Experimental Study on Velocity Ratio and Mechanical Efficiency of Differential Wheel and Axle Mechanisms

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Abstract: A basic yet complex simple machine with applications in many mechanical systems is the differential wheel and axle. The purpose of this study is to investigate and evaluate the differential wheel and axle's mechanical advantage and velocity ratio. To understand its functioning properties, the study combines mathematical derivations, theoretical analysis, and practical considerations. Through examining these variables, this study advances our knowledge of the machine's effectiveness and possible uses in many technical domains.

Index Terms: Differential Wheel, Axle Mechanisms, velocity ratio

1. Introduction:

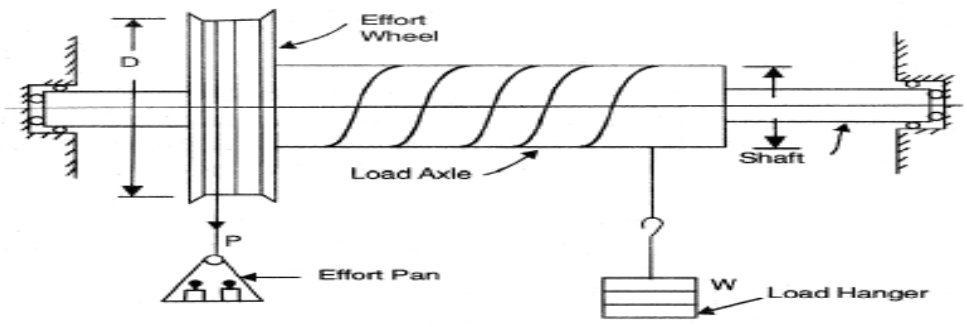
Utilizing the concepts of rotational motion, the differential wheel and axle is a crucial mechanical device that transmits torque and generates mechanical advantage. Its design consists of two wheels with different diameters joined by an axle in common. Because of this configuration, rotational force can be transferred between the wheels, resulting in differences in mechanical advantage and velocity ratio. A machine's mechanical advantage is the force that is produced by using the machine multiplied by the applied input force. Concurrently, the velocity ratio establishes the angular velocity ratio between the larger and smaller wheels, influencing rotational speed at the price of increased force.

This research delves into the comprehensive analysis of the Differential Wheel and Axle's mechanical advantage and velocity ratio. The investigation involves theoretical formulations, mathematical expressions, and practical considerations to evaluate these essential parameters

2. Main Body:

2.1 Theoretical Framework:

Differential axle and wheel : It is different from simple axle and wheel machine because of its axle configuration.Instead of prismatic single axle in simple wheel and axle ,step down axles are used in differential axle and wheel.This machine has a better mechanical advantage as compared to single axle and wheel.Two axle of different diameters are coaxially fitted with spindle,with which wheel is also coaxially attached.The effort is applied through wrapped string around this wheel.Another string is wound over two axles and carries load with help of movable pulley.The rope on the wheel and similar axle are wound in the same direction,where as that on the larger axle is in opposite direction .When an effort is applied through the wheel,The rope on the wheel and similar axle gets unwound but gets wound on the larger axle,thus lifting the load.



2.2 Mechanical Advantage Analysis:

The Mechanical Advantage of a simple machine is expressed as It is ratio of load to effort applied.The mechanical advantage of the Differential Wheel and Axle is calculated by comparing the input force exerted on the larger wheel to the output force acquired on the smaller wheel.

Mechanical Advantage = Load / Effort

It has no unit as Load and Effort has the same unit and due to ratio it cancels.

2.3 Velocity Ratio Analysis:

The velocity ratio is defined as It is ratio of distance traveled by effort to distance traveled by load.The velocity ratio in the Differential Wheel and Axle signifies the ratio of angular velocities between the larger and smaller wheels. It determines the trade-off between force amplification and rotational speed.

Velocity ratio = Distance Moved by Effort / Distance Moved by Load

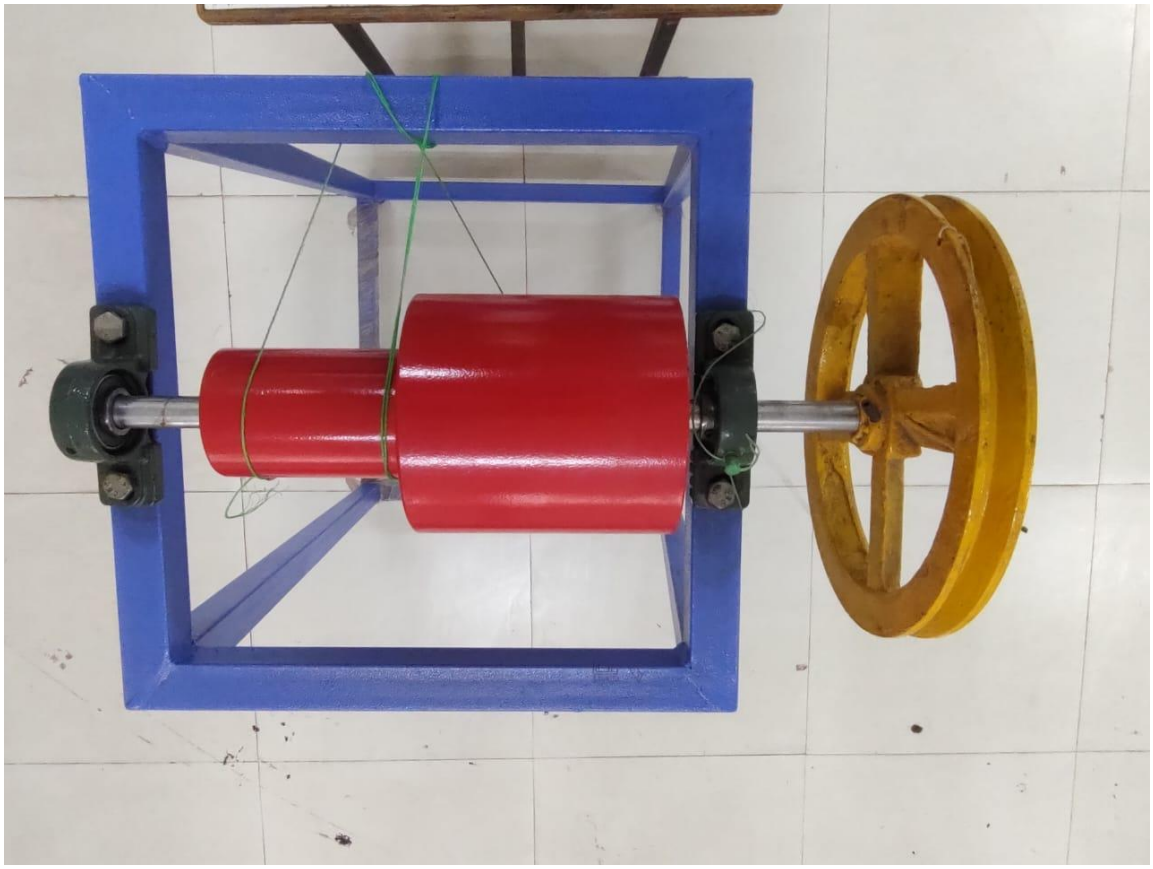
Velocity ratio = 2D/(d1-d2)

D = Diameter of Effort Wheel

d1=Diameter of larger Axle d2 = Diameter of smaller axle

Velocity ratio also has no unit.

Experimental Setup :



Observations and Calculations:

Effort Wheel Diameter D = 23..22 cm Larger Diameter d1 = 14.33 cm smaller Diameter d2 = 7.96 cm

Velocity ratio = 2D/(d1-d2)

V.R = (2 * 23.22)/(14.33-7.96)

V.R = 7.29

Observation Table:

S.R NO	LOAD W (N)	EFFORT P(N)	MECHANICAL ADVANTAGE	VELOCITY RATIO	EFFICIENCY (%)	IDEAL EFFORT Pi(N)	EFFORT LOST IN FRICTION Pf(N)
1	981	192	5.10	7.29	69.35	134.59	57.41
2	1471.5	388	3.19		51.98	201.85	186.15
3	1962	420	4.67		64.06	269.13	150.87
4	2452.5	1490	5		68.58	336.41	153.69
5	2943	8862	4.28		58.71	403.70	282.5

Results:
The average efficiency of Differential wheel and Axle is 62.53 %

The Average Effort lost in Friction Pf is 166.124 N

Conclusion:

Mechanical efficiency, which accounts for the effectiveness of the machine in transmitting force without dissipation, is compromised by inherent friction within the system.

Frictional forces at the wheel and axle interfaces result in energy dissipation, leading to a loss of mechanical advantage and a decrease in overall efficiency.

Addressing frictional losses, can enhance the overall effectiveness of these machines, ensuring better utilization of input energy and reducing unnecessary wear and tear, thus optimizing their functionality in various applications.

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