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ASSESSING THE CONDUCTIVITY OF WIRES UNDER DIFFERENT COATING TYPES

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Abstract

This study investigates the impact of different types of coatings (A, B, C and D) on the conductivity of wire. The experiment employed a one-way ANOVA followed by post hoc analysis using Tukey's Honest Significant Difference (TukeyHSD) test to determine significant differences between the coatings. The results indicated that coatings A, B, C and D have a significant effect on wire conductivity ($F (3, 16) = 29.79$, $p<0.05$). Post hoc analysis revealed significant differences between the following pairs of coatings: C-A, D-A, C-B, and D-B ($p<0.05$). These findings suggest that the choice of coating significantly impacts wire conductivity and may guide manufacturers in selecting coatings based on specific conductivity requirements.

Keywords: Wire, Conductivity, Coating

INTRODUCTION

Electrical conductivity is a fundamental property that determines the ability of a material to facilitate the flow of electric current. In the context of electrical and electronic systems, the conductivity of wires and coatings plays a crucial role in the efficient and reliable transmission of electrical signals and power. Understanding the factors that influence the conductivity of wires and coatings is essential for the design, development, and optimization of various electronic and electrical applications.

The conductivity of a wire is primarily dependent on the material composition, cross-sectional area, and length of the wire. Metals, such as copper and aluminum, are commonly used as conductors due to their high electrical conductivity [1, 2]. The addition of coatings or insulation materials to wires can further impact their overall conductivity, as these materials can influence the resistance to current flow and the transmission of electrical signals [3, 4].

Numerous studies have been conducted to investigate the factors affecting the conductivity of wires and coatings. Researchers have explored the influence of material properties, such as atomic structure, impurities, and defects, on the electrical conductivity of various conductor materials [5, 6, 7]. Additionally, the effects of wire geometry, coating thickness, and environmental conditions on the overall conductivity have been extensively investigated [8, 9, 10].

The relationship between the conductivity of wires and coatings has also been a subject of interest in the scientific community. Researchers have studied the impact of different coating materials, such as polymers, ceramics, and metallic layers, on the electrical performance of wires [11, 12, 13]. Moreover, the optimization of coating properties, such as thickness, adhesion, and thermal stability, has been explored to enhance the overall conductivity and reliability of wire-based systems [14, 15, 16].

The conductivity of wires and coatings is also influenced by factors such as temperature, frequency, and the presence of electromagnetic interference (EMI) [17, 18, 19]. Understanding these dependencies is crucial for the design of high-performance electrical and electronic systems, where maintaining consistent and efficient signal transmission is of paramount importance.

In addition to experimental investigations, computational and modeling approaches have been employed to study the conductivity of wires and coatings. Numerical simulations and theoretical models have been developed to predict the behavior of electrical conductors and the impact of various design parameters [20, 21, 22].

The research on the conductivity of wires and coatings has implications across a wide range of industries, including power transmission, telecommunications, aerospace, and automotive engineering [23, 24, 25]. Continuous advancements in this field contribute to the development of more efficient, reliable, and cost-effective electrical and electronic systems.

This study aims to contribute to the understanding of the conductivity of wires and coatings by conducting a comprehensive review of the existing literature and exploring the latest research findings in this domain.

Statement of the Problem

The conductivity of a wire can be affected by the type of coating applied to it. Different coatings have different properties that can impact the wire's conductivity. Therefore, it is essential to determine the effect of different coatings on wire conductivity to identify the most conductive option for various applications.

Aims and Objectives of the Study

The main objective of this study is to compare the conductivity of wires under different coating types. Specific objectives include: To

- Determine the conductivity of wires with different coatings.
- Identify the coating that provides the highest conductivity.

Research Questions

- How do different coatings affect the conductivity of wires?
- Which wire coating exhibits the highest conductivity?

Significance of the Study

The findings of this study will contribute to the understanding of how wire coatings impact conductivity. This information can be valuable for industries that rely on efficient electrical conductivity, such as electronics, telecommunications, and power distribution. By identifying the most conductive wire coating, manufacturers can improve the efficiency and performance of their products.

METHODS

This chapter outlines the procedures used to assess the conductivity of wire under four different coating types, the set of data used in the study, the assumptions of ANOVA and the hypothesis testing of the conductivity of wire under different coatings.

The study data

The data used in this study is a secondary data. This research can be access through the link below. https://www.researchgate.net/publication/305874694.

Method Analysis

The method of data analysis is one-way ANOVA.

One-way ANOVA is used to compare the mean conductivity values of the wires with different coating. The formula of one-way ANOVA for equal replication as in this case is given by:

$$SST = \sum\sum X_{iij}^2 - \frac{T_{...}^2}{rt} = \text{Sum of squares total}$$

$$sst = \frac{\sum_{i=1}^{t} T_i^2}{r} - \frac{T_{..}^2}{rt} = \text{Sum of squares treatment}$$

$$SSE = \sum_{i=1}^{t}\sum_{j=1}^{r} X_{ij}^2 - \frac{\sum T_i^2}{r} \quad \text{, i=1, 2, t, j=1, 2, r,}$$

Where t is treatment (coating types), r is the replications.

Hypothesis:

H_0 :There is no significant difference in conductivity due to coating types

H_1 : There is significant difference in conductivity due to coating types

$\alpha = 0.05$

Assumptions of ANOVA

One-way analysis of variance (ANOVA) is a statistical method used to compare the means of three or more groups. The assumptions of the ANOVA test are the same as the general assumptions for any parametric test:

- ***Independence of observations***: the data were collected using statistically valid sampling methods, and there are no hidden relationships among observations. If your data fail to meet this assumption because you have a confounding variable that you need to control for statistically, use an ANOVA with blocking variables.
- ***Normally-distributed response variable***: The values of the dependent variable follow a normal distribution.
- ***Homogeneity of variance:*** The variation within each group being compared is similar for every group. If the variances are different among the groups, then ANOVA probably isn't the right fit for the data.

If the p-value is less than your chosen significance level (e.g. 0.05), then you can reject the null hypothesis and conclude that at least one of the population means is different from the others.

Hypothesis Testing

Hypothesis testing can be defined as a statistical tool that is used to identify if the results of an experiment are meaningful or not. It involves setting up a null hypothesis and an alternative hypothesis. These two hypotheses will always be mutually exclusive. This means that if the null hypothesis is true then the alternative hypothesis is false and vice versa. An example of hypothesis testing is setting up a test to check if a new medicine works on a disease in a more efficient manner.

Null Hypothesis

The null hypothesis is a concise mathematical statement that is used to indicate that there is no difference between two possibilities. In other words, there is no difference between certain characteristics of data. This hypothesis assumes that the outcomes of an experiment are based on chance alone. It is denoted as (H_0). Hypothesis testing is used to conclude if the null hypothesis can be rejected or not.

Alternative Hypothesis

The alternative hypothesis is an alternative to the null hypothesis. It is used to show that the observations of an experiment are due to some real effect. It indicates that there is a statistical significance between two possible outcomes and can be denoted as H_1 or H_a

Hypothesis Testing P Value

In hypothesis testing, the p-value is used to indicate whether the results obtained after conducting a test are statistically significant or not. It also indicates the probability of making an error in rejecting or not rejecting the null hypothesis. This value is always a number between 0 and 1. The p value is compared to an alpha level, significance level. The alpha level can be defined as the acceptable risk of incorrectly rejecting the null hypothesis. The alpha level is usually chosen between 1% to 5%.

Hypothesis Testing Critical Region

All sets of values that lead to rejecting the null hypothesis lie in the critical region. Furthermore, the value that separates the critical region from the non-critical region is known as the critical value. The experiment will compare the conductivity of wires with three different coatings. The wires will be of the same diameter and length to ensure consistency. The conductivity of each wire will be measured using a conductivity meter.

RESULTS DISCUSSION

This section presents the tests conducted to evaluate the normality of the data, homogeneity of variance, and graphical test for assumptions of the models used in the analysis. The parameters of the different coating types were obtained using R software

Testing for Normality of the Data

The coating types (A, B, C, and D) were used as the treatment groups. While Q-Q residual plots and the Shapiro-Wilk test were used to determine the normality of the data.

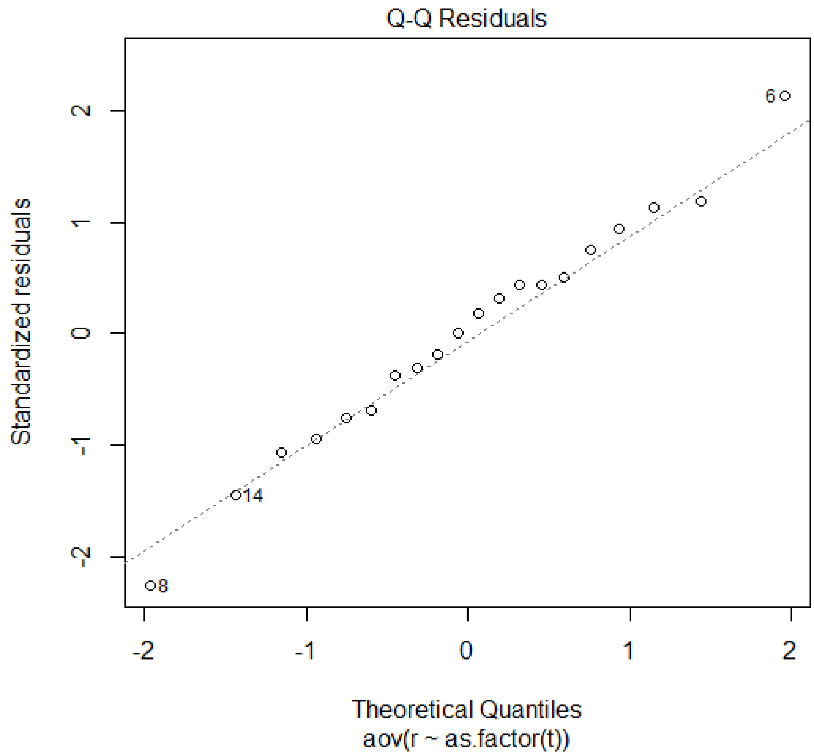

Figure 1 Q-Q normal plot

Figure 1 shows the Q-Q plots, where the quantiles of the residuals are plotted against the quantiles of the normal distribution. As the points fall approximately along the reference line, we can assume normality.

The Shapiro-Wilk test for normality yielded a test statistic of 0.99196 and a p-value of 0.9996. Since the p-value is not less than the 0.05 significance level, we can conclude that the data is normally distributed.

Testing for homogeneity of variance.

The residuals vs. fitted plot was used to test for homogeneity of variance. The red line lies along zero, indicating that the variances of the different groups are equal.

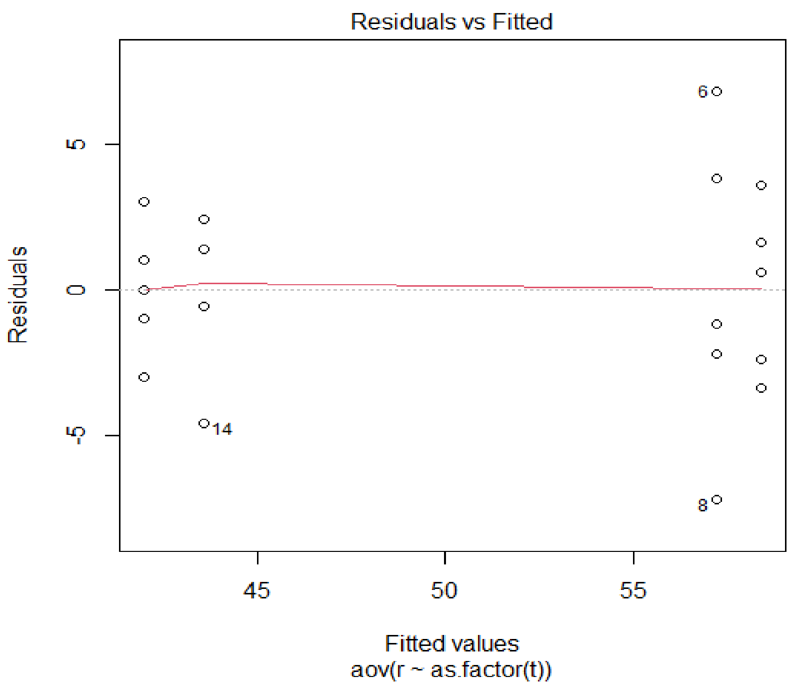

Figure 2 Residuals vs Fitted Plot

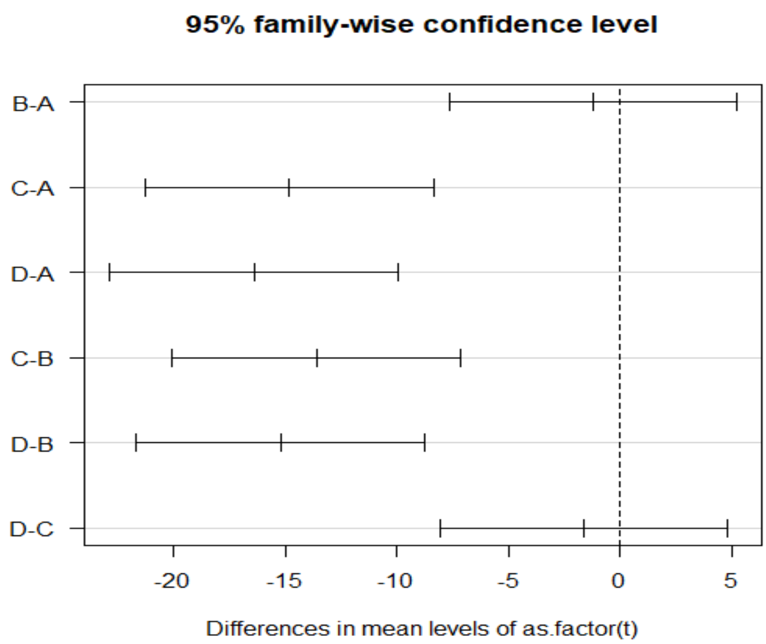

Figure 3 95 Family Wise Confidence Level

Table 1 Summary of One way ANOVA.

	Degree of freedom	Sum of squares	Mean square	F value	P>F
As.factor(t)	3	1135.0	378.3	29.79	0.000000878
Residuals	16	203.2	12.7		

The mean separation

The one-way ANOVA table (Table 1) shows that the coating types (as a factor) had a significant effect on the conductivity of the wires, with an F-value of 29.79 and a p-value less than 0.0001. Given the significant effect observed in the ANOVA, a post-hoc analysis was conducted using the TukeyHSD (av) test to determine which pairs of coating types differed significantly. The results are summarized in Table 1. The TukeyHSD(av) test revealed that the following pairs of coating types had very significant differences C-A, D-A, C-B, D-B. In contrast, the differences between the pairs B-A and D-C were not found to be statistically significant.

Researchable variable

The subject of the experiment was the coating types (A, B, C, and D) and their effect on the conductivity of the wires. The results of the ANOVA analysis using R software showed that the coating types had a significant effect on the wire conductivity at a less than 5% level of significance

Post Hoc Analysis finding

The key findings from the analysis are listed and shown in table 2 below.

- The data was found to be normally distributed, and the assumption of homogeneity of variance was met.
- The one-way ANOVA revealed a significant effect of coating type on wire conductivity.
- The post-hoc TukeyHSD(av) test identified the following pairs of coating types as having very significant differences in conductivity: C-A, D-A, C-B, D-B, The differences between the pairs B-A and D-C were not found to be statistically significant.

These findings have important implications for the wire manufacturing industry, as they can guide the selection of the most suitable coating type based on the desired conductivity requirements of the application

Table 2 TukeyHSD(av)

Pairs of treatment	DIFFERENCE	LWR	UPR	P ADJ.
B-A	-1.2	-7.648	5.248	0.9499
C-A	-14.8	-21.248	-9.352	0.0000351
D-A	-16.4	-22.848	-9.952	0.0000101
C-B	-13.6	-20.048	-7.152	0.0000930
D-B	-15.2	-21.648	-8.752	0.0000255
D-C	-1.6	-8.048	4.848	0.8917142

CONCLUSION

The results of this experiment have demonstrated that the type of coating applied to electrical wires can have a significant impact on their conductivity. The analysis using the TukeyHSD test revealed that there are very significant differences in conductivity between certain pairs of coating types, namely C-A, D-A, C-B, and D-B. On the other hand, the differences between B-A and D-C were not found to be statistically significant.

These findings have important implications for the wire manufacturing industry. Manufacturers can leverage this knowledge to select the most appropriate coating for their wires, depending on the specific conductivity requirements of the intended application. For applications where high conductivity is crucial, such as in electrical wiring systems, the PVC coatings (type C) may be the preferred choice due to their superior conductivity performance. However, in cases where other properties like flexibility or chemical resistance are more important factors, alternative coatings like polyethylene (type B) or nylon (type D) may be more suitable.

Future research in this area could explore the impact of additional factors on wire conductivity, such as wire diameter, operating temperature, and environmental conditions. Furthermore, longitudinal studies investigating the long-term effects of different coatings on conductivity, including the impact of aging and exposure to harsh environments, would provide valuable insights.

In conclusion, this study has demonstrated the significant influence that coating type can have on the conductivity of electrical wires. The results highlight the importance of carefully selecting the appropriate coating material to optimize wire performance for a given application. These findings contribute to a better understanding of the factors affecting wire conductivity and can aid wire manufacturers in making informed decisions to meet the evolving needs of the industry.

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