

The Influence of Mechanical Parameters on Dielectric Characteristics of Rigid Electrical Insulating Materials

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Abstract. Rigid electrical insulating materials are used in the manufacture of work equipment with electric safety function, being mainly intended for use in the energy sector. The paper presents the results of the research on the identification of the technical and safety requirements for rigid electrical insulating materials that are part of the electrical insulating work equipment. The paper aims to show the behaviour of rigid electrical insulating materials under the influence of mechanical risk factors, in order to check the functionality and to ensure the safety function for the entire life time. There were tested rigid electrical insulating equipment designed to be used as safety means in electrical power stations and overhead power lines.

1. Introduction

Insulated work equipment used in the working process, according to the provisions of the Technical Instructions, which contain technical and safety instructions, must ensure the highest safety level for workers against the risk factors of accident and professional disease, without generating themselves a risk both for the user and for other people in the work environment [1].

This means, first of all, that protective equipment (equipment that is part of the work equipment category as defined by Executive Order no. 1146/2006) must form a barrier between the user and the environment, thus the risk on user to be as small as possible, under the permissible limit which might lead to injury or professional disease.

Also, protective equipment must not cause any danger to the user, such as: injuries, toxic emissions, emissions of corrosive substances, etc.).

It is known that most hazardous factors in the work environment act insidiously or abruptly, so it is impossible for the exposed person to seize the risk in a timely manner in order to avoid injury or professional illness [4, 8].

Studies on the behaviour over time of the protective equipment in use have made it clear that they lose their dielectric characteristics due to mechanical damage, the aging of materials, inappropriate use, etc.

Analysing the statistic weight of the factors that influence the safety characteristics over time it is found that the mechanical factors during use, followed by the aging of the protective materials, have a large share.

From the monitored work equipment categories it was found that 37% of them have scratches, 23% material bruises, 10% cracks.



The mechanical demands during the use of the protective equipment, require the choice, even from the design, of materials that are both electrically and mechanically resistant to technical characteristics and safety requirements to be tested.

2. Identification of the specific mechanical safety requirements

The identification of the specific technical and mechanical safety requirements that the rigid electro-electrical insulating materials, which are part of the electro-electrical insulating work equipment, have to be based on:

- field of use (type and technical characteristics of electrical installations to be used);
- the operating principle and the way of use;
- usage limits;
- unappropriated usage practices;
- environmental work requirements;
- technical criteria;
- the results of the safety tests for compliance certification, in order to certify the quality of the safety and the periodic tests (visual tests and verifications of electrical characteristics);
- the level of technical progress [7].
- user / consumer expectations regarding the safety of the work equipment in question [6, 7].

In Figure 1 the mechanical and safety requirements applicable to rigid electrical insulating materials are identified.

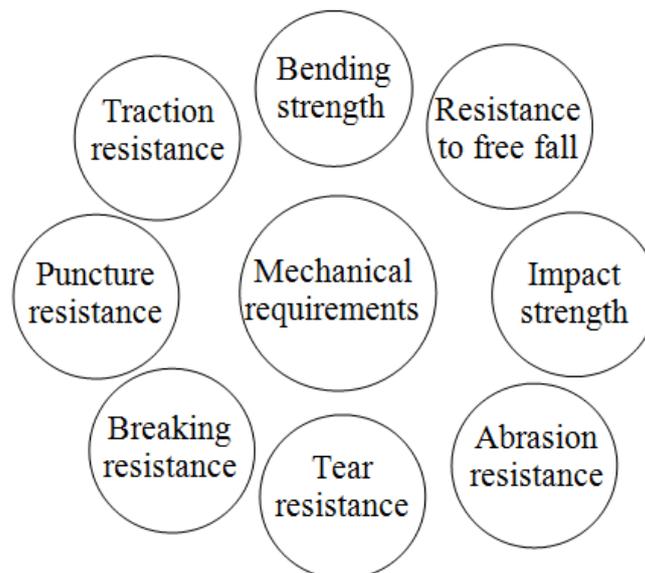


Figure 1. Mechanical and safety requirements applicable to rigid electrical insulating materials.

The influence of the mechanical factors on the dielectric characteristics of the rigid electrical insulating materials was studied on the following types of protective equipment: electrical insulating shutter. Electrical insulating shutters are protective equipment that applies between the disconnector's mobile (the disconnector is in open position) and fixed contacts [2].

A total of 9 types of electrical insulating shutters designs have been tested and monitored. Three are made of a material made by an extrusion process from non-plasticized polypropylene (PP), three other electrical insulating shutters designs are made from extruded material of non-plasticized PVC type S and three electrical insulating shutters designs are made from glass fiber reinforced polyester resin (GFRPR).

The three protection equipment models have been checked for compliance and security certification and have been monitored since commissioning for 5 years through examinations, visual inspections, and dielectric features. The three protection equipment models have been tested for compliance and safety certification and have been monitored since commissioning for 5 years, through examinations, visual inspections, and dielectric characteristics.

These characteristics are the maximum values of forces and stress that could be transmitted by the protective equipment or to which they might be subjected. Some of the mechanical tests, such as proofing of breakage and traction resistance, were performed on specimens obtained from the basic material, and some tests performed on materials cut from the body of the electrical insulating equipment presented as sample.

Part of the mechanical tests such as mechanical shock test with pendulum, bending, shock at free fall, were performed on the functional equipment, in order to assess the behaviour of the material after having undergone hot bending, clipping and bonding .

3. Experimental procedures

Mechanical tests were performed on specimens of protective materials and / or equipment that were conditioned by storing in a relaxed position for 24 hours at room temperature (24 ± 2) ° C and (50 ± 5) % RH, standard atmosphere B [10]. In table 1 shows the list of mechanical stresses in which samples of the material used to make the electrical insulating shutters were tested.

Table 1. List of mechanical stresses.

No. crt.	Mechanical stress	Maximum allowed limis
1	Traction	min. 12 N/mm ²
2	Bending	10 daN
3	Puncture	min. 45 N
4	Impact	20 J
5	Free falling	1,5 m
6	Endurance	100 mounting / dismounting
7	Abrasion	2000 cycles

For determination of mechanical stresses to which the material samples and the protective equipment were subjected, the provisions of the national and European standards were also taken into account [3].

4. Results and discussions

Protective equipment or samples of the collected material were tested for dielectric properties at the beginning of the study, and after each mechanical stress. For dielectric test, 50 kV in three points was applied, and held for 3 minutes. The electrodes used in this test are two cylinders of 25 mm in diameter and 25 mm in height and 75 mm in diameter and 25 mm in height, respectively.

Figure 2 shows the leakage current for all nine electrical insulating shutters made by the same manufacturer, before the mechanical stresses are performed.

The order in which the mechanical stresses were performed at the start of the study was random, during the study the order of the test was established.

Verification of mechanical resistance to puncture was performed on circular specimens with a diameter of 50mm. The longitudinal speed applied was 500 ± 50 mm / min. It was measured the force at which the material was punctured. The results of the verification are shown in Figures 3 and 4.

The traction strength test was performed on dumbbells. The applied test speed was 50mm / min. The results for non-plasticized PVC type S are shown in Table 2, and for Fiberglass reinforced polyester resin (FGRPR) in Table 3.

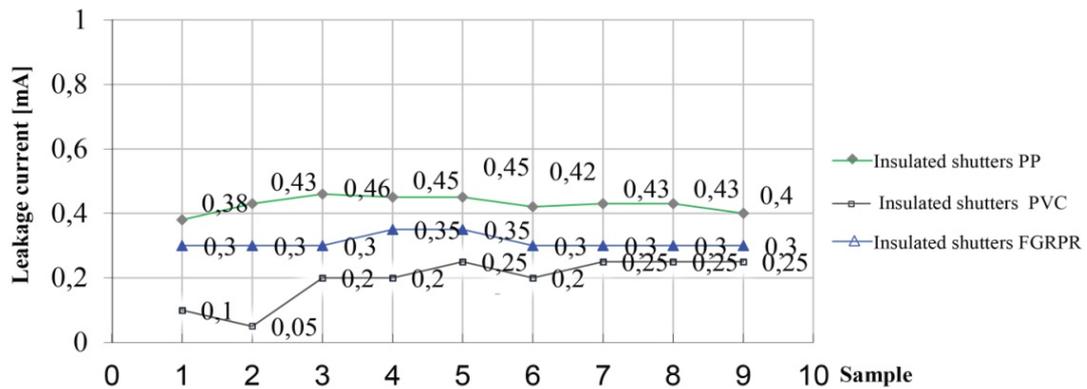


Figure 2. Leakage current values - before mechanical tests.

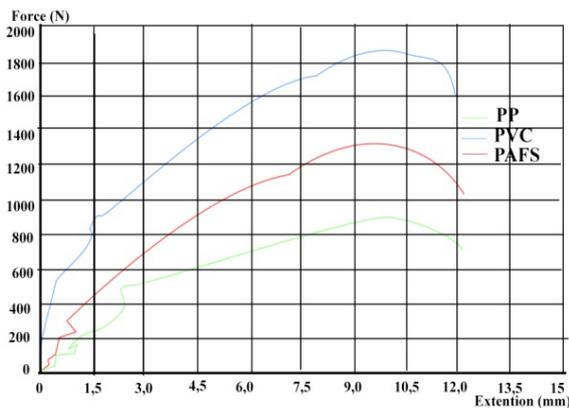


Figure 3. The behaviour of samples to puncture.

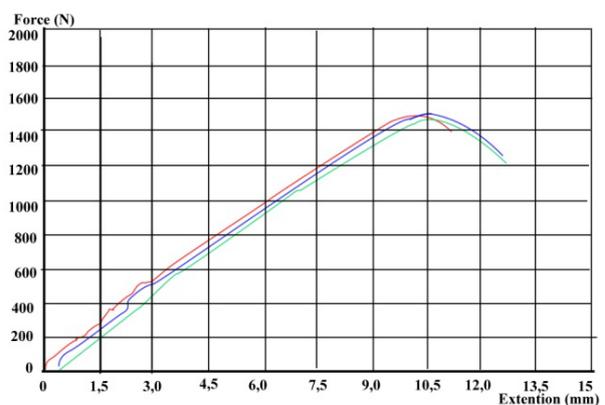


Figure 4. The behaviour of polypropylene (PP) samples, to puncture. Test on 3 specimens.

Table 2. Traction resistance test results for non-plasticized PVC type S.

Sample No.	Dimensions of dumbbell specimens (cm)		F_{tear} (N)	$\bar{\sigma}_{\text{tear}}$ (N/mm ²)	
	b	h		$\bar{\sigma}_{\text{tear } i}$	$\bar{\bar{\sigma}}_{\text{tear}}$
1	4.1	6.1	1530	61.2	61
2	4.0	6.4	1520	59.4	
3	4.0	6.4	1490	58.2	
4	4.3	6.2	1710	64.1	

Table 3. Traction resistance test results for non-plasticized PVC type S.

Sample No.	Dimensions of dumbbell specimens (cm)		$\bar{\sigma}_{\text{tear}}$ (N/mm ²)	
	b	h	$\bar{\sigma}_{\text{tear } i}$	$\bar{\bar{\sigma}}_{\text{tear}}$
1	4.0	6.2	65.3	62
2	4.2	6.2	59.3	
3	4.1	6.1	56.6	56
4	4.2	6.3	55.4	

The mechanical shock test was carried out on complete equipment, including accessories, with a shock test pendulum consisting of an oscillating arm around the horizontal axis and a hammer fixed to its lower part. The test consisted in the application of hits including on each corner (made by hot bending) and in areas as close as possible to soldering and fixing by gluing, with a mechanical shock effect of 2 Nm. After the mechanical shock test, dielectric rigidity was tested. Figure 5 gives the leakage current values. The dielectric characteristics are maintained.

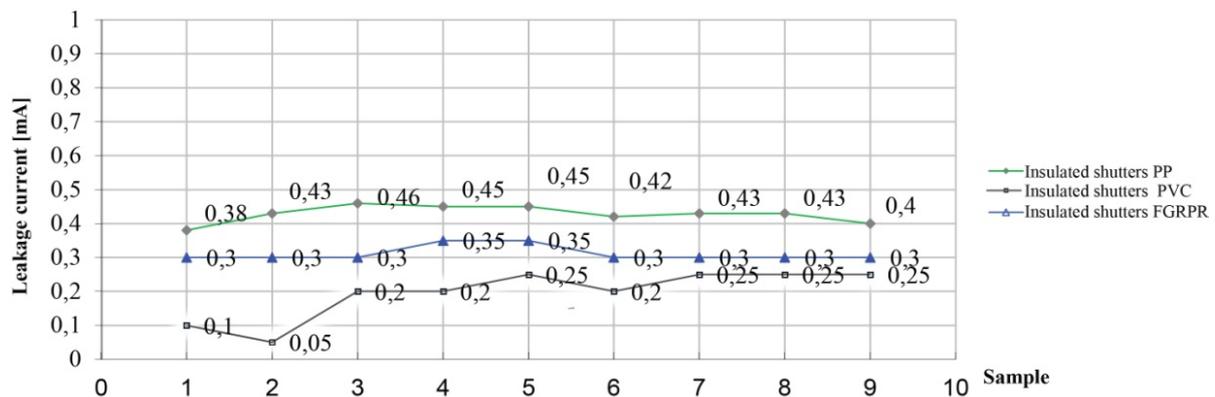


Figure 5. Leakage current values- after testing mechanical shock.

Verification of free fall resistance was performed on complete equipment, including accessories, the purpose of the verification being to check the material and the bending and binding of the material.

The equipment was dropped on a hard floor (concrete) from a height of 1.5 m, from different positions: vertical, horizontal, oblique. After the free falling test, dielectric rigidity was tested. Figure 6 shows the leakage current values. The Leakage current on the PVC specimen is above the 1 mA limit, due to bad processing of the corners. The PVC specimen was replaced.

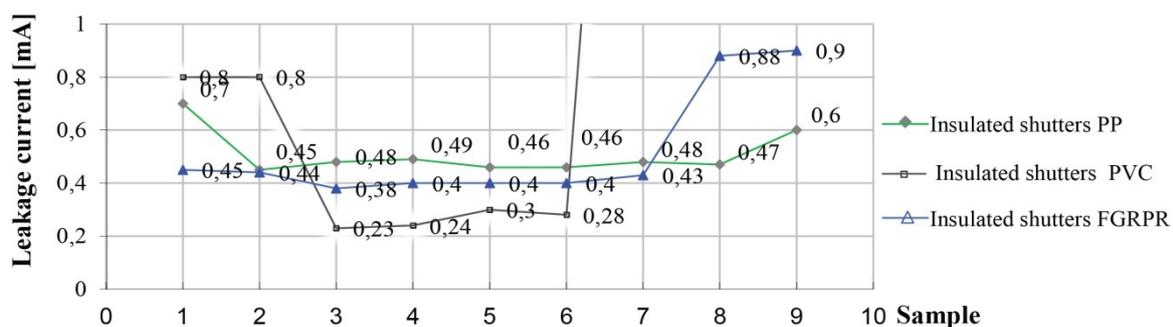


Figure 6. Leakage current values - after testing on free falling resistance.

Verification of endurance consisted in performing 100 mounting / dismantling of the electrical insulating shutters on the contacts of a 20 kV disconnector. At the end of the test, the 9 specimens had scratches on 30% of the surface. Immediately after this test, the dielectric rigidity was tested. Figure 7 shows the leakage current values. Decrease of dielectric characteristics is noted. As a result of the deterioration in the test, the materials were also tested for abrasion.

The study continued by performing mechanical tests after which the dielectric properties were tested at the end.

Test methods have been developed in the study to verify the mechanical safety characteristics of the electrical insulating shutters, which must not show on both sides harmful physical irregularities such as: protrusion that prevents the uniformity or smoothness of the surface, for example: cracks,

cuts, foreign conductive particles embedded in the material, creases, bumps, air bubbles, protuberances or protruding protrusions of the mould. These harmful physical irregularities can't guaranty the dielectric characteristics of the protective equipment, with serious consequences on the user's health and safety and the risk of damage to the electrical panels in which they are used.

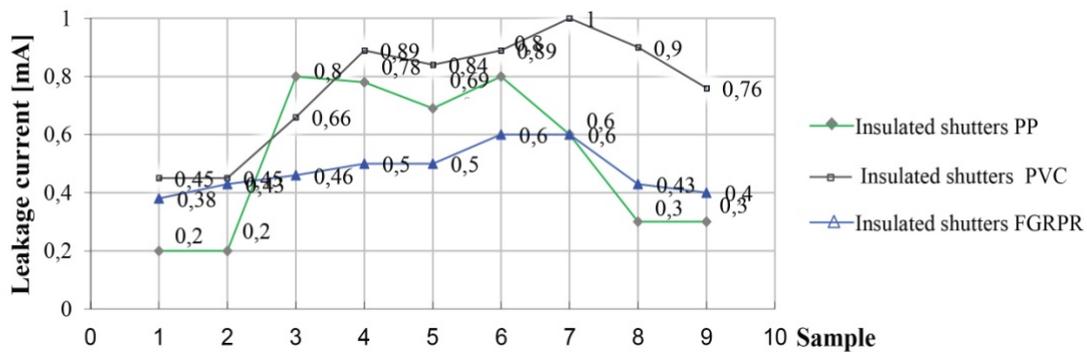


Figure 7. Leakage current values - after checking for resistance to endurance.

The samples of rigid electrical insulating material tested to mechanical puncture resistance were taken within 5 years from the manufacturers, in order to evaluate and verify the behaviour over time of various electrical insulating materials that are the basis of the manufacture of protective equipment for use in electrical installations.

The behaviour of rigid electrical insulating materials designed to make electrical insulating shutters was demonstrated by tests performed on specimens made from polypropylene (PP), PVC type S, and fiber glass reinforced polyester resin (FGRPR) respectively.

It is noted that the electrical insulating shutters made of polypropylene (PP) are more mechanically resistant than those made of PVC type S and FGRPR, maintaining the technical characteristic for a longer period of time, and guaranties the dielectric characteristics, both under normal and exceptional or unexpected working conditions [3, 4, 9].

The electrification plates made of non-plasticized polypropylene (PP) blends allow this to be used for a longer time than those made from PAFS, and PVC, which has led the manufacturers of rigid protective equipment to replace the composition and structure of the electrical insulating material during the period of the 5 years that were the subject of the study.

It is found that, depending on the content of the non-plasticized mixture from which the electrical insulating plate is made, the mechanical strength of the electrical insulating material is different, with effect on the preservation of the dielectric characteristics and the duration of use.

The inappropriate use of the materials for the protection equipment has a negative effect on the efficiency of the protection characteristic of the equipment in use and the duration of their use in the electrical installations, contributing to the increase of the non-security costs and of the investment expenses, having an effect on the competitiveness of the company and users' safety at work.

The electrical insulating shutters made of polypropylene (PP) allow to be used for a longer time than those made from FGRPR and PVC, which has led the manufacturers of rigid protective equipment to replace the composition and structure of the electrical insulating material within these 5 years, in which the study was performed.

It is found that, depending on the content of the non-plasticized mixture of electrical insulating shutters, the mechanical strength of the electrical insulating material is different, with effect on the preservation of the dielectric characteristics and the duration of use.

The inappropriate use of the materials has a negative effect on the efficiency of the safety characteristics of the equipment in use and the duration of their use in the electrical installations, contributing to the increase of the non-safety costs and of the investment expenses, having an effect on the competitiveness of the company and users' safety at work [1].

5. Conclusions

The choice of materials from which rigid protective equipment is made is a determining factor in ensuring occupational health and safety [2, 5]. Due to inappropriate use of materials from which protective equipment is made, they may suffer damage during use in electrical installations, losing their dielectric characteristics due to the mechanical parameters and the efficiency of the structure of electrical insulating material. Over time, it has been found that there is a need to apply procedures for testing different work equipment with protective functions, both at the level of the users and the installation in which they are used.

By eliminating these testing practices, in the last 15 years, it has been noted the need to improve the technical characteristics of rigid protective equipment, as a result of their behaviour over time, both in terms of reliability and safety features, in order to protect workers in electrical installations.

To guarantee the safety characteristics of work equipment with electrical insulating function, intended mainly for use in the energy sector, it must ensure a high degree of dielectric parameters for rigid electrical insulating materials and to reduce the mechanical risk factors resulting from the nature and structure of chosen electrical insulating material.

The behaviour of rigid electrical insulating materials is determined by the influence of mechanical risk factors in order to guarantee the functionality of the protective equipment and to ensure the safety function throughout their use as protective means in electrical power stations and overhead power lines.

6. References

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