Effect of Load Cell Load Calibration on Electric Wheelchair

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ABSTRACT
This study aims to analyze the effect of load cell calibration on the response of electric wheelchairs in responding to changes in the user's body position. Load cells, as the main component in measuring loads, have a crucial role in ensuring the operation of electric wheelchairs is effective and safe. This study explores how proper calibration can affect the wheelchair's ability to adjust to changes in load that occur due to variations in the user's body position and weight. In addition, this study also identifies the effect of load cell measurement accuracy on the effectiveness and comfort of electric wheelchair operation. The results show that proper load calibration improves the responsiveness of the wheelchair to user commands, ensures load stability, and improves comfort in wheelchair use. Decreased load cell measurement accuracy can cause inaccuracy in operation, which has an impact on reducing the quality of user mobility. Based on these findings, it can be concluded that accurate and regular load cell calibration is essential to improve the effectiveness and safety of electric wheelchair use.

Keywords: Load calibration, load cell, electric wheelchair, movement response, effective operation.

Introduction

Mobility is a basic need for every individual to be active independently. However, for some people, especially people with physical disabilities or patients who have suffered severe injuries, the ability to move independently can be very limited. In this situation, a wheelchair becomes a very important aid. A wheelchair allows individuals to maintain mobility, even though it is limited, in order to carry out daily activities such as working, interacting socially, or simply moving around the house. According to data from the Central Statistics Agency (BPS), the number of people with physical disabilities in Indonesia is estimated to reach 3.01 million people. A figure that illustrates the high need for effective and efficient mobility aids in the country.

However, the use of manual wheelchairs still requires the power of the user or the help of others to operate it, especially for individuals who experience total paralysis or difficulty moving their bodies. This dependence can reduce their independence and pose challenges in living their daily lives. Along with the development of technology, innovations in the field of mobility aids, especially electric wheelchairs, continue to be developed to answer this challenge. Electric wheelchairs allow users to be more independent, because they no longer need external assistance to move. However, more sophisticated innovations are needed so that electric wheelchairs can function more intuitively and responsively to user needs.

One of the latest innovations that has been introduced is an electric wheelchair control system that uses a load cell sensor. A load cell is a sensor designed to detect changes in weight or pressure, which is then translated into an electronic signal to move the wheelchair. In electric wheelchair applications, load cells can be used to detect changes in the user's body position, such as when they lean forward, backward, left, or right. With this system, the wheelchair can move automatically according to the direction of the user's body movement. For example, when the user leans forward, the wheelchair will move forward, while if the user leans to the left, the wheelchair will turn to the left, and so on. This system allows users to control the wheelchair in a more natural and simple way, thereby increasing their autonomy in moving.

While this innovation promises to be a major advancement in mobility aid technology, there are still a number of challenges that need to be overcome to optimize the performance of these load cell-based electric wheelchairs. One of the main challenges is the calibration of the load cell. Proper calibration is essential to ensure that the sensor can provide an accurate response to changes in the user's body position. Factors such as the user's weight, load distribution, and sensor sensitivity can affect the accuracy of the wheelchair control system. For example, users with different body weights may provide different pressure signals to the load cell sensor, which can affect the wheelchair's response.

In this context, research on the effect of load calibration on load cells becomes very relevant. Improper calibration can cause the wheelchair to not respond properly to user movements, which in turn can reduce the effectiveness of this assistive device. Therefore, this study aims to analyze the effect of load calibration on load cells on the ability of electric wheelchairs to respond to user weight. A deeper understanding of the relationship between load calibration and load cell performance is expected to provide a significant contribution to the development of more responsive electric wheelchairs that are in accordance with the needs of various types of users.

With the results of this study, it is hoped that a more optimal electric wheelchair design can be obtained, which not only increases the independence of people with disabilities in carrying out their daily lives, but also improves their overall quality of life. This research also has the potential to pave the way for further development in wheelchair technology that can be adjusted to the various needs of users, including those with very diverse physical conditions.

Formulation of the problem:

1) How does load cell calibration affect the response of an electric wheelchair in responding to changes in the user's body position?
2) Does the user's weight affect the load cell's ability to control an electric wheelchair?
3) To what extent does the accuracy of load cell measurements affect the effectiveness of electric wheelchair operation?

Literature Review

A. Electric wheelchair

Electric wheelchairs are a very important mobility aid for individuals with special needs. Along with the development of technology, electric wheelchairs are now equipped with various sensors and systems that can improve comfort, safety, and effectiveness of their use. One important component in an electric wheelchair is the load cell, which is used to measure the load received by the wheelchair, such as the user's body weight. Proper calibration of the load cell is important so that the system can provide accurate and reliable results.

Figure 1. Electric Wheelchair

B. Load Cell and Functions on Electric Wheelchairs
A load cell is a sensor used to measure force or load by converting the force into a measurable electrical signal. In electric wheelchairs, load cells function to monitor the user's weight, detect load distribution, and provide important information used to regulate motor performance, adjust seat position, and improve user comfort. Load cells are commonly used to measure force in a variety of applications, including industry, healthcare, and transportation.

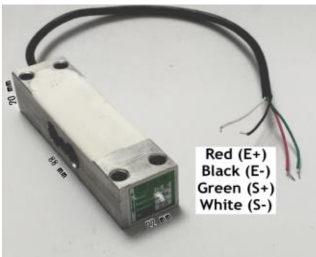

Figure 2. Load Cell Sensor

C. Load Cell Calibration
Load cell calibration is the process of ensuring that the sensor provides accurate readings and corresponds to the load value received. This process involves comparing the load cell readings to a known reference load value. Poor calibration can result in inaccurate readings, which can affect the performance of the electric wheelchair, such as inaccurate detection of the user's weight or inability to adjust the motor speed efficiently. Several previous studies have shown that the accuracy of calibration can affect the measurement results in various applications. For example, in a weight measurement system, poor calibration can cause inaccuracies that affect the quality of data used by the system. Therefore, proper calibration is essential to obtain valid data that can be used to improve the performance of the electric wheelchair.

Figure 3. Load Cell Calibration

D. Effect of Calibration on Electric Wheelchair Performance

Proper load cell calibration can significantly improve the performance of an electric wheelchair. For example, accurate load measurements allow the wheelchair to adjust motor power and load distribution, which in turn can improve energy efficiency and battery life. Poor calibration can cause the wheelchair to fail to properly detect changes in load, which can result in suboptimal energy use and reduced battery life. Additionally, proper calibration is also critical to improving user comfort. Electric wheelchairs often come with suspension systems or adjustable seats, and accurate load measurements allow for better automatic adjustments to the user's comfort.

E. Calibration Method on Load Cell

Various calibration methods are used to ensure the accuracy of the load cell. One commonly used method is calibration using a known load standard, where the measurement value of the load cell is compared with a given standard load value. In addition, calibration can also be done using a certain calibration factor calculated based on experiments or laboratory tests. Research by Zhang et al. (2018) showed that the use of more varied load standards in calibration can improve the measurement accuracy of the load cell. In the case of electric wheelchairs, this can ensure that the sensor can measure the load properly, regardless of various factors such as the user's sitting position or load distribution.

F. Challenges in Load Cell Calibration on Electric Wheelchairs

Some challenges in calibrating load cells on electric wheelchairs include external factors that can affect measurement accuracy, such as changes in temperature, humidity, or even mechanical damage to wheelchair components. In addition, uneven load distribution or varying user positions can cause errors in measurements that need to be taken into account during calibration. Research by Saito et al. (2016) suggests the use of adaptive calibration techniques that can adjust for these external factors and provide more stable measurement results.

Research Method

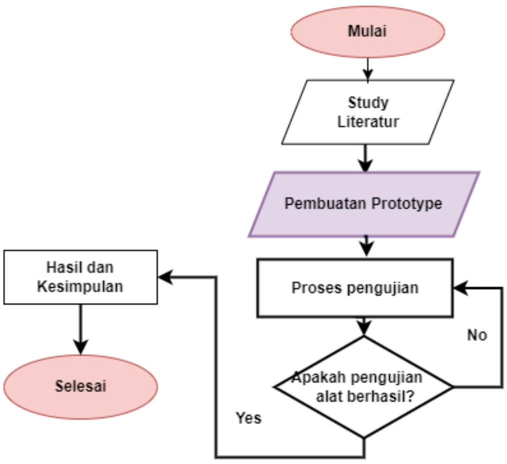

Figure 4. Flowchart

The following is a flowchart description:

1) Start: The starting point of the process.

2) Literature Study: Conducting research and reviewing relevant literature to understand theoretical background or gather information.
3) Prototyping: Designing and developing a prototype based on literature studies and the problems encountered.
4) Process: Testing or analyzing prototypes through experiments or practical applications.
5) Was the Tool Testing Successful? Decision Point:
6) If "Yes", proceed to Results and Conclusions.
7) If "No", go back to "Prototyping" to refine the design or approach.
8) Results and Conclusions: Based on successful testing, analyze the data and summarize the results.
9) Done: The process ends here.

This flow shows the process of developing and testing the tool, from research to final conclusions.

Results and Discussion

1. Analysis of Voltage (V), Current (I), and Power (Watt)

Voltage (V): The initial charging voltage started at 12.15 V at 05:40 and increased gradually to a peak value of 14.24 V at 09:00. This increase in voltage reflects the normal charging process, where the voltage approaches the maximum value of the battery as the battery capacity becomes fuller.

Current (I): The initial charging current was 11.46 A at 05.40, then slowly decreased to 9.37 A at the end of charging (10.00). The decrease in current during charging is an indication that the battery is starting to reach its full capacity, in accordance with the characteristics of the battery charger which adjusts the current based on the battery power requirements.

Power (Watts): The average power during the charging process ranges from 130.6 W to 143.1 W. This power value is quite stable, which shows the efficiency of the battery charger in providing energy to the battery consistently throughout the charging process.

Table 1. Test Results for Battery Charging Time with Battery Charger

Time	Voltage (V)	Current (I)	Power (Watts)	Energy (Wh)	Percentage (%)
05.40	12.15	11.46	139.2	32.4	0%
06.00	12.72	11.02	141.1	55.2	15.98%
07.00	13.30	10.57	139.2	100.3	25.08%
08.00	13.83	10.34	143.1	246.2	50.39%
09.00	14.24	9.64	136.9	354.1	75.87%
10.00	13.94	9.37	130.6	411.8	100%

a. Capacity Analysis (Wh) and Percentage of Filling

Energy Stored (Wh): Total energy stored during charging increased from 32.4 Wh at the start of charging to 411.8 Wh at full capacity. This increase is in line with expectations, with initial charging showing a faster charging rate, and slowing down as it approaches full capacity.

Fill Percentage (%): In the test table, the filling percentage increases gradually:

a. In the first hour, the battery capacity rose from 0% to 25.08%.
b. At 08.00, capacity reached 50.39%.
c. At 10:00, the battery reached 100% with a total charging time of 4 hours and 20 minutes.

Faster charging times in the early phase are a result of the power being efficiently absorbed by the discharged battery. The charging phase slows down towards the end of the process as the battery reduces the rate of power absorption to prevent overcharging.

b. **Efficiency and Practicality of Charging**

Charging with a battery charger shows time efficiency and practicality, especially as a backup option at night. In less than 5 hours, the battery can be fully charged, making it a fairly reliable solution for emergency needs.
However, it should be noted that using a battery charger as the primary charging method requires monitoring parameters such as maximum voltage to avoid battery damage. In addition, charging too often with a battery charger can affect the battery's lifespan if the charging process does not comply with the manufacturer's recommendations.

Charging the battery using a battery charger is very suitable for emergency needs, but users need to ensure that the charging process is carried out with monitoring of important parameters such as voltage and current. For regular charging, it is recommended to use a special charger with an automatic feature that can cut off the power flow when the battery is full to extend the battery life. Monitoring the charging time, power efficiency, and battery temperature during charging is also important to maintain battery performance in the long term. Thus, charging the battery using a battery charger can be a practical and effective solution, especially for emergency conditions, as long as it is carried out with the appropriate procedure.

2. **DC Motor Testing on Electric Wheelchairs**

Based on the tests conducted on the electric wheelchair DC motor, the analysis of motor performance in terms of speed, input power, and distance traveled at various loads shows a direct relationship between the applied load and the wheelchair performance. The following is a discussion of the test results:

a. Effect of Load on Speed

No Load (0 kg): The wheelchair speed reaches 0.90 m/s or 3.2 km/h with an input power of 160.4 Watts. This shows the optimal performance of the motor without external load constraints.

Load 70 kg: Speed decreases to 0.44 m/s or 1.6 km/h with an input power of 143.6 Watts. This decrease is reasonable considering the load that increases the resistance on the motor, so the motor works harder to move the wheelchair.

Maximum Load (80 kg and above): At loads of 80 kg and 100 kg, the wheelchair cannot move. This indicates the limit of the DC motor's ability to produce torque to overcome resistance that exceeds its maximum capacity.

Table 2. DC motor test results

No.	Load (Kg)	Distance (m)	Time (seconds)	Speed (m/s)	Power (in) (Watt)
1	0	10	11.09	0.90	160.4
2	53	10	15.37	0.69	158.9
3	65	10	19.16	0.52	149.6

4	70	10	22.28	0.44	143.6
5	80	10	0	0	0
6	100	10	0	0	0

b. Relationship between Input Power and Load

The input power to the motor shows a decreasing trend as the load increases. For example:

a. At a load of 0 kg, the input power reaches 160.4 Watts.
b. At a load of 70 kg, the input power drops to 143.6 Watts.

This decrease in input power is due to the decrease in motor speed as the load increases. With the motor turning slower, the input power requirement is also reduced, even though the torque produced is greater.

c. **Calculation of Distance Traveled**

No Load: At a speed of 0.90 m/s or 3.2 km/h, the wheelchair can travel up to 4 km if driven continuously for 1 hour and 15 minutes. This shows ideal performance for light use. 70 kg load: The speed drops to 0.44 m/s or 1.6 km/h, and the maximum distance traveled drops to 2 km in the same duration. This decrease shows that the efficiency of the motor decreases as the load increases, resulting in greater energy consumption for the same distance.

d. **Implications**

Performance Deterioration with Load: The greater the load applied, the lower the speed and range of the wheelchair. This is due to the increased resistance of the movement which affects the efficiency of the motor. Load Capacity Limit: The maximum operational load of the DC motor is below 80 kg. Using the wheelchair above this capacity will cause the motor to be unable to move, which can damage the motor or the power system. Efficiency and Operating Duration: With a battery capacity that supports operation for 1 hour and 15 minutes, the user must consider the distance traveled according to the load carried to avoid running out of power in the middle of the trip.

Motor Capacity Optimization: To increase lifting capacity, it is necessary to consider using a DC motor with higher torque specifications or a gear system that can increase thrust.

Load Management: It is recommended to limit the load to below 70 kg to maintain the performance and efficiency of the wheelchair.

Battery Upgrades: Increasing battery capacity can extend ride time and range, especially for heavy-duty applications. Additional Testing: Conduct tests on terrain with varying gradients to better understand motor performance in real-world conditions. This testing allows the electric wheelchair to be optimized for users with specific needs, taking into account energy efficiency and operating load limits.

3. Average Speed of Electric Wheelchair.

This test aims to determine the ability of electric wheelchairs to perform mobility in various movement command conditions, both without load and with load. The parameters measured include average speed based on distance traveled and travel time.

Average No-Load Speed: From the test, it is known that the electric wheelchair without load has an average speed of 1.47 m/s in forward condition. This shows the optimal performance of the wheelchair in no-load condition, with fast response time for each movement command (forward, backward, turn right, turn left, and stop).

Average Speed with Load: In the test with a load of 30 kg, the average speed in the forward condition decreased to 0.79 m/s. This decrease is reasonable because the increase in load causes the DC motor to work harder. This result indicates that the load affects the performance of the wheelchair, both in terms of travel time and power efficiency.
This test also proved that the wheelchair remained responsive to movement commands, even with additional loads, thus qualifying for use in real-world conditions.

Tabel 3. Average Speed Electric Wheelchair

No.	Condition	Distance (m)	Travel Time (seconds)	Average Speed (m/sec)
1	No Load (Forward)	5	3.38	1.47
2	With Load 30 kg (Forward)	5	6.28	0.79

Testing can be extended with a wider variety of loads to determine the maximum performance limits of the DC motor. Additional research on battery and motor life under various loads is also recommended to ensure the reliability of the wheelchair in long-term use.

Average Speed of Electric Wheelchair Without Load is Known:

- Distance (s) = 5 meters
- Time (t) = 3.38 seconds

Asked:

- Average velocity (V) in m/s

Solution:

$$V=\frac{s}{t}$$

$$V=\frac{5}{3,38}$$

V= 1.47m/sec

Average Speed of Electric Wheelchair with 30 kg Load is Known:

- Distance (s) = 5 meters
- Time (t) = 6.28 seconds

Asked:

- Average velocity (V) in m/s

Solution:

$$V=\frac{s}{t}$$

$$V=\frac{5}{6,28}$$

V= 0.79m/sec

Average Speed of Electric Wheelchair: This test aims to measure the ability of electric wheelchairs to perform mobility in various movement command conditions, both without load and with load. The parameters measured include average speed based on distance traveled and travel time.

In the no-load test, the electric wheelchair recorded an average speed of 1.47 m/s under forward command conditions. This result shows that the wheelchair has optimal performance under no-load conditions, with fast response times for various movement commands, such as forward, backward, turn right, turn left, and stop.

In contrast, in the test with a load of 30 kg, the average speed of the wheelchair in the forward condition decreased to 0.79 m/s. This decrease is understandable because the increase in load makes the DC motor work harder. This decrease in speed indicates that the additional load significantly affects the performance of the wheelchair, both in terms of travel time and power efficiency.

Nevertheless, the test results show that the wheelchair remains responsive to movement commands, even with additional loads. This ensures that the electric wheelchair meets the criteria for use in real conditions.

To gain a more complete understanding, testing can be expanded to use a larger variety of loads to determine the maximum performance limits of the DC motor. Additional research on battery life and motor performance under various load conditions is also recommended to ensure the reliability of the wheelchair in long-term use.

Conclusion

Based on the discussion above, it can be concluded that the load calibration on the load cell has a very large influence on the response of the electric wheelchair in responding to changes in the user's body position. Proper calibration ensures that the load cell can detect changes in load accurately, allowing the wheelchair to respond quickly and in accordance with user commands.

In addition, the user's weight affects the load cell's ability to control the electric wheelchair. In this case, good calibration can adjust the wheelchair's operation to various body weight variations, which will improve the user's comfort and safety in mobility.

The accuracy of load cell measurements also affects the effectiveness of electric wheelchair operation. Inaccurate or improperly calibrated load cells can cause inaccuracy in operation, which has an impact on reducing wheelchair performance. Therefore, proper calibration and accurate measurements are essential to ensure that electric wheelchairs can function optimally, provide comfort, and support user mobility effectively. Thus, this study emphasizes the importance of load cell calibration and measurement accuracy to improve the effectiveness of electric wheelchair operation and ensure optimal performance for its users.

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