Polymer and FRP Technology - An Alternative to Conventional Porcelain for Future Power Sector

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Abstract

The Insulators play a prominent role in the power sector industry. Insulator is used to control the excess voltage and current in the transmission and distribution lines. From the early days, porcelain insulators have been used in power lines, but now as there is a development in the technology porcelain insulators are slowly being replaced by Composite Polymer Insulators. SPARK INSULATORS Pvt. Ltd is where our thesis is carried out. SPARKIL is a manufacturer of composite polymer insulators. As the number of power lines are increasing the cost of maintenance of the lines and insulators are also increasing. It is essential to bring down the cost for maintenance. The main objective of this thesis work is to provide the information on how the composite polymer insulators are manufactured at SPARKIL and some information about the rubber injection moulding machine which is a crucial machine for the production of composite polymer insulators along with the methods to improve the production of composite polymer insulators.

1. Introduction

An insulator is a component which inhibits the flow of heat or electricity. And this property is known as insulation. Insulator is usually made up of materials which are tough and also which have high dielectric strength. Insulator plays a crucial role in the transmission and distribution lines. It provides all the insulation required between the line conductors and supports to inhibit the flow of leakage current from the conductors on the electrical lines to the earth. A good insulator should possess the following properties:

- High Mechanical Strength
- High Electrical Resistance
- High Relative permittivity
- Non-porous and free from impurities
- High ratio of puncture strength to flashover voltage.

The insulator should have high mechanical strength so that it could withstand conductor load, wind load etc. It should also have high electrical resistance and relative permittivity because it has to avoid leakage currents to the earth.

Porcelain which is a ceramic material is the most used material for insulators in overhead lines but glass, steatite and other special composite materials are used to a limited extent. Porcelain is manufactured by firing a mixture of kaolin, feldspar and quartz at a higher temperature. It is tougher than glass mechanically and is resistant to change of temperatures. Though porcelain has better properties compared to glass it has several limitations. The limitations are as follows:

- High Maintenance Cost
- Heavy and Bulky
- Highly fragile to shock and vibrations
- Expensive
- More susceptible to vandalism
- High risk of breakages

To overcome the above drawbacks a new technology has emerged. This technology involves the polymer silicone rubber and fibre reinforced plastic (FRP).The insulator manufactured with the polymer silicone rubber and FRP has overcome all the disadvantages of porcelain insulator.

2. History of Polymer Insulator

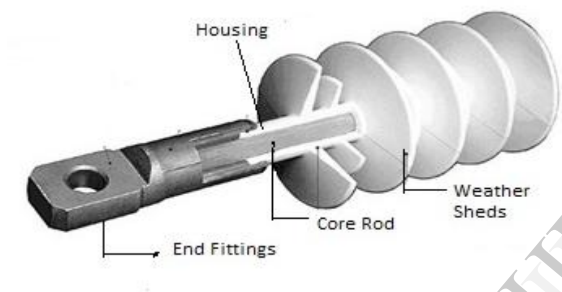
The polymer insulator first commercially came into existence in the mid1940s. The first used polymers bisphenol epoxy resins. In 1957, Cycloaliphatic epoxy resins were introduced and were found to be superior to bisphenol epoxy resins as they were resistant to carbon formation. However, a lot of problems were caused due to the polymer insulators in the early days.

In the 1960s epoxy resin fibre glass rod was developed and on this rod the porcelain sheds were manufactured. But it is not widely used because of the developments in light weight polymeric materials. As the developments progressed in the late 1960s and early 1970s the first generation of commercial polymeric transmission line insulators were introduced. But the results of first generation polymeric insulators were disappointing for higher voltages. After an intensive research second generation polymeric insulators were introduced. These insulators have improved tracking free sheds, better corona resistance and slip free end fittings. The polymer insulators which are using today are manufactured widely with the materials of fibre reinforced plastic and silicone rubber.

3. Description

The polymer insulator consists of three main components. The components are as follows:

- Core rod
- Housing
- End fittings



Φιγ 1. Πολψμερ Ινσυλατορ Χομπονεντσ

Core Rod

Core rod is the major component of the polymer insulator. It is essential for the insulator as it provides the mechanical strength as well as electrical insulation properties. In the recent days this core rod is widely made up of glass fibre reinforced plastic (FRP).

Fibre reinforced plastic is a reinforced fibre made up of polymer matrix. The polymer matrix must be able to saturate properly and be able to bond with the fibres in the prescribed curing time. For the maximum adhesion the matrix should bond with the fibre reinforcement. The polymer used is polyester thermosetting plastic or epoxy, vinylester. The FRP used in the insulators are boron free ECR (Electrical and Corrosion Resistant) grade. The FRP is made boron free so that it will not be affected by moisture and even acid. Textile glass fibre which is a mixture of different proportions and combinations of SiO_2, Al_2O_3, B_2O_3, CaO or MgO in a powder form is the major material of FRP. The combination of textile fibre glass is heated directly to a temperature about 1300 degree Celsius to melt. The melted mixture is died to extrude the filament of glass fibre. Now, these filaments are wound into rolls for further processing.

The following are the properties possessed by the Fibre Reinforced Plastic are as follows:

- High Thermal Insulation
- Cost effective
- Good Chemical and corrosion resistance
- Ultra-Violet Radiation stability
- Can be bonded readily with dissimilar materials
- High mechanical strength at low weight

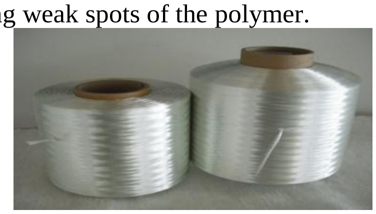
The properties that can be improved by alteration of matrix, chemical addition or other formulation are as follows:

- Chemical and corrosion resistance
- Structural Integrity
- Thermal Insulation
- Abrasion Resistance
- Bondage to dissimilar materials
- Fire Hardness

The FRP rod used in the insulator is manufactured by a process called Pultrusion. It is a continuous process for manufacture of composite materials with identical cross-section. In this process fibres are impregnated with resins and it goes into preforming system and pulled through the heated die for the resin to undergo polymerization. After the FRP rod is manufactured it is cut by the diamond cutter for the required length. After it is cut it is heated in a over for 130 degree celsius so that it acquires all the mechanical and electrical properties required for the insulation.

Advantages and Drawbacks of Fibre Reinforced Plastic:

FRP allows orientation of glass fibres to suit the design. Specifying the orientation can enhance the strength and resistance to deformation of the polymer. Glass reinforced polymers are strongest when polymer forces are parallel and weakest when the forces are perpendicular, Thus this is both an advantage and disadvantage depending on the usage. The weak spots of perpendicular fibres may result in material failure. Thus it is essential to eliminate weak spots. It is eliminated when forces which are perpendicular to one orientation must be parallel to another orientation eliminating weak spots of the polymer.



Φιγ 2. Γλασσ φιβρε ρολλ

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Tests on FRP rod:
It is essential to check the authenticity of the FRP rod. Therefore tests has to be conducted. The tests are as follows:

- Dye-penetration test
- Water Diffusion Test

Φιγ 3. Φιβρε Ρεινφορχεδ Πλαστιχ Ροδ

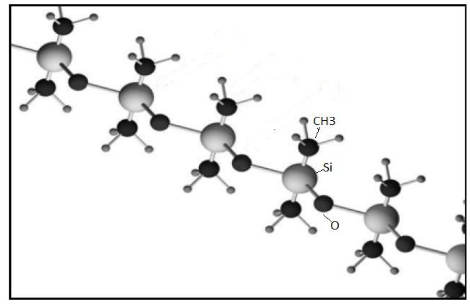
Housing

The insulator consists of housing in addition to core rod because it is essential to provide the creepage distance for the insulator. Silicone rubber is widely used as housing material for manufacturing polymer insulator. Silicone is a polymer containing bonding of silicon, carbon, hydrogen and oxygen. Silicone polymer rubber is stable, non- reactive and resistant to extreme environment and temperatures. The temperature range of silicone rubber is -55 degree Celsius to 300 degree Celsius.
The advantages of silicone rubber as housing material are as follows:

- Longer life in harsh environments
- Unaffected by rain, snow, humidity, UV rays for many years.
- Large range of operating temperatures
- Good insulating properties that do not change
- Easier to fabricate and produce
- Flexible and resists compression.
- Excellent sealing property

This silicone rubber has to cured in order to mould the sheds on the FRP rod. The silicon rubber is an adhesive gel in an uncured state, to cure, it has to be vulcanised. It is carried out in a two stage process at the manufacturing time and then in a post cure process.

The weather sheds of silicone rubber are manufactured on FRP rod with the help of rubber injection moulding machine. The FRP rod is applied with the prime coating for the silicone rubber to stick on it. The dimensions of the FRP rod and weathering sheds depend on the voltage ratings of insulator and the client requirement.



Φιγ 4. Σιλονε Πολψμερ Στρυχτυρε

Tests on silicone rubber:

A series of tests are to be conducted on the silicone rubber to check its quality and reliability. The tests are as follows:

- Tensile Strength
- Elongation at break
- Tear strength
- DC volume Resistivity
- Specific Gravity
- Dielectric Strength
- Hardness
- Resistance to weathering and UV
- Resistance to tracking and erosion.

End Fittings:

End fittings are the extreme parts of the insulator. They connect the insulator to a tower or conductor. These end fittings decide whether the insulators are placed horizontally or vertically i.e., post or pin or suspension insulator. Ball and socket type, clevis and tongue type , Y clevis type are some of the types of end fittings. These end fittings are normally made up of cast iron and galvanized. These are attached to the FRP rod by the means of crimping. The higher rated insulators are crimped before the moulding whereas low rated insulators are crimped after moulding. The constructional requirements of end fittings that are to be pondered are as follows:

- Length of the FRP rod into the end fitting
- Wall thickness of the fittings
- Mechanical requirements of the inner wall
- Preparation of the FRP rod
- Stability of the attachment hardware

Φιγ 5. Χριμπινγ οφ Ινσυλατορ

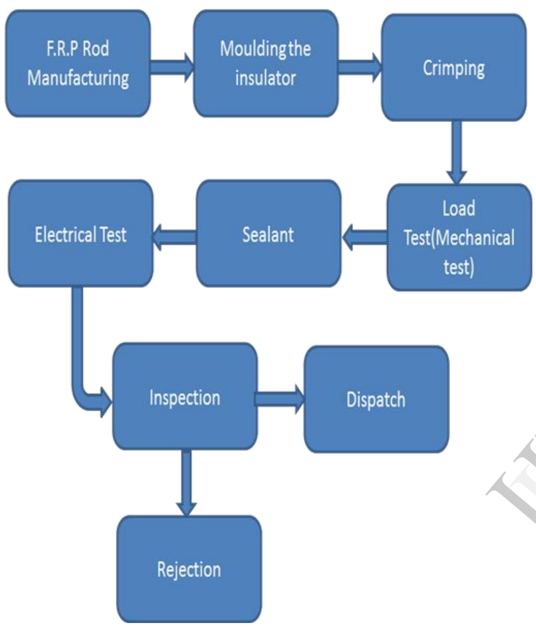
Tests on End Fittings:

The following are the tests that are conducted on the end fittings to check its quality:

- Visual Examination
- Galvanization test

4. Production of the Polymer Insulator

The following bock diagram gives the systematic procedure of manufacturing the polymer insulator:

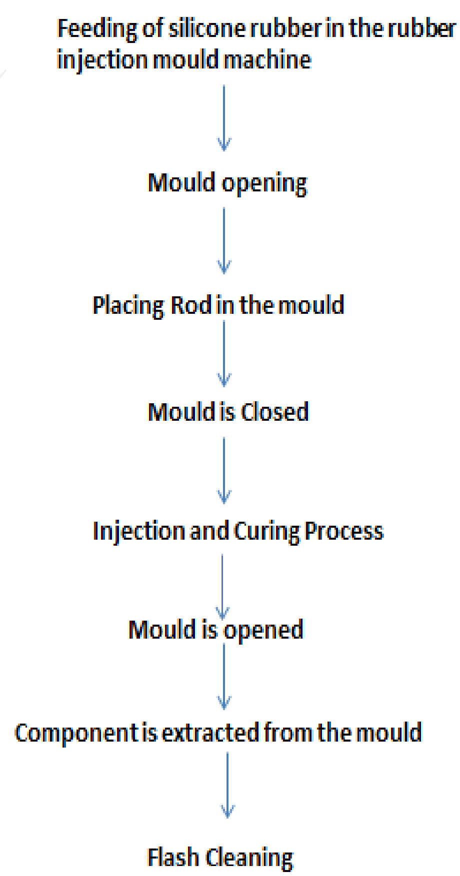


Φιγ 6. Βλοχκ διαγραμ οφ Μανυφαχτυρινγ Πολψμερ Ινσυλατορ

The FRP rod is manufactured by a means of pultrusion process. The step by step processes involved in this process are as follows:

- The fibre glass rolls one by one are guided through the guide plate to resin impregnator.
- Now, it is carried to the performer which contains a measured amount of resin called ‘Prepreg’. Here the dry fibres are wetted with resins.
- The resins are the mixture of measured quantities of Araldite, Hardnary, Dolomite, Accelerator and Zinc Sterate.
- After performer it is passed through forming and curing die where the temperature is maintained through electrical heating. The forming and curing die is responsible for the shape and size of the rod.
- Now the rod which is forming is pulled by the pulling system to develop tensile strength.
- Through the pulling system the finished rod is obtained.
- The rod is cut for the required length by cut of saw which is usually a diamond cutter.

After the FRP rod is manufactured, the housing and weathering sheds have to mould on the rod. This is done using rubber injection moulding machine. The machine consists of two servo motors. The machine is automatic and can be controlled using panel board. The control part consists of number of relays and controls used for controlling temperature, pressure, curing time, injection time etc. The machine works on the hydraulic principles. The machine consists of mould for the formation of weather sheds and housing. The design of the mould depends on the ratings of the insulator and the environmental conditions where it has to be installed. The step by step processes involved in rubber injection moulding machine for manufacturing insulator are as follows:



Φιγ 7. Προχεσσεσ ινϖολϖεδ ιν Ρυββερ ινφεχτιον μουλδι νγ μαχηινε

The rubber injection moulding machine employed in SPARKIL belongs to RA series which is manufactured by DEKUMA.
The specifications of the machines are as follows:

Model No.-RA500:

Ταβλε 1 □Σπεχιφιχατιονσ οφ ΡΑ500

Parameter	Unit	Value
Injection Pressure	bar	1150/1480
Injection Volume	cc	12600/10000
Clamping force	kN	5000
Mould Opening Stroke	mm	700
Distance between Heating Plates	mm	940
Minimum Mould thickness	mm	240
Heating Plate Dimensions	mm	630*1500
System Pressure	bar	220
Machine Weight	ton	19
Machine Dimension	m	5.65*3*3.8
Hydraulic Pump Motor Power	kW	30
Heating Plate Power	kW	36
Total Power	kW	72

Model No.-RA1200:

Ταβλε 2 □Σπεχιφιχατιονσ οφ ΡΑ1200

Parameter	Unit	Value
Injection Pressure	bar	1200
Injection Volume	cc	25000
Parameter	**Unit**	**Value**
Clamping force	kN	12000
Mould Opening Stroke	mm	700
Distance between Heating Plates	mm	1050
Minimum Mould thickness	mm	350
Heating Plate Dimensions	mm	800*2600
System Pressure	bar	210
Machine Weight	Ton	49
Machine Dimension	m	6.7*4.8*4
Hydraulic Pump Motor Power	kW	60
Heating Plate Power	kW	90
Total Power	kW	170

After moulding, it has to be crimped. The force for the crimping has to be applied according to the ratings of insulator. The following table gives the amount of force that has to apply for the different ratings of insulators.

Ταβλε 3 – Φορχε το βε αππλιεδ ον Ινσυλατορ φορ Χριμπ ινγ

Rating of the Insulator	Force applied in kN
11kV	5
33kV	45
132kV	120

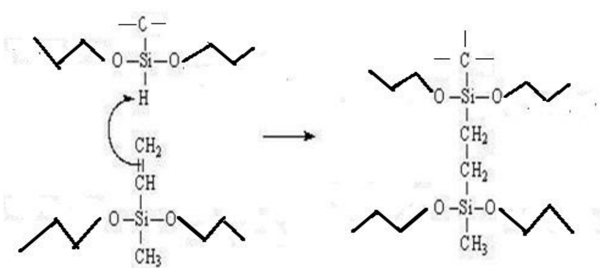
Now the finished insulator has to undergo mechanical test followed by electrical tests. After testing the insulators are inspected for any damage. If found they are rejected and remaining are dispatched.

5. Methods to improve Production of a Polymer Insulator

The following are the methods to improve the production of polymer insulator.

5.1 Reduction of Curing time

In order to produce more number of insulators curing time has to be reduced. To reduce the curing time composition of silicone has to be changed. For this purpose a compound of platinum complex has to be mixed with hydride and vinyl functional of siloxane polymer so that an ethyl bridge is formed between the two. This ethyl bridge makes the silicone rubber cure quickly.



Φιγ 8. Ετηερ Βριδγε

5.2 By Radiation Process

The compositions of silicone rubber are unstable to dirt and wet surfaces for a prolonged exposure. To avoid this we go for radiation process. In this process a three dimensional network is formed. In this radiation process the rubber is exposed to ionization radiation from ether radioactive sources or highly accelerated electrons. The drawback of this process is the emission of noxious fumes and degradation of products of peroxide. However, due to this process there is an increase in heat stability and shape of the insulators.

5.3 By using Single shed Repair mould

During flash cleaning to remove excess rubber it has to be cut .During cutting the shed might get cut accidentally resulting in the rejection of insulator. This results in lot of loss. In order to reduce this it is essential to repair the shed and restore the insulator preserving its quality. To do this we go for single shed repair mould. Through this we can rebuilt the cut shed.

6. Advantages and Disadvantages of Polymer Insulator

6.1 Advantages

The advantages are as follows:

- Excellent Hydrophobicity: Due to excellent resistance to pollution and hydrophobic properties the insulator provides good insulation without need of greasing in humid, dense fog, heavy rain and polluted climates resulting in low maintenance costs.
- Low Leakage Current : Polymer Insulators have very low leakage current due to high dielectric strength.
- Light Weight: It is light in weight compared to porcelain insulators but offer equal to better strength. Polymer Insulators are 90% lighter than porcelain insulators.
- Resistant to breakages: These insulators are flexible therefore offers greater resistance to breakages.
- Good Compact Design: It saves lot of space at very low costs
- Safety against Vandalism: Due to its flexibility and strength polymer insulators are highly resistant to breakage due to throwing stones etc.

- Aesthetic design: These insulators got a good design and appearance.

- Low Processing Time: These insulators manufacture in short time compared to porcelain insulators. It exhibits a stable long term operating behaviour for more than 30 years of outdoor exposure without any alteration in insulation properties .

- Design Flexibility: There is a lot of flexibility in the design of insulators allowing it to suit for the changes in creepage distance independent of length and aero dynamic profile,

6.2 Disadvantages

The disadvantages are:

- Mechanical failure may occur due to over crimping of polymer which results in cracks in the core rod.

- Due to improper sealing or unwanted gap between the weather sheds and core rod moisture may enter resulting in electrical failure of the insulator.

- If any failure occurs in these insulators, it is difficult to detect immediately.

7. Conclusion

Polymer insulators have demonstrated an outstanding level to withstand in a polluted environment and also proved to be better than the conventional porcelain insulators. Detailed information is given about the polymer insulators and all the necessary methods to improve its production. However there is always a need to improve the insulators to reduce the failures and to increase its lifespan. Due to the prominent advantages like low maintenance, low cost, properties like hydrophobicity and low processing time made this insulator more reliable.

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