Engineering and Technology Journal e-ISSN: 2456-3358

Volume 11 Issue 03 March-2026, Page No.- 9220-9224

DOI: 10.47191/etj/v11i03.13, I.F. – 8.595

© 2026, ETJ

Taguchi-Based Analysis of Sandblasting Parameters for Low Carbon Metal Surface Treatment

Joko Yunianto Prihatin[1], Farit Ardiyanto[2], Slamet Pambudi[3]

[1]Departement of Mechanical Engineering, Sekolah Tinggi Teknologi "Warga" Surakarta, Jl.Raya Solo-Baki Km.2 Kwarasan, Sukoharjo, Indonesia 57552

[2]School of Engineering Technology, University College TATI (UC TATI), Teluk Kalong, 24000 Kemaman,Terengganu, Malaysia

[3]Departement of Electronical Engineering, Sekolah Tinggi Teknologi "Warga" Surakarta, Jl.Raya Solo-Baki Km.2 Kwarasan, Sukoharjo, Indonesia 57552

ABSTRACT: Sandblasting is a method for cleaning the surface of metal materials from contamination by rust, paint, salt, oil or to obtain a profile character by roughening or smoothing the surface. The technique applied is to spray abrasive material with compressed air on the surface of the specimen. The problem that occurs is air pollution, because the waste produced from the use of silica sand is included in the category of Hazardous and Toxic Materials waste (B3). The aim of this research is to determine the composition of a mixture of air and abrasive that is safe and also capable of producing maximum cleaning of metal surfaces. Taguchi OA L9 experimental design method with 4 factors and 3 levels on the surface area value of sandblasting results applied in this study. The discussion analysis applies microstructure, coating analysis, raw material cost analysis so Anova and effect main SNR Taguchi statistic analysis and combinated literature approach. The results obtained show that the sand material and compressor air pressure used in the sandblasting process greatly affect the results of the surface peeling area of the low carbon plate material. The best results of the sandblasting process area were obtained with specimen composition 3122. Application of beach sand type at a volume of 450ml, compressor air pressure 2 kg/cm^2 at a distance of 30mm. The compressor air pressure greatly influences the dominant results of the peeling area of the low carbon plate material surface in the sandblasting process

KEYWORDS: Sandblasting; Air Pressure; Beach Sand; Surface Area; Waste; Microscope; Taguchi

I. INTRODUCTION

Car painting is one of the business opportunities in the automotive world that is quite profitable considering the increasing rate of used cars. People often repaint their cars due to accidents, prolonged use, the effects of rainy weather where the water corrodes and the heat can cause damage to the car body, or an attempt to renew the car's color(Huilcapi et al., 2020). When dealing with vehicles that are affected by rust or have a layer of paint that has stuck, sandblasting is the best choice to clean it effectively(Ogrodniczek et al., 2025). Apart from being able to clean the surface of iron materials from contamination such as rust, oil, paint, salt, and others. This service is also able to repair old paint that has been damaged or faded on the material itself(Nugraha et al., 2025). Sandblasting is a method for cleaning the surface of contaminated materials such as rust, paint, salt, oil and so on or to obtain the profile character of the material either to roughen or smoothen it, this method is often applied to metal-based surfaces. This process is generally carried out before carrying out the material surface coating process with the aim of increasing the adhesion of the coating to the material surface. The sandblasting surface cleaning method is carried out by spraying abrasive material, usually silica sand or steel grit, with relatively high pressure on a surface. Apart from that, the purpose of forming this roughness profile is to create an adhesive layer so that a good level of adhesion can be achieved between the metal surface and the protective material (Ogrodniczek et al., 2025) (Pramana Aji, et al., 2025). However, there are problems and negative impacts that result if the implementation does not comply with operating standards, including: Firstly, the sandblasting process generally occurs chemically, using chemicals in it, so the waste produced from this process is included in the category of Hazardous and Toxic Materials waste (B3). type B232-1 which is not good for the environment and human health (Palabiyik et al., 2013), (Primaningtyas et al., 2024). Determination of the type of abrasive sand and spraying technique This can contribute to air pollution which needs to be managed properly to minimize environmental impacts. (Yu et al., 2022), (Ratri et al., 2024),(Irawan et al., 2025).

Taking into consideration these potentials and constraints, it is necessary to develop appropriate, efficient, and environmentally friendly sandblasting techniques. By achieving optimal composition, the paint thickness value on the resulting surface is able to meet the needs of saving and being time efficient for the subsequent manufacturing process

II. RESEARCH METHODOLOGY

Research Location

This research was conducted at the "Mandiri Teknik" automotive engineering workshop in Sukoharjo city. The analysis and discussion of the results of this research were carried out in the fluid laboratory of the mechanical engineering department of STT Warga Surakarta from April to September 2025 This research was funded by an applied research program grant from the Directorate General of Science and Technology for the 2025 budget year..

Material and Methods

The method applied is an innovative sandbasting engineering technique with NDT (non-destructive test) testing of the thickness of the paint layer on the surface of carbon iron against variations of 4 factors at 3 levels. The amount of abrasive material used depends on the hardness of the material being processed (Śmielak et al., 2023). The abrasive material factor of beach sand with a density of 1000 kg/m^3, river sand 2000 kg/m^3 and silica sand 3000 kg/m^3 (Azis et al., 2024). The spraying distance to the vertical specimen according to the car body illustration is varied at 20mm, 30mm and 40mm (Li et al., 2025). The variations in the factor levels are as explained in the table below

Table 1. Sandblasting NDT (Non Destructive Test) Research Variables

Factor	Level		
	1	2	3
Compressor air pressure/injector (kg/cm2)	1	1.5	2
Density of sand (Kg/m3)	29.000 (beach)	2600 (river)	2700 (silica)
Volume of sand (ml)	250	450	650
Spray distance (mm)	20	30	40

Quality characteristics are assigned a certain maximum nominal value.If the value is closer to a certain maximum nominal value, then the quality is optimum.This value means larger the better. The statistical approach method uses the Taguchi OA L9 experimental design which consists of 9 factor level compositions (Knypiński et al., 2023), (Laganà & Faccì, 2025), (Hemeda et al., 2024), (BRUNO RĂDULESCU□, 2021). The variation of the factor levels for collecting data from NDT tests on the thickness of the paint layer was repeated 3 times (Prihatin et al., 2023).(, et al., 2025)

Next, a portable blasting cabinet is made from a drum consisting of a frame mica sheet, chemical gloves, spray distance suit, specimen holder, 6 bar air manometer. Meanwhile, the supporting measuring tools include vernier calipers, 1000 gram digital scales, measuring cups, stopwatches, 120 kg compressors, and microscopes.

The next stage is to make 27 carbon iron sheet specimens measuring 50 x 50 x 1 mm. The specimen is a miniature of the car body surface that will be repainted. One side of the surface of the specimen was painted using oil-based spray paint in 3 thin layers. Then dry it at ambient air temperature for 2 days. The specimens are numbered on the back surface according to the composition sequence in the experimental design table (Homa et al., 2017), (Radek, 2023).

Based on the variation of the factor level from the Taguchi OA L9 table, the blasting/spraying process is continued on the vertical side of the specimen surface in a horizontal direction for 30 seconds. The data obtained from the sandblasting results is in the form of a cross-section of the specimen surface which is eroded on the horizontal middle side. And the analysis was carried out using a visual NDT test of the microstructure using a Ts-100 optical microscope at a magnification lens of 200 times (Channa et al., 2024), (Cheng et al., 2025).

Furthermore, the data from observations using a microscope were analyzed for the microstructure and surface area of the eroded paint. So, by analyzing the related literature approach, conclusions can be drawn regarding the composition of factor levels that are able to show maximum and minimum erosion capabilities.

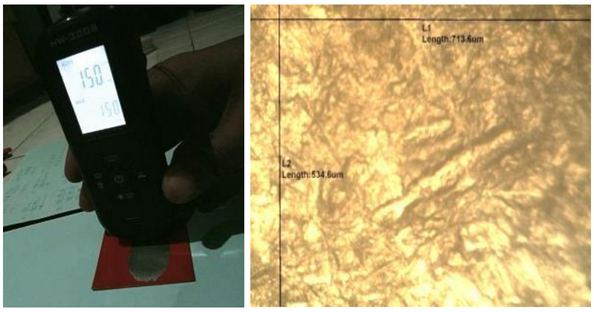

Figure 1. Coating Thicknes Test Sandblasting Result

Testing the thickness of the paint layer still attached to the specimen. Data collection of the thickness of the sandblasted paint layer was then carried out using the HW300S digital visual measuring tool. This tool has the following size specifications: 120mmx45mmx23mm, Resolution 0.01mm/1mil and measurement accuracy of 3% + 1um, uses the principle of electromagnetic induction and eddy current effects to automatically detect substrate characteristics.

Raw material cost test using. Data collection on the volume of consumption of abrasive sand media using a digital scale with a capacity of 10 kg and a measuring cup

Next, it is analyzed using signal to noise ratio statistics against each quality standard. That the results of the visual test on the largest surface erosion area are of better quality LTB. Meanwhile, the test results for the thickness of the eroded paint layer and the smallest volume of sand usage costs mean that the STB is of better quality. Then, an analysis of the effect of each factor on the average value and SNR value was carried out to find the optimal composition value for the sandblasting process.Next, an ANOVA analysis was carried out to determine the ranking value of the influence on each composition. Ultimately by grouping and comparing the results of calculating the ranking between Anova, SNR, the effect of each factor can determine the conclusion of an effective composition (Prihatin et al., 2023)

III.RESULT AND DISCUSSION

Result

The application of the variation of the factor levels from the Taguchi OA L9 table is focused on determining the etching/blasting treatment of 27 carbon iron sheet specimens (Doğukan Duymaz, 2025), (Knypiński et al., 2023). So that The results obtained from several tests include.

Raw material cost test. The remaining abrasive sand after use in each composition of the experimental design was weighed in a measuring cup and a 1000 kg scale

Test the microstructure with a t100w microscope. Based on the blasting results, visual NDT observations were then carried out using a microscope. The microstructure and cross-sectional area of the eroded paint surface of each specimen can be clearly seen.

Table 2. Microstructur NDT (Non Destructive Test) of sandblasting results

Test No	Basic mark (variabel-level and Factor)	Coating area removed (mm^2)	Ranking coating removed
1	1111	250	20
2	1222	450	30
3	1333	650	40
4	2123	450	40
5	2231	650	20
6	2312	250	30
7	3132	650	30
8	3312	250	30
9	3321	450	20

Coating thicknes test. The surface layer of the specimen that had peeled off was measured for the thickness of the remaining paint at 3 points horizontally.This test uses coating thickness hw300t with calibration management every 6 measurements.

Discussion

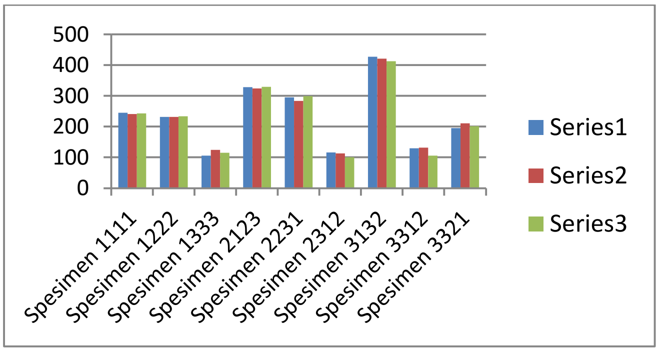

Figure 2. raw material of galvanis consumtion of sandblasting

The analysis of the remaining sand volume for use is the best in composition 3, namely 1333 to 538 grams. An air pressure of 1 bar and a spraying distance of 40mm has been able to produce a fairly high flow rate, so that the air pressure in the ventury gun decreases and accelerates the flow of silica sand with a density of 2700kg/m3.Meanwhile, the smallest volume of remaining sand is in composition no. 9, namely composition 1111, which is 9 grams.(Zicari et al., 2024). The minimum volume of sand used is best at test number 6, namely composition 2312, amounting to 110 grams. The use of 1.5 bar air pressure at a spray distance of 30 mm is able to create a slow flow of silica sand. The greater the air pressure applied, the slower the flow of abrasive sand. Meanwhile, the largest volume of sand used is at no. 7 with a composition of 3132, reaching 420 grams.(Lechte et al., 2025), (Zicari et al., 2024).

Based on the image above, it shows that the volume of sand used is the least and the best is in test number 6, namely composition 2312 amounting to 110 grams. The use of 1.5 bar air pressure at a spray distance of 30 mm is able to create a slow flow of silica sand. The greater the air pressure applied, the slower the flow of abrasive sand. Meanwhile, the largest volume of sand used is at no. 7 with a composition of 3132, reaching 420 grams (Abdulkarim et al., 2015), (Zicari et al., 2024).

Raw material cost . Obtained from calculations based on the table 5 above. The price of silica sand is Rp. 25,000/kg and beach sand is Rp. 15,000/kg. The lowest consumption cost of sand usage is in composition 2. In composition 1222, this means that the pressure of 1 bar at a spraying distance of 30mm causes the flow pressure in the venturi gun to decrease, so that the river sand does not flow smoothly enough. The price of river sand is Rp. 10,000/kg, with a usage of only 232.67 grams, so it only costs Rp. 2,326.67. Meanwhile, the highest cost is in test number 7, composition 3132, amounting to IDR 6,300.(Durmuş et al., 2025).

Table 3. Galvanis Raw Material Cost of Sandblasting Results

Basic mark (variabel-level)	analysis		
	Type of sand	Sand of consumption (gram)	Cost (Rp)
1111	beach	243.00	3645
1222	river	232.67	2326.667
1333	silica	115.00	2875
2123	Beach	327.00	4905
2231	River	292.67	2926.667
2312	Silica	110.00	2750
3132	Beach	420.00	6300
3312	Silica	122.67	3066.667
3321	Silica	202.33	5058.333

The results of the shortcomings in the research on the application of river sand as an abrasive medium in the sandblasting process are different from the potential capabilities of mechanical properties in the following tests. The results of research on the superior characteristics of concrete sand made from river sand show that the physical properties of density and compressive strength exceed the target by 36% (Opara et al., 2018). On the one hand, it shows that the average compressive strength is 1.16 N/mm^2

according to the NIS 2007 and ISO 848492-1994 standards (Babatunde Ogunbayo and Clinton Aigbavboa., 2022).

Figure 3 main effect plot for means of sandblasting coating thicknes

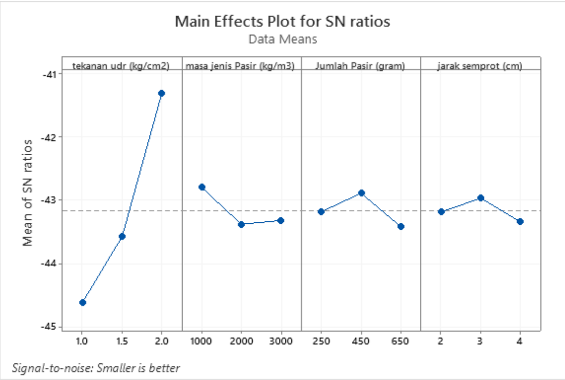

Figure 4 main effect plot for SN ratio of sandblasting coating thicknes

Based on the analysis image of the main effect of STB smaller the better than the average and the SNR value related to the thin consumption of the paint surface attached to the specimen, it is proven that a confirmation test is still needed. Testing is still being carried out again with the composition A3 B1 C2 D2 as confirmation to obtain the optimal coating thickness value (Peñuela-Cruz et al., 2023), (Prihatin et al., 2023).

Even though they show different rankings, the results of the proposed designs obtained are the same.In daily operations in the factory, there is no difficulty in changing settings so that different rankings are not a problem. So must be choose the A1 B2 C3 D4 are optimum.

IV. CONCLUSION

Based on sandblasting tests on galvanis iron using microstructure analysis, abrasive sand consumption analysis, and coating layer thickness analysis, it can be concluded that. :

1. The compressor air pressure greatly influences the dominant results of the peeling area of the low carbon plate material surface in the sandblasting process.
2. The best effectiveness and efficiency of the sandblasting process is in the specimen composition 3122. Application of beach sand type at a volume of 450ml, compressor air pressure 2 kg/cm^2 at a distance of 30mm.

REFERENCES

1. Abdulkarim, R., Akinnigbagbe, E., Imo, D., Imhansoloeva, M., Aniebone, V., Ibitola, M., Faleye, B., Shonde, O., & Appia, Y. (2015). Grain size analysis of beach sediment along the barrier bar lagoon coastal system, Lagos, Nigeria; its implication on coastal erosion. Global Journal of Geological Sciences, 12(1), 31. https://doi.org/10.4314/gjgs.v12i1.4
2. Azis, Y., Zahrina, I., Fadli, A., & Hazzamy, M. A. (2024). Utilization of Bengkalis Beach Sand Silica as Raw Material in the Synthesis of Zeolite 4A. Science and Technology Indonesia, 9(2), 244–250. https://doi.org/10.26554/sti.2024.9.2.244-250
3. Babatunde Ogunbayo and Clinton Aigbavboa. (2022). Quality Assessment of Sandcrete Blocks Produced with River Sand in OgunState, Nigeria. SARChl in Sustainable Construction Management and Leadership in the Built Environment, University of Johannesburg, Johannesburg, South Africa, January 2021. https://doi.org/10.1007/978-3-030-48465-1_65
4. Beredugo, C. P., Akpobi, E. D., & Yakubu, Y. (2025). Optimization of Delonix Regia Seed Oil Extraction using Taguchi Orthogonal Array Design. Engineering and Technology Journal, 10(08), 6056–6065. https://doi.org/10.47191/etj/v10i08.03
5. BRUNO RĂDULESCU□, M.-C. R. (2021). TAGUCHI'S METHOD IMPLEMENTED FOR WIND BLADE DESIGN (p. 5). BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI. https://doi.org/DOI:10.2478/bipcm-2021-0004
6. Channa, M. Y., Anwar, J., Kalsoom, R., & Abidi, S. H. I. (2024). Qualitative analysis of rivers sand sources (Silica sand, Ravi river sand, Indus river sand, and Jhelum river sand) for metal casting: a comparative study. Engineering Research Express, 6(3), 35435. https://doi.org/10.1088/2631-8695/ad7cc2
7. Cheng, Q., Zhao, B., & Dong, C. (2025). Structural Design and Analysis of Hydraulic Sandblasting Perforation Device. Academic Journal of Science and Technology, 14(3), 136–140. https://doi.org/10.54097/ee8pbg59
8. Doğukan Duymaz, S. K. (2025). Taguchi / Machine Learning Hybrid Framework for Optimization of Particulate Drug Delivery Systems. Bio Rxiv, August. https://doi.org/10.1101/2025.08.16.670654
9. Durmuş, H., Çömez, N., & Gül, C. (2025). Effect of sandblasting and aging on structural and mechanical properties of Inconel 625 coated steels for marine applications. Materialpruefung/Materials Testing, 67(3), 446–456. https://doi.org/10.1515/mt-2024-0388
10. Hemeda, E. S., Bashandy, A. A., & Nasser, A. A. (2024). Improving Mechanical Properties of Recycled Aggregate Pervious Concrete Using Taguchi Method. Civil and Environmental Engineering, 20(2), 1186–1202.

https://doi.org/10.2478/cee-2024-0087

11. Homa, P., Tryba, B., & Gęsikiewicz-Puchalska, A. (2017). Impact of paint matrix composition and thickness of paint layer on the activity of photocatalytic paints. Polish Journal of Chemical Technology, 19(1), 113–119. https://doi.org/10.1515/pjct-2017-0016
12. Huilcapi, M., Armas-Vega, A., Cardenas, A. F. M., Araujo, L. C. R., Ocampo, J. B., Bandeca, M. C., de Siqueira, F. S. F., & Loguercio, A. (2020). Effect of surface treatments on the adhesive properties of metallic brackets on fluorotic enamel. Dental Press Journal of Orthodontics, 25(4), 59–67. https://doi.org/10.1590/2177-6709.25.4.059-067.oar
13. Irawan, I., Martini, S., & Roni, K. A. (2025). the Effect of Silica Fume Pozzolan Percentage As a Partial Cement Substitution on Concrete Compressive Strength. 10(09), 7183–7187. https://doi.org/10.47191/etj/v10i09.31
14. Knypiński, L., Reddy, A. V., Venkateswararao, B., & Devarapalli, R. (2023). Optimal design of brushless DC motor for electromobility propulsion applications using Taguchi method. Journal of Electrical Engineering, 74(2), 116–121. https://doi.org/10.2478/jee-2023-0015
15. Laganà, F., & Faccì, A. R. (2025). Parametric optimisation of a pulmonary ventilator using the Taguchi method. Journal of Electrical Engineering, 76(3), 265–274. https://doi.org/10.2478/jee-2025-0027
16. Lechte, C., Hohmann, E., Wiegand, A., & Kanzow, P. (2025). Effect of Different Working Settings of Sandblasting on Resin Composite Repair Bond Strength. Materials, 18(2). https://doi.org/10.3390/ma18020313
17. Li, Y., Wang, H., Hua, W., Fan, J., Wang, H., & Qing, Y. (2025). Effects of sandblasting angle on coating removal. Journal of Physics: Conference Series, 3009(1), 0–6. https://doi.org/10.1088/1742-6596/3009/1/012021
18. Nugraha, F. T., Widjaja, R. S., Hermawan, Y. A., Yulianto, T., & Rejeki, S. (2025). Design of an Automated Dust Collector for Sandblasting Machine to Support the Implementation of a Green Shipyard. IOP Conference Series: Earth and Environmental Science, 1473(1), 1–9. https://doi.org/10.1088/1755-1315/1473/1/012070
19. Ogrodniczek, J., Rudawska, A., Skoczylas, A., & Kocira, S. (2025). Improving the Adhesive Properties by Sandblasting the Surface with Copper Slag and Glass Beads. Materials, 18(8), 1–16. https://doi.org/10.3390/ma18081746
20. Opara, H. E., Eziefula, U. G., & Eziefula, B. I. (2018). Comparison of physical and mechanical properties of river sand concrete with quarry dust concrete. Selected Scientific Papers - Journal of Civil Engineering, 13(s1), 127–134. https://doi.org/10.1515/sspjce-2018-0012
21. Palabiyik, S. S., Girgin, G., Tutkun, E., Yilmaz, Ö. H., & Baydar, T. (2013). Immunomodulation and oxidative stress in denim sandblasting workers: Changes caused by silica exposure. Arhiv Za Higijenu Rada i Toksikologiju, 64(3), 431–437. https://doi.org/10.2478/10004-1254-64-2013-2312
22. Peñuela-Cruz, C. E., Márquez-Herrera, A., Aguilera-Gómez, E., Saldaña-Robles, A., Mis-Fernández, R., Peña, J. L., Caballero-Briones, F., Loeza-Poot, M., & Hernández-Rodríguez, E. (2023). The effects of sandblasting on the surface properties of magnesium sheets: a statistical study. Journal of Materials Research and Technology, 23(January), 1321–1331. https://doi.org/10.1016/j.jmrt.2023.01.117
23. Pramana Aji, H., & . S. (2025). Sanding Machine Powered By 2 X 150 WP Solar Panels. Engineering and Technology Journal, 10(08), 6409–6411. https://doi.org/10.47191/etj/v10i08.36
24. Prihatin, J. Y., Pangestu, B. A., Kristiyono, R., & Sulistyadi, S. (2023). Experimental test analysis of hydram pump flow rate using L9 Taguchi at fish pond aquaculture. Journal of Engineering and Applied Technology, 4(1), 33–39. https://doi.org/10.21831/jeatech.v4i1.58352
25. Primaningtyas, W. E., Auliyasari, I., Pratiwi, W. D., Nisazarifa, A., Nursyifaulkhair, D., & Rosalina, A. (2024). Analysis of Fly Ash and Sandblasting Waste Addition in Cementitious Composite Lawn Table Reinforced by Cocofiber and Wiremesh. International Journal of Marine Engineering Innovation and Research, 9(4), 750–756. https://doi.org/10.12962/j25481479.v9i4.21852
26. Radek, N. (2023). Performance tests of paint coatings used for masking armaments and military equipment. Technical Transactions, 1(2023), 1–9. https://doi.org/10.37705/techtrans/e2023008
27. Ratri, T. M., Prastiwi, A. W., Hudha, M. I., & Rahman, N. A. (2024). Silica Extraction Based on Quartz Sand Waste Sandblasting PT. Dok Lamongan with Base Method. Reka Buana : Jurnal Ilmiah Teknik Sipil Dan Teknik Kimia, 9(2), 238–246. https://doi.org/10.33366/rekabuana.v9i2.6034
28. Śmielak, B., Klimek, L., & Krześniak, K. (2023). Effect of Sandblasting Parameters and the Type and Hardness of the Material on the Number of Embedded Al2O3 Grains. Materials, 16(13), 1–11. https://doi.org/10.3390/ma16134783
29. Yu, Z., Dong, Y., Zheng, G., Jiang, X., Cheng, X., Yang, X., Chang, K., & Li, X. (2022). Influence of micro sandblasting on the surface integrity of the AlTiN-coated tools. International Journal of Advanced Manufacturing Technology, 120(1–2), 1359–1372. https://doi.org/10.1007/s00170-022-08890-1
30. Zicari, F., Monaco, C., Vivan Cardoso, M., Silvestri, D., & Van Meerbeek, B. (2024). Bonding Effectiveness of Veneering Ceramic to Zirconia after Different Grit-Blasting Treatments. Dentistry Journal, 12(7). https://doi.org/10.3390/dj12070219