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# Recycle and Surface Coating of the Scrap Carbon Strips

**N. Rezaei Ansaroudi[1], K. Yildizli[1], G. Uğuz[2],
Y. Y. Büyüklü[3], O. Köseoğlu[4] and A. Döndür[5]**

[1]Department of Mechanical Engineering, Ondokuz Mayıs University, Samsun, Türkiye
[2]Department of Chemical Engineering, Ondokuz Mayıs University, Samsun, Türkiye
[3]Yeşilyurt Demir Çelik Vocational School , Ondokuz Mayıs University, Samsun, Türkiye
[4]Mechanical and Electrification Hall, SAMULAŞ, SAMSUN, Türkiye
[5]GRAFITOR LLC, GRAFITOR LLC, ATAKUM SAMSUN, Türkiye

## Abstract

In this study, we reconsider a sustainable recycling labour plans from the scrap carbon strips. Surface coating method was also improved in order to fill unbalanced worn surface and channel of the carbon strips. Solid lubrication feature and high current collection capacity were observed and testified of surface coating layer which is made from the recycled graphite powders of the scrap carbon strips. In conclusions, new recycled, upcycled products and their production methods are improved.

**Keywords:** carbon strip , wear, coating, scrap, pantograph–catenary interaction, recycle.

## 1 Introduction

The current collector carbon strips, assembled on a pantograph, are in friction contact with just below the energized catenary line [1]. Resulting from the copper catenary line surface friction contact, graphite wear debris removed from the carbon strips covers on all catenary lines [2]. They deposits on the top surface of railway transport sets. This solid powder emission is wide spread of a black-colored thin graphite powder deposition on metro train and high-speed rail stations. Every years, graphite surface wear problem leads to abandoned graphite mass losses during the electric-railway operations as graphite deposits are not methodically recollected. The graphite surface is solid lubricant, not flammable, high resistant to arcing and it is of very low electric resistance. However, the graphite is solubility in water and hangs on air. That is why, the graphite contamines the soil and water sources. Graphite powder depositions can be made short circuit for electrification equipments and solid carbon emission for railways and their environments.

Pantography is a steel and aluminum constructed catanery contact mechanism on trains and trams [3-6]. That`s why, energized copper wire are collected high current by means of carbon strips. The carbon strips rubs on the catenary copper wire in way of zig zag motions [7-10]. The carbon strips, recalled as current collector or the graphite plate, which is almost the 60 mm in width and in the 1.25 m length and the 22 mm in thickness. For the high speed trains, against to the wind resistance, aerodynamic pantograph is designed[11], which is smaller volume than those on tramways. The graphite plate is of solid lubricant and graphite adhesion preserve the all catanery line. However, due to friction contact, the carbon strips surface wears and consume in dry and rainy railway operation conditions[12].
Wear debris removed from graphite surface of the carbon strips deposits on the trams, metro or underground sets which is of black-colored powder coated. Leading state companies RER in France, DB in Germany, TCDD Türkiye.
Used pantography mechanisms can be repaired. However, the worn carbon strip cannot.
In this study, we attempt to make graphite surface coating on the worn surface of the carbon strip as if it was a rubber coated truck tire with vulcanisation. Furthermore, it is struggle for improvement a new recycling process of waste carbon strips storing problem in electrification facilities and maintenance hall of the railway companies.
Light railway tram and electric train sets, there is at least a pantograph which is assembled two carbon strips, with respect to collecting current for the catenary line. Double floored public trains have three carbon strips every sets. Every carbon strips exceeds up to 1000 ampere conductive. Their work life is an approximately 1 year under dry and watery friction conditions. The main problem is scrap storage of the worn carbon strips as in Fig.1. Any their collection, classification and recycling procedure or cooperation protocol has not been reported yet.

Figure 1: The scrap carbon strips: Courtesy of SAMULAŞ, Tramway Operation of LLC of Samsun Municipality TÜRKİYE

Where the countries call for solving waste of hazardous effect and lands and atmosphere, the carbon footprint calculated the equivalent emission on the aircrafts, shipping and motor vehicles. Waste of the solid carbon parts (i.e carbon strips, brushes) neglects in the railway operations. Actually, the running out of solid carbon is more basic in total kg because their weight and quantities of the carbon strips and carbon brushes as a current collector.

On railway logistic, increasing demands will be growth in need for the carbon and graphite electrification materials. Rescue solution for the carbon strips are either surface repair receipt and/or recycling method. Up to now, applications are on new designs of the carbon strips and performances. Realistic solution for railway electrification facilities is recycling of the worn carbon strips and then, the graphite powders and aluminium ingots can be regenerated as semi-products.

European Community announced as the railway year of 2021. As of 2050, the community estimates that railway gross transportation will be two higher times by trains, three times by high-speed trains and the 90% decrease in the greenhouse gases than that being now. In case of drastically a decrease in diesel and coal fuelled carbon strips, resulting from tribological interactions, i.e. friction, wear and solid lubrication, on energized catenary wires[13-14]. A new pantograph tribometer was designed to be entered velocity data profile for city railway routes [15]. Surface profile renewable-layered carbon strips and can be refurbished spare parts of aftermarket manufacturers in the old infrastructure of city centers and suburban contentions by light tramways and metro lines. As growing as, the carbon strip consumption in the railway routes, their waste will be simultaneously depositing in pantograph repair and maintenance facilities.

The locomotive battery-powered shunting locomotive has been designed to serve in industrial and railway logistics operations, including depots, shunting yards. Equipped with advanced electric traction systems and batteries, delivers ideal zero-emission performance, insignificantly reducing its carbon footprints. Despite the fact a great many of railway manufacturers were made carbon footprint measurement in atmosphere [16], waste of the solid carbon machine and electrical parts was not taken into account in solid carbon emission for resulting from especially electric locomotives, COCO, tramways and high speed trains in railways routes. During in cutting and milling of the scrap carbon strips broken carbon parts and graphite powders contamines the soul and water.

Not being re-used, the scrap carbon strips are deposited in maintenance halls for trains, trams and high-speed rail trucks.

We reconsider a sustainable recycling labor plans from scrap carbon strips that will be possible with recycling. Grafitor® is the first entrepreneurship company model. Recently, recycled graphite-based new products were submitted in this paper.

## 2 Methods

The scrap carbon strips can be fractured with impacting and monotonic loading. However, the fractured graphite layer side cannot insufficiently be removed from the aluminium base profile by periodically hammering, impact and flexure loads and even high-pressured water-jet cutting in Fig.2, because of strong interface adhesion between graphite layer and aluminium base profile. There is a need for more effective delamination method. The best slice is found on vertical saw machine. A new cutting tool (skate board) were improved by the grand number TEYDEB 2020-2 1507 7201128 Grafitor LLC by The Scientific and Research Council of TÜRKİYE (TÜBİTAK).

Figure 2: Rough surface profile of a scrap carbon strip after abrasive added water jet cutting at 4000 MPa. (Jet-leg effect was seen on the cutting surface and penetration is weak in transverse cutting direction)

### 2.1 Recycling

The linear skateboard holder was designed for a vertical saw in Fig.3. The scrap carbon strip is rotated at 90º clockwise and fastened to the skateboard which moves the strip to the saw. The scrap carbon strips have cut dividing into two layers in longitudinal direction in Fig.4. The removed aluminum profile side was melted by induction heating and poured into the cast iron mold in Fig.5. The melt was solidified the as-cast aluminum ingot.
The graphite layer was destroyed by shredder. The broken parts were milled and transformed to graphite powders, classified into finer mesh sizes.

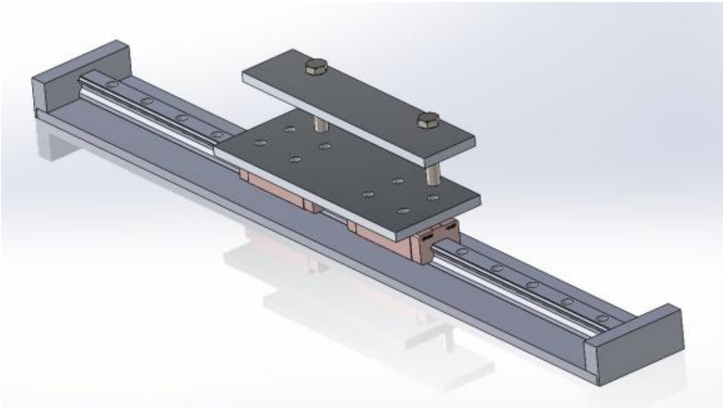

Figure 3: A linear skateboard holder for cutting of the scrap carbon strip (Designed by Grafitor ®

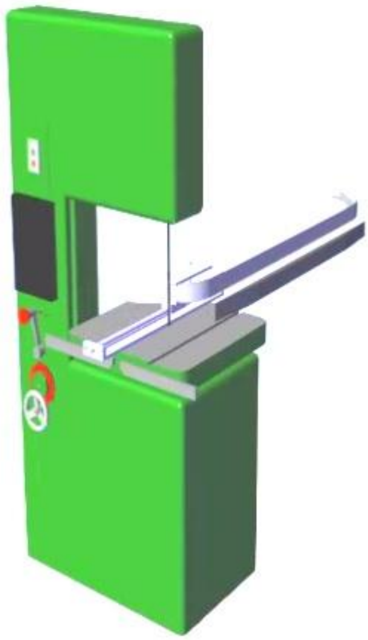

Figure 4: Linear saw cutting direction in the vertical moving saw tool. (Designed by Grafitor ®)

Figure 5: Melted aluminum alloy casting mold for ingot solidification

## 2.2. Surface Coating

Recycled graphite powder was used as raw material in surface coating. As the graphite powder is rigit and cannot be shaped. Therefore the graphite paste was prepared for large surface filler coating by Grafitor LLC.

For serial graphite surface coating of the worn-surfaced carbon strips, the heater two long dies were designed and also machine tools assembled on an industrial hydraulic press.

The graphite dough were prepared by kneading and poured into the designed mold couple in Fig.6. The worn surfaced carbon strip was previously fixed on the bottom die. Afterwards, the 700 g weighted graphite filler dough was exactly coated on the unbalanced worn original carbon strip. The top die was closed on surface and baked at high current temperature under 80 bar.

Figure 6: Surface coating baking process by Grafitor LLC.

# 3 Results

In this paper, the results are summarized under two subtitles: recycled and upcycled products.

## 3.1. Recycled products

The nominal 40 micron particle size graphite powder was obtained by ring grinding in Fig.7. Graphite powders milled graphite was transformed to expanded graphite with heat treatment and chemical methods.


Figure 7: Graphite powder samples bottled in different mesh sizes, nominal 50-100 microns by Grafitor LLC.

Aluminum base profile, graphite layer-free, was melted at 650 ºC and casted in a nodular cast iron mold. The as-cast aluminum ingot for industrial wire drawing and re-casting are seen in Fig.8.


Figure 8: As-cast aluminum alloy ingot from the scrap aluminum profile

### 3.2. Upcycled products

Reproducible from the scrap carbon strips, graphite paste was obtained and graphite layer was coated for refurbishment of the wear and craters on surface profile carbon strips in Fig 9. Graphite plate as a glass holder and slider graphite plate for bottling industry was used against to thermal erosion.

Figure 9: A graphite surface coated carbon strip in this study

The cross section of double graphite layer, the original and graphite paste and coating, are given in Fig.10.

Figure 10: The cross section of coated graphite surface layer after running out of the scrap carbon strip surface manufactured by SHUNK Hoffman Co Company.
(Black layer: Later filled surface layer and bottom gray layer: Original graphite layer

# 4 Conclusions and Contributions

In this paper, the carbon strip cutting and surface coating aspects were improved. For recycling and surface coating of the scrap carbon strips, new baking molds and machine tools are designed and manufactured.

Recycled graphite surface coating is conductive up to 402 Ampere current. The coating can be applied for local wear craters and channels of the carbon strips. However, re-usage in tramways of full surface coating on the scrap carbon strips needs two fold higher (approx. 1000 A) current conductivity at 750 V and 1500 V limitations from graphite layer surface.
In terms of safety for the surface coating, the procedure should be tested and certificated in accordance with EN 50405 railways carbon strips standard.

If the quantity and design weight of the carbon strips are reconsidered, the solid carbon emission can be calculated. Graphite is a critical for railways and there is need for more enterprises in field of the recycling scrap carbon strips.

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