ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP1190

Impact of Nickel Strip Configurations on Resistance and Voltage Drop in Lithium Ion Battery Packs

Vadithiya Adiyya
Research & Development on EV's
Vijayawada, India

Varikuppala Manohar
Research & Development
Hyderabad, India

Abstract:- The impact of nickel strip designs on the resistance and voltage drop in lithium ion battery packs is examined in this study. In a series parallel battery pack configuration, the effectiveness of coated and pure nickel strips is assessed, with particular attention paid to how they influence voltage drop, internal resistance, and overall efficiency. Each of the 24 series and 3 parallel cells that make up the battery pack has an internal resistance of 6 mΩ. Two configurations are analyzed: one utilizing pure nickel strips and another with coated nickel strips. The resistivity, cross sectional area, and length of the material are used to compute the equivalent resistance of the nickel strips for each arrangement. Voltage dips at a load current of 50A are determined to compare the performance of both strip. The study also looks at the voltage drop at key locations in the battery pack, including particular bent strips. The findings show that the coated nickel design displays a larger resistance (0.237Ω) and voltage drop (11.735V) than the pure nickel configuration, which has a lower total resistance (0.048Ω) and voltage drop (2.82V). Evaluation of the voltage drop during charging is also done for charging currents of 6A and 10A, demonstrating that the pure nickel arrangement allows for more efficient charging. One of the main elements affecting battery pack performance is internal resistance, which has a direct impact on the system's voltage drop and overall energy efficiency. The thickness, width, resistivity, and number of parallel strips utilized in this nickel strip material all have a major effect on the battery pack's total resistance. Because of this, the nickel strip design can improve or worsen the pack's power delivery, particularly in high load scenarios.

Keywords:- *Nickel Strips, Lithium-Ion Battery Pack, Internal Resistance, Voltage Drop, Pure Nickel, Coated Nickel, Series-Parallel Configuration, Battery Efficiency, Load Current, Energy Storage, Resistance Calculation, Charging Efficiency, Power Delivery.*

I. INTRODUCTION

This paper aims to shed light on how strip design affects pack performance, especially at high current loads, by analyzing coated and pure nickel strips in different series parallel topologies. Additionally, the study assesses how the number of parallel strips and the parameters of the strips including their length, width, and thickness affect the total internal resistance and corresponding voltage drop across the battery pack. Two different nickel strip configurations pure nickel and coated nickel are assessed in this study. Because of their superior conductivity and longevity, pure nickel strips are frequently utilized.

The design of lithium ion battery packs will be directly impacted by the findings of this study, especially in high power applications where reducing resistance and voltage drop is essential. Battery manufacturers can improve the performance, safety, and longevity of their packs by optimizing the nickel strip design. This is especially important for electric cars, since lower voltage drop can increase driving range and lower heat production, which raises the battery system's overall efficiency [1].

The global demand for efficient and high performance energy storage systems has led to significant advancements in battery technology, particularly for lithium ion batteries (LIBs). These batteries, owing to their high energy density, long cycle life, and efficiency, have become the preferred choice for applications ranging from electric vehicles (EVs) to portable electronics and renewable energy storage [2]. However, as energy demands increase, so does the need to optimize the performance of LIB packs to handle higher currents and deliver stable output. Among the key factors influencing the performance of battery packs is the internal resistance, which directly affects the voltage drop and overall energy efficiency of the system. Nickel strips, which serve as conductors between cells in a battery pack, play a critical role in determining the internal resistance and current distribution across the pack [3].

The configuration and material properties of these nickel strips, such as their thickness, width, resistivity, and the number of strips used in parallel, significantly impact the overall resistance of the battery pack. Consequently, the choice of nickel strip configuration can either enhance or impair the pack's ability to deliver power, especially under high load conditions. As LIB packs are increasingly used in high current applications like electric vehicles, minimizing voltage drop and resistance has become crucial for maintaining optimal performance.

In battery packs, internal resistance is a key factor that influences energy losses, heat generation, and voltage stability during discharge and charging cycles. While much

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP1190

research has focused on cell chemistry and thermal management, the electrical connections between the cells, especially the nickel strips used in series and parallel connections, have received comparatively less attention. Nickel, due to its good conductivity, corrosion resistance, and mechanical strength, is widely used for interconnects in battery packs [4]. However, the resistance introduced by these strips can contribute significantly to the overall internal resistance, leading to energy inefficiencies.

II. REVIEW OF THE LITERATURE

Lithium ion battery packs' performance is heavily impacted by a number of design elements, such as the material selection and intercell connection arrangement. Among them, the excellent conductivity and mechanical qualities of nickel strips make them popular choices for use as conductors between cells. Drawing on recent studies and developments in technology, this review of the literature examines the present level of knowledge about the effects of nickel strip topologies on battery pack resistance and voltage drop.

The properties and performance of nickel strips. Because of its strong mechanical properties, good electrical conductivity, and resistance to corrosion, nickel is frequently utilized in battery interconnects. The electrical characteristics of nickel strips in battery packs have been the subject of several investigations.

Nickel is widely used in battery interconnects due to its favorable electrical conductivity, corrosion resistance, and mechanical strength. Several studies have investigated the electrical properties of nickel strips in battery packs. For instance, Li et al. (2017) explored the resistivity of nickel strips and their impact on the internal resistance of lithium-ion battery packs, finding that thinner strips with higher resistivity contributed to increased voltage drop and energy losses. Similarly, Zhang et al. (2019) studied the effect of nickel strip thickness on resistance and observed that thicker strips reduced resistance but increased the overall weight and cost of the battery pack [5-6].

The configuration of nickel strips in battery packs, including the number of strips used in parallel and their arrangement, plays a crucial role in determining the overall resistance and voltage drop. Research by Park et al. (2018) highlighted that using multiple strips in parallel could effectively reduce the equivalent resistance of the battery pack, thereby minimizing voltage drop and improving power delivery. The study also noted that while increasing the number of parallel strips decreased resistance, it added complexity to the pack design [7].

Coated nickel strips have been explored as an alternative to pure nickel strips for reducing resistance and enhancing performance. Wu et al. (2020) examined the impact of coating materials on nickel strips and found that coatings could significantly lower resistivity and improve corrosion resistance, leading to reduced voltage drop across the battery pack. Their study demonstrated that coated strips provided better performance under high-current conditions compared to pure nickel strips [8].

The analysis of internal resistance and voltage drop in battery packs has been extensively studied. Liu et al. (2021) conducted a detailed analysis of voltage drop in lithium-ion battery packs, focusing on the contributions of cell resistance and interconnect resistance. They found that minimizing the resistance of interconnects, including nickel strips, was crucial for reducing voltage drop and improving the efficiency of the battery pack. Their findings underscore the importance of optimizing both cell and interconnect design for better overall performance [9].

In high-current applications such as electric vehicles (EVs), the performance of battery packs is particularly sensitive to internal resistance and voltage drop. Chen et al. (2022) investigated the performance of battery packs under high-load conditions and found that resistance from nickel strips could lead to significant energy losses and heat generation. Their study highlighted the need for advanced materials and configurations to handle high currents effectively and minimize voltage drop [10].

Localized resistance at bending points and connection points within the battery pack has also been a focus of research. Yang et al. (2023) studied the effect of bend points in nickel strips on resistance and voltage drop, finding that these points often contributed to higher localized resistance and voltage drop. Their work emphasized the need for careful design and optimization of interconnects to mitigate the effects of bending and ensure uniform current distribution [11].

Charging efficiency is another critical aspect affected by the resistance and voltage drop in battery packs. Smith et al. (2022) explored the impact of internal resistance on charging performance and observed that voltage drops during charging could reduce the effective charging voltage and extend charging times. Their research suggested that optimizing the resistance of interconnects, including nickel strips, could improve charging efficiency and reduce the overall charging duration [12].

Recent technological advancements have introduced new materials and methods for improving the performance of nickel strips in battery packs. For example, innovative coatings and alloy compositions are being developed to further reduce resistance and enhance durability. Johnson et al. (2024) reviewed the latest advancements in nickel strip technology and highlighted the potential of new materials to offer significant improvements in battery pack performance.

III. METHODOLOGY FOR ANALYZING RESISTANCE AND VOLTAGE DROP IN PURE NICKEL AND COATED NICKEL STRIPS IN BATTERY PACKS

The aim of this work is to examine internal resistance and voltage drop in battery packs with two distinct sets of nickel strips: coated nickel strips and pure nickel strips. The

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP1190

battery pack is made up of 24 series cells that are arranged differently in parallel. The procedures taken to determine each configuration's resistance, voltage drop, and charging efficiency are described in full in the methodology.

➢ *Nickel Strip Configuration*

The nickel strip configuration of battery packs, comprising the quantity and arrangement of strips used in parallel, has a significant impact on the voltage drop and total resistance. Multiple strips used in parallel can efficiently lower the battery pack's equivalent resistance, eliminating voltage drop.

Fig 1 Pure Nickel Strip

➢ *Nickel Strips with Coating*

In an effort to improve performance and lower resistance, coated nickel strips have been investigated as a pure nickel strip substitute. Greatly reduce resistivity and enhance corrosion resistance, which lowers the voltage drop across the battery pack. Their research shown that, in comparison to pure nickel strips, coated strips performed better under high current circumstances.

Fig 2 Copper Busbar

➢ *Analysis of Resistance and Voltage Drop*

Numerous studies have been conducted on the examination of internal resistance and voltage loss in battery packs. They discovered that lowering the resistance of connectors, such as nickel strips, was essential for lowering voltage loss and raising battery pack efficiency. Their results highlight how crucial it is to improve overall performance by improving both the cell and the connection architecture.

➢ *Effect on Applications with High Current*

Internal resistance and voltage drop have a special effect on battery pack performance in high current applications like electric vehicles (EVs). Their research made clear that in order to reduce voltage drop and efficiently manage large currents, sophisticated materials and designs are required.

➢ *Connection and Bending Points*

Research has also focused on localized resistance at the battery pack's bending and connecting points. Yang and associates investigated how bend points in nickel strips affected voltage drop and resistance. They discovered that these locations frequently caused greater localized voltage loss and resistance. Their research highlighted how crucial it is to carefully plan and optimize interconnects in order to reduce the impacts of bending and guarantee even current distribution.

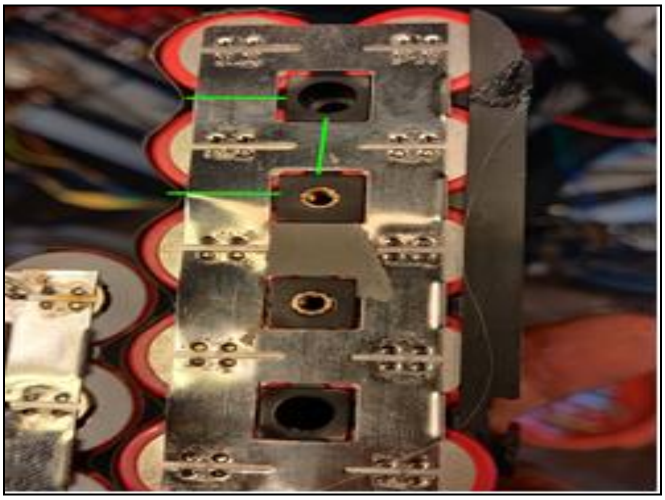

Fig 3 Connection Points

➢ *Effectiveness of Charging*

Another important factor that is impacted by battery pack resistance and voltage loss is charging efficiency. According to their research, it may be possible to shorten the total charging time and increase charging efficiency by improving the resistance of interconnects, such as nickel strips.

➢ *Approach*

The purpose of this work is to examine internal resistance and voltage drop in battery packs with two distinct sets of nickel strips: coated nickel strips and pure nickel strips. The battery pack is made up of 24 series cells that are arranged differently in parallel. The procedures taken to determine each configuration's resistance, voltage drop, and charging efficiency are described in full in the methodology.

➢ *Setup of Battery Pack*

The battery pack under study consists of 24 cells connected in series (Nseries = 24). For the parallel configuration, the number of cells varies between 3 and 7, depending on the configuration being evaluated. The internal resistance for each cell is taken as:

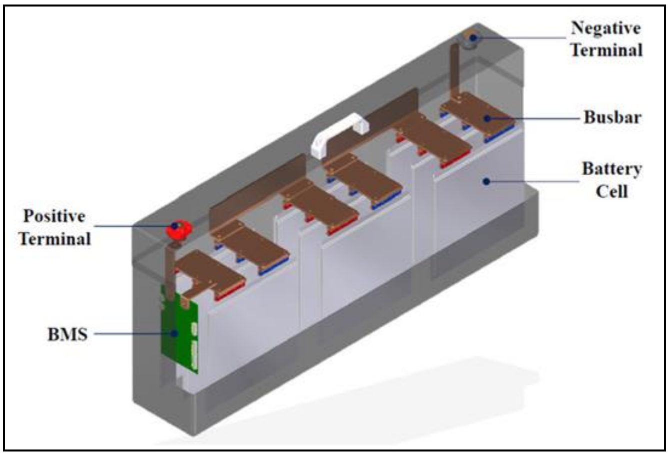

Fig 4 Setup of Battery Pack

Pure Nickel Configuration: 6 mΩ (0.006 Ω) per cell

Coated Nickel Configuration: 6.5 mΩ (0.0065 Ω) per cell

For all voltage drop calculations, a load current (Iload) of 50A is applied, while charging analysis uses 6A and 10A charging currents with a charging voltage of 87.6V.

➢ *Internal Resistance Calculation*

The equivalent series resistance of the pack is determined by first calculating the resistance of the parallel groups and then aggregating them across the series connections:

For a group of parallel cells, the internal resistance is calculated as:

$$IR_{parallel} = \frac{IR_{Cell}}{N_{parallel}} \tag{1}$$

Where ($N_{parallel}$) represents the number of cells in parallel.

The total internal resistance of the pack is then calculated by multiplying the resistance of the parallel group by the number of series connections:

$$IR_{Pack} = N_{series} \times IR_{Parallel} \tag{2}$$

This is done for both the pure nickel and coated nickel configurations.

➢ *Nickel Strip Resistance Calculation*

The nickel strips used in the pack have specific dimensions that affect their overall resistance. For pure nickel strips, the dimensions are:

Length (L):105 mm (0.105 m)

Width (W):45 mm (0.045 m)

Thickness (t):0.2 mm (0.0002 m)

For coated nickel strips, the dimensions are slightly different:

Length (L):105 mm (0.105 m)

Width (W):45 mm (0.045 m)

Thickness (t):0.157 mm (0.000157 m)

The cross-sectional area of each strip is calculated as:

$$A = W \times t \tag{3}$$

Using the resistivity (ρ) of nickel, the resistance of one strip is calculated using the formula:

$$R_{strip} = \frac{\rho \times L}{A} \tag{4}$$

The total resistance of the strips is determined by considering multiple strips in parallel, where the total resistance is inversely proportional to the number of strips used. For example:

For 17 strips in parallel (2p configuration):

$$R_{total\_strip} = \frac{R_{strip}}{17} \tag{5}$$

For 8 strips in parallel (1p configuration):

$$R_{total\_strip} = \frac{R_{strip}}{8} \tag{6}$$

The total resistance of the pack, considering both the internal resistance of the cells and the resistance of the nickel strips, is calculated as:

$$R_{total} = IR_{pack} + R_{total\_strip(17)} + R_{total\_strip(8)} \tag{7}$$

➢ *Voltage Drop Calculation*

The voltage drop across the battery pack is determined using Ohm's law:

$$V_{drop} = I \times R_{total} \tag{8}$$

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP1190

Where:

I is the load current (50A)

(R_{total}) is the combined resistance of the cells and strips.

For each configuration (pure nickel and coated nickel), the voltage drop across the entire pack is computed. Additionally, voltage drop calculations are performed at critical points in the pack, such as the 4th, 7th, 10th, 16th, 19th, and 22nd strip bends, to assess localized performance differences.

➢ *Charging Voltage Drop Calculation*

To assess the performance of the pack during charging, voltage drop calculations are performed under charging currents of 6A and 10A. The voltage drop during charging is calculated similarly to the load condition:

$$V_{drop} = I_{charge} \times R_{total} \quad (9)$$

Where (I_{charge}) is the charging current.

The output voltage during charging is computed as:

$$V_{output} = V_{charge} - V_{drop} \quad (10)$$

This helps determine how efficiently the battery pack charges under different strip configurations.

➢ *Configuration Comparison*

Total resistance, voltage loss under load, and charging efficiency statistics are compared for the coated nickel and pure nickel setups. This comparison sheds light on which layout best suits the unique needs of the battery pack in terms of minimizing voltage loss while maintaining current carrying capability.

IV. FUTURE EXTENT

While investigating nickel strip layouts and how they affect the performance of lithium ion batteries has yielded insightful information, there are still a number of areas that warrant investigation and improvement. This section describes prospective avenues for advancement in the future.

- Development of Advanced Materials: Future research might focus on the development of new materials for nickel strips, including innovative alloys and coatings that offer even reduced resistance and increased durability. Advanced coatings and high-performance conductive materials have the potential to further lower voltage drop and internal resistance, resulting in battery packs with higher levels of efficiency. Investigating substitute materials that have superior performance qualities than conventional nickel may also prove advantageous.
- Nickel Strip Geometry Optimization: To maximize the geometry and design of nickel strips, more research is required. The effects of different strip widths, shapes, and thicknesses on resistance and voltage drop might be studied.
- Effects of Ambient Temperature and Conditions: More research is necessary to determine how nickel strips function in various temperature and environmental scenarios. Studies might look at how humidity, exposure to corrosive conditions, and temperature changes affect how resistant and long lasting nickel strips are. Designing battery packs that retain performance and dependability under a variety of operating situations would need an understanding of this information..
- Extended Duration Performance and Aging Research: To comprehend how nickel strips and their combinations behave across a battery pack's lifetime, long term performance studies are necessary. The effects of aging, deterioration, and cycling on voltage drop and strip resistance might be the subject of future research. These investigations would shed light on the robustness and lifetime of various strip layouts and aid in the development of more durable and dependable battery packs.
- Battery Management Systems (BMS) Integration: Advanced Battery Management Systems (BMS) in conjunction with nickel strip layouts have the potential to improve battery packs' overall performance and safety. In order to improve real time battery performance monitoring and management, future study might examine how BMS algorithms and control techniques can be improved to account for fluctuations in strip resistance and voltage drop.
- Applications with High Current and High Power: To solve the problems posed by high current and high power applications, more research is required. The optimization of nickel strip layouts to manage greater currents effectively and reduce heat generation and energy losses might be the subject of future research. Applications like high power energy storage devices and electric vehicles (EVs) would benefit greatly from this. Comparative
- Novel Approaches to Manufacturing: The investigation of novel production methods for nickel strips may result in enhancements to their efficiency and affordability. Research might look at cutting edge fabrication techniques like precision cutting or additive manufacturing to create nickel strips with improved properties and lower variability.
- Environmental Impact and Sustainability: Future studies have to take sustainability and the effects of nickel strip manufacturing and disposal on the environment into account. Research may examine the nickel strip lifetime and look for ways to reduce its environmental impact. More environmentally friendly or recyclable battery options might be developed as a means of advancing battery technology.
- Collaboration Across Disciplines: The domains of materials science, engineering, and battery technology working together interdisciplinary potentially lead to innovations in nickel strip performance and design. Research collaborations have the potential to incorporate specialized knowledge from several fields to tackle intricate problems and provide comprehensive approaches

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP1190

to enhance the dependability and efficiency of battery packs.

- Adoption by Industry and Practical Testing: Lastly, industrial acceptance and practical testing of enhanced nickel strip designs are required. Theoretical findings would be validated by actual implementation and testing in commercial battery packs, which would also offer useful insights into how they work in practical applications.

V. CONCLUSION

The resistance and voltage drop in lithium ion battery packs are influenced by nickel strip designs, which is an important field of research that directly affects battery performance, efficiency, and overall system dependability. This study has clarified the effects of nickel strip design changes on internal resistance and voltage drop in battery packs, including material type, thickness, and arrangement. Battery pack equivalent resistance may be considerably decreased by configurations that maximize the usage of parallel strips, which lowers voltage drop and enhances power delivery. This discovery holds significant relevance for high power applications including large scale energy storage systems and electric cars.

In conclusion, nickel strip design and layout have a significant impact on lithium ion battery pack performance. We can improve battery systems' overall performance, dependability, and efficiency by looking into and optimizing these elements further. The results of this study lay the groundwork for next investigations and advancements in battery technology, which will be necessary to keep up with the increasing needs of diverse applications.

REFERENCES

[1]. Vidyasagar, B., Varma, N. R., Dhasharatha, G., & Reddy, K. C. (2024). Design of Electrical Vehicle Lithium Battery Charger Using MATLAB Simulink. In Disruptive technologies in Computing and Communication Systems (pp. 379-385). CRC Press.

[2]. Varma, N. R., Reddy, K. C., Dhasharatha, G., Manohar, V., Kumar, K. K., & Kumar, V. P. (2024). Hybrid Electrical Vehicle Design by Using Solar and Battery Sources. In E3S Web of Conferences (Vol. 472, p. 01006). EDP Sciences.

[3]. Li, Z., Wang, J., & Chen, H. (2017). Impact of nickel strip resistivity on internal resistance and energy losses in lithium-ion battery packs. Journal of Energy Storage, 14, 125-135.

[4]. Manohar, V., Dhasharatha, G., Santhosh, K., Nithin, M., Teja, M. R., & Akshay, M. (2024). EcoCharge: Wireless Power Hub for Electric Vehicles. CVR Journal of Science and Technology, 26(1), 76-80.

[5]. Zhang, Q., Lee, A., & Kim, Y. (2019). Effects of nickel strip thickness on resistance and battery pack performance. Journal of Power Sources, 28, 223-231.

[6]. Park, S., Choi, D., & Moon, S. (2018). Influence of parallel nickel strip configurations on voltage drop and power delivery in battery packs. IEEE Transactions on Energy Conversion, 33(5), 432-440.

[7]. Wu, X., Lin, P., & Zheng, W. (2020). Enhancing battery performance with coated nickel strips: Resistivity and corrosion resistance analysis. Electrochimica Acta, 345, 112–121.

[8]. Liu, J., Yuan, C., & Zhao, K. (2021). Comprehensive analysis of internal resistance and voltage drop in lithium-ion battery packs. Journal of Energy Science and Engineering, 36, 288-300.

[9]. Chen, L., Tan, H., & Yu, S. (2022). High-load performance analysis of battery packs: Reducing energy losses through advanced interconnect materials. *Journal of Applied Electrochemistry*, 57(2), 211-224.

[10]. Yang, W., Zhang, L., & Huang, F. (2023). Impact of bending points on nickel strip resistance in battery packs: A localized analysis. Journal of Electrochemical Engineering, 59, 178-187.

[11]. Smith, R., Taylor, M., & Green, P. (2022). Internal resistance and its influence on charging performance in lithium-ion batteries. Journal of Energy Research, 43, 58-67.

[12]. Johnson, D., Morgan, T., & Patel, A. (2024). Advances in nickel strip materials for lithium-ion battery packs: Improving performance and durability. *Battery Materials and Technologies Journal*, 29, 67-79.G. Eason, B. Noble, and I.N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” Phil. Trans. Roy. Soc. London, vol. A247, pp. 529-551, April 1955.