Comparative Analysis of Surface Roughness influenced by Alumina Powder on Different Lapping Plates using the Surface Lapping Process Technique to the C3604 Brass Material

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ABSTRACT

This research aims to study the surface roughness influenced by alumina powder on different lapping plates using surface lapping process technique for C3604 brass material. The comparison was made between using a cast iron lapping plate and a brass lapping plate. The design and analysis of a factorial experiment were applied to analyze the impact of three factors: alumina powder size with levels of 0.05, 0.30, 1.00, and 3.00 µm, lapping time with levels of 30, 60, 90, 120, 150, and 180 min, and the type of lapping plate (cast iron or brass). The response variables in the factorial experiment included two Ra-values, on the x-axis and on the y-axis. These variables were analyzed to determine their correlation with the surface quality of C3604 material in the lapping process. During sample preparation for the experiment which was conducted to measure surface roughness, 200 g of alumina powder, 150 ml of alumina powder lubricant, and 1 L of water were used. In the final statistical analysis, the brass lapping plate was selected to determine the most suitable values for the response variables. The analysis resulted in 0.1132 µm roughness on the x-axis and 0.1076 µm on the y-axis. It was found that the optimal alumina powder size and lapping time were 0.30 µm and 90 min, respectively. The statistical analysis carried out in this research revealed a high level of desirability, which was found to reach 95.41%. This means that the recommended combination of 0.30 µm alumina powder size and 90 min lapping time resulted in highly satisfactory outcomes based on multiple response criteria. The high desirability value signifies that this

combination is considered optimal and provides a superior surface quality for the C3604 brass material in the lapping process.

Keywords-alumina powder; lapping process; factorial experiment

I. INTRODUCTION

The lapping process is profoundly influenced by numerous input parameters, emphasizing the importance of factors like machining speed, pressure, and the duration of contact between the lap plate, the abrasive paste, and the workpiece. Quality holds a crucial role in the contemporary manufacturing industry, being the singular element that can impact customer satisfaction. Whether encountered in small-scale enterprises or in the expansive aerospace sector, surface quality is assessed through the product's surface roughness [1-3]. The lapping process is employed to attain top-notch quality alumina through plane lapping and polishing. These methods are widely utilized for achieving meticulous and refined abrasive finishing [4-5] Currently, the automotive, sanitary, furniture, and electronic industries are experiencing ongoing growth and expansion. This expansion emphasizes the need for comprehensive research and analysis of functional surfaces, particularly those requiring exceptionally high surface roughness, to enhance product value and optimize results. Among the methods utilized to refine industrial surfaces, the practice of polishing holds a prominent position, with lapping standing out as a technique that provides precise control over workpiece surfaces through material removal or polishing [6-8]. Lapping and polishing procedures primarily depend on the interaction of the sliding friction between particles and the workpiece's surface. In these processes, a lap or polishing pad (also known as a polisher) moves across the surface of the workpiece, causing slurry particles resembling sand or mud to be propelled against the surface where they make contact. This sliding friction plays a crucial role in material removal and surface refinement, leading to the desired surface finish [9-10]. Lapping offers notable advantages, such as high efficiency, adaptability, precision, and minimal surface damage, which render it widely adopted for creating both flat and intricate surfaces. When compared to conventional machining methods like cutting, milling, and drilling that employ geometric tools, lapping demonstrates significantly enhanced capabilities. Its efficiency and versatility establish lapping as the preferred method for achieving meticulous surface textures across various industrial applications [11-13]. Lapping is a widely used technique to refine surfaces of various shapes, enhancing precision and quality, which is especially crucial for devices reliant on the alumina base layer. Solid abrasives fixed on a lapping disc form a specialized tool for high-speed machines, allowing precise control over surface finishing. Accurate measurement is paramount for evaluating and supervising surface quality, ensuring alignment with specifications and tolerances in high-precision technologies associated with surface polishing [14-17]. Thorough consideration of the surface polishing process is influenced by numerous factors that are identified through experimentation. These factors exhibit variability and encompass parameters, such as the choice of abrasive materials, formulation of abrasive paste or slurry, applied pressure, scrubbing duration, and inherent characteristics of the workpiece material [19]. Attaining the desired quality and precision of surface shape in the lapping process often necessitates specialized shaping methods. These methods require continuous experimentation to ensure optimal effectiveness. Through systematic exploration of various shaping techniques, such as precise control of lapping pressure, manipulation of relative motion between the lap and the workpiece, or adjustment of abrasive slurry composition, manufacturers can enhance the surface shape to meet precise specifications [18, 20-21]. Analysis of Variance (ANOVA) [22] serves as a valuable tool for fine-tuning and optimizing the lapping process. Researchers can statistically analyze the effects of different factors on the process and determine their significance using this approach [23-24].

This analysis helps identifying the factors that have the most substantial influence on surface roughness, facilitating appropriate adjustments. This study also aims to improve the accuracy of surface roughness measurements [25]. Lapping plates made of brass and cast iron were compared, focusing on the effects of four different alumina abrasives of sizes 0.05 μm, 0.30 μm, 1.00 μm, and 3.00 μm on the average surface roughness (Ra). Additionally, the study examined the impact of lapping time (30, 60, 90, 120, 150, and 180 min) on C3604 brass material during the lapping process. Utilizing Design of Experiments (DoE) principles, a comprehensive statistical analysis of various process parameters was conducted to determine their significance. The research results provide insights into the differences between brass and cast-iron lapping plates and the correlation between alumina abrasive type and surface roughness in C3604 brass material. These findings enhance the understanding of how different lapping conditions influence surface finish quality, thereby informing the selection of optimal process parameters for improved surface roughness.

II. EXPERIMENTAL PROCEDURE

Brass C3604 stands as a versatile alloy containing copper, zinc, and other essential elements. This variety of brass offers an exceptional selection for diverse applications across various industries due to its favorable mechanical properties. The primary constituents of C3604 brass are copper and zinc (65-80% by weight), with the remaining 20-35% encompassing tin (1-2%), aluminum (0.02-0.6%), nickel (0.02-0.07%), lead (0.01-0.05%), iron (0.01-0.07%), and manganese (0.001%). For the test specimen process, C3604 brass material in flat bar form of 26 × 40 × 8 mm was ground to with a milling machine. Subsequently, the surface underwent a smooth grinding process using an aluminum oxide grinding wheel. The specific grinding stone utilized in this experiment was a white stone of aluminum oxide type, measuring 205 × 19 × 31.75 mm with a Ra grinding from 0.1 to 0.5 μm, as illustrated in Figure 1.

During the experimental phase, the commencement of the fine skin process involved meticulous blending of precise quantities of 200 g alumina powder, 150 ml alumina powder lubricant, and 1 L of water to achieve the desired ratio. The target arithmetic mean surface roughness value (Ra) is between 0.1 and 0.5 µm. Following this, the surface finishing machine (lapping machine) was activated, as depicted in Figure 2. The mixture was allowed to blend for approximately 5 min before proceeding. Subsequently, the workpieces were placed on the plate and were divided into 4 sets, each containing 9 pieces. Every set utilized alumina polishing powder of a different size: 0.05 µm for set 1, 0.30 µm for set 2, 1.00 µm for set 3, and 3.00 µm for set 4. The workpieces were then polished sequentially by C3604 brass material placed on the polishing plate of the surface treatment machine, as portrayed in Figure 3. The experiment was conducted by varying the time intervals of the surface finishing process, namely 30, 60, 90, 120, 150, and 180 min. The surface roughness value was measured using a microscope (3D Measuring Laser Microscope, Model OLS5000) by assessing the surface roughness value of the four sets. Each piece underwent measurement at 5 points. The measurement procedure involved taking the piece and utilizing a 20x magnification. The surface roughness value was then measured at specific points: the top right corner (TR), the bottom right corner (BR), the top left corner (TL), the bottom-left corner (BL), and the center point (C), as shown in Figure 4. The experimental data underwent a thorough analysis, which included the calculation of arithmetic mean surface roughness values for each specified time period. These findings are graphically presented to provide both a concise summary and a comprehensive understanding of how the timing of the surface improvement process correlates with the surface roughness of the material. By visually illustrating these relationships, the analysis offers valuable insights into the impact of treatment time on enhancing surface quality, shedding light on how varying the duration of the lapping process influences the final surface finish. This detailed examination aims to identify the optimal time parameters that lead to significant improvements in surface characteristics, thereby contributing to the development of more efficient and effective lapping procedures. Ultimately, this in-depth analysis will report the optimum practices for achieving superior surface quality in industrial applications.

Fig. 1. The process of grinding a flat surface.

(a) (b)

Fig. 2. (a) Alumina (Al_2O_3) powder, (b) lapping machine.

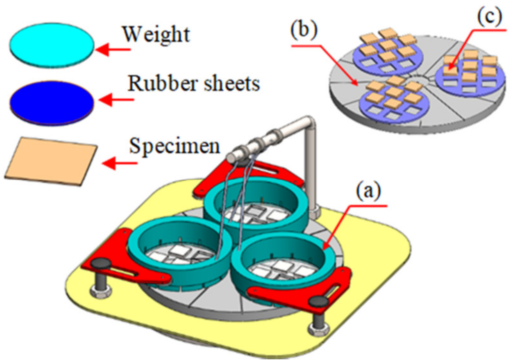

Fig. 3. (a) Conditioning rings, (b) polishing plate, (c) specimen.

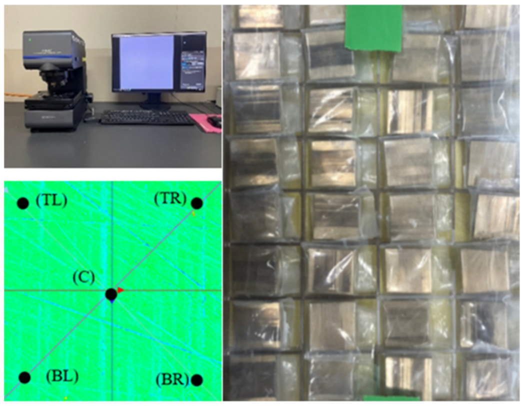

Fig. 4. 3D Measuring laser microscope OLS5000 and measured points.

III. RESULTS

The statistic ANOVA performed on the multi-response data revealed significant findings at a 95% confidence level. Both the main effect term and the interaction term were found to be statistically significant, indicating that the factors under investigation have a substantial influence on the measured outcomes. The Pareto chart further supported these results, with all bars exceeding the critical reference line of the P-value statistic at a 95% confidence level, underscoring their importance in the experimental results. The experiment focused on studying the effects of adjusting the time interval in the fine finishing process on average surface roughness data (Ra-value) obtained from brass C3604 specimens using a grinding wheel. Time intervals of 30, 60, 90, 120, 150, and 180 min were carefully chosen for data collection. The selection of these intervals aimed to evaluate the impact of varying durations on Ra. The collected data included two key response variables: Ra-value and the type of lapping plate (cast iron or brass). In the factorial experiment, two Ra-values, specifically Ra on the x-axis and Ra on the y-axis, were considered as part of the analysis. The Ra-values represent the average surface roughness of the brass C3604 specimens, which is a critical parameter used to evaluate the surface quality and smoothness. The experiment involved measuring Ra-values for each specimen subjected to different time intervals in the fine finishing process. Tables I-IV contain the experimental data. Analysis of these data allows researchers to draw meaningful conclusions about the optimal time interval for achieving the desired surface quality.

TABLE I. SURFACE ROUGHNESS (RA) DATA FOR CAST IRON PLATE (X-AXIS)

Alumina size (µm)	Lapping time (min)					
	30	60	90	120	150	180
0.05	0.199	0.191	0.276	0.130	0.149	0.253
0.05	0.101	0.224	0.153	0.146	0.145	0.228
0.05	0.113	0.152	0.214	0.126	0.183	0.359
0.05	0.156	0.266	0.154	0.139	0.143	0.209
0.05	0.180	0.155	0.200	0.155	0.193	0.200
0.30	0.112	0.666	0.103	0.200	0.149	0.198
0.30	0.156	0.672	0.115	0.200	0.135	0.156
0.30	0.143	0.315	0.155	0.197	0.127	0.093
0.30	0.155	0.592	0.134	0.210	0.116	0.143
0.30	0.157	0.587	0.167	0.185	0.115	0.102
1.00	0.146	0.222	0.150	0.146	0.135	0.234
1.00	0.201	0.159	0.148	0.156	0.182	0.204
1.00	0.193	0.173	0.164	0.095	0.159	0.191
1.00	0.168	0.133	0.174	0.121	0.146	0.109
1.00	0.171	0.160	0.170	0.182	0.143	0.214
3.00	0.180	0.192	0.212	0.151	0.278	0.202
3.00	0.117	0.253	0.236	0.196	0.180	0.161
3.00	0.127	0.225	0.257	0.207	0.191	0.183
3.00	0.102	0.206	0.280	0.242	0.163	0.187
3.00	0.110	0.248	0.200	0.230	0.221	0.167

TABLE II. SURFACE ROUGHNESS (RA) DATA FOR CAST IRON PLATE (Y-AXIS)

Alumina size (µm)	Lapping time (min)					
	30	60	90	120	150	180
0.05	0.193	0.155	0.252	0.106	0.153	0.263
0.05	0.179	0.217	0.192	0.163	0.165	0.198
0.05	0.143	0.159	0.186	0.133	0.174	0.344
0.05	0.153	0.232	0.173	0.131	0.170	0.209
0.05	0.124	0.155	0.169	0.148	0.152	0.233
0.30	0.140	0.741	0.115	0.201	0.129	0.135
0.30	0.115	0.930	0.134	0.221	0.127	0.135
0.30	0.173	0.772	0.162	0.194	0.113	0.079
0.30	0.140	0.534	0.147	0.206	0.110	0.119
0.30	0.171	0.661	0.156	0.199	0.097	0.100
1.00	0.163	0.204	0.146	0.131	0.153	0.179
1.00	0.202	0.233	0.129	0.139	0.159	0.211
1.00	0.186	0.157	0.164	0.143	0.128	0.158
1.00	0.161	0.133	0.171	0.113	0.127	0.168
1.00	0.192	0.129	0.160	0.147	0.123	0.174
3.00	0.173	0.242	0.160	0.298	0.207	0.200
3.00	0.121	0.218	0.184	0.375	0.191	0.180
3.00	0.103	0.237	0.226	0.206	0.190	0.195
3.00	0.094	0.206	0.229	0.354	0.205	0.164
3.00	0.105	0.235	0.176	0.203	0.199	0.186

TABLE III. SURFACE ROUGHNESS (RA) DATA FOR BRASS PLATE (X-AXIS)

Alumina size (µm)	Lapping time (min)					
	30	60	90	120	150	180
0.05	0.230	0.163	0.185	0.192	0.256	0.238
0.05	0.228	0.185	0.153	0.190	0.201	0.216
0.05	0.219	0.215	0.148	0.233	0.224	0.250
0.05	0.167	0.167	0.279	0.174	0.199	0.253
0.05	0.163	0.188	0.195	0.229	0.233	0.192
0.30	0.185	0.089	0.100	0.191	0.240	0.205
0.30	0.183	0.096	0.112	0.188	0.253	0.165
0.30	0.148	0.152	0.126	0.199	0.203	0.212
0.30	0.141	0.196	0.115	0.276	0.233	0.228
0.30	0.128	0.094	0.113	0.191	0.210	0.202
1.00	0.209	0.289	0.142	0.173	0.168	0.206
1.00	0.180	0.304	0.130	0.187	0.203	0.244
1.00	0.247	0.274	0.164	0.203	0.247	0.268
1.00	0.270	0.338	0.144	0.203	0.153	0.195
1.00	0.217	0.274	0.148	0.169	0.139	0.228
3.00	0.206	0.186	0.165	0.216	0.316	0.262
3.00	0.166	0.284	0.142	0.261	0.269	0.227
3.00	0.187	0.308	0.401	0.318	0.258	0.256
3.00	0.187	0.357	0.320	0.278	0.357	0.265
3.00	0.134	0.272	0.247	0.224	0.293	0.305

TABLE IV. SURFACE ROUGHNESS (RA) DATA FOR BRASS PLATE (Y-AXIS)

Alumina size (µm)	Lapping time (min)					
	30	60	30	120	30	180
0.05	0.188	0.127	0.220	0.216	0.197	0.222
0.05	0.196	0.199	0.186	0.205	0.170	0.208
0.05	0.173	0.211	0.175	0.119	0.173	0.221
0.05	0.160	0.186	0.227	0.176	0.162	0.187
0.05	0.124	0.189	0.227	0.201	0.223	0.152
0.30	0.185	0.064	0.091	0.190	0.183	0.156
0.30	0.167	0.075	0.101	0.190	0.205	0.144
0.30	0.143	0.152	0.115	0.207	0.170	0.164
0.30	0.139	0.236	0.118	0.275	0.188	0.209
0.30	0.096	0.098	0.113	0.285	0.215	0.198
1.00	0.194	0.132	0.130	0.167	0.130	0.201
1.00	0.189	0.174	0.117	0.209	0.201	0.202
1.00	0.177	0.201	0.130	0.170	0.182	0.208
1.00	0.156	0.212	0.117	0.114	0.170	0.215
1.00	0.148	0.201	0.125	0.122	0.129	0.252
3.00	0.173	0.165	0.163	0.152	0.185	0.270
3.00	0.145	0.256	0.140	0.165	0.151	0.111
3.00	0.161	0.153	0.302	0.207	0.146	0.113
3.00	0.159	0.221	0.165	0.201	0.205	0.187
3.00	0.175	0.230	0.194	0.175	0.175	0.169

The results of the factorial experiment analysis, as presented in Tables V and VI clearly indicate the influence of the considered factors on the average surface roughness (Ra) of the brass C3604 test piece. These factors include the alumina size (A), which encompass four different values, i.e. 0.05 µm, 0.30 µm, 1.00 µm, and 3.00 µm, the lapping time (B) with values of 30, 60, 90, 120, 150, and 180 min, and (C) the type of lapping plate (cast iron or brass).

TABLE V. RESULTS FROM FACTORIAL Ra ANALYSIS (X-AXIS)

Source	DF	SS	MS	F-value	p-value
Model	47	1.18134	0.02513	14.24	< 0.001
Linear	9	0.26077	0.02897	16.41	< 0.001
Alumina powder (A)	1	0.02444	0.02444	13.84	< 0.001
Lapping time (B)	3	0.05312	0.01770	10.03	< 0.001
Lapping plate (C)	5	0.18321	0.03664	20.75	< 0.001
2-way interactions	23	0.49811	0.02165	12.27	< 0.001
Alumina powder* lapping time	3	0.09784	0.03261	18.47	< 0.001
Alumina powder* lapping plate	5	0.12408	0.02481	14.06	< 0.001
Lappingtime* lapping plate	15	0.27619	0.01841	10.43	< 0.001
3-way interactions	15	0.42246	0.02816	15.95	< 0.001
Alumina powder* Lapping time*lapping plate	15	0.42246	0.02816	15.95	< 0.001
Error	192	0.33897	0.00176	-	-
Total	239	1.52031		-	-

TABLE VI. RESULTS FROM FACTORIAL Ra ANALYSIS (Y-AXIS)

Source	DF	SS	MS	F-value	p-value
Model	47	1.80146	0.03832	24.89	< 0.001
Linear	9	0.30910	0.03434	22.31	< 0.001
Alumina powder (A)	1	0.02697	0.02696	17.51	< 0.001
Lapping time (B)	3	0.04568	0.01522	9.89	< 0.001
Lapping plate (C)	5	0.23645	0.04729	30.71	< 0.001
2-way interactions	23	0.81765	0.03555	23.09	< 0.001
Alumina powder* lapping time	3	0.07682	0.02560	16.63	< 0.001
Alumina powder* lapping plate	5	0.21811	0.04362	28.33	< 0.001
Lappingtime* lapping plate	15	0.52273	0.03484	22.63	< 0.001
3-way interactions	15	0.67471	0.04498	29.21	< 0.001
Alumina powder* Lapping time*lapping plate	15	0.67471	0.04498	29.21	< 0.001
Error	192	0.29563	0.00154	-	-
Total	239	2.09709		-	-

The analysis considered both the main effect of each parameter, representing its individual impact on Ra, and the interaction between parameters, signifying their combined influence. The statistical analysis was conducted at a 95% confidence level, with the results demonstrating the significant influence of each parameter and their interactions. The P-Value being less than the α value of 0.05 confirms the statistical significance at a 95% confidence level. These substantial findings underscore the critical importance of meticulously considering both the size of the alumina particles and the lapping time when determining the resulting Ra of the brass C3604 test piece. In addition, the type of lapping plate employed also plays a notable and influential role in shaping the Ra outcome. Therefore, for achieving optimal results, it is imperative to carefully select and control these variables in the lapping process.

Residual analysis, particularly using the Pareto chart of the standardized effects, provides crucial insights when conducting factorial experiments. By analyzing the Pareto chart, it becomes evident that the interaction term ABC, which represents the combined influence of alumina powder, lapping time, and lapping plate type, exceeds the critical lines. This observation indicates that all three factors significantly impact the workpiece roughness after the fine lapping process. The presence of the ABC interaction term beyond the critical lines suggests that the combined effect of alumina powder, lapping time, and lapping plate type plays a crucial role in determining the quality of the workpiece surface. This interaction may indicate that these factors work together synergistically or antagonistically, influencing the outcome of the fine lapping process. The significance of these factors and their interaction is visually depicted in Figures 5 and 6. For manufacturers and researchers, understanding the influence of factors A, B, and C, as well as their interaction, is essential for optimizing the fine lapping process. This knowledge enables them to make informed decisions regarding the optimal selection of alumina powder, lapping time, and lapping plate type to achieve the desired workpiece surface roughness.

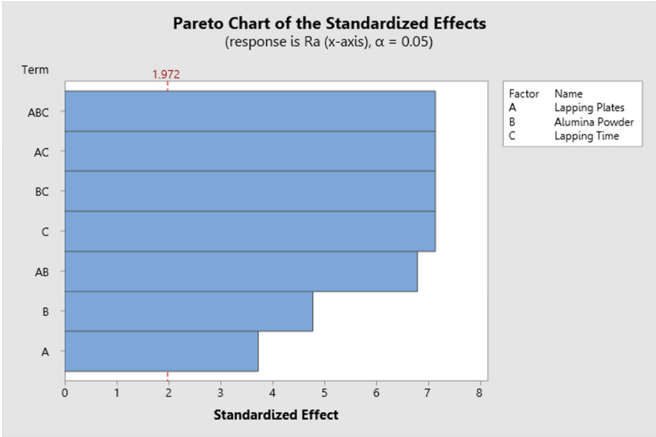

Fig. 5. Pareto chart (x-axis).

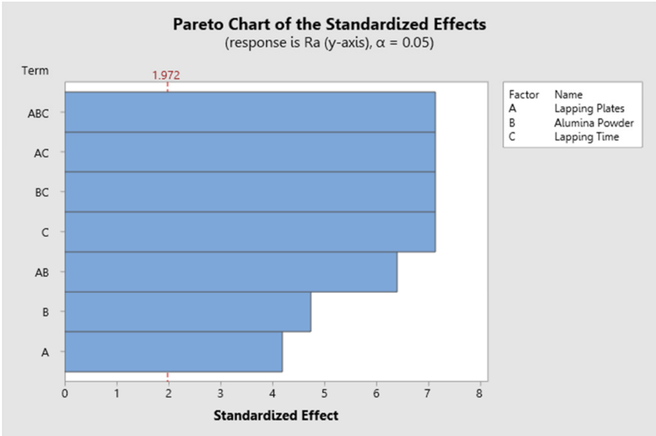

Fig. 6. Pareto chart (y-axis).

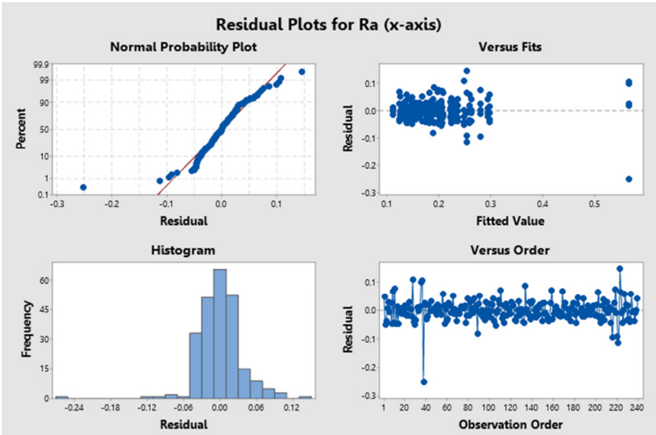

Fig. 7. Residual plots (x-axis).

Residual analysis involves checking the normality of the residuals' distribution through a normal probability plot. In good data, the residuals should follow a normal distribution. To assess the constant variance of the residuals, a Versus Fits graph is used. In good data, the variability of residuals should be fairly consistent. Additionally, the independence of residuals is checked using a Versus Order graph. In good data, the plot should exhibit a random scatter without any specific patterns. Control charts are vital tools in statistical process control, commonly employed to monitor and analyze processes over time. The criteria and assumptions are shown in Figures 7 and 8. These charts provide a clear illustration of the characteristics of good control charts.

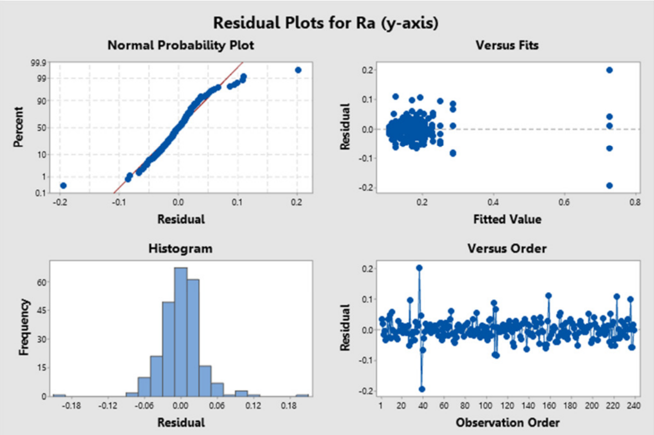

Fig. 8. Residual plots (y-axis).

After analyzing the main effect plots presented in Figures 9 and 10, it becomes apparent that the three parameters do not align parallel to the reference line along the horizontal axis. This observation underscores the influence of these parameters on the mean Ra response of the C3604 brass specimen. These results are in line with the conclusions drawn from the factorial experimental analysis, as detailed in Tables V and VI. Upon closer examination of the parameter interactions depicted in Figures 11 and 12, a clear pattern emerges. The graph indicates a reciprocal influence. However, even with a statistical confidence level of 95%, this divergence retains its statistical significance. As a result, it can be inferred that the combined effect of these three parameters significantly impacts the mean Ra response of the C3604 brass specimen, aligning consistently with the findings extracted from the experimental analysis. These factorial results persistently echo throughout Tables V and VI.

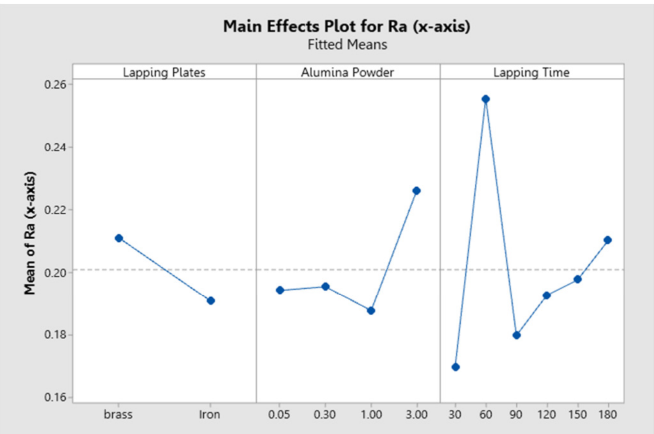

Fig. 9. Main effects (x-axis).

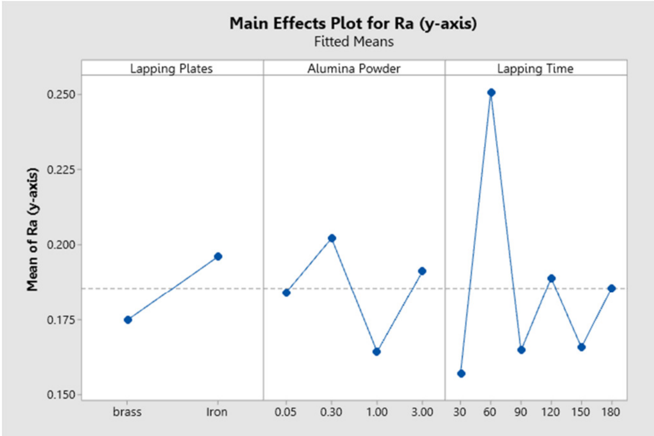

Fig. 10. Main effects (y-axis).

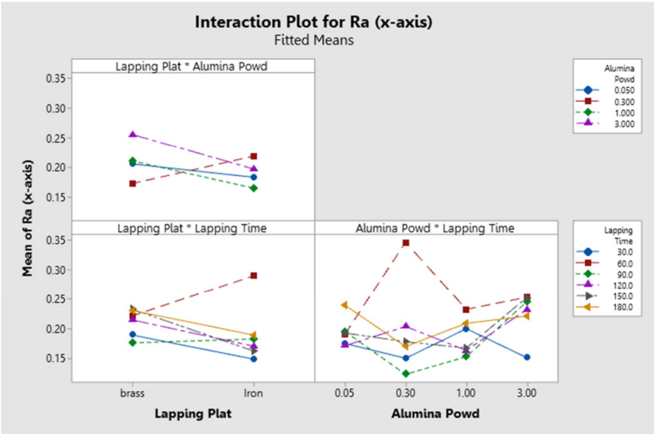

Fig. 11. Interaction plot (x-axis).

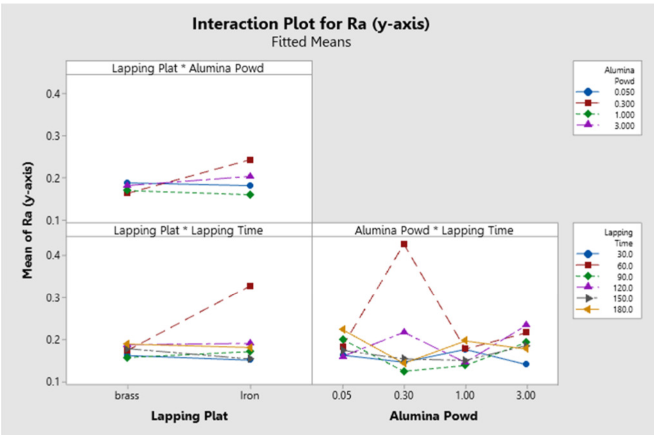

Fig. 12. Interaction plot (y-axis).

To identify the optimal parameters for achieving a high-quality work surface, all considered parameters play pivotal roles. For C3604 brass material, the superior quality of brass is manifested in its lowest average roughness (Ra), denoting the minimal value. Through thorough analysis, it was concluded that the brass lapping plate was the preferred choice. The optimal conditions encompassed the use of an alumina polishing powder with a size of 0.3 µm and a lapping time of 90 min. Moreover, the confidence level of Ra on the x-axis was assessed at 95.84%. This concurs with attaining an Ra value with a measurement resolution on the x-axis of 0.1132 µm. Correspondingly, the confidence level of the Ra value on the y-axis reached 94.96%, leading to the lowest Ra value on the y-axis, measuring 0.1076 µm. These findings are visually presented in Figure 13.

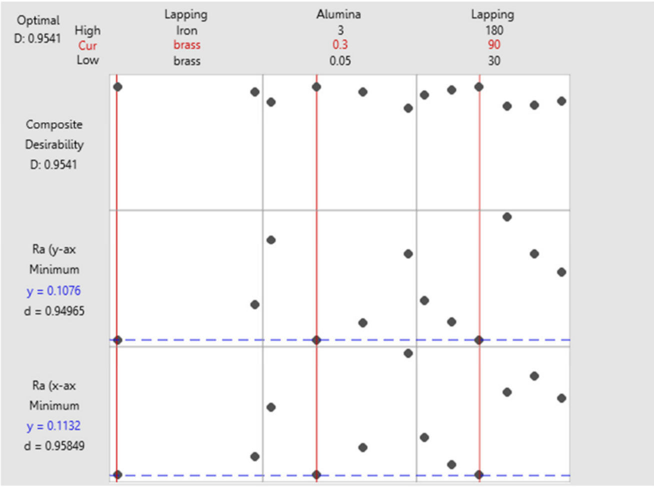

Fig. 13. Response optimization.

IV. CONCLUSIONS

The lapping process is widely acknowledged as a meticulous machining technique that offers numerous advantages in achieving remarkable flatness and surface finish. Nevertheless, it does have specific limitations, and ongoing advancements in material engineering and technology which are crucial in addressing these constraints and instrumental in elevating the overall efficiency and efficacy of the lapping process. The purpose of this research was to conduct a comparison of the influence of alumina powder on surface roughness by deploying a surface refinement technique for C3604 brass material. This investigation involved a comparison between the utilization of a cast iron lapping plate and a brass lapping plate. To accomplish this, a factorial experiment was designed and executed with the intent of analyzing the influence of three critical factors, the size of alumina powder, the lapping time, and the type of the employed lapping plate. The study incorporated four distinct alumina powder sizes: 0.05 µm, 0.30 µm, 1.00 µm, and 3.00 µm and six different lapping times: 30, 60, 90, 120, 150, and 180 min, on two lapping materials (cast iron and C3604). The findings yielded valuable insights into the impact of alumina powder on surface roughness and the consequent surface quality attained for C3604 brass material through a surface refinement technique. The selection of the brass lapping plate emerged as a result of the analysis. The outcome of the analysis yielded the following values for surface roughness: 0.1132 µm on the x-axis and 0.1076 µm on the y-axis. The research determined that the optimal alumina powder size was 0.30 µm, while the appropriate lapping time was 90 min. The conducted statistical analysis within this research unveiled a high level of confidence, as evidenced by the desirability value, which reached a substantial 95.41%. The outcomes of this research carry significant practical implications for industries and professionals involved in surface refinement procedures, particularly when working with C3604 brass material. The study's recommendations, pointing toward an optimal alumina powder size of 0.30 µm and a lapping time of 90 min, offer clear and well-defined starting points for industries which seek to achieve high surface quality. The implementation of these precise parameters has the potential to lead to enhanced surface finishes in the production of C3604 brass components.

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