PERFORMANCE INVESTIGATION OF WHEEL AND DIFFERENTIAL AXLES IN ENGINEERING MECHANICS LAB

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Abstract- The objective of the paper is to test the performance of the wheel and differential axles apparatus used in engineering mechanics laboratory. Author finds the Mechanical Advantage, velocity ratios using experimental data and theoretical data provided by the manufacturer of the apparatus, theoretical and experimental efficiency, ideal and frictional load and effort. For the purpose of investigation of performance of the apparatus, author also plots various graphs; between effort and load, between ideal effort and load to be lifted, between frictional effort and load, between M.A. and load, between efficiency and load. The main reader and beneficiary of this work are B.Tech./M.Tech. Students and researcher in the initial stage of their work in the field of mechanical design.

Keywords- Mechanical Advantage, Velocity Ratio, Efficiency

I. INTRODUCTION

Wheel and differential axes’ apparatus is shown in Figure-1. Mechanical Advantage (M.A.) is defined as ratio between load (W) to be lifted and effort (P) applied to raise the load. Velocity Ratio (V.R.) is defined as the ratio of distance moved by the effort (x) to the distance moved by the load (y). Ideal Effort (Pi) is the greatest effort needed to raise a given load by the wheel and differential axle of the apparatus, considering it to be ideal. i.e. Pi = W/V.R.

Frictional Effort (Pf) is the frictional force activated between the surfaces of the pulley / axle and cord. Ideal Load (Wi) is the hypothetical Load by applying ideal effort. Frictional Load (Wf) is the increased load because of friction. In ideal machine there are no frictional losses. i.e. Output = input. The efficiency of ideal equipment is 100%. Maximum efficiency (ηmax) is the ratio of maximum mechanical advantage and velocity ratio.

The efficiency of a reversible equipment is always > 50 %. Hashiguchi et.al. [1] written on unconventional friction. Kartal [2] worked on concept of torsional contact between elastically similar flat-ended cylinders. Eriten et. al.[3] presented the behavior of flat rough surfaces. Kostas et.al [4] worked on the coefficient of friction between the inter particles. Chiew et.al[5] presented a friction model identification. Piatkowski et.al[6] made a dynamic friction models. Kostas [7] experimented on mechanical inter particle loading apparatus. Dong et.al.[8] made a wear reduction model.

Deepak et. al. [9] showed the effect of roughness on coefficient of friction. Cura et. al.[10] gave a wear formulation approach. Saha et.al.[11] presented a modified friction model. Aita et.al. [12] shown their work on nonlinear friction models. Putelat et. al.[13] shown their work on frictional waves and Tsampras et al[14] explained an experimental study of friction devices and rubber bearings.

The author has also taken some text/relations/or other materials from a number of references.
NOTATIONS USED
In the present study, the notations and terminology used are as follows.
W = Load to be lifted,
Wf = Frictional load,
Wi = Ideal load,
P = Effort to be applied to lift load W,
Pi = Ideal effort,
Pf = Frictional effort,
D = Diameter of the effort pulley,
d1 = diameter of axle-1,
d2 = diameter of axle-2,
M.A. = Mechanical Advantage = W/P,
x = Distance moved by effort P,
y = Distance moved by load W,
V.R. = Velocity Ratio = Distance moved by Effort / Distance moved by Load.
Now, considering one revolution of effort pulley,
(V.R.)True = Distance moved by Effort for one revolution of the effort pulley / Distance moved by Load vertically = \( \pi D \) / \( \frac{\pi d_1 - \pi d_2}{2} \) = \( 2 \pi D / (\pi d_1 - \pi d_2) \),
(V.R.)Exp = Distance moved by Effort / Distance moved by Load = x/y,
\( \eta \) = Efficiency = M.A. / V.R.,
(\( \eta \))True = Efficiency (True) = M.A. / (V.R.)True,
(\( \eta \))Exp = Efficiency (Experimentally) = M.A. / (V.R.)Exp.,
FL = Friction Loss = 1 – Efficiency (\( \eta \)),
(FL)True = Friction Loss = 1 – (\( \eta \))True,
(FL)_{\text{Exp}} = \text{Friction Loss} = 1 - (\eta)_{\text{Exp}}.

II. METHODOLOGY

Wrap the one cord on the wheel and second cord on both differential axles as shown in Figure-1. Now, Suspend some weight on the load pulley and some effort on differential axles cord and note down the starting and final positions of load and effort from a reference level.

Add some weight on the effort hanger and load pulley. Increase the weights till the effort just starts moving down. Now, note down the value of W and P and corresponding values of x and y. this is the first set of observation reading. Now again, Increase the weight W and repeat the experiment. Measure the diameters of wheel and both the differential axles. Measure the diameter of cords if appreciable. Calculate M.A., V.R. and Efficiency and plot various graphs.

OBSERVATIONS

1. Circumference of the effort wheel (D) = 920 mm,
2. Circumference of the bigger axle (d1) = 460 mm,
3. Circumference of the smaller axle (d2) = 210 mm,
4. Velocity ratio of the machine = 2D/(d1 - d2) = 7.36

Table 1: Observation For Wheel And Differential Axle

| S.N | Load to be Effort (W(N)) | Distance Effort (P(N)) | Distance Wheel (P(N)) | M.A. = (V.R)_{\text{Exp}} | (V.R)_{\text{Th}} | Pi = | Pf = | Wi = | WF = | Efficiency | Friction Loss |
|-----|------------------------|-----------------------|-----------------------|---------------------------|------------------|-----|-----|-----|-----|------------|--------------|
| 1   | 15                     | 3.5                   | 920                   | 115                       | 4.3              | 736 | 7.36 | 2.018 | 1.45 | 25.76     | 10.76        |
| 2   | 25                     | 4.3                   | 920                   | 116                       | 5.6              | 730 | 7.36 | 3.397 | 1.1  | 33.12     | 8.12         |
| 3   | 30                     | 5.5                   | 920                   | 114                       | 6.0              | 742 | 7.36 | 4.076 | 0.92 | 36.8      | 6.8          |
| 4   | 35                     | 5.3                   | 920                   | 111                       | 6.4              | 760 | 7.36 | 4.735 | 0.74 | 40.48     | 5.48         |
| 5   | 45                     | 7.5                   | 920                   | 115                       | 6.4              | 681 | 7.36 | 6.114 | 0.89 | 51.52     | 6.52         |
| 6   | 50                     | 8.3                   | 920                   | 130                       | 6.6              | 708 | 7.36 | 6.793 | 0.81 | 53.996    | 5.916        |
| 7   | 55                     | 8.5                   | 920                   | 135                       | 6.6              | 681 | 7.36 | 7.473 | 0.83 | 61.088    | 6.088        |
| 8   | 60                     | 9.2                   | 920                   | 132                       | 6.7              | 697 | 7.36 | 8.152 | 0.85 | 66.14     | 6.24         |
| 9   | 65                     | 9.7                   | 920                   | 137                       | 6.7              | 697 | 7.36 | 8.812 | 0.87 | 71.392    | 6.392        |
| 10  | 70                     | 10.5                  | 920                   | 135                       | 6.7              | 681 | 7.36 | 9.511 | 0.99 | 77.28     | 7.28         |

III. RESULT AND DIACUSSION

Average M.A. = 6.19
Maximum M.A. = 6.7
Average (V.R.)_{\text{Exp}} = 7.12
Average (V.R.)_{\text{True}} = 7.36
Average Efficiency, (\eta)_{\text{Exp}} = 87 %
Average Efficiency, (\eta)_{\text{True}} = 84.1 %
Average Friction loss, (F.L.)Exp =13%
Average Friction loss, (F.L.)True = 15.1 %
Maximum M.A=1/m= 6.7

Maximum Efficiency= (1/m V.R).100= 94.1 %

The detailed result analysis is given in Table-1. The relation between the effort applied (P) and load (W) to be lifted is shown in Figure-2. The relation between Mechanical Advantage (M.A.) and load to be lifted (W) is shown in Figure-3. Figure-4 shows the relationship between ideal effort (Pi) and load (W). Figure-5 illustrates the relationship between efficiency (ɳ) and load (W). The relation between frictional effort (Pf) and load to be lifted(W) is shown in Figure-6.
Figure 3: Graph between Mechanical Advantage (M.A.) and Load to be lifted (W)

\[ P_i = \frac{W}{(V.R.)\text{Th} (N)} \]

Figure 4: Graph between \( P_i \) and \( W \)

Figure 5: Graph between Efficiency (\( \eta \)) and Load (\( W \))
IV. CONCLUSIONS

It is clear from Figure -1 that almost at all the points, the effort (P) is directly proportional to the load to be lifted (W). Since the efficiency is greater than 50 %, therefore, this equipment is reversible. Figure-3 illustrates the relation between M.A. and W. we observe that after 50N, the value of M.A. becomes almost constant. It is also clear from Figure-4 that Pi is directly proportional to the load (W) to be lifted. It is evident from Figure-5 that after 50N of load, the efficiency of the equipment becomes constant.

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