WWW.IJRPR.COM

**International Journal of Research Publication and Reviews**

Journal homepage: www.ijrpr.com ISSN 2582-7421

# An End-To-End Methodology for Battery Pack Design and Manufacturing for Electric 2-Wheelers

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A B S T R A C T

Owing to the Paris Agreement, recent trends show the growing popularity of Electric Vehicles for reducing CO2 emissions in India. Thus, Electric 2-wheelers can be used for last-mile deliveryin the e-commerce sector to avoid unprecedented pollution considerably.

Battery Cell Chemistry selection and Battery Packaging are tedious but important tasks in the Electric 2-Wheeler Industry. Currently, industries follow the Iterative Process approach followed by experimental validation which is both expensive and time-consuming. This paper provides an insight into Cell Level Modelling, Equivalent Circuit Model, Mechanical robust packaging, Electrical Simulations, Thermal Simulations, and experimental validation for Electric Cargo 2- wheeler for last-mile delivery. Initially, mechanical packaging posed constraints for cell chemistry selection. Considering parameters such as Specific Energy, Specific power, and Lifespan, an appropriate cell was chosen. Special emphasis was given to IP67 rating considering the Indian Road terrain and Crash Scenario. Battery Pack Thermal Management for our Electric Cargo 2-wheeler was kept in prime focus considering great chances of thermal runaway in Lithium-Ion battery pack. An efficient natural air-cooling system was designed, Thermal Simulations of which were performed on ANSYS. These simulation results were then compared with real-time experimental outputs. State of Charge (SOC) obtained from MATLAB Simulink was estimated using Kalman Filtration while Specific Power was also verified.

Lastly, experimental validation of Voltage, Current, Power Output, and Temperature was compared with Simulink Model and Thermal Model respectively. We found it to be in the maximum error window of 7%. This flexible design methodology can prove to be useful in the rapid designing and prototyping of battery packs in electric vehicles. Using this technique, industries can save considerable time and capital.

Keywords:Keywords: Electric Vehicle, Battery Pack, Equivalent Circuit Modelling, MATLAB Simulink,IP67Compliant

## 1. INTRODUCTION

In recent years, there has been a significant increase in the number of aggressive goals aimed at achieving cleaner energy. All the major automaker companies are developing electric mobility strategies. For example, the state of Hawai'i has goals of 100% clean energy and transportation by 2045. With the expected high penetration of electric vehicles and electrochemical energy storage, there is a need to better understand and predict battery pack performance and durability. The main technology used in EVs is the lithium-ion battery, which has been evolving rapidly for the past two decades. As this technology matures, the challenges are how to make battery packs cheaper, more efficient, smaller, and lighter. With several physical phenomena occurring simultaneously inside the battery, which are affected by the environment in which it operates, it is difficult to encompass them all in the design phase. The optimization of every design detail takes a lot of computational, human and material resources to accomplish. Moreover, for every new design, each step must be repeated. This makes the process very difficult to be implemented in a fast, efficient, cost effective and flexible way. Therefore, this optimization process should be automated to reduce the time to market of battery packs.

This project deals with the manufacturing of IP67 battery pack to be used in a commercial electric two-wheeler.

### ProblemStatement

Design and Manufacture Battery Pack for Electric 2- Wheeler which is IP67 compliant.

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### 1.1 Objectives

1 To design and manufacture a compact battery pack for an electric two-wheeler.

2 To quantify cell-to-cell variations for different pack configurations.

3 To optimize thermal management of lithium-ion cells in battery packs.

4 To reduce the time required to design a battery pack based on requirements.

5 To validate the performance parameters by actual experiments.

6 To comply with IP67 rating.

### 1.2 Scope

1. A light weight and compact battery pack can improve the performance of the vehicle.
2. Maximum charge dissipation can be procured for longer ride range.
3. Power losses due to heat generation within the battery pack can be minimized.
4. Trial-and-Error design philosophy would not be used, thus saving companies aconsiderable amount of time and money.

### 1.3 Methodology

Proposed methodology flowchart is as follow:

## 2.DESIGN

***2.1 Study of Types of Cells: -***

**•Nickel-Cadmium**

The nickel–cadmium battery (Ni-Cd battery or NiCad battery) is a type of rechargeable battery with electrodes made of nickel oxide hydroxide and metallic cadmium. The abbreviation Ni–Cd is derived from the chemical symbols nickel (Ni) and cadmium (Cd): the abbreviation NiCad is a registered trademark of SAFT Corporation, despite the fact that this brand name is commonly used to describe all Ni–Cd batteries.

A Ni-Cd cell has a maximum electromotive force of 1.3V. Ni-Cd batteries are available in a variety of sizes and capacities, ranging from portable sealed types that can be interchanged with carbon-zinc dry cells to large capacity Ni-Cd batteries.

Ventilated cells are used for both standby and motive power. When compared to other types of rechargeable cells, they have a good cycle life and performance at low temperatures, as well as a fair capacity, but their major advantage is their ability to deliver nearly their full rated capacity at high discharge rates (discharging in one hour or less). The materials, however, are more expensive than those used in lead–acid batteries, and the cells have high self-discharge rates.

At one time, sealed Ni-Cd cells were widely used in portable power tools, photography equipment, flashlights, emergency lighting, hobby R/C, and portable electronic devices. The superior capacity of nickel-metal hydride batteries, combined with recent cost reductions, has largely replaced Ni-Cd use. Furthermore, the environmental impact of disposing of the toxic metal cadmium has significantly reduced its use. Ni-Cd batteries can now only be supplied within the European Union for replacement purposes or for specific types of new equipment, such as medical devices.

Larger ventilated wet cell Ni-Cd batteries are used in emergency lighting, standby power, and other applications.

**•Nickel-Metal Hydride**

A rechargeable battery is a nickel metal hydride battery (NiMH or Ni–MH). The positive electrode chemical reaction is similar to that of the nickel–cadmium cell (NiCd), as both use nickel oxide hydroxide (NiOOH). The negative electrodes, on the other hand, are made of a hydrogen-absorbing alloy rather than cadmium. NiMH batteries can have two to three times the capacity of NiCd batteries of the same size, as well as a significantly higher energy density, though not as high as lithium-ion batteries.

**•Lead Acid**

The lead–acid battery, which was invented in 1859 by French physicist Gaston Plante, is the first type of rechargeable battery. Despite having a very low energy-to-weight and energy-to-volume ratio, the cells' ability to supply high surge currents results in a relatively large power-to-weight ratio. These characteristics, combined with their low cost, make them appealing for use in motor vehicles to supply the high current required by starter motors.

Lead–acid batteries are widely used because they are less expensive than newer technologies, even when surge current is not a concern and other designs could provide higher energy densities. In 1999, lead–acid battery sales accounted for 40–45 percent of the value of batteries sold worldwide (excluding China and Russia), equating to a $15 billion manufacturing market. Large-format lead–acid designs are commonly used for backup power supplies in cell phone towers, high-availability settings such as hospitals, and stand-alone power systems. Modified versions of the standard cell may be used for these roles to improve storage times and reduce maintenance requirements. Gel-cell and absorbed glass-mat batteries, collectively known as VRLA (valve-regulated lead–acid) batteries, are commonly used in these roles.

The chemical energy of the battery is stored in the potential difference between pure lead on the negative side and PbO2 on the positive side, plus the aqueous sulfuric acid, when the battery is charged. The electrical energy released by a discharging lead–acid battery can be attributed to the energy released when the strong chemical bonds of water (H2O) molecules are formed from acid H+ ions and PbO2 ions. Conversely, during charging, the battery acts as a water-splitting device.

**•Lithium-Ion Polymer**

A lithium polymer battery, also known as a lithium-ion polymer battery (abbreviated as LiPo, LIP, Li-poly, lithium-poly, and others), is a rechargeable lithium-ion battery that uses a polymer electrolyte rather than a liquid electrolyte. This electrolyte is made up of high conductivity semisolid (gel) polymers. These batteries have a higher specific energy than other lithium battery types and are used in applications where weight is an important consideration, such as mobile devices, radio-controlled aircraft, and some electric vehicles.

**•Lithium-ion batteries**

Li-ion batteries work by transporting lithium ions between the anode and the cathode via an electrolyte that is both electronically insulating and ion-conductive. The lithium-ion (Li-ion) battery has emerged as the most promising battery candidate for applications requiring high power and energy density. Li-ion batteries have largely replaced other types of batteries based on different chemistries, such as Ni–Cd and NiMH cells, particularly in advanced portable electronics. Recently, with significant advancements in as a flexible power source.The high level of interest in this area has resulted in a number of research projects involving polymer and textile-based substrates. Paper or paper-like Li-ion batteries have also been investigated due to I their intrinsic properties, such as high surface roughness and a porous structure for improved power generation, and (ii) the mechanical flexibility required to fully realise flexible electronics.

***Selection of Cells***

The Selection is to be done with the help of weighted point methodDifferent types of batteries available in the market are:

1. NickelCadmium(NiCd)
2. Nickel-MetalHydride(NiMH)
3. LeadAcid
4. LithiumIon(Li-ion)
5. LithiumIon(Li-ionpolymer)

Weightages for parameters to select battery are as follows:

- EnergyDensity-5
- CycleLife-4
- FastChargeTime-3
- Cost -2

Table2.2.1: Differenttypesofcellsandtheirproperties

| **Battery** | **EnergyDensity(Wh/kg)** | **CycleLife** | **Fast Charge Time(Hr)** | **Cost($)** |
|---|---|---|---|---|
| NiCd | 80 | 1500 | 1 | 50 |
| NiMH | 120 | 500 | 2 | 60 |
| LeadAcid | 50 | 300 | 8 | 25 |
| Li-ion | 160 | 3000 | 2 | 100 |
| Li-ionpolymer | 130 | 500 | 2 | 100 |

Table2.2.2: Weightage Points byWeightedPointMethod

| **Battery** | **Energy Density (Wh/kg)** | **CycleLife** | **Fast Charge Time (Hr)** | **Cost($)** | **Total** |
|---|---|---|---|---|---|
| NiCd | 0.740741 | 1.03448276 | 1.142857 | 0.413793 | 3.331874 |
| NiMH | 1.111111 | 0.34482759 | 0.571429 | 0.344828 | 2.372195 |
| LeadAcid | 0.462963 | 0.20689655 | 0.142857 | 0.827586 | 1.640303 |
| Li-ion | 1.481481 | 2.06896552 | 0.571429 | 0.206897 | **4.328772** |
| Li-ionpolymer | 1.203704 | 0.34482759 | 0.571429 | 0.206897 | 2.326856 |

Hence,byusing weightedpointMethod wechose**Lithium-IonCell**.

***2.2 Study of Different Types of Cell Chemistries of Lithium-Ion***

There are Number of cell Chemistries Available of Lithium-ion, some of them are as Follows:

• Lithium-Cobalt Oxide

The chemical compound lithium cobalt oxide, also known as lithium cobaltate or lithium cobaltite, has the formula LiCoO. Because the cobalt atoms are formally in the +3oxidation state, the IUPAC name lithium cobalt (III) oxide was coined. Lithium cobalt oxide is a crystalline solid that is dark blue or bluish-gray in colour and is commonly used in the positive electrodes of lithium-ion batteries.

- **Lithium Manganese oxide**

A lithium-ion manganese oxide battery (LMO) is a type of lithium-ion cell that has a cathode made of manganese dioxide, Mn. They work on the same intercalation/de-intercalation principle as other commercialised secondary battery technologies, such as. Cathodes based on manganese-oxide components are abundant on the planet, cheap, non-toxic, and have higher thermal stability.

- **Lithium Nickel Manganese Cobalt Oxide**

Lithium nickel manganese cobalt oxides (abbreviated Li-NMC, LNMC, NMC, or NCM) are lithium, nickel, manganese, and cobalt oxides. They are represented by the general formula LiNixMnyCozO2. The most important representatives have a near-zero x + y + z composition, with a trace of lithium on the transition metal site. The composition of commercial NMC samples typically contains 5% excess lithium. Materials in this group have a layered structure and are structurally similar to lithium cobalt (III) oxide (LiCoO2), but they have an ideal charge distribution of Mn (IV), Co (III), and Ni (II) at the 1:1:1 stoichiometry.For charge balance, the nickel in more nickel-rich compositions is more oxidised. NMCs are among the most important lithium ion storage materials in lithium-ion batteries. They are used on the positive side of the cell, which serves as the cathode during discharge.

- **Lithium-Ion Phosphate**

The lithium iron phosphate battery (LiFePOBattery) or LFP battery (lithium ferrophosphate) is a type of lithium-ion battery that uses a graphitic carbon electrode with a metallic backing as the cathode and a graphitic carbon electrode with a metallic backing as the anode. LiFePO has a lower energy density than lithium cobalt oxide (LiCoO) and a lower operating voltage. LiFePO's main disadvantage is its low electrical conductivity. As a result, all of the LiFePO cathodes under consideration are LiFePO/C. LiFePO is finding a variety of roles in vehicle use, utility scale stationary applications, and backup power due to its low cost, low toxicity, well-defined performance, long-term stability, and LFP batteries do not contain cobalt.

- **Lithium Nickel Cobalt Aluminium Oxides**

The lithium nickel cobalt aluminium oxides (NCA) are a class of metal oxides. Some of them are significant because they are used in lithium-ion batteries. On the positive pole, NCAs are used as active materials (which is the cathode when the battery is discharged). NCAs are mixed oxides made up of the cations of the following chemical elements: lithium, nickel, cobalt, and aluminium. The general formula for the most important representatives is LiNixCoyAlzO2 with x + y + z = 1. In the case of the NCA containing currently available market batteries, which are also used in electric cars and electric appliances ,At a nominal voltage of 3.6 V or 3.7 V, the voltage of those batteries is between 3.6 V and 4.0 V. LiNi0,84Co0,12Al0,04O2 is a version of the oxides that are currently in use in 2019.

- **Lithium Titanate**

Lithium titanate is a chemical compound with the formula Li2TiO3. It is a white powder with a melting point of 1,533 degrees Celsius (2,791 degrees Fahrenheit).

The anode component of the fast-charging lithium-titanate battery is lithium titanate. It is also used as an additive in porcelain enamels and titanate-based ceramic insulating bodies. Because of its high stability, it is frequently used as a flux. Metatitanate pebbles, along with other lithium ceramics, have been the subject of recent research efforts toward tritium breeding materials in nuclear fusion applications.

### 2.3 Selection of Cell Chemistry

Weightages for parameters to select chemistry are as follows:

- SpecificEnergy-5
- CycleLife-3
- CostperkWh – 2

Table2.4.1: DifferentTypesofChemistry andtheirProperties

| Chemistry | SpecificEnergy (Wh/kg) | CycleLife | CostperkWh |
|---|---|---|---|
| LCO | 200 | 1000 | 250 |
| LMO | 150 | 700 | 400 |
| NMC | 220 | 2000 | 700 |
| LFP | 120 | 2000 | 400 |
| NCA | 260 | 500 | 350 |
| LTO | 80 | 3000 | 800 |

Table2.4.2: WeightagePoints byWeightedPointsMethod

| Chemistry | SpecificEnergy (Wh/kg) | CycleLife | Cost perkWh | Total |
|---|---|---|---|---|
| LCO | 0.970874 | 0.326087 | 0.55036856 | 1.847329 |
| LMO | 0.728155 | 0.228261 | 0.34398035 | 1.300397 |
| NMC | 1.067961 | 0.652174 | 0.19656020 | **1.916695** |
| LFP | 0.582524 | 0.652174 | 0.34398035 | 1.578679 |
| NCA | 1.262136 | 0.163043 | 0.39312040 | 1.818300 |
| LTO | 0.38835 | 0.978261 | 0.17199018 | 1.538601 |

By using weighted point method for selection of Li-ion chemistry, we selected **Lithium NickelManganese Cobalt Oxide (LiNiMnCoO2) – NMC.**

Lithium-Ion Cell is Available in Different Shapes Such as: -

1. Cylindrical cell: - It has a high specific energy, good mechanical stability, and is well suited for automated manufacturing. Cell design allows for additional safety features that are not available in other formats. It cycles well, has a long calendar life, and is inexpensive, but its packaging density is less than ideal. The cylindrical cell is a popular choice for portable applications.
2. Prismatic cell: - For stability, cells are encased in aluminium or steel. The cell, which can be jelly-rolled or stacked, saves space but is more expensive to manufacture than a cylindrical cell. Prisma cells are used in electric powertrains and energy storage systems today.
3. Pouch cell: - In a bag, Cells employs laminated architecture. It is lightweight and inexpensive, but exposure to humidity and high temperatures can shorten its life. Adding a light layer of stack pressure prolongs longevity by preventing delamination. Swelling of 8–10 percent over 500 cycles must be considered with some cell designs. Large cells work best with light loading and moderate charge times. The pouch cell is growing in popularity and serves similar applications to the prismatic cell.

Considering all factors, we found out that Li-ion cell having Lithium Nickel Manganese Cobalt Oxide (LiNiMnCoO2) – NMC chemistry with cylindrical shape is better to use as per our need.

## 2.4 Basic Battery Pack Sizing and Modelling

- **Constraintsfromindustry:**

Motor: Rated Power = 2 kWRated
voltage=48V

Required Range:

80km/chargeConsideredAverageSpeed:60km/h

Calculations:

Power Consumption for 1 hour at 60km/h:

$$= \frac{2000W}{60km/h}$$

= 33.33Wh/km

Now, we have motor of 48V, so to calculate Ah, we have:

$$= \frac{33.33Wh/km}{48V}$$

= 0.6943 Ah/km

Tocalculate Ah ofbattery:

= 0.6943 x 80

= 55.55 Ah

If use of battery after 80km is 90%, then:

Required Ah = 55.55 x 1.1

= 61.1 Ah

So, we have battery with 48V and 61.1Ah.

Therefore, Capacity = 48 x 61.1

= 2932.8 Wh

Selected Lithium-ion Cell has:

V = 3.7 V

A = 2900 mAh

Therefore, cells in series = $\frac{48}{3.7}$

= 12.97

≈ 13 cells

Cells in parallel = $\frac{61.1}{2.9}$

= 21.068

≈ 22 cells

Therefore, total cells = 13 x 22

=286 cells

Cell Configuration: 22P 13S

Therefore, the calculated Cell Configuration for the battery pack is 22P 13S.

## Space constraints:

The application of this battery pack is an electric cargo 2-wheeler. Thus, we need to consider the space available to accommodate the battery pack.

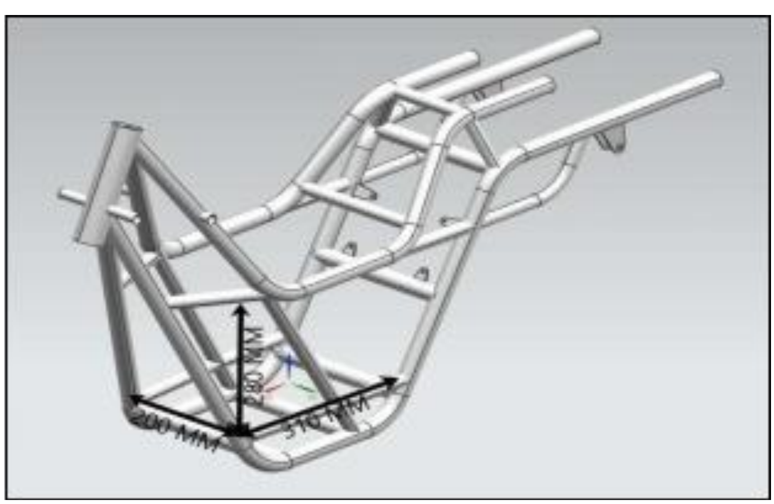



Fig 2.5.1: Frame of Electric Cargo 2-wheeler with dimensions of battery compartment shownin black

So, dimensions of the battery compartment are: 310mm x 280mm x 200mm

Thus, to accommodate the designed battery pack inside the space comfortably, we needed toarrange the cells such that they formed two layers. Each layer contains 143 cells (11P 13S).

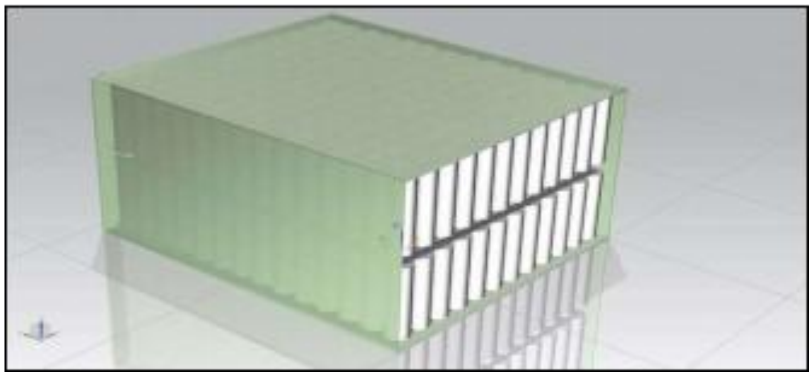


Fig 2.5.2: Battery Pack with casing

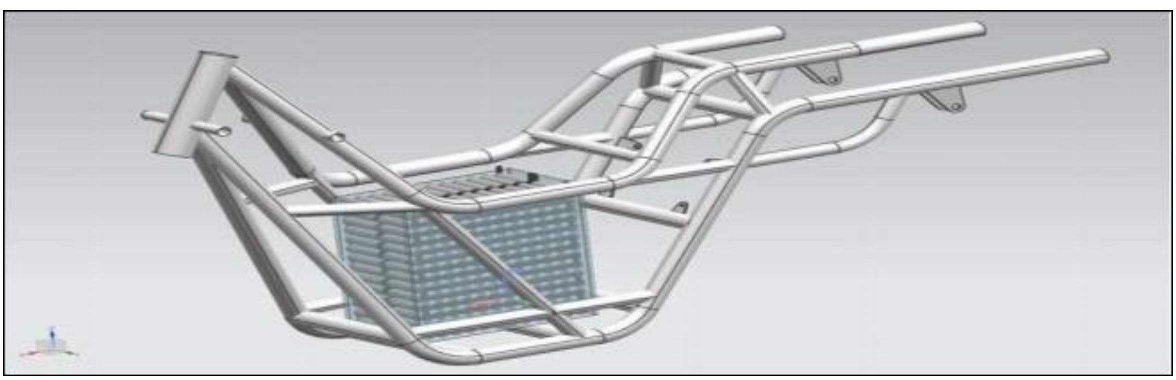


Fig .5.3: Battery Pack accommodated inside vehicle frame

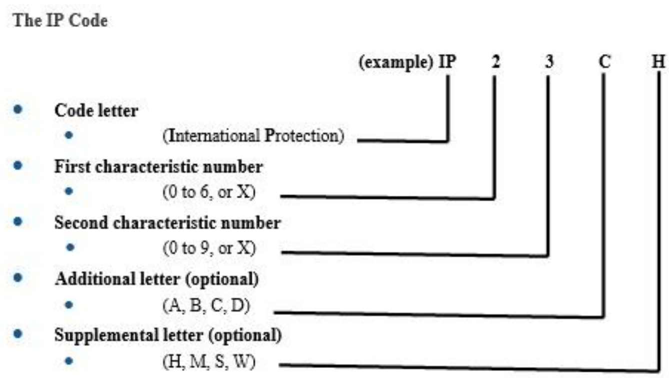
### *3.6 Study of IP67 Degree of Protection*

For a battery pack to be used in a commercial electric 2-wheeler, it must be IP 67 compliant. Rating Code:

- IEC 60529
- BS EN 60529
- NEN-EN-ISO 20653

Definition:

• Protection of persons against access to hazardous parts within the enclosure.
• Protection of equipment within the enclosure against solid foreign object ingress.
• Protection of equipment inside the enclosure from the effects of water ingress.
Enclosure: A component that protects equipment from certain external influences and, in any direction, from direct contact.




IP X_ : Access to hazardous parts

Table 3.6.1: IP X- Access to hazardous parts

| First Characteristic Number | Description of Protection Against | Definition |
|---|---|---|
| 0 | No Protection | --- |
| 1 | Access to hazardous parts with the back of a hand | The access probe, sphere of 50 mm Ø, shall have adequate clearance from hazardous parts |
| 2 | Access to hazardous parts with a finger | The jointed test finger of 12 mm Ø, 80 mm length, shall have adequate clearance form hazardous parts |
| 3 | Access to hazardous parts with a tool | The access probe of 2,5 mm Ø shall not penetrate |
| 4 | Access to hazardous parts with a wire | The access probe of 1,0 mm Ø shall not penetrate |
| 5 | Access to hazardous parts with a wire | The access probe of 1,0 mm Ø shall not penetrate |
| 6 | Access to hazardous parts with a wire | The access probe of 1,0 mm Ø shall not penetrate |

IP X_ : Ingress of Solid Foreign Objects

Table 3.6.2: IP X- Ingress of Solid Foreign Objects

| First Number | Description of Protection Against | Definition |
|---|---|---|
| 0 | No Protection | --- |
| 1 | Solid foreign objects of 50 mm Ø and greater (50 N) | The object probe, sphere, shall not fully penetrate |
| 2 | Solid foreign objects of 12,5 mm Ø and greater (30 N) | The object probe, sphere, shall not fully penetrate |
| 3 | Solid foreign objects of 2,5 mm Ø and greater (3 N) | The object probe, sphere, shall not penetrate at all |
| 4 | Solid foreign objects of 1,0 mm Ø and greater (1 N) | The object probe of 1,0 mm Ø, shall not penetrate at all |
| 5 | Dust-protected | Ingress of dust is not totally prevented, but dust shall not penetrate in a quantity to interfere with satisfactory operation of the apparatus or to impair safety |
| 6 | Dust-tight | No ingress of dust |

### 4) IP _X : Ingress of Water

Table 3.6.4: IP-X- Ingress of Water

| Second Number | Test Means | Duration of Test |
|---|---|---|
| 0 | No test required | --- |
| 1 | Drip box, enclosure on turntable | 1 mm/min, 10 min |
| 2 | Drip box, enclosure in 4 fixed positions of 15° tilt | 3 mm/min, 2.5 min for each position of tilt |
| 3 | Oscillating tube, ±60° from vertical max. 200 mm distance Or spray nozzle 'showerhead' ±60° from vertical | 0.07 l/min per hole by number of holes, 10 min 10 l/min, 1 min/m², at least 5 min |
| 4 | Oscillating tube, ±180° from vertical max. 200 mm distance Or spray nozzle 'showerhead' all sides | 0.07 l/min per hole by number of holes, 10 min<br>10 l/min, 1 min/m², at least 5 min |
| 5 | Water jet hose nozzle 6.3 mm, 2.5m to 3 m distance | 12.5 l/min, 1 min/m², at least 3 min |
| 6 | Water jet hose nozzle 12.5 mm, 2.5m to 3 m distance | 100 l/min, 1 min/m², at least 3 min |
| 7 | Immersion tank Water 0.15m above top of enclosure, water 1m above bottom of enclosure | 30 min |
| 8 | Immersion tank Water level by agreement | By agreement |
| 9 | Fan jet nozzle, enclosure on turntable, 0°/30°/60°/90° | 15 l/min, 80°C, 30 s per position (small units), 1 min/m², at least 3 min (large units) |

**Thus, an IP67 compliant battery pack will be such that no dust particles and watermolecules can enter into the housing.**

## Conclusion

We are in process to design, manufacture and test an IP67 compliant battery pack that will be used in a cargo electric 2-wheeler, which will be used for last-mile deliveries across India. The project will also facilitate quicker prototyping and design finalizing, which will save both, time and money of the companies which are trying to take India towards a greener and better future by introducing electric vehicles that are affordable for the common public.

## Future Scope

The next decade is expected to be the decade of the fully electric automobile. With battery prices reportedly falling 73 percent since 2010, electric cars are expected to be as affordable as gasoline-powered vehicles in the near future. According to the International Energy Agency, up to 20 million electric vehicles will be on the road by 2020, with that number expected to rise to 70 million by 2025. Countries all over the world are realising the potential of e-mobility. While China encourages e-mobility through tax breaks, EV credit policies, research subsidies, and other means, countries such as the United Kingdom, France, Norway, and India are looking to adopt e-mobility on a larger scale. ,having expressed a desire to phase out gasoline and diesel engines entirely over the next few decades India stands to benefit greatly from widespread adoption of e-mobility. Manufacturing of e-vehicles and their associated components is expected to increase the share of manufacturing in India's GDP to 25% by 2022 under the Make In India programme.On the economic front, widespread adoption of electric vehicles is expected to save $60 billion in oil imports by 2030; currently, imports meet 82 percent of India's oil demand. The cost of electricity as a fuel could fall as low as Rs 1.1/km, allowing an electric vehicle owner to save up to Rs 20,000 for every 5,000 km driven. Finally, electrification will aid in the reduction of vehicular emissions, a major contributor to air pollution that costs the economy an average of 3% of its GDP each year.

At the national level, there has been a concerted policy push to promote e-mobility, particularly with the ratification of the Paris climate agreement. The National Electric Mobility Mission Plan (NEMMP) 2020 and the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) schemes were both announced with the goal of transitioning automobiles to an all-electric future by 2030. Furthermore, compared to other categories, electric vehicles have a lower GST rate (12%).

The desire for fast-charging batteries with extended driving range is driving demand for electric vehicles. The primary challenge for automotive players today is to develop high-quality batteries that are long-lasting, safe, and capable of storing a large amount of energy. Lithium-ion batteries have emerged as the most suitable option in today's ecosystem.

The future scope of electric vehicles is very bright because of following reasons-

1. Dropping battery cost
2. improved range
3. More number of electric charge stations
4. Auto industry is embracing electric vehicles
5. Global imperative to cut down pollution and oil dependency

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