clutch plate.

S/n	Load (Weight) (gm)	Loading Speed (RPM)	Loading or output Torque (Nm)	Output Power (kw)
1	0	∞	0	0
2	200	1300	0.059498	8.100
3	400	1140	0.1189952	14.207
4	600	990	0.179239	18.583

5	800	860	0.237991	21.434
6	1000	735	0.297488	22.899

Graphical presentation of torque as displayed in table 3 may pose some limitation, hence the need to present it in a standard form as shown in table 4.

Table 4: Comparison of speed, torque $x\ 10^{-3}$and power of a loaded clutch plate.

S/n	Load (Weight) (gm)	Loading Speed (RPM)	Loading or output Torque (Nm) $x\ 10^{-3}$	Output Power (kw)
1	0	∞	0	0
2	200	1300	59.498	8.100
3	400	1140	118.9952	14.207
4	600	990	179.239	18.583
5	800	860	237.991	21.434
6	1000	735	297.488	22.899

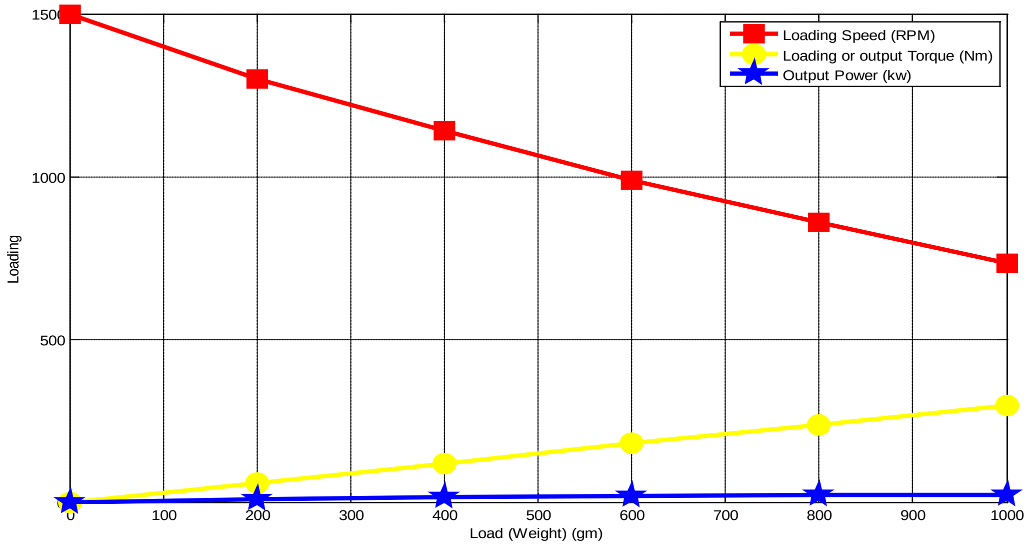


Figure 4: Comparison of speed, torque and power of a loaded clutch plate.

Graphical plot of this relationship in table 4 is shown in fig. 4. It is observed that as load on clutch increases the angular speed of clutch shaft decreases. It is indicated by the red plot. However, the toque on shaft and power or energy per revolution gradually increases with increasing load. These are also indicated with the yellow and blue plots respectively. The rate of power and torque increment are comparatively significant up to 600-gram load point, the rate power increment is relatively low due to load on clutch. Thus load, torque and power give us linear relationship. Power of 22.899 Kilowatt is maximum at maximum load of 1 Kg but speed decreases up to 735 RPM. Whereas speed is high at 1300 RPM when load is 200 gram and power show 8.1 Kilowatt at this speed. It is clearly shown that load and speed give us non-linear inverse relationship. Graph shows that initially load is very low at 200 gm at that time speed is about 1300 RPM but speed decreases according to increment in load which is shown by inverse relationship. But Torque and Power value rises because Torque and Power are proportional to the applied load.

4.0 Conclusion

The result of this experiment and the analysis that followed explains the working of a clutch system under load conditions. It establishes the fact that clutches can be deployed for coupling an engine with the load to do work. It also establishes the fact that load on a clutch plate is inversely proportional to speed, while there are proportional relationships with torque and power. This result could be a useful tool in the study of clutch actuation technologies, especially in heavy-duty vehicles.

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