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# Evaluation of LSZH Materials of Network Data Cables

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## Abstract

In general network data transmission cables have Low Smoke Zero Halogen (LSZH) or Halogen Free Fire Retardant (HFFR) materials as outer protection covering or sheathing. During the fire and smoke property assessment such type of network cables adequately meet the requirement of the standard with respect to fire retardancy and smoke release. In one of the cables, the smoke properties are found in order, however, it did not meet the flame retardancy properties such as Oxygen Index and Temperature Index. To figure out the reason two different samples, *i.e.*, passed and failed are subjected to various material characterization assessments such as Thermo Gravimetric Analysis (TGA) and Fourier Transform Infrared Spectroscopy (FTIR) are carried out. The physical properties such as Tensile Strength, % Elongation and Hot deformation characteristics are also carried out for both samples. From the results, it has been observed that the percentage weight of the inorganic material present in the LSZH materials, non-uniform dispersion of these filler materials and the type of filler materials play a vital role in influencing the fire and smoke properties of the LSZH sheathing materials. The optimum selection of organic filler material and the correct method of mixing is required to achieve the desired properties.

**Keywords:** Flame Retardancy, Low Smoke Zero Halogen (LSZH), Network Cables, Smoke Density

## 1. Introduction

Network Data Cables, specifically twisted pair cables designed for Ethernet-based computer networks, serve as a crucial medium for data transmission. CAT 6 cables, in particular, are widely employed for computer networking purposes. Constructed with four pairs of copper wires dedicated to data transfer, these cables feature an outer protective covering typically made of LSZH to enhance fire safety.

To assess the characteristics of the LSZH material used in the outer sheathing of CAT 6 cables, various fire and smoke tests, including Oxygen Index, Temperature Index, Halogen Content, Flammability, and Smoke Density tests, are conducted. This paper focuses on the evaluation of the properties of the outer LSZH sheathing of CAT 6 cables.

## 2. Assessment Techniques

### 2.1 Fire Retardance Property

The flame retardancy of the outer LSZH material is evaluated based on the Oxygen Index and Temperature Index values. The Oxygen Index represents the minimum concentration of oxygen required for the LSZH material to sustain combustion. A higher oxygen concentration needed implies a greater flame retardancy, indicating that the material requires higher oxygen levels to support burning under prevailing ambient conditions. The Temperature Index is a linearly extrapolated temperature value derived from measuring the oxygen index at three elevated temperatures. It signifies the minimum temperature at which the LSZH material continuously burns at 21% ambient oxygen. In the flammability test, the material's vertical propagation nature is examined

### 2.2 Halogen and Smoke Properties

Ideally, the LSZH material should be free of halogens, with a specific emphasis on chlorine. The assessment of chlorine content in the material is conducted using the IEC 60754 (Part-1) test method[1]. Furthermore, the absence of halogens is confirmed through the IEC 60754 (Part-2) test method[2], which involves dissolving the gases emitted from the material in distilled water and evaluating the solution's pH and conductivity.

The measurement of smoke density in LSZH material gauges the light obscuration caused by the smoke emitted

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from the material. Following the ASTM D 2843 standard[3], the smoke density test is conducted on molded samples of LSZH material for 4 minutes, with the result expressed as a smoke density rating, representing the average smoke density.

For cables, the IEC 61034 test method is applicable[4], involving the selection of a specified number of one-meter length cables based on their diameter. In this method, the other combustible materials within the cable construction are exposed to fire for 40 min. The evaluation is based on the minimum transmittance observed during the test.

The CAT 6 cables considered for this study are shown in Figure 1.



**Figure 1.** A view of CAT 6 cables.

# 3. Test Results

## 3.1 LSZH Proerties

The results of LSZH properties of various CAT 6 cables are tabulated in Table 1.

**Table 1.** Results of CAT 6 LSZH cables

| Properties | CAT 6 Unarmoured LSZH Cable | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| OI (%) | 28 | 35.5 | 34 | 34 | 38.5 |
| TI (°C) | 90 | 300 | 300 | 290 | 310 |
| Halogen(%) | 0 | 0 | 0 | 0 | 0 |
| Smoke Density Rating (%) | 10.8 | 4.8 | 4.1 | 4.5 | 4.6 |
| Minimum Transmittance (%) | 61 | 91 | 88 | 92 | 91 |

The findings indicate that the majority of the cables exhibit superior flame retardant and smoke properties. However, one of the cables did not meet the necessary flame retardant test requirement, and the material's halogen content was found to be zero, confirming its classification as LSZH. Generally, the required values for oxygen index and temperature index properties are a minimum of 29% and a minimum of 250°C and one of the cables is not meeting this. The observed smoke density rating of this particular cable is also slightly higher compared to the other cables. The value of minimum transmittance observed for the same cable also shows a difference compared to other cables. In this particular test, the eight numbers of the entire cable of 1 m length were bundled together and tested for smoke emission. Hence in this, the other insulation material also contributes to the smoke generation and low transmission results. However, the halogen, smoke density rating and transmittance values of this failed cable fall within the requirement of the standard.

Therefore, to conduct a more in-depth analysis, studies on the density of the material, TGA, FTIR analysis, hot deformation, tensile strength and elongation at break are carried out for both the passed and failed LSZH material. The passed LSZH material is termed as LSZH 1 and the failed one is termed as LSZH 2.

## 3.2 Material Characteristics

Polymeric material density refers to the correlation between the total mass and volume of the material. This metric is utilized to examine structural changes and evaluate the overall composition of the polymer. Furthermore, density acts as a means to assess material uniformity across various applications. The table provides the mass and density values for both samples.

**Table 2.** Density Values of LSZH materials

| Sample | Density (g/cm$^3$) | Percentage of Residue from TGA analysis (%) |
|---|---|---|
| LSZH 1 | 1.50 | 45 |
| LSZH 2 | 1.42 | 55 |

Table 2 reveals a distinction between the two samples in both density and observed percentage of residue. The LSZH 2 sample exhibits a slightly lower density compared to the LSZH 1.

In Thermo Gravimetric Analysis (TGA) the mass change of the sample over a temperature while heating at a constant

rate is measured. In TGA, the Decomposition Temperature and percentage of Residue of the material can also be evaluated. Figures 2 and 3 show the TGA graphs of the LSZH 1 and LSZH 2 sheath materials.

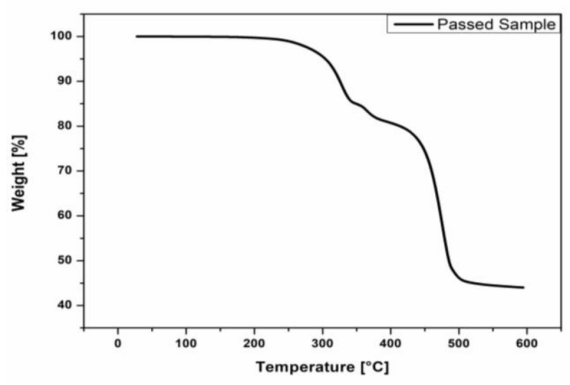



**Figure 2.** TGA of LSZH 1 material.

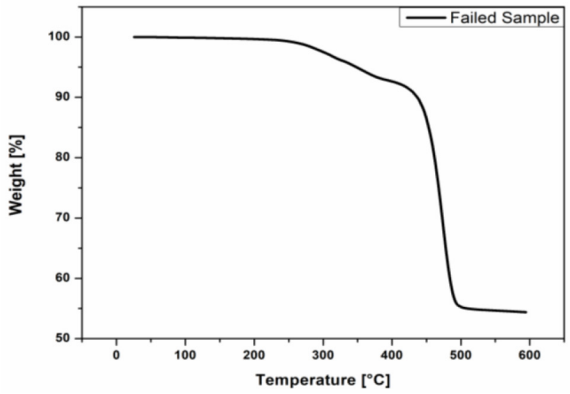



**Figure 3.** TGA of LSZH 2 material.

Examining Figures 2 and 3, it is evident that the percentage of residue varies between LSZH 1 and LSZH 2 materials. For the LSZH 1 sample, the residue constitutes approximately 45% of the sample's weight, while for the LSZH 2 sample, the residue comprises about 55% of the sample's weight. Notably, the mass loss initiates around 300°C for both samples. The decomposition temperature for both samples is nearly identical, with a range of around 490°C. Between 300 °C and 500°C, the samples undergo decomposition in two stages. The polymer content experiences complete degradation, while the filler does not decompose and remains as a residue. Therefore, the increased residue in LSZH materials suggests a higher filler content, essential for achieving the desired fire retardant and low smoke properties. The reason for the change in the weight of residue could be attributed to the uneven distribution of the inorganic filler content between both LSZH samples or due to the usage of different organic filler materials[5].

## 3.3 Fourier Transform Infrared Spectroscopy

The infrared spectrum of a molecule serves as a distinctive fingerprint for identification through comparison with reference spectra. The functional groups linked to the molecule generate identifiable and consistent absorptions in the spectrum, offering insights into whether the molecule comprises linear or branched chains. Additionally, the infrared spectrum can indicate the presence of unsaturation or aromatic rings in the structure, as well as help deduce the existence of specific functional groups. Furthermore, it allows for determining the local orientation of the group and its placement within the structure's environment. The functional groups observed with both LSZH samples are given in Table 3[6,7].

**Table 3.** FTIR Results LSZH samples

| Sample | Group Frequency ($cm^{-1}$) | Functional group/ assignment |
|---|---|---|
| LSZH 1 | 3620 | tertiary alcohol |
| | 3525, 3433, 3393 | Hydroxy group, H-bonded OH stretch |
| | 2916, 2849 | methylene C-H asymmetric stretch and symmetric stretch |
| | 1738 | aromatic combination band |
| | 1462, 1372 | Methyl C-H asymmetric bend and symmetric bend |
| | 1240 | skeletal C-C vibration |
| | 1014, 967 | Cyclohexane ring vibrations |
| | 792 | aromatic C-H out-of-plane bend |
| | 729 | C-Cl stretch |
| LSZH 2 | 3525 | Hydroxy group, H-bonded OH stretch |
| | 2916, 2849 | methylene C-H asymmetric stretch and symmetric stretch |
| | 1739 | aromatic combination band |
| | 1412 | methyl (CH3) groups |
| | 1238 | skeletal C-C vibration |
| | 1019, 967 | Cyclohexane ring vibrations |
| | 872 | characteristic peaks of calcite |
| | 798 | aromatic C-H out-of-plane bend |
| | 729 | C-Cl stretch |
| | 711 | characteristic peaks of calcite |

The peaks observed with both samples are almost the same. However, the intensities of some of the peaks are different for both samples which can be observed in Figures 4 and 5. The initial peaks such as 3525, 3433, and 3393 $cm^{-1}$ correspond to the Hydroxy group which is responsible for the generation of water when the material is under fire and for achieving fire retardancy. For the LSZH 2 sample, these hydroxy groups are not of prominent intensity. In the case of the LSZH 2 sample, the peak has decreased in density at peak 1412 $cm^{-1}$ belonging to vibrations of OH Bonds. The 1412 $cm^{-1}$ peak in FTIR spectroscopy is typically associated with bending vibrations of methyl (CH3) groups in organic compounds. This peak is often observed in various polymers, particularly those containing alkyl groups such as Polyethene (PE) and Polypropylene (PP). The intensity and shape of the OH stretching vibration peak can provide information about the strength and nature of hydrogen bonding in a molecule. Hydrogen bonding interactions between OH groups and other functional groups or molecules can significantly influence the physical and chemical properties of substances.

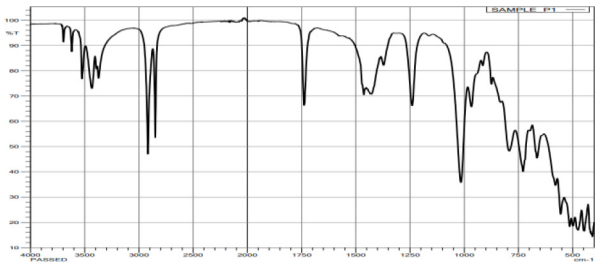


**Figure 4.** FTIR of LSZH 1 material.

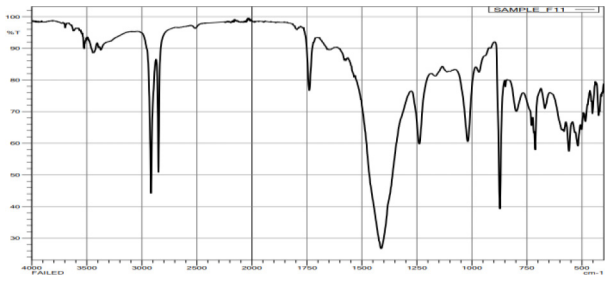


**Figure 5.** FTIR of LSZH 2 material.

From the observed FTIR spectra, it is observed that between the range group frequencies of 300°C to 1750°C, the peaks are almost the same for both the LSZH samples. However, before 300°C and after 1750°C, there is a difference between the observed peaks in both samples which could be attributed to the non-uniform dispersion of filler materials[5].

## 3.4 Tensile and Elongation Properties

Both LSZH samples are evaluated for their tensile and elongation properties as per the applicable standard BS EN 50290-2-27. The tensile and elongation properties are measured for the un aged and aged samples of LSZH sheathing. The samples are aged for 168 h duration at a temperature of 100±2°C. The observed results are shown in the Tables 4 and 5.

**Table 4.** Results of Tensile Strength of LSZH Samples

| Sample | Tensile Strength N/mm² | | % Variation |
|---|---|---|---|
| | BA | AA | |
| LSZH 1 | 11 | 11.1 | 1.1 |
| LSZH 2 | 12.3 | 12.4 | 1.3 |

**Table 5.** Results of Elongation of LSZH Samples

| Sample | Elongation at break (%) | | % Variation |
|---|---|---|---|
| | BA | AA | |
| LSZH 1 | 204.5 | 145.5 | -28.9 |
| LSZH 2 | 177.0 | 125.5 | -29.1 |

As per the product standard BS EN 50288-7[8], the requirement values for tensile strength and percentage elongation at break are at least 9 N/mm² and 125%, respectively. The maximum allowable percentage variation of aged samples for tensile strength and percentage elongation at break is ± 30% compared to un aged samples.

Hence from the results, it is observed that both the LSZH Samples are meeting the requirement of the standard in terms of tensile, elongation and percentage variation. However, the elongation values of the LSZH 2 sample are lower compared to the LSZH 1 sample in both prior to ageing and after ageing cases which indicates that the LSZH 2 material loses its flexibility or elongating nature in a faster manner[9]. The tensile strength of the LSZH 2 sample was higher than the LSZH 1 sample, however, the corresponding elongation of LSZH 2 is lower than the LSZH 1. This might be due to the poor interfacial adhesion between the polymer and the filler[10].

Higher elongation values suggest that the polymer can undergo more stretching or deformation before it breaks, indicating greater flexibility. This property is essential in various applications where the material needs to withstand bending, stretching, or other forms of mechanical stress without fracturing or failing. Conversely, lower elongation values imply that the material is more brittle and less capable of withstanding deformation before failure.

### 3.5 Pressure Test Properties

The pressure test or hot deformation test has also been for both the LSZH Samples and the results are tabulated as shown in Table 6. In this test the samples were to a temperature of 80±2°C in an oven for a duration of 4 h, hanging from a holder with a weight attached to their low end. The weight is determined according to the test standard and depends on the sample cross-section. This test is to determine the resistance of thermoplastic materials to deformation when subjected to mechanical pressure at high temperatures.

**Table 6.** Results of hot deformation of LSZH samples

| Sample | Hot Deformation (%) | Specified Value of Hot Deformation (%) |
|---|---|---|
| LSZH 1 | 4.19 | 50 |
| LSZH 2 | 8.80 | |

From Table 6, it is understood that both the samples meet the requirement of the standard and there is a visible change among themselves.

## 4. Analysis of Results

The various assessment results of LSZH materials of the CAT 6 cables are analyzed for the possible reason for the failure of one of the LSZH materials. The optimum amount of inorganic filler material needs to be mixed with the base material to achieve the required physical, chemical, fire retardancy and smoke properties. From the analysis, it is observed that the density of the LSZH 2 is lower than the LSZH 1 sample which is attributed to the non-selection of optimum percentage of inorganic filler materials. This is also visible in the case of TGA analysis, wherein the residue of LSZH 2 was 55% and the residue of LSZH 1 was 45% indicating the high filler content in the failed sample. This also may be related to the non-uniform mixing of the filler material with the base material. The difference in the observed FTIR peaks and intensity of both the LSZH materials also reveals that the dispersion of the filler material is not uniform in the failed material. The tensile and elongation properties also show distinguishable differences between both the passed and failed samples. The high filler content in the failed sample might have improved the tensile strength but the polymer might not be sufficient to hold the filler content and the elongation has decreased. The percentage elongation of the failed sample after aging is marginally meeting the requirement of the standard. The percentage of hot deformation is also higher with the LSZH 2 sample and however within the required value of the standard.

The LSZH 2 sample also meets the properties such as tensile, elongation, hot deformation, smoke release and halogen content as that of the other LSZH 1 sample. However, the LSZH 2 does not meet the requirement of oxygen index and temperature index values. They are related to the flame retardancy of the material. Hence the variation in the filler content in weight, and the non-uniform dispersion could have influenced this property to be very low. Hence it is evident that the optimum selection of the filler materials and proper uniform blending of the filler material with the base material is required to achieve the desirable physical and fire retardant and smoke properties of the special sheathing materials.

## 5. Conclusion

From the studies carried out the following conclusions are drawn.

1. The flame retardancy of LSZH material depends upon the optimum selection of appropriate organic filler material and uniform dispersion of the filler in the base material.
2. If there is variation in the percentage of organic filler material, it not only affects the fire retardancy characteristics but also affects the after ageing physical properties such as tensile strength, and percentage elongation.
3. The type of inorganic filler material also plays an important role in achieving the desired flame retardancy and smoke properties.
4. The suitable and optimum inorganic filler material needs to be selected in such a way the material does not pose the required physical, chemical and fire and smoke properties even after thermal ageing
5. The optimum percentage of filler material is required so that the base polymer can properly hold the filler material with adequate interfacial adhesion.

## 6. Acknowledgement

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