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Study of the co-efficient of static friction between different pairs of surfaces using Inclined Plane Apparatus

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Abstract

In this paper author determines the performance of the inclined plane to understand facts and concepts of development of frictional force with respect to applied external force causing motion or tends to cause the motion. The paper determines the coefficient of friction between various pairs of surfaces and compares the same with the available values of coefficient of friction in the literature. Apart from the angle of repose, a graph between F(Friction force) VS P (Effort applied) has been drawn and mechanical advantage, velocity ratio and efficiency of the inclined plane are determined. The work is extremely useful for B.Tech./M.Tech. Students and research scholars for their project/thesis work.

Keywords:

Coefficient of Friction, Mechanical Advantage, efficiency, velocity ratio

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1. Introduction

If a body slides over another body, the force acting between the two surfaces which opposes the motion, is known as friction.Patil et. al. [1] showed in their paper the technique to minimize the human labour by the application of a screw jack. Tarachand [2] showed the way for getting the optimum efficiency of a screw jack. Author has consulted a lot of text books like [3-14] and extracted some data for research purposes.Hashiguchi et.al.[15] gave the theory of unconventional friction.Kartal [16] gives the idea of tensional contact between elastically similar flat-ended cylinders. Eriten et. al.[17] explained the behavior of flat rough surfaces. Kostas et.al [18] described the coefficient of friction between the inter particles. Chiew et .al[19] explained the friction model identification. Piatkowski et.al.[20] explained dynamic friction models. Kostas [21] developed micro mechanical inter particle loading apparatus. Dong et.al.[22] worked on wear reduction model. Deepak et. al. [23] showed the effect of roughness on coefficient of friction. Cura et. al.[24] gave the wear formulation approach. Saha et.al.[25] presented modified friction model. Aita et.al. [26] worked on nonlinear friction models. Putelat et. al.[27] presented work on frictional waves and Tsampras et al[28] presented an experimental study of friction devices and rubber bearings. Table-1 shows the values of co-efficient of friction for different surfaces. Force of friction (static and kinetic) is proportional to normal reaction, dependent on type and condition of contact surfaces and independent of contact area. The apparatus (shown in Figure-1) consists of a wooden plane having adjustment for setting the required angle precisely with graduated arc and vertical scale is provided. A frictionless pulley is attached to the end by means of clamp adjustable to any necessary position. Apparatus is supplied with a wheeled trolley and a set of slide draws having bottom of different materials, string and pan. When a body slides upon another body, the property b virtue of which the motion on one body relative to another is retarded is known as friction. The frictional force is directionally proportional to the normal reaction 'N', i.e. $F \alpha N$ or $F = \mu N$ or $\mu = F / N$. Suppose, a body of weight W is to be lifted by an inclined plane with an effort (P) When load just moves upwards, a frictional force F acts downwards which opposes its motion. Now, for equilibrium (see Figure-3), F = P – W sin α and N = W cos α. Therefore,

$$\mu = \frac{F}{N} = \frac{P - W\sin\alpha}{W\cos\alpha}$$

Mechanical advantage $(M.A) = \frac{W}{P}$

Velocity ratio $(V.R) = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$

Let effort P comes down through one centimetre, movement of the load along the plane = 1 cm

Vertical uplift of load $= 1 \times \sin\alpha$

$$V.R. = \frac{1}{1 \times \sin\alpha} = \text{cosec}\,\alpha$$

$$\%\ \text{efficiency} = \frac{M.A}{V.R.} \times 100$$

Table-1: Coefficient of friction for various dry surfaces

S.N.	Name of surfaces	Range of coefficient of friction (μ)
1	Metal on Metal	0.15-0.6
2	Metal on wood	0.2-0.6
3	Metal on stone	0.3-0.7
4	Metal on leather	0.3-0.6
5	Stone on stone	0.4-0.7
6	Earth on earth	0.2-1.0
7	Rubber on concrete	0.6-0.9

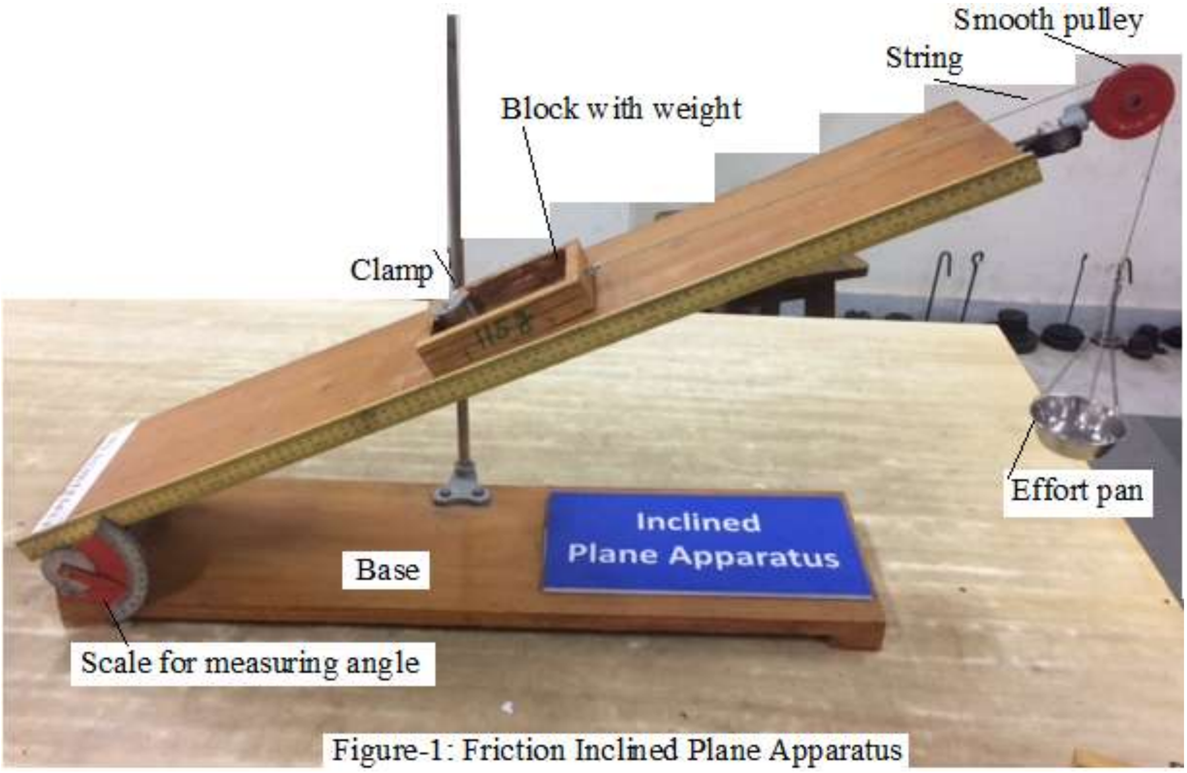

Figure-1: Friction Inclined Plane Apparatus

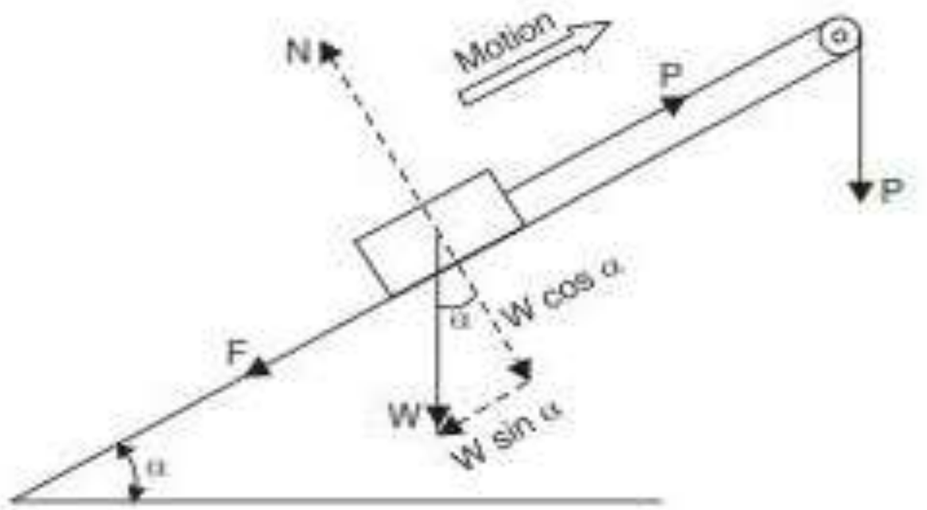

Figure-2: F.B.D. of Inclined Plane Apparatus

2. Notations Used

W = Weight of the block placed on horizontal/inclined surface,
R = N = Normal reaction of the surface,
P = Effort applied to the block,
F = Static force of friction,
Fm = Maximum limiting force of static friction,
Fk = Kinetic force of friction,
μs = Coefficient of static friction,
μk= Coefficient of kinetic friction,
M.A. = Mechanical Advantage = W/P,
V.R.=Velocity Ratio = distance moved by effort/ distance moved by load,
Let effort (P) comes down through 1 centimeter, movement of load along the plane = 1cm,
Vertical uplift of load = 1 * sin α = sin α,
V.R. = 1/ sin α = cosec α,
Efficiency (η) = M.A. / V.R.

3. Methodology

Take the inclined plane apparatus (shown in Figure-1), keep it first horizontal and put the slider on it. Increase the inclination angle of the inclined board gradually till the slider just starts to slide downwards on it. Note the angle in this position. This is known as the angle of repose. Place the slider on the plane with the desired angle α. Tie the slider to the pan with the help of a thread passing over the pulley. Now, put the weights in the pan till the slider just starts moving. Note down the weights. Measures the angles of inclination from the scale provided and determine the value of coefficient of friction. Calculate .M.A., V.R. and efficiency.

4. Observations

Table-2: Coefficient of friction betwee various surfaces using Inclined Plane Apparatus

Type of Surfaces	S.N.	Angle of inclination (α) Degrees	Angle of inclination (α) rad	Total weight of the slider W (gm)	Weight of pan+ weight in the pan P (gm)	F = P-W sin α (gm)	μs = F/W Cos α	Average μs	M.A.= W/P	V.R. = cosec α	Efficiency (η)= M.A./V.R
	0	10	0.175	0	0	0.0	0				
	1	10	0.175	70	40	27.8	0.404		1.8	5.8	30.4
	2	10	0.175	80	45	31.1	0.395		1.8	5.8	30.9
Wood	3	10	0.175	100	50	32.6	0.331		2.0	5.8	34.7
and	4	10	0.175	110	55	35.9	0.331	0.283304	2.0	5.8	34.7
Wood	5	10	0.175	130	60	37.4	0.292		2.2	5.8	37.6
	6	10	0.175	150	65	39.0	0.264		2.3	5.8	40.1
	7	10	0.175	180	72	40.7	0.230		2.5	5.8	43.4
	8	10	0.175	210	80	43.5	0.211		2.6	5.8	45.6
	9	10	0.175	220	82	43.8	0.202		2.7	5.8	46.6
	10	10	0.175	250	86	42.6	0.173		2.9	5.8	50.5
	1	10	0.175	75	25	12.0	0.162		3.0	5.8	52.1
	2	10	0.175	86	25	10.1	0.119		3.4	5.8	59.7
Wood	3	10	0.175	96	30	13.3	0.141		3.2	5.8	55.6
and	4	10	0.175	112	35	15.6	0.141	0.14955	3.2	5.8	55.6
Glass	5	10	0.175	130	45	22.4	0.175		2.9	5.8	50.2
	6	10	0.175	150	50	24.0	0.162		3.0	5.8	52.1
	7	10	0.175	125	40	18.3	0.149		3.1	5.8	54.3
	8	10	0.175	140	45	20.7	0.150		3.1	5.8	54.0
	9	10	0.175	170	55	25.5	0.152		3.1	5.8	53.7
	10	10	0.175	190	60	27.0	0.144		3.2	5.8	55.0
	1	10	0.175	75	45	32.0	0.433		1.7	5.8	28.9
	2	10	0.175	86	50	35.1	0.414		1.7	5.8	29.9
Wood	3	10	0.175	96	55	38.3	0.405	0.3221	1.7	5.8	30.3
and	4	10	0.175	112	60	40.6	0.368		1.9	5.8	32.4
Leather	5	10	0.175	130	65	42.4	0.331		2.0	5.8	34.7
	6	10	0.175	150	70	44.0	0.298		2.1	5.8	37.2
	7	10	0.175	125	50	28.3	0.230		2.5	5.8	43.4
	8	10	0.175	140	55	30.7	0.223		2.5	5.8	44.2
	9	10	0.175	170	70	40.5	0.242		2.4	5.8	42.2
	10	10	0.175	190	85	52.0	0.278		2.2	5.8	38.8

5. Results and Discussion

The final results are listed in Table-3. We see that all the results are within limits.Figure-3 shows the relationship between friction force F and effort P which is a straight line. The slope of this graph gives the coefficient of friction.

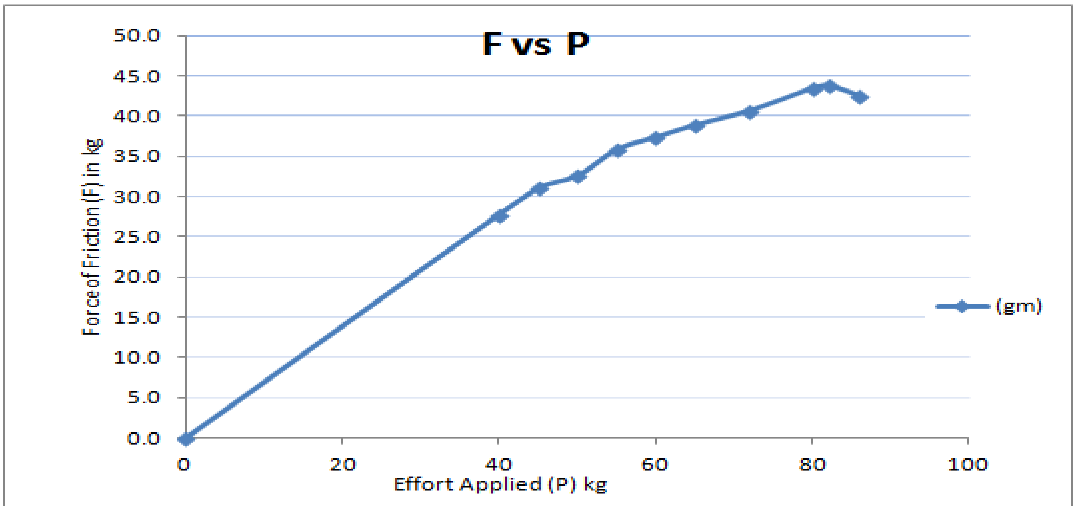

Figure-3: Graph showing Friction force (F) against Effort (P) between Wood and Wood surfaces

Table-3: Results and Discussion

S.N.	Name of property	Wood-wood	Wood-glass	Wood-leather
1	Average coefficient of friction	0.28	0.15	0.322
2	Average Mechanical	2.225	3.122	2.085
3	Average Velocity Ratio (V.R.)	5.758	5.758	5.758
4	Average Efficiency (η)	38.65	54.22	36.21
5	Friction Loss(1- η)	0.716	0.85	0.678

6. Conclusion

From Table-3, we see that the coefficient of friction between wood and leather surfaces are higher than between the wood-wood and wood and glass surfaces. We should take care that Pulley should be frictionless and any knot in the string should be avoided . Weight in the pan must be placed gently and keep string parallel to the smooth and cleaned inclined plane.

Sufficient lubrication must be done on the pulley to optimize the friction.

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