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Research Article

Experimental study on removal of phenol formaldehyde resin coating from the abrasive disc and preparation of abrasive disc for polishing application

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In the automotive and aerospace industry, abrasive products lodge the major portion of the machining applications. Among that, the coated abrasive disc is used for a finishing application. Once the disc is fully consumed, the disc is unused and considered waste. The present work focuses on removing phenol-formaldehyde resin coating, and the fiber backing is reused for the same coated abrasive disc production application as flexible fiber backing. A sandblasting technique removes phenol-formaldehyde resin coating and embedded abrasive grains. During the fiber backing recovery process, the experimental parameters such as abrasive pressure, abrasive type, abrasive size, and orientation of the disc are varied to find out the optimal surface roughness value for reusing the produced coated abrasive discs. The results highlight that the recovered backing has an abrasive size of 120 mesh pressure of 0.20 MPa, an abrasive type of garnet, and a standoff distance of 1 mm. Surface features such as surface roughness and micrographs of the eroded surface are analyzed. Finally, the recovered backing was reused in the coated abrasive disc production, and the performance of the recovered disc was compared with the standard discs. The recovered fiber backing disc product was similar to a standard fresh disc.

1. Introduction

Abrasive products are energy-intensive materials and are mainly used to machine the high volume of material removed. Recycling abrasive products open up economic and environmental benefits to abrasive product manufacturers and society [1]. Bonded and coated abrasives are the two types of abrasives product. Authors have previously attempted to recycle connected abrasive products such as vitrified [2], resinoid [3] grinding wheels from the flange portion of the spent grinding wheel. Recovering the abrasive grains from the part adds wealth in terms of economics. The abrasive grains are sharp and potentially reused in the same abrasive applications. Various separation methods are available to recover the abrasive grains from the bonded products. But in the case of coated products, a tiny layer of abrasive grains is deposited on the fiber backing. So, the recovery of abrasive grains is not possible, but recovering the fiber backing from the spent portion is possible. This recycling of fiber backing from the spent abrasive discs reduces raw material cost by 30% for the coated abrasive disc production. Based on the 3R policy, every material should be reused somewhere as a resource [4]. Spent-covered abrasive consists of phenol-formaldehyde resin coat and fiber backing. Improper disposal of this waste adds up to the more serious environmental problems such as pollution and water hampering. Recovery of fiber backing is necessary for abrasive product consumers and producers for the ecological benefits.

Researchers are attempting to recover the fiber backing from the coated abrasive disc using the chemical method [5]. The results highlighted that utilizing chemical solutions affects fiber quality in fiber entanglement. So more suitable manner such as the mechanical erosion method has opted for the backing recovery process. Many studies concentrate on the sandblasting or shot peening method for improving the bonding characteristics of materials.

Djokovic et al. studied the peel strength of the carbon fiber-reinforced epoxy composite. The effect of the composite surface structure was optimized concerning varying the blasting time, nozzle distance. The results highlight that increasing the blasting intensity leads to an increase in the surface roughness and increases the higher peel of strength of the composites [6]. Sabari Nathan et al. studied the abrasion resistance property of the grinding wheel rejects included concrete. The results highlight that addition of grinding wheel waste has increased the abrasion resistance of the concrete up to 40% [7]. Okada et al. has studied the sandblasting experiment on the yttria-stabilized tetragonal zirconia polycrystals. The investigation was conducted with different pressure, standoff distance, and particle size. The optimal sandblasting condition for the yttria-stabilized tetragonal zirconia polycrystals is the pressure of 0.25-0.30 MPa with a sandblasting time of 10 s [8]. Li et al. studied the adhesion performance of aluminum-lithium alloy joints using a sandblasting technique. The results show that increases in the abrasive particle size and sandblasting pressure have increased the substrates' surface roughness, which results in improved shear strength of the joints [9].

Coated abrasive products offer a massive market potential in a variety of applications. Coated abrasives are composed of three layers deposited on the backing material: a base layer, a raincoat, and a size coat [10], and based upon the type of backing, the product was classified as a sheet, cloth, and discs. The fiber backing is costlier and is used for heavy-duty applications. The primary element in the coated products is a type of support. Based on this, the product was classified. Among the various coated products, the recovery of support material is recovered for the fiber backing type only. Many types of research are done to recover the fiber from the spent materials. Senophiya et al. has recovered fiber from the spent printed circuit boards. So, there is more research on fiber backing recovery by using the chemical separation method [11]. This present work concentrates on removing phenol-formaldehyde resin coat by sandblasting technique and can be further reused to make coated abrasive discs.

Recycling is the critical element of the 5R principle. The cost imparted to the recycling process is useless [12]. So, the recovered fiber backing is reused to prepare coated abrasive discs. Currently, there are limited researches on the usage of coated abrasives for the finishing application.

Kuo et al. studied the multiple criteria optimizations for the coated abrasive grinding of titanium alloy using the minimum quantity lubrication (MQL) technique. The experiment was conducted by varying the grit number, loading pressure, and grinding speed: the general rapid abrasive and adhesive wear on the coated abrasive discs using coarse abrasive grits. In the case of fine abrasives, abrasive wear and clogging will have occurred at the higher grinding speed [13].

In this current work, vulcanized fiber backing is recovered using the sandblasting technique, and the recovered support is used to make the coated abrasive discs. The experimental approach was carried out to determine the surface roughness of the fiber backing recovered by sandblasting technique. After recovering fiber backing, the discs are used for the coated abrasive disc production. The performance of the standard and newly developed coated abrasive discs are analyzed, and the experimental results got reported. The optical microscopic technique studied surface characterization of the performance evaluated coated abrasive discs.

2. Materials and methods

2.1. Raw materials:. Spent coated abrasive discs of 120 grit were selected as the raw material for the backing recovery process. The coated abrasive disc comprises resin, abrasive grain, and fiber backing. Possibilities of recycling paper and cloth are complex, in case of recovering of fiber backing is possible. At the end of usage of coated abrasive discs, the support is left and thrown off as waste. The backing comprises of maker resin coat and blunted abrasive grains. Direct coating of the next layer of abrasive grains can cause a peel of the resin and abrasive grains from the fiber backing. To maintain the uniformity of the surface of the fiber discs, the fiber backing should be sandblasted to remove the maker coat from the fiber backing. Figure 1 shows the schematic layout of the fiber backing recovery experiment and again reused for the coated abrasive disc production.

They have selected a mechanical sandblasting erosion process to remove the resin coat from the fiber backing surface. The experiments are conducted in the sandblasting machine with the portable suction type (Make: Vegan controls, Coimbatore, India). The experiments are conducted with various experimental conditions, shown in Table 1. During the sandblasting experiment, an abrasive particle is mixed with high-pressure compressed air, blasted on the target material. The mixed air is passed through the workpiece through the nozzle of diameter 1 mm.

2.2. Experimental procedure. The backing recovery experiments selected the spent coated abrasive discs of 120 grit. While several diameters are available, chose a disc of 127 mm for this study. Because commercially, this 127 mm diameter has higher market potential and sales than 178 mm and 101 mm discs. To analyze the impact of each parameter, the experiment was conducted by maintaining all the parameters constant and changing the respective responsive parameter.

Initially, the coated abrasive discs are clamped at an angle of 60o, and the experiment was conducted with an

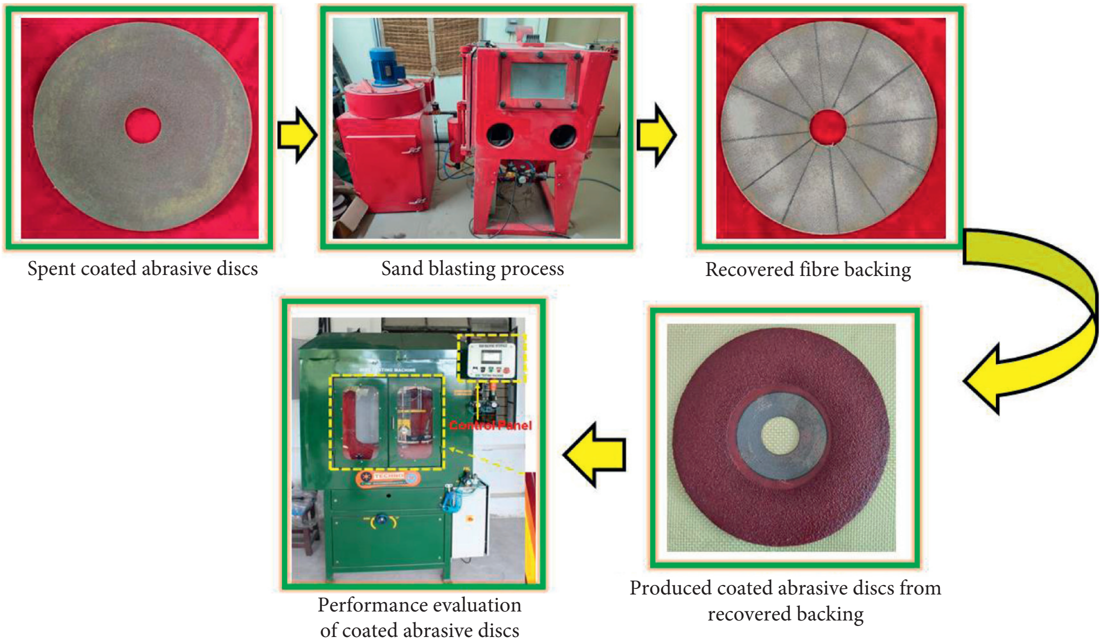

FIGURE. 1: Schematic layout of fiber recovery and coated abrasive disc production

TABLE 1: Parameter and its experimental range for the sandblasting experiment.

Parameter	Unit	Range
Blasting pressure	MPa	0.2, 0.5, 0.8
Abrasive	-	Silicon carbide, Alumina, Garnet
Size of abrasive	Mesh	80, 100, 120
Standoff distance	Mm	1, 3, 5

experimental condition for 10 minutes. The measurable output response such as surface roughness is considered as output response for the sandblasting experiments. Surface roughness such as average roughness value (Ra) of the sandblasted abrasive discs are measured by using contact type stylus profilometer (Mitutoyo Surftest SJ-301) with a cut off length of 8 mm. Recovered backing surface and newly developed coated abrasive discs to be analyzed by using an optical microscope (Make: Olympus, Japan).

2.3. Production of coated abrasive discs. In the present work, the coated abrasive discs are produced in the individual disc coating setup. The standard and recovered fiber backing is used for the coated abrasive disc production. In the first abrasive disc production, the resin was coated on the fiber backing surface utilizing the spin coating technique. Brown alumina abrasive grains of 60 grits are coated on the abrasive discs by grain coating using electrostatic projection to coat the fiber backing. The final resin coat is applied on the abrasive disc as the sizer coat for the abrasive holding in the discs.

The electrostatic grain coating technique uses the 60 grit abrasive grains on the fiber backing. Used standard and recovered backing for the fiber disc production and compared the performance of both the discs to evaluate the suitability of the usage of the discs. Produced discs are cured in the furnace, and it's flexed 5-7 times to introduce the flexibility of the produced discs.

Performance analysis of standard and recovered fiber backing used coated abrasive discs:

The performance of the produced coated abrasive disc is analyzed by using the coated abrasive performance evaluation machine (Make: Techno Machine Products, India). Specification of the performance evaluation machine is tabulated in Table 2. we tested the performance of the produced coated abrasive discs by maintaining the constant machining parameters output Calculated material removal rate based upon the formula (1).

$$\text{Material Removal rate} = \frac{\text{Weight of material removed}}{\text{time taken for machining}}. \quad (1)$$

For every 5 minutes, the workpiece weight and disc weight were measured using a digital weighing balance of 0.001 accuracies. The experiment is repeated five times to understand the deviation in the experimental results.

The machined surface of the coated abrasive discs is characterized in the optical microscope to analyze the chance of metal clogging and built-up in the coated abrasive discs.

3. Results and discussions:

The mechanical erosion process opted to recover the fiber backing compared with other recovery processes. Due to it doesn't affect the quality of the abrasive discs like fiber tangling and bending of the fiber. The response value such as surface roughness is considered output for the recovery experiment.

Experimental approach and its effect of various process parameters of mechanical erosion process:

Table 2: Specification of performance evaluation machine

Parameter	Range
Angle grinder size	5 inch
Maximum Loading RPM	11,000
Machine displacement	200 mm
Maximum depth to cut	4 to 5 mm
Tilting angle	15 to 25°

3.1. Impact of blasting pressure:. The experimental result clearly shows the effect of blasting pressure concerning the value of surface roughness of the recovered fiber backing. The experiment was carried out with different blasting pressure of 0.2, 0.5, and 0.8 MPa. Figure 2 shows the experimental output results of the surface roughness value concerning erodent pressure. The results highlight that the increases in the blasting pressure show increases in the surface roughness of the surface of the fiber backing. The maximum surface roughness value of 4.512 μm was observed on the highest blasting pressure of 0.8 MPa. At higher blasting pressure, there is a chance of high-impact energy. There is a chance of penetration of abrasive particles on the backing surface, which increases the surface roughness of the fiber backing [14]. The optimal blasting pressure for the recovery of fiber backing by using a mechanical erosion process is 0.2 MPa.

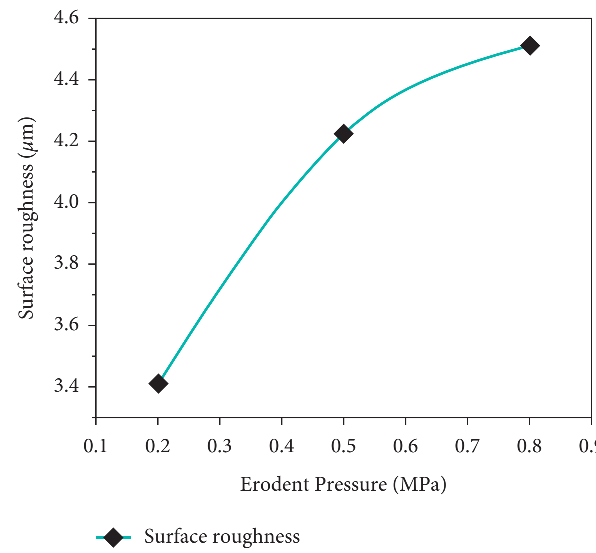

Figure 2: Effect of blasting pressure concerning surface roughness value.

3.2. Effect of abrasive type. The experimental results of various abrasives are shown in figure 3. The experiments are carried out with three different abrasives: alumina, silicon carbide, and garnet. The results clearly show that the usage of silicon carbide abrasive shows the highest surface roughness value of 4.131 μm, followed by alumina of 3.66 μm, and garnet of 2.947 μm. from the results, the lowest surface roughness was observed on the garnet abrasive grains. This is due to higher hardness abrasive which can penetrate faster, and higher depth, which results in more elevated surface roughness value observed on the SiC abrasive grain used recovery process [15].

The optimal abrasive grain for the recovery of fiber backing will be garnet abrasive grain.

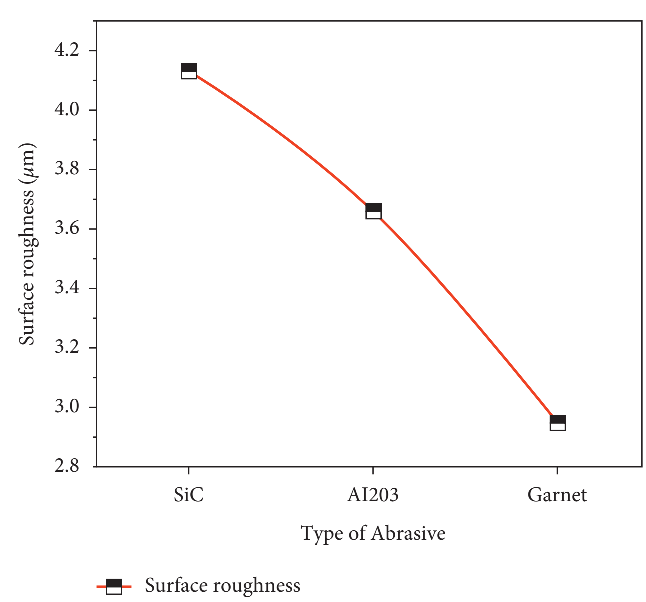

Figure 3: Effect of various abrasives with respect to surface roughness value.

3.3. Effect of abrasive size. Figure 4 shows the surface roughness value of the sandblasted coated abrasive disc concerning the variation in the abrasive particle size. The experimental results clearly show that an increase in the abrasive particle size decreases the surface roughness for the surface of recovered fiber backing. For conducting experiments, various abrasive particle sizes of 80,100 and 120 mesh are considered. The results show that the experimental surface roughness concerning 80 grit abrasive grain will be 3.731 μm, followed by 100 grit of 3.32 μm and 120 grit of 2.724 μm. The lower surface roughness at the lower grit number is due to the smaller particle size. The interaction of particles and grooves production is smaller than other two-particle measures such as 80 and 100 grit. [16]. The optimal parameter for the abrasive particle size for the recovery of fiber backing will be 120 grits.

3.4. Effect of standoff distance. Figure 5 (a) shows the surface roughness analysis of recovered fiber backing results for variation in the standoff distance. The experiment was conducted by varying the standoff distances of 1, 3, and 5 mm. The results show that increases in the standoff distance have increased the surface roughness value. The maximum surface roughness value of 3.972 μm was observed on the highest standoff distance of 5 mm, followed by 3.744 μm at 3mm and 3.445 μm at a 1 mm distance from the workpiece nozzle. The reason for the increase in the surface roughness by increasing the standoff distance is that the jet energy was lower at a higher space, which results in improper removal of resin from the backing surface [17]. The optimal standoff distance value for obtaining a lower surface roughness value will be 1 mm.

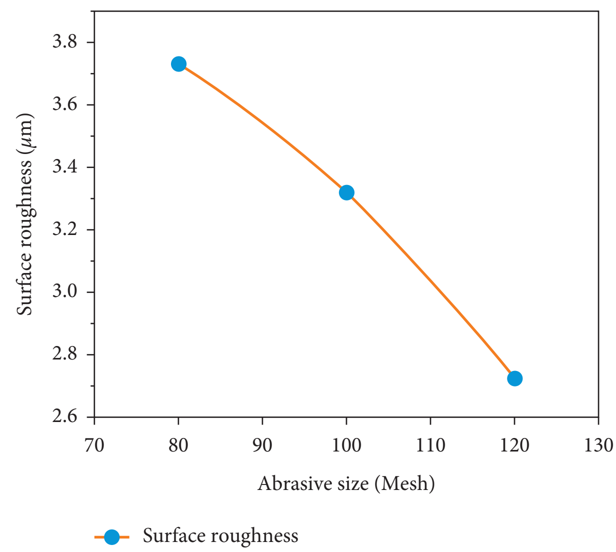

FIGURE 4: Effect of abrasive size with respect to surface roughness value.

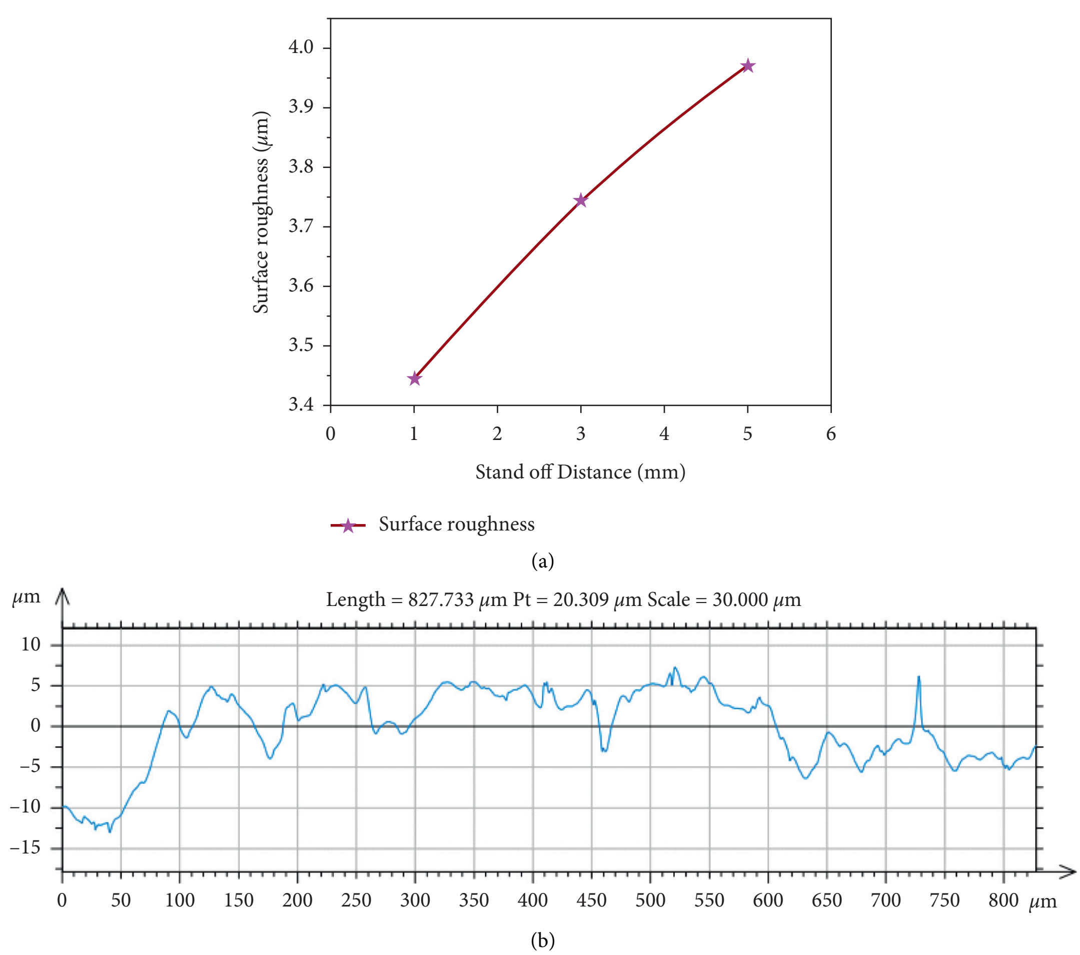

FIGURE 5: (a) Effect of standoff distance concerning surface roughness.(b)Surface roughness profile of the optimized condition for the recovered fiber backing.Performance analysis of reused fiber backing in coated abrasive application

3.5. Optimal combination for the recovery of fiber backing:. From the overall experimental results, the optimal combination for the recovery of fiber backing will be basting pressure of 0.2 MPa, abrasive type of garnet, abrasive size of 120 mesh, and standoff distance of 1 mm. Based on the experimental results, underwent the optimal combination

Table 3: Characteristics of coated abrasive discs for the current experiment

Backing Type	Grit size	Type of coating	Grit type
Standard	60	Electrostatic	Alumina
Recovered	60	Electrostatic	Alumina

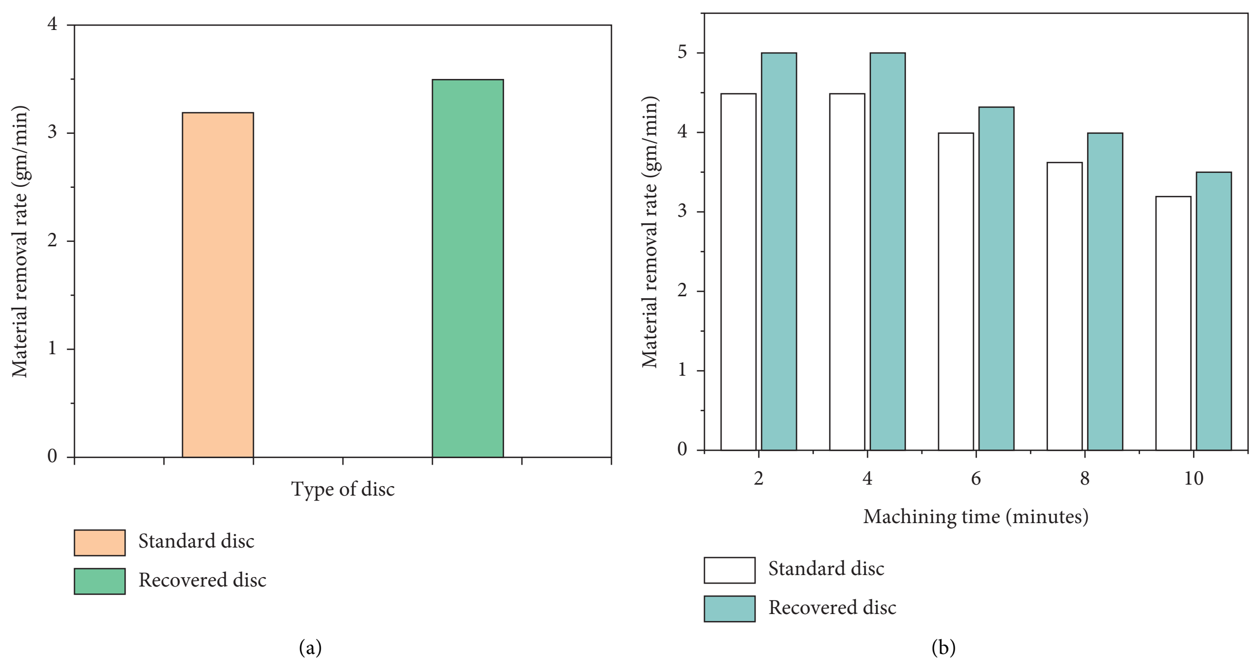

Figure 6: Material removal rate of performance results of coated abrasive discs

for the testing process, and the average surface roughness observed on the surface of the fiber backing will be 1.635 μm. It is observed from figure 5 5(b).

3.6. Production of coated abrasive discs. The recovered fiber backing is reused in the production of coated abrasive disc. The present work used standard brown alumina of 60 grit as abrasive for the coated abrasive disc production. Two different types of backings, such as standard and recovered backings, were selected for the backing material. Phenol formaldehyde resin was used as a resin for the base and topcoat. Table 3 shows the detailed characteristics of coated abrasives used for the experiments.

Produced coated abrasive discs as per industrial standards. Initially, the backing material was weighed and placed the disc in the maker unit. The primary coating of coated disc production is maker coat, which is necessary for sticking grain on the surface of the fiber backing during grain coating. Electrostatic projection of grains was utilized for the better anchorage of the grains. The grains were moved uniformly using the belt conveyor in the electrostatic unit. Due to applied voltage, the grains jump upwards and adhere to the resin surface of the fiber discs with sharp edges facing away from the backing. Then cured the discs in an oven.

A Sizer coat is the final coating process in which the coated grains are covered with a single layer of sizer resin. The sizer coat locks the abrasive grains during machining operations. Then cured the discs in an oven. The cured discs were placed in a humidity chamber for one day to improve their properties. Finally, the discs were flexed up and down using a roller flexing machine. The performance of the flexed discs was evaluated using an automatic performance evaluation machine. A squared rod of 50 mm^2 mild steel was used as a workpiece for the performance evaluation test.

Figure 6 6(a) shows the material removal rate of coated abrasive discs of standard and recovered backings. The recovered backing shows similar results and a better material removal rate from the experimental observation. This may be due to the formation of crater and valley during abrasive blasting, leading to better anchoring of resin bond with fiber backing and abrasive grain. This will be evident from the 3D surface roughness images shown in figure 6. Figure 6 6(b) shows the material removal rate for every 2 minutes of interval. The result shows that for the first 2 minutes, both the standard and recovered used backing discs show a higher material removal rate than the 4^{th}, 6^{th}, 8^{th}, and 10^{th} minutes. This may be attributed to the adhesive wear of the eroded metal piece that clogged on the coated abrasive surface.

Figure 7 (7a-b) shows new abrasive discs of standard and recovered backing before starting machining. Figure 7 (7c-d) shows the used disc of recovered backing at the 6^{th} and 10^{th} minutes during performance evaluation. Optical images depict that at the 10th minute, abrasive

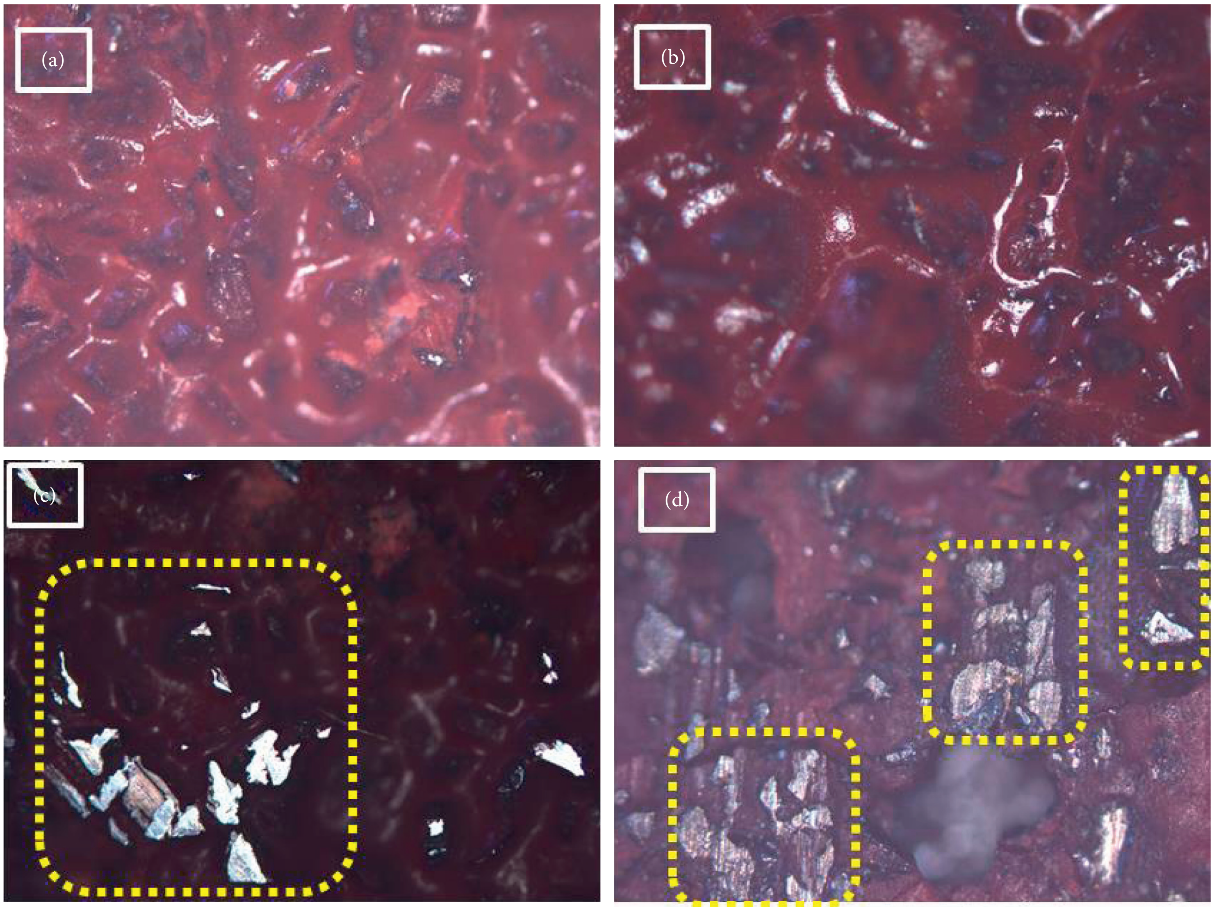

Figure 7: Optical images of produced coated abrasive discs (a) Standard disc (b) Recovered disc, (c) Performance evaluated recovered coated disc at 6th minute, and (d) Performance evaluated recovered coated disc at 10th minute.

discs show more metal clog than the 6^{th} minute. This results in a decrease in material removal rate during the grinding operation.

In both cases, an increase in the machining time shows a decrease in the material removal rate. The experimental results indicate that the recovered backing has similar cutting action to the standard backing disc. This confirms that it is possible to reuse the recovered backing in coated applications.

4. Conclusions

The mechanical erosion process is employed to recover the fiber backing in this research work. Then the recovered fiber backing is used to prepare the coated abrasive discs. The present study of places is the impact of various experimental conditions such as blasting pressure, abrasive type, abrasive size, and standoff distance. From the experimental results following conclusions are made.

- Compared with the chemical method of fiber backing mechanical erosion method, which recovers the fiber backing similar to new disc as appearance entirely. The discs are free from damage, and the surface can be resin coating.
- The optimal combination for the recovery of fiber backing will be basting pressure of 0.2 MPa, abrasive type of garnet, abrasive size of 120 mesh, and standoff distance of 1 mm.
- Coated abrasive discs re-manufactured with the recovered fiber backing show similar performance results with the standard discs.
- This shows it is possible to reuse the recovered backing on the same coated abrasive disc production.
- Such a method will reduce the cost of coated abrasive discs and reduce the need for sending the used fiber backing to landfills.

Data Availability

The data used to support the findings of this study are included in the article. Should further data or information be required, these are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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References

[1] B. Linke, *Life Cycle and Sustainability of Abrasive Tools*, Springer International Publishing, Midtown Manhattan, New York City, 2016.

[2] P. Sabarinathan, V. E. Annamalai, S. S. Kumar, and A. Xavier Kennedy, "A study on recovery of alumina grains from spent vitrified grinding wheel," *Journal of Material Cycles and Waste Management*, vol. 21, no. 1, pp. 156–165, 2019 Jan 22.

[3] P. Sabarinathan, V. E. Annamalai, and A. Xavier Kennedy, "On the use of grains recovered from spent vitrified wheels in resinoid applications," *Journal of Material Cycles and Waste Management*, vol. 22, no. 1, pp. 197–206, 2020 Jan.

[4] L. Liu, Y. Liang, Q. Song, and J. Li, "A review of waste prevention through 3R under the concept of circular economy in China," *Journal of Material Cycles and Waste Management*, vol. 19, no. 4, pp. 1314–1323, 2017.

[5] P. Sabarinathan, V. E. Annamalai, R. Balakrishnan, and A. C. Kuriakose, "Process optimization for recovery of fiber backing from coated abrasive disks," *Chemical Engineering Communications*, vol. 208, no. 6, pp. 893–902, 2021 May 3.

[6] E. Njuhovic, A. Witt, M. Kempf, F. Wolff-Fabris, S. Glöde, and V. Altstädt, "Influence of the composite surface structure on the peel strength of metallized carbon fibre-reinforced epoxy," *Surface and Coatings Technology*, vol. 232, pp. 319–325, 2013.

[7] P. Sabarinathan, V. E. Annamalai, and P. Sangeetha, "Mechanical and abrasion resistance properties of concrete containing recycled abrasive waste as partial replacement of fine aggregate," *Arabian Journal for Science and Engineering*, pp. 1–0, 2021 Apr 19.

[8] M. Okada, H. Taketa, Y. Torii, M. Irie, and T. Matsumoto, "Optimal sandblasting conditions for conventional-type yttria-stabilized tetragonal zirconia polycrystals," *Dental Materials*, vol. 35, no. 1, pp. 169–175, 2019 Jan 1.

[9] J. Li, Y. Li, M. Huang, Y. Xiang, and Y. Liao, "Improvement of aluminum lithium alloy adhesion performance based on sandblasting techniques," *International Journal of Adhesion and Adhesives*, vol. 84, pp. 307–316, 2018 Aug 1.

[10] S. N, A. K. S, P. A, and G. S, "Studies on semi-crystalline poly lactic acid (PLA) as a hydrophobic coating material on kraft paper for imparting barrier properties in coated abrasive applications," *Progress in Organic Coatings*, vol. 145, Article ID 105682, 2020 Aug 1.

[11] J. Senophiyah-Mary, R. Loganath, and T. Meenambal, "A novel method for the removal of epoxy coating from waste printed circuit board," *Waste Management & Research: The Journal for a Sustainable Circular Economy*, vol. 36, no. 7, pp. 645–652, 2018 Jul.

[12] M. Gautam and M. Agrawal, "Greenhouse gas emissions from municipal solid waste management: a review of global scenario," *Environmental Footprints and Eco-design of Products and Processes*, vol. 9, pp. 123–160, 2021.

[13] C. Kuo, Y. Hsu, C. Chung, and C.-C. A. Chen, "Multiple criteria optimisation in coated abrasive grinding of titanium alloy using minimum quantity lubrication," *International Journal of Machine Tools and Manufacture*, vol. 115, pp. 47–59, 2017 Apr 1.

[14] S. Palaniyappan, V. E. Annamalai, S. Ashwinkumaran, D. Thenmuhil, and D. Veeman, "Utilization of abrasive industry waste as a substitute material for the production of fireclay brick," *Journal of Building Engineering*, vol. 45, Article ID 103606, 2022 Jan 1.

[15] P. Andrzej, "Experimental research into alternative abrasive material for the abrasive water-jet cutting of titanium," *International Journal of Advanced Manufacturing Technology*, vol. 97, no. 1-4, pp. 1529–1540, 2018 Jul 1.

[16] K. Balaji and N. Yuvaraj, *Influence of different abrasives mixtures on abrasive water jet drilling of die steel Innovative Design Analysis and Development Practices in Aerospace and Automotive Engineering 2021*, pp. 511–519, Springer, Singapore, 2021.

[17] P. Sabarinathan, V. E. Annamalai, and K. Rajkumar, "Sustainable application of grinding wheel waste as abrasive for abrasive water jet machining process," *Journal of Cleaner Production*, vol. 261, p. 121225, 2020 Jul 10.