Study on fabrication of copper metal powder/epoxy resin composite conductive glue as electrical contacts of the brush to engine

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ABSTRACT

In this paper, the effect of copper metal powder and epoxy resin mixture on the fabrication process of the conductive glue system as electrical contact part of the brush to the engine on the naval battleship was studied. The copper metal/epoxy ratio in the glue was adjusted from 40 to 85 wt%, then evaluated by determining structure, conducting, and other mechanical properties. The optimal glue system has a very small electrical resistance of 0.0010 Ω, and a wire pulling force of 486.0 N. Results showed that the copper metal powder/epoxy composite glue system has properties equivalent to the currently used Russian product.

Keywords: Epoxy resin; Copper powder; Conductive glue; Electrical contact; Brush.

1. INTRODUCTION

Nowadays, conducting by conductive glue/adhesive powder is a commonly used method for small and medium sized carbon brushes, which has been studied and frequently used worldwide [1-3]: graphite and copper powder was mixed and used as a binding powder [4], or a mixture of nickel powder (6 - 40%) and copper powder (94 - 60%) for the same purpose [5]. Jiayan Luo [6] has published research on conductive glue based on graphene oxide, MnO_2 powder, and PTFE-based carbon nanotubes used for supercapacitor electrodes. In addition, in electronic and civil engineering, conductive silver glue, conductive tape, etc., are also used quite commonly. However, the type of conductive glue/adhesive powder used in connecting wires and brushes on naval combat ships has not yet been officially published.

Conductive glue/adhesive powder needs to meet the following requirements: a small transition resistance, which does not affect the electrical properties of the brush. At the same time, withstand the load current when the brush works. The binding must be strong so that the lead wire and brush bonding are maintained throughout the working process. According to the GOST standard 52157-2003 [7], a number of specifications for electrical contacts of brushes with motors used on naval combat ships: with a wire cross-section of 4-6 mm^2 (transition resistance between brushes) and conductor $\leq$ 0.0025 Ω, conductor pulling force $\geq$ 120 N); with wire cross section of 8 - 16 mm^2 (transition resistance between brush and conductor $\leq$ 0.00125 Ω, wire pulling force $\geq$ 150 N) [8, 9].

Therefore, in this article, the research on selecting a suitable conductive glue system for use in the electrical connection of the brush to the engine on a naval battleship will be presented, results showed that the glue system properties are equivalent to Russian products.

2. EXPERIMENTAL

2.1. Chemicals and apparatus

- Copper powder (sigma aldrich, US), particles size ≤ 45 μm, purity: 99.7%.

- YD128 epoxy (Kudo, Korea), viscosity at 25 °C: 11500 - 13500 cPs, EEW: 184 - 190 g/eq, Specific Gravity at 20 °C: 1.17, δ_b: 609 kg/cm^2, Resistivity: 3,4 × 10^{18} Ωm.

- Ball miller (ZENKO) at Institute of Chemistry and Materials.

2.2. Fabrication and analysis

2.2.1. Sample fabrication

- Create a glue system with copper powder/epoxy ratio ranging from 40 to 85 weight percent.

- The fabricated samples were used to connect the brush to the wires (figure 1).

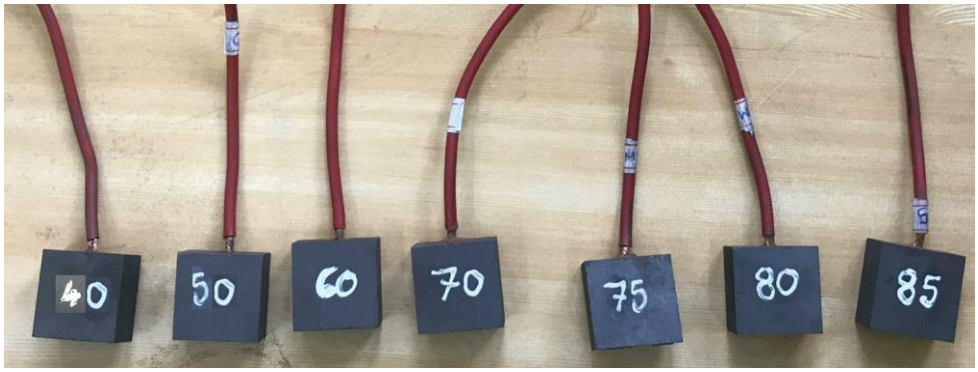


Figure 1. *Samples with different copper powder/epoxy ratios were used for the brush to wire connection.*

2.2.2. Sample analysis

- SEM and EDX analysis was performed on Jeol JSM-6510LV (Japan) at Institute of Tropical Technology/Vietnam Academy of Science and Technology.

- Resistance measuring instrument to determine transition resistance between brushes and wires: Multimeter measuring device Fluke 8588A (US) at Institute of Technology.

- Determine wire pulling force by pulling test device XL-TST-5 (China) at Institute of Chemistry and Materials.

3. RESULTS AND DISCUSSION

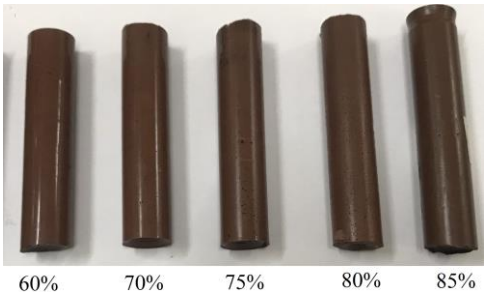
3.1. Fabrication of conducting glue system

The research team conducted an experiment by mixing copper powder and epoxy resin to create an adhesive system between the wire and the carbon brush. The results of making samples of glue systems with different compositions are shown in figure 2.

The conductive glue samples, after curing with the composition of copper powder and epoxy mixed together, became a grain-reinforced composite material, with the matrix epoxy resin and copper powder as reinforcement. With a different composition of copper powder and epoxy, the surface of the composite is distinctive. Conductive glue samples with a copper/epoxy powder ratio of about 70% to 80% had a smooth surface without pitting spots like samples with a copper/epoxy powder ratio of 85%. The reason may be

at the high copper/epoxy powder ratio, the epoxy resin binder content is small, not enough to bond the copper powder, affecting the strength of the bond between the brushes and electrical conductors.

a. Copper powder.

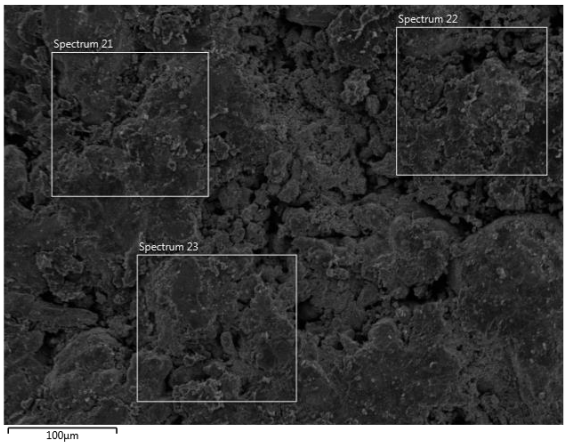


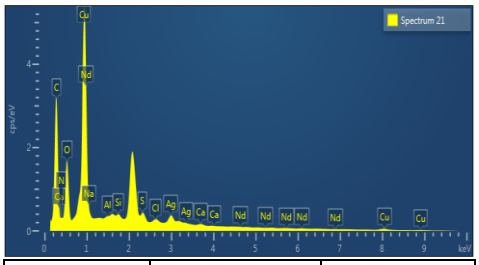
b. Conductive glue after pressed.

Figure 2. *Fabricating adhesive system with different compositions.*

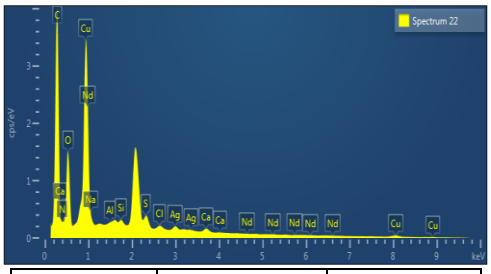
3.2. Effects of composition on the adhesive system

The study also determined the composition of different conductive glue samples using by EDX method. The results of the composition analysis of 2 conductive glue samples are shown in figure 3 and figure 4.

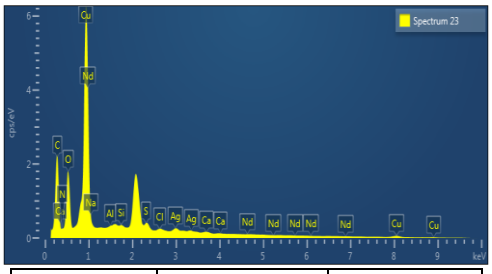




Elements	Weight,%	Atom,%
Cu	35.95	11.71
C	35.23	65.72
O	12.23	15.83
Nd	4.24	0.61
Rest	12.35	-



Elements	Weight,%	Atom,%
Cu	40.14	13.72
C	32.44	58.65
O	12.91	17.52
Nd	4.79	0.72
Rest	9.72	-



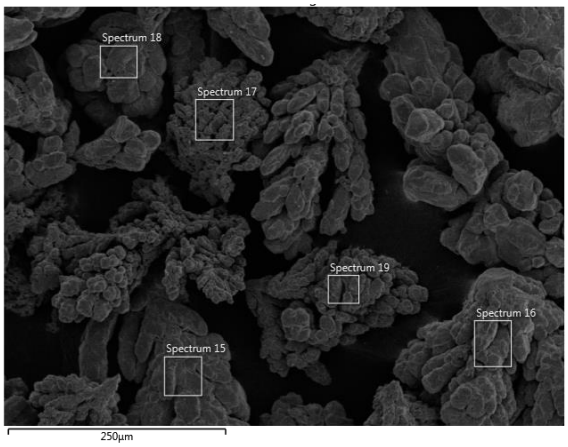
Elements	Weight,%	Atom,%
Cu	43.37	15.99
C	28.81	56.21
O	12.56	18.40
Nd	7.40	1.20
Rest	7.86	-

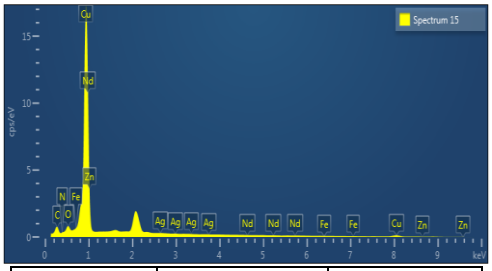
Figure 3. *Sample with copper powder/epoxy ratio at 40 wt%.*

Figure 3, with the ratio of copper powder/epoxy powder is 40% by mass, shows that

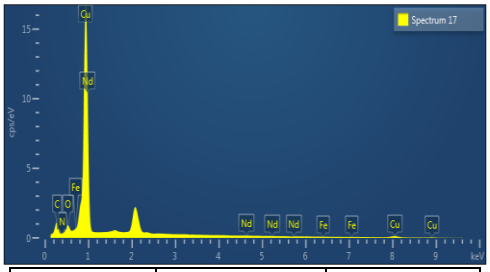
the copper powder is not enough to bond together into a continuous system for the conductivity to be guaranteed. The composition from EDX analysis at the sample locations is relatively uniform, showing that the fabricated sample has a homogenous powder distribution in the regions.

Observing the EDX results in figure 4 at different locations of the conductive glue system with a copper powder/epoxy composition ratio of 80% by weight, the distribution of copper powder is relatively homogenous. The data confirmed copper powder/epoxy content of 80 wt%, which is optimal to ensure cohesion and continuity throughout the conductive glue.

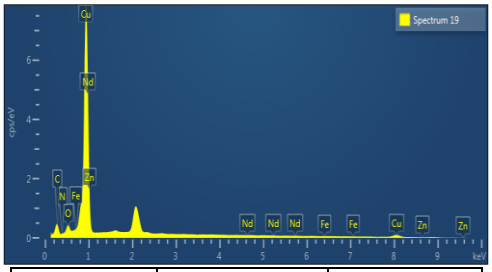




Elements	Weight,%	Atom,%
Cu	81.12	59.10
C	7.96	30.69
O	1.97	5.70
Nd	7.09	2.27
Rest	1.86	-



Elements	Weight,%	Atom,%
Cu	80.25	52,42
C	11.26	38,89
O	2.41	6,26
Nd	2.18	1,47
Rest	3.9%	-



Elements	Weight,%	Atom,%
Cu	79.66	51.69
C	10.94	37.54
O	2.58	6.65
Nd	4.84	1.38
Rest	1,98	-

Figure 4. *Sample with copper powder/epoxy ratio at 80 wt%.*

3.3. Conductive glue characteristic

Experiments were conducted to evaluate the conductivity of the glue system when connecting the conductors and brushes with different conductive adhesives (copper powder/epoxy). The results from the analysis of the resistance properties of the connection part and the wire pulling force are shown in table 1.

Table 1 shows that when the copper powder content in the conductive glue system is less than 40%, the glue cannot conduct electricity. This can be explained by the amount of copper powder is not enough to continuously bind together in the adhesive system, causing disruption of the electric current. When the amount of copper powder used increases, the conductivity of the sample is improved, which was confirmed by a

decrease in connection resistance. But that means the epoxy content is reduced, hence the decrease in adhesion. At 85% weight in copper, the epoxy content was not enough to create a strong binding, as the wire pulling force was dropped to 145.2 N. In addition, when the copper powder content is too high, many cracks will appear in the glued joints, negatively impact the conductivity. The resistance of the connection soars to 0.1174 Ω, which is much higher than the sample with a copper powder content of 80% by weight. Therefore, in this study, 80% copper powder/epoxy conductive glue composition is selected for the best properties: small connection resistance and high wire pulling force; fabricated samples have properties equivalent to the Russian product in use.

Table 1. *Effect of copper powder/epoxy ratio on the glue system properties.*

No.	Sample	Resistance of connection part (Ω)	Wire pulling force (N)
0	Russian sample	0.00628	475.5
1	M40	Non-conductive sample	264.8
2	M50	0.4050	371.0
3	M60	0.2574	538.8
4	M70	0.0404	476.0
5	M75	0.0177	773.0
6	M80	0.0010	486.0
7	M85	0.1174	145.2

4. CONCLUSIONS

In this study, the copper/epoxy powder conductive glue system with the ratio of 80% by mass was successfully fabricated to use to connect electric wires and brushes. Lower the copper composition has a negative impact on the conductivity, but too much copper used also causes a detrimental effect on the mechanical connection properties, as a small amount of epoxy can't hold the mass together. The product sample, after manufacturing has high conductivity, proven by determining the small connection resistance of only 0.0010 Ω and the large wire pulling force reaching 486.0 N, these properties are equivalent to the Russian product.

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TÓM TẮT

Nghiên cứu chế tạo hệ keo dẫn điện compozit bột đồng kim loại/nhựa epoxy làm bộ phận tiếp điện của chổi than đến động cơ

Trong bài báo này, nhóm tác giả nghiên cứu ảnh hưởng của thành phần phối liệu bột đồng kim loại và nhựa epoxy đến quá trình chế tạo hệ keo dẫn điện cho bộ phận tiếp điện của chổi than đến động cơ dùng trên các tàu chiến hải quân. Hệ keo dẫn điện được thay đổi thành phần tỷ lệ bột đồng/epoxy từ 40 đến 85% khối lượng, sau khi chế tạo được quan sát, đánh giá tổ chức và tính chất dẫn điện, cơ lý. Hệ keo tối ưu sau khi chế tạo có điện trở phần kết nối rất nhỏ 0,0010 Ω, lực nhổ dây 486,0 N. Kết quả nghiên cứu chế tạo được hệ keo compozit bột đồng/epoxy có tính chất tương đương với sản phẩm đang sử dụng của Nga.

Từ khóa: Nhựa epoxy; Bột đồng; Keo dẫn điện; Tiếp điện; Chổi than.