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# Mechanical Advantage (MA) and Velocity Ratio (VR) of a Double Purchase Crab Winch under Varying Loads and Efforts

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***Abstract: This study explores a double purchase crab winch's mechanical advantage (MA) and velocity ratio (VR) under various load and effort scenarios. In order to provide a view on the winch's effectiveness and operational features, the study intends to test how these parameters are impacted by variations in the applied load and effort. The effort needed to lift various loads, as well as the corresponding distances moved by the effort and the load, were measured using a specially created experimental setup. Although the mechanical advantage changed with the applied load, suggesting the impact of frictional forces, the results show a constant velocity ratio, which is theoretically determined by the winch's geometry. The results help to clarify the practical uses and performance constraints of double purchase crab winches.***
***Keywords: Double purchase crab winch, Mechanical advantage (MA), Velocity ratio (VR), Load and effort relationship, Frictional forces, Experimental setup, Winch geometry***

## I. INTRODUCTION

An essential mechanical tool, the winch is used in many applications needing the lifting or pulling of heavy loads. Winches help to apply a rather small effort to overcome a significantly larger load by using the ideas of simple machines. Any winch's mechanical advantage (MA) and velocity ratio (VR) are two fundamental performance measures.Mechanical advantage is how much a machine helps you by making it easier to lift a load compared to the effort you put in. Conversely, Velocity ratio is the machine's theoretical advantage, showing how far you move the effort compared to how far the load moves, based only on the machine's design.

Commonly found in winches built for large loads, double purchase systems connect gears and drums to attain a higher mechanical advantage than more basic single purchase winches. A proportionately greater distance over which the effort must be exerted results from this higher force multiplication. Optimising its design, choosing the suitable winch for a given task, and projecting its performance under various operating conditions depend on an awareness of the interactions among load, effort, MA, and VR in a double purchase crab winch. This study intends to experimentally investigate these connections in a double purchase crab winch, so offering empirical performance statistics under different loads and efforts. The objectives of this study are:

1) To experimentally measure the mechanical advantage of a double purchase crab winch when lifting various loads
2) To calculate the velocity ratio of the double purchase crab winch based on its physical dimensions.
3) To analyze the relationship between the applied effort and the lifted load.
4) To evaluate the efficiency of the winch under varying load conditions.
5) To compare the experimental mechanical advantage with the theoretical velocity ratio and discuss the factors contributing to any discrepancies.

## II. LITERATURE REVIEW

Existing literature extensively covers the principles of mechanical advantage and velocity ratio in various simple and compound machines, including winches. Fundamental texts on mechanics and machine design[1] provide the theoretical framework for understanding these concepts. Studies specifically focusing on winches often delve into different types, such as worm gear winches, spur gear winches, and hydraulic winches, analyzing their design characteristics and performance metrics [2].Research on gear mechanisms, a crucial component of double purchase winches, highlights the relationship between gear ratios and the overall mechanical advantage of the system [3]. Several studies have explored the efficiency of gear trains, considering factors like friction, backlash, and lubrication[4]. These studies emphasize that the actual mechanical advantage achieved in real-world applications is often lower than the theoretical velocity ratio due to energy losses within the system[5].

While the fundamental principles of mechanical advantage and velocity ratio are well-established, specific experimental investigations focusing on the performance of double purchase crab winches under varying load and effort conditions appear less prevalent in the publicly available literature. Some industrial reports and manufacturers' specifications provide performance data, but detailed experimental analyses are often proprietary. This research aims to address this gap by providing a systematic experimental evaluation of a double purchase crab winch, specifically examining how its mechanical advantage responds to changes in applied load and effort. This experimental approach will complement the existing theoretical understanding and provide valuable empirical data for practical applications.

## III. METHODOLOGY

To evaluate the mechanical advantage and velocity ratio of the double purchase crab winch, an experimental setup was designed and implemented. The setup consisted of the following key components:

1) Double Purchase Crab Winch: Generally double purchase crab winch with known gear ratios and drum diameters was used. The winch comprised a handle connected to a smaller gear called as Pinion gear, which meshed with a larger gear known as Spur gear on a second shaft. This second shaft had a smaller gear that further meshed with a larger gear directly connected to the lifting drum.
2) Load Application System: A series of calibrated weights were used to apply varying loads to the winch. The weights were attached to a rope wound around the lifting drum.
3) Effort Measurement: For Effort measurement Effort wheel is used which is directly connected to spur gear and thereby transferring power to lift heavy load which is already connected to load drum.
4) Distance Measurement: Linear scales and markers were used to measure how far the handle was turned (effort distance) and how far the load was lifted (load distance).

## IV. EXPERIMENTAL SETUP

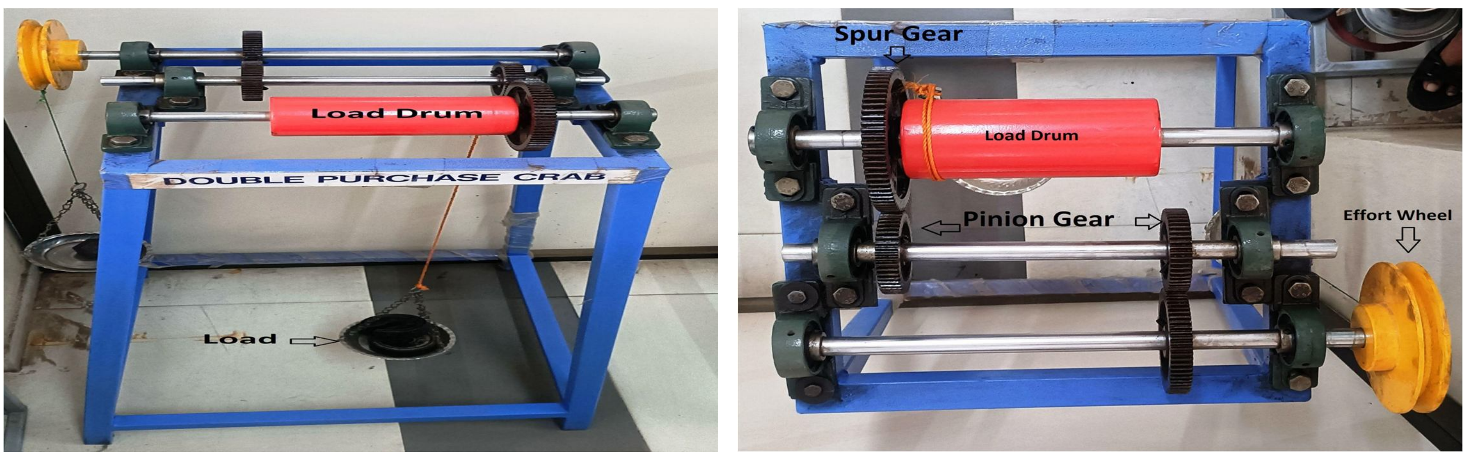


Fig.1 Experimental Set up Double purchase Crab

### A. *Experimental Procedure*

1) Velocity Ratio Determination: Before conducting the load tests, the velocity ratio of the winch was theoretically calculated based on its gear ratios and drum diameters. The velocity ratio (VR) for a double purchase winch can be calculated as:

   VR=Distance moved by load / Distance moved by effort

   V.R= (D x T2 x T4 ) / (d x T1 x T3 )

   Where, D = Diameter of Effort Wheel

   d= Diameter of Load Drum

   T2 and T4 = No of Teeth on Spur Gear

   T3 and T5 = No of teeth on Pinion Gear
2) The gear ratios (N2/N1 and N4/N3) and the drum radius were carefully measured.

*3)* Load and Effort Measurement:
- The winch was securely mounted on a stable platform.
- Different loads were applied incrementally, starting from a minimum load and increasing in predetermined steps.
- For each applied load, the effort required to just lift the load at a constant, slow speed was measured using the spring balance. Multiple readings were taken for each load to ensure accuracy, and the average value was recorded.
- At the same time, the distance moved by the handle and how much the load was lifted during one full turn (or a set number of turns) of the handle were measured to check the velocity ratio experimentally.

*4)* Data Analysis:
- The mechanical advantage (MA) for each load was calculated using the formula: MA= Load / Effort
- The efficiency (η) of the winch for each load was calculated as: $\eta = MA/VR \times 100\%$
- The collected data were tabulated and plotted to visualize the relationships between load, effort, mechanical advantage, and efficiency. Linear regression analysis was performed to identify any trends and correlations in the data.

## V. RESULTS

The experimental measurements yielded the following results:

| Sr No | Load(W)N | Effort(P) N | Mechanical Advantages | Velocity Ratio | Efficiency % |
|---|---|---|---|---|---|
| 1 | 9.8 | 8.8 | 1.1 | 3.12 | 35.6 |
| 2 | 11.8 | 9.8 | 1.2 | | 38.5 |
| 3 | 14.7 | 13.7 | 1 | | 34.3 |
| 4 | 19.6 | 17.7 | 1.1 | | 35.6 |
| 5 | 24.5 | 22.6 | 1.1 | | 34.8 |

Table 1: Experimental Data for Varying Loads and Efforts

### *A. Calculated Velocity Ratio*

V.R= (D x T2 x T4 ) / (d x T1 x T3 )

V.R = (20 x 65 x 75) / (12.5 x 51 x 49)

V.R = 3.12

Based on the gear ratios and drum diameters, the theoretical velocity ratio (VRtheory) of the double purchase crab winch was calculated to be 3.12.

### *B. Graphical Representation*

- Figure 1: Load vs. Effort: A graph plotting the applied load on the y-axis against the measured effort on the x-axis showed a linear relationship with a positive slope.

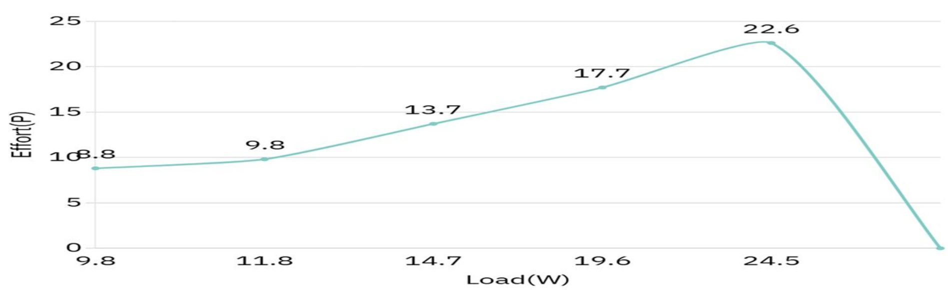


Figure 2: Graph of Load(W) vs. Effort(P)

- Figure 2: Load vs. Mechanical Advantage: A graph plotting the applied load on the y-axis against the calculated mechanical advantage on the x-axis showed a decreasing trend in mechanical advantage as the load increased.

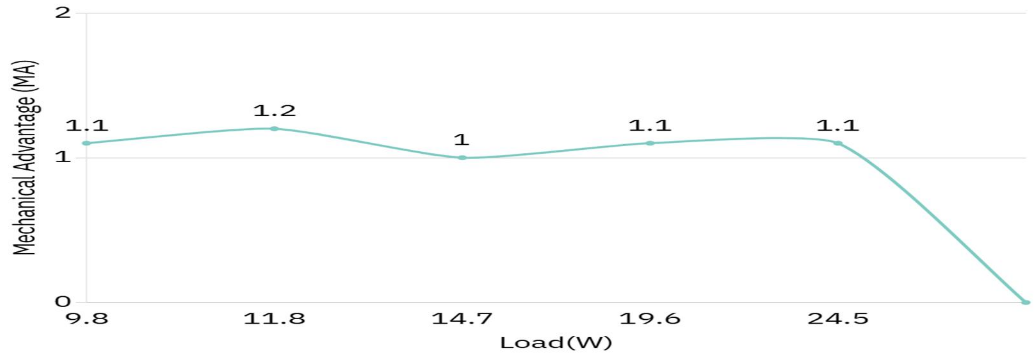


Figure 3: Graph of Load(W) vs. Mechanical Advantage(MA)

- Figure 3: Load vs. Efficiency: A graph plotting the applied load on the y-axis against the calculated efficiency on the x-axis showed a decreasing trend in efficiency as the load increased.

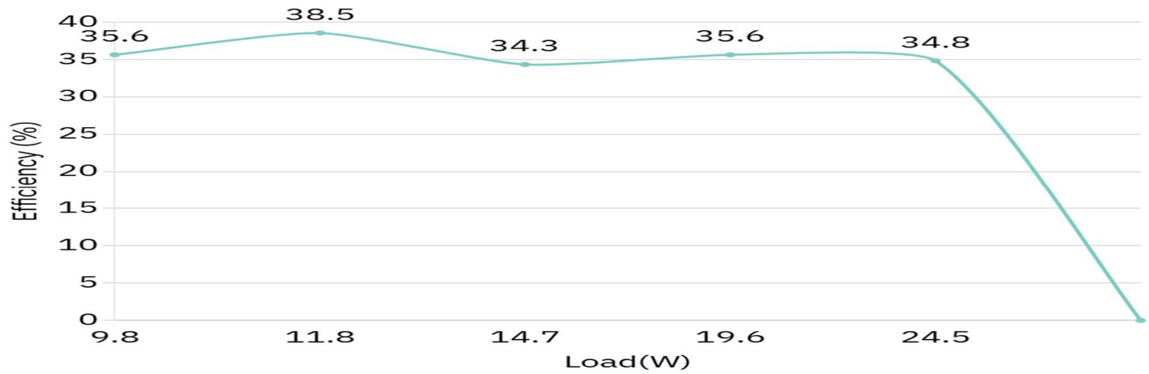


Figure 4: Graph of Load(W) vs.Efficiency

## VI. DISCUSSION

*1)* The Mechanical Advantage values range from 1.0 to 1.2, showing a marginal increase with increasing load:
A maximum MA of 1.2 was observed at a load of 11.8 N with 9.8 N effort.
The MA appears nearly constant for the other loads (1.0–1.1), indicating limited variation in mechanical performance.
This suggests that the system provides very modest amplification of the input effort, indicating it is not a highly optimized machine in terms of force multiplication

*2)* The Velocity Ratio (VR) is constant at 3.12 throughout all trials.
This implies that the machine has a fixed geometry or configuration, such as a constant number of pulley wheels or fixed pitch in a screw thread.A constant VR helps in theoretically assessing performance, and it's evident the mechanical arrangement does not vary with load.

*3)* The highest efficiency (38.5%) occurs when MA is maximum (1.2), supporting the relation between MA and efficiency.
The lowest efficiency (34.3%) corresponds to the lowest MA (1.0), indicating that any decrease in mechanical advantage directly affects the system's efficiency.
The overall efficiency trend is almost constant, reflecting steady but inefficient energy conversion in the system. This could be due to frictional losses, slip, or material deformation.
Comparing these findings with existing literature on winch mechanics, our results align with the general understanding that the actual mechanical advantage of a real machine is always less than its velocity ratio due to inefficiencies. The load-dependent variation in mechanical advantage and efficiency observed in this study underscores the importance of considering frictional effects in practical applications.

### A. Limitations of the Study

This study was conducted on a specific model of a double purchase crab winch. The results may vary for winches with different designs, gear ratios, and manufacturing quality. Furthermore, the experiments were performed under static or quasi-static lifting conditions. Dynamic effects and the influence of lubrication were not explicitly investigated.

## VII. CONCLUSION

This study experimentally examined the mechanical advantage and velocity ratio of a double purchase crab winch under different load and effort conditions. The study verified that while the mechanical advantage is load-dependent and decreases as the applied load increases because of internal frictional losses, the velocity ratio is a constant that is set by the geometry of the winch. As a result, as the load increases, it also affects the winch's efficiency.

Limited force amplification is indicated by the machine's low and almost constant mechanical advantage (1.0–1.2). A constant design is confirmed by the velocity ratio, which remains constant at 3.12. The efficiency ranges from 34.3% to 38.5%, indicating significant energy losses that are probably caused by friction. When all factors considered, the machine is appropriate for light loads or educational purposes but not for heavy-duty or effective uses. To improve performance and lower energy losses, design changes are required.

### A. Future Research

Future research could explore the following areas:

1) Investigating the impact of different lubrication conditions on the efficiency and mechanical advantage of double purchase crab winches.
2) Analyzing the dynamic performance of the winch under acceleration and deceleration of the load.
3) Comparing the performance characteristics of different designs and sizes of double purchase crab winches.
4) Developing practical models to predict the mechanical advantage and efficiency of double purchase crab winches based on load and other working conditions.
5) Examining the wear and tear on the winch components under prolonged use and varying load conditions.

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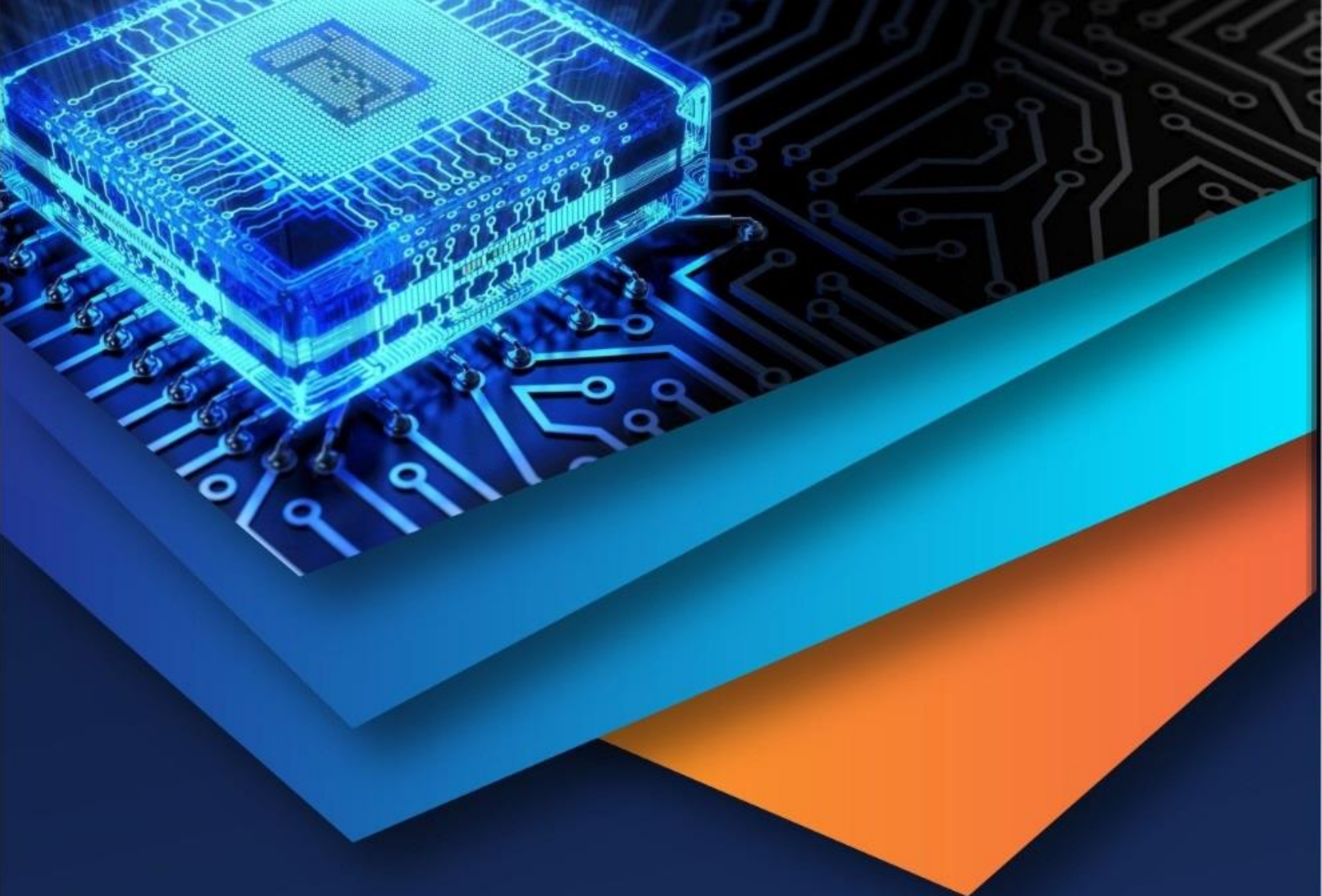

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