International Journal of Electrical and
Electronics Engineering (IJEEE)
ISSN(P): 2278-9944; ISSN(E): 2278-9952
Vol. 7, Issue 2, Feb - Mar 2018, 9-16

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

BRITTLE FRACTURE OF GRP ROD USED IN POLYMERIC INSULATORS AN EXPERIMENTAL STUDY

***Nagaraj. H. P*[1], *K. N. Ravi*[2] *& N. Vasudev*[3]**

[1]*Research Scholar, VTU-RRC, Sapthagiri College of Engineering, Bangalore, Karnataka, India*

[2] *Department of EEE, Sapthagiri College of Engineering, Bangalore, Karnataka, India*

[3]*Additional Director, High Voltage Division, CPRI, Bangalore, Karnataka, India*

ABSTRACTS

In this paper, a detailed study has been carried out on the failure of Glass reinforced polymers (GRP) used in composite insulators. Different GRP rods were tested in inclined plane test and a portion of the sample of GRP rods were tested to obtain brittle fracture in the laboratory. The severity of HNO_3 solution used in the tests were 0.1N and 0.5N. Two different electrode materials of copper and stainless were used in the experiment. After obtaining the erosion of the material, the rod was subjected to mechanical tensile load test. A sample rod has yielded prior to specified mechanical load.

This experimental work has been carried out in laboratory in order to simulate the brittle fracture.

KEYWORDS: *Corona Effect, Glass Reinforced Polymers (GRP), HNO_3*

Article History

Received:* *24 Feb 2018* | *Revised:*02 Mar 2018 | *Accepted:* *06 Mar 2018

INTRODUCTION

Glass fibres are the most commonly used materials in various types of Polymer matrix composites. The main advantages of using glass fibre reinforced composites are; their properties like high strength to weight ratio, good chemical resistance capacity, good insulating property, good moisture resistance capacity and low weight are much better than porcelain and glass insulators. Three fibers, Glass, Aramid and Carbon fibers are most commonly used. Unidirectional Glass Reinforced Polymers (GRP) that are used in the manufacture of composite insulators which has got good mechanical and electrical properties.

The glass fibers are made of various types of glasses depending upon the fiberglass usage. These glasses contain silica or silicate, with varying amounts of oxides of calcium, magnesium and Boron. Fiberglass is a strong, lightweight material and is used in many products. Although, it is not as strong and stiff as composites based on carbon fiber, it is less brittle, and its raw materials are much cheaper. Other common nomenclatures for fiber-glass are glass-reinforced plastic (GRP), glass-fiber reinforced plastic (GFRP).

Electrical, Mechanical, environmental stresses and thermal are the main reasons for the degradation of the composite insulators. The mechanical and thermal stresses can be avoided up to some extent by handling the insulators properly. Whereas, the influence of environmental and electrical stresses on the ageing of GRP are difficult to assess and avoid.

Hence, it may cause major defects in the composite insulators. Environmental stresses which include mainly humidity, wind, snow, moisture, pollution etc., may cause certain damage on the polymer housing and fiber-glass rod.

The efficiency of the GRP rods will decrease due to the following reasons.

- Corona
- Absorption of moisture
- Composition of the material
- Mechanical load

The composite insulator mainly contains core material, rubber housing and the end fittings. The core material is made of Glass reinforced polymer to distribute the tensile load. The rubber housing helps to provide electrical insulation and protects the GRP from variation in atmospheric condition. The materials used for end fitting are cast iron or forged steel or aluminum etc. Typical construction of Composite insulator is shown in Figure 1.

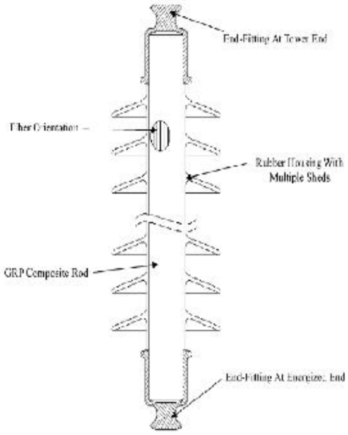

Figure 1: Composite Insulator

Failure Modes of Composite Insulators

Mechanical failure of GRP rod is characterized by one or more of the following

- Smooth fracture surfaces mostly running perpendicular to the rod axis
- Stepwise formations of smooth surfaces
- Fibres and resin break on the same plane

After the damage of the polymeric sheaths, the fibre-glass rod will be exposed to ambient conditions which are subjected to moisture, humidity, high voltage and tensile load.

Various stages of failure modes include chalking, crazing, cat scratch, grease leakage, erosion, de-bonding, splitting, peeling, and puncture, tracking and brittle fracture. Erosion is irreversible and non-conducting degradation of the surface of the insulator that occurs by major loss of material, which significantly reduces the thickness of the polymer sheath that prevents moisture ingress to the core rod.

Tracking is also irreversible degradation by formation of conductive paths developing on the surface of an insulating material. These cracks have the appearance of carbon tracks which cannot be easily removed and are conductive even when they are dry. The erosion of the fibre - glass rod will reduce the cross sectional area which may cause breakage. Breakage of an insulator core rod will no longer support conductor.

Study of Brittle Fracture in Lab

In order to understand the failure of GRP due to brittle fracture and to reduce the breakages, it is very much necessary to study the phenomena in the laboratory. After obtaining the brittle fracture in the lab on various GRP materials and analyzing the results, it is possible to select the proper material for GRP rods. The details of the experiments and procedure for obtaining Brittle fracture in the laboratory have been given in the section below.

Experimental Set-Up

Experimental setup for carrying out brittle fracture Tests in the laboratory is shown in schematic diagram Figure 2. The procedure adopted is similar to that of the procedure adopted in inclined plane test [1] and the

Experimental setup is as shown in Figure 3. Solution used for the brittle fracture experiment is of 0.1 and 0.5 Normal of HNO_3 solution. The voltage is applied between the electrodes which are of copper foils. The duration of voltage applied was about 60 min. Periodic inspections and observations were made and samples were assessed.

Sample of polymeric insulators GRP rod was considered and the test was carried out on the sections of GRP rod, with and without polymer shed.

0.1N and 0.5N of HNO_3 solution is prepared by using a nitric acid solution in the laboratory. Transformer of 5kVA was used as Test source. Mechanical load was applied after the erosion of fiber glass materials.

Procedure

The GRP rod of 15mm diameter and 150mm length was placed for testing in the stand. Copper foils were used as electrodes with 4cm distance between electrodes. A nozzle was fixed over the rod for proper drip of nitric acid of 0.1N solution. Drops were directed to drip at line end of electrode along the GRP rod. Variable voltage is applied to the specimen from a source 230V/5kV transformer. The voltage was applied to one of the electrodes and the other was earthed. The duration of the tests was about 60 minutes. The drip rate of the solution was also varied so that the critical drip rate can be evaluated. The setup is shown in the schematic diagram.

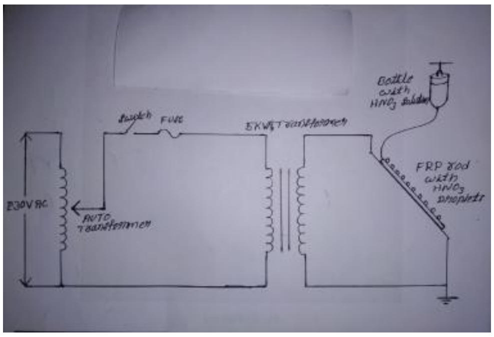

Figure 2: Schematic Diagram

Figure 3: Test Arrangement for GRP Rod

Before Testing **After Testing at 1.6KV**

Figure 4: FRP Rods Before and After the Tests

RESULTS AND DISCUSSIONS

A number of experiments were carried out in order to understand brittle fracture of GRP rod. The following results are arrived at based on the experiment and observations.

Table 1

Sl No	Source Voltage(kV)	Gap between Electrode(cm)	Flow Rate (Drops /min)	Duration
Severity 0.1N				
1	2.4	4	30	60
2	2.4	4	20	60
3	1.4	4	10	60
Severity 0.1N				
1	1.6	4	30	60
2	2.4	4	20	60
3	1.4	4	10	60

When copper foils were used as electrodes, it was found during an experiment, that copper was forming cupric sulphate on the surface of GRP rod. This formation was leading to permanent surface conduction on the GRP rod. Hence, it was thought that it can be avoided in subsequent experimentations. The second setup of the experiment was initiated using stainless steel foils, in which there was no formation of conductive paths on the surface. Further tests were conducted using stainless steel foils as electrodes and there was no conductive path between the electrodes.

After Testing

At 2.4KV (a)

At 1.4KV (b)

At 1.6KV (c)

After Wash (d)

Figure 5: GRP Rods after Tests

Applying Mechanical Load

Since the mechanical load was not applied during the above tests, GRP rod was subjected to tensile strength test. The GRP rod got fractured at peak load of 68KN. The photograph of brittle fracture is as shown in Figure 4. It can be seen from the results that the GRP rod is of very good quality.

Figure 6: Brittle Fracture

REPORT

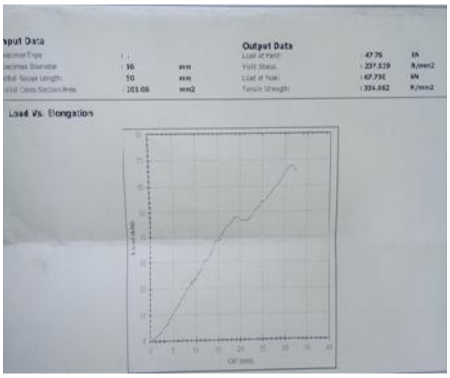

Figure 7

CONCLUSIONS

The gradual deterioration of the fiber glass rod is closely studied and recorded. The effect of the solutions of severity 0.1N and 0.5N of HNO3 concentrations was studied. The sample on which the erosion were observed are subjected to mechanical load & it was found that the fracture has occurred resembling the brittle fracture. Severe scintillations & deep erosion were observed on the fiber glass rod. The rod was subjected to tensile load & at 69KN, the fracture has occurred. On the observation of failure, it can be seen that, the brittle fracture occurred at the eroded zone. Further application of the rod under the mechanical stress leads to the complete brittle fracture. Thus Brittle fracture was obtained in the Lab by causing erosion on the fibre and on application of tensile load.

REFERENCES

1. *Refat Atef Ghunem, "Using the inclined-plane test to evaluate the resistance of outdoor polymer insulating materials to electrical tracking and erosion IEEE Electrical Insulation Magazine , Volume: 31, Issue: 5, Sept.-Oct. 2015.*
2. *M.Kumosa, L.Kumosa, and D. Armentrout, "Failure analyses of non-ceramic insulators: Part II The brittle fracture model and failure prevention, IEEE Elect. Insul. Mag., Jul./ Aug. 2005.*
3. *M.Kuhl, "FRP rods for brittle fracture resistant composite insulators, IEEE Transactions on Dielectrics and Electrical Insulation , Volume: 8, Issue: 2, Apr 2001.*

4. *Ashok Kumar, Corona Effect on Transmission Lines, International Journal of Electrical and Electronics Engineering Research (IJEEER), Volume 3, Issue 5, November-December 2013, pp. 133-136*
5. *Abraiz Khattak and Muhammad Amin, "Influence of stresses and fillers on the aging behavior of polymeric insulators", Rev. Adv. Mater. Sci. 44 (2016) 194-205*
6. *Schmuck, F., de Tourreil, C., Brittle Fractures of Composite Insulators an Investigation of their Occurrence and Failure Mechanisms and a Risk Assessment, CIGRE WG 22-03, 2003.*
7. *L. Kumosa, D. Armentrout, B. Benedikt, M. Kumosa, "An investigation of moisture and leakage currents in GRP composite hollow cylinders", IEEE Trans. Dielect. Elect. Insul., 2005.*
8. *Nagaraj H.P, Vasudev N, Ravi K.N, Shivakumara Aradhya, "Behaviour of water droplets on polymer surface", 2012 IEEE 10th International Conference on the Properties and Applications of Dielectric Materials, Bangalore, India, pp. 1-4, 2012*