Advances in Engineering Research, volume 166
3rd International Conference on Automation, Mechanical Control and Computational Engineering (AMCCE 2018)

# Optimization of Sandblasting Process of Complex 3D Surface Polishing Using Variable Viscoelastic Diamond Abrasive Particles

Jung-hua Tung[1, 4, a)], Cheng-shun Chen[2, b*)], Wen-yu Zhao[3, c)] and Cher-Ming Tan[4, d)]

[1] *Graduate institute of mechanical and electrical engineering, National Taipei university of Technology, Taipei, 10608, Taiwan*
[2] *Graduate institute of manufacturing technology, National Taipei university of Technology, Taipei,* 10608, *Taiwan*
[3] *School of Chemistry and Chemical Engineering, Inner Mongolia University of Science and Technology, Baotou, 014000, China*
[4] *Centre for reliability sciences and technologies, Chang Gung University, Taoyuan, 33302, Taiwan*

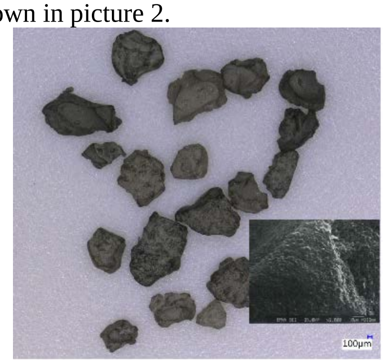
a)fred.tung@yahoo.com.tw
b) cshchen@ntut.edu.tw
c) zhaowenyu2011@hotmail.com
d)chermingtan@mail.cgu.edu.tw

**Abstract.** This paper reports a type of abrasive polish method. Controlling the environmental aqueous rust inhibitor content can change its viscoelasticity to adhere diamond particles on polymer materials. Using the sandblasting mechanism, the elastic abrasive with fine diamond particles adhered to them collides with the workpiece. The abrasive particles deform and slide on the workpiece surface, so that the diamond particles on the abrasive surface can cut onto the surface peak of the workpiece. Thus, the surface of the material with complicated morphology can be rapidly and precisely polished. The friction generated by the abrasive on the surface of the workpiece will cause the rust inhibitor solution to evaporate, resulting in reduced viscosity, leaving the diamond particles to gradually fall off from the abrasive. Applying the Taguchi method, the robust parameters for viscosity and injection angle were identified. The surface roughness of the tooling steel by using the identified parameters was found to decrease from Ra=1.47 μm to Ra=0.2 μm in 3 minutes. Its polishing application for inner angle and inside curved face of the two different die materials has 40 times higher efficiency as compared to the traditional polishing process.

**Keywords:** Sandblasting Process, Polishing, Abrasive Particles, Workpiece Surface, Taguchi Method

## INTRODUCTION

The surface of the inner corner and the curved surface in the polishing process is technically challenging. Known three-dimensional polishing techniques such as electrolytic polishing [1], fluid abrasive polishing [2], and chemical mechanical polishing [3] are all polished low efficiency and poor stability make technology stagnate。 Sandblasting is a kind of polishing method that can achieve three-dimensional operation and high efficiency. In this paper, innovative low-density PA12 particulate materials (1 to 2 mm in diameter) as shown in Fig. 1 and used in conjunction with this sandblasting polishing principle. This material has viscoelasticity with its water content so that the surface can adhere the diamond microparticles. Its working method is that when the abrasive particles impact the workpiece, the abrasive particles deform to eliminate the reaction force of the nozzle and the abrasive particles slide on the surface of the workpiece. Therefore, the diamond particles adhering to the abrasive grains can cut a sharp peak on the surface of the workpiece to achieve a smooth and bright effect, and the abrasive grains are recycled. as shown in picture 2.



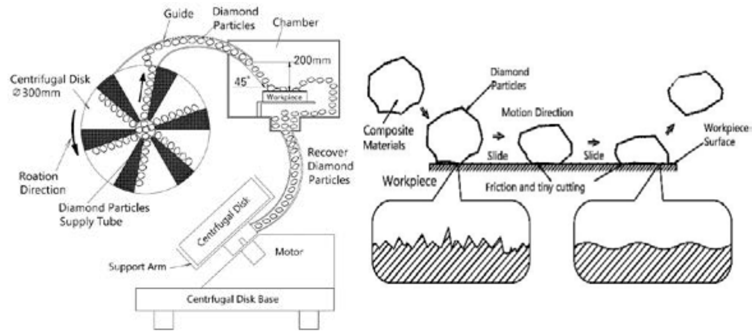




**FIGURE 1.**Viscoelastic diamond abrasive

**FIGURE 2.** Composite materials infiltrate diamond particles and sandblast polishing operation diagram [1]

## EXPERIMENTATIONS

Taguchi's experimental method is one of the many experimental designs (DoE). That use smaller number of experiments to achieve robust parameter. Comparing the response surface method (RSM) statistics and mathematical model established by Box and Wilson in 1951, Taguchi method is more suitable for the experiment in this paper. Firstly, the content of water-based rust agent can vary the viscoelasticity of the abrasive. This in turn will affect the collision time of the abrasive grains on the workpiece surface as well as the adhesion of the abrasive with the attached diamond particles. Secondly, the injection angle will determine the pressure of the abrasive grains when it hit the workpiece. Thirdly, the sandblasting time will directly affect amount of cutting on the workpiece surface. Finally, the workpiece surface roughness value will affect the sandblasting efficiency. Therefore, we choose four control factors and three level of Taguchi experimental method as shown in Table 1. From the $L^9$ (3^4) orthogonal table of Taguchi experiment can then be known the values of the displacement y and the η value [η = log (y)] for optimum polishing can be determined. whereas the redistribution factor for optimum polishing is shown in Figure 3.

Table 1 Sandblasting polishing control factors and levels of Taguchi method experiment

| Factors | Description | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|
| M | Water Content | 15% | 20% | 25% |
| A | Polish Angle | 25° | 45° | 65° |
| T | Polish Time | 1.5min. | 3min. | 4.5min.. |
| W | Workpiece | Ra=2 μm | Ra=1.75 μ | Ra=1.47 μ |

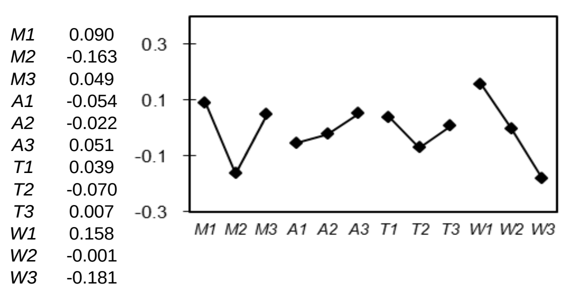



**FIGURE 3.** Factor reaction graph

## RESULTS AND DISCUSSION

From the experimental results, the robust parameters were identified which are as follows: water-based antirust solution content of 20%, spray angle of 25°, processing time of 3 minutes, and the workpiece surface roughness of Ra = 1.47μm. The best polishing efficiency parameter combination is M2A1T2W3. Figure 4 shows the workpiece surface photographs taken by the KEYENCE VHX-500 3D optical microscope before and after polishing for 3 minutes respectively at working condition of M2A1W3.

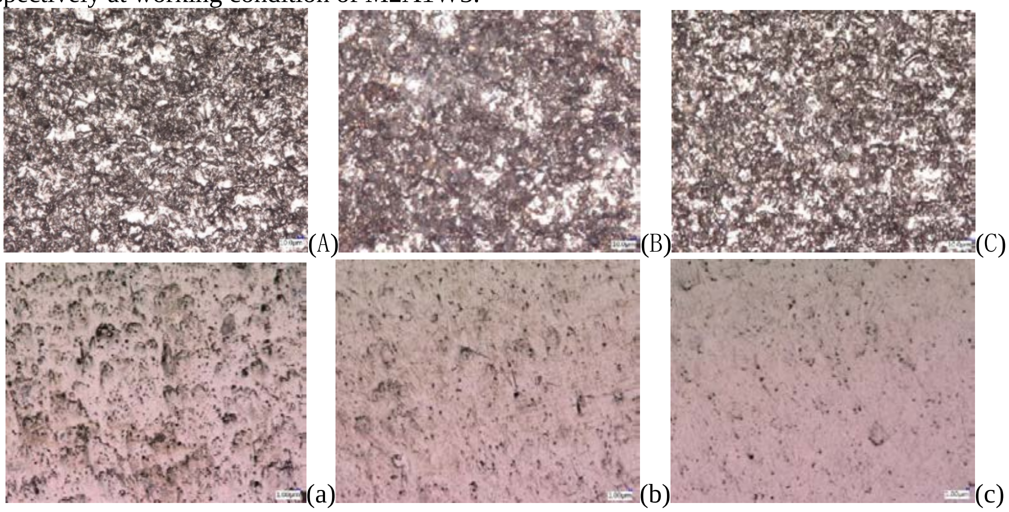



**FIGURE 4.** (A) Before processing Ra = 2.00 μm (up left), (a) After processing Ra = 1.42 μm (down left)(B) Before processing Ra = 1.75 μm (up middle),(b) After processing Ra = 0.36 μm (down middle)(C) Before processing Ra = 1.47 μm (up right),(c) After processing Ra = 0.23 μm (down right)Before processing Ra = 1.75 μm (up middle),(b) After processing Ra = 0.36 μm (down middle) (C) Before processing Ra = 1.47 μm (up right),(c) After processing Ra = 0.23 μm (down right)

Applying the robust parameters identified in Taguchi method on the abrasive, the results on the two different lamp shade molds are as follows shown in Figure 5. Initially, the roughness of both SKD61 and aluminum lamp mold are of the value of Ra=0.4 μm. When #3000 diamond particle is adhered to abrasive particles and used to polish the SKD61 mold for 5 minutes, the roughness decreases to Ra=0.12 μm, The roughness decreases to Ra=0.06 μm when abrasive that is adhered with #20000 diamond particle size is used for 3 minutes. The same parameters are also applied on aluminum lamp mold. It was found that the roughness of lamp mold decreases to Ra=0.1 μm and Ra=0.047 μm respectively when #3000 diamond particle are used for 5 minutes and #20000 diamond particle are used for 3 minutes. According to the data provided by the mold factory (Cosmovac Industries, Ltd.), this advanced abrasive polishing is 65 times and 40 times the efficiency of conventional artificial polishing for the cooperative diamond particle size. According to the results of the factor diagram in Figure 3, if the content of water-based anti-rust solution in the adjustable viscoelastic polishing abrasive is too high, the Tanδ value will be low, implying that the elasticity is poor and the viscosity is high. Therefore, the abrasive will slide on the workpiece for a long time and adhere to its surface. On the contrary, if the abrasive has a low water-based anti-rust solution content, its δ will become high and the elasticity will increase, thus will causing the abrasive particles to rebound from workpiece surface, which causes the abrasive to lose its polishing function. This shows that the adjustable viscoelastic polishing abrasive can be both viscous and elastic at the same time. As such, it is appropriate to 20% choose the Water-based anti-rust solution content (M2).When the particle size and hardness of the workpiece are fixed, the removal volume increases, in a directly proportional manner with the angle. However, due to the limitation of polishing, the particles must be sliding on the workpiece surface, so a smaller spray angle of 25 ° (A1) is used. When pressure and injection speed are fixed, the removal volume increases directly proportional to the polishing time. It is known from Figure 3 that 3 minute (T2) has a higher processing efficiency which is also consistent with the formula $\Delta z=\int_0^t k_p\, vp\,dt$. Finally, the smaller the workpiece thickness, the more likely it is to achieve polishing goals. As shown in Figure 5, when the polishing time is long small workpiece surface roughness tend to get high efficiency and high polishing accuracy. Finally, the best method of sandblasting and polishing is used to process the two different materials, and the roughness value and processing time are obtained. Experiments showed that its efficiency increased more than 40 times as compared its traditional method recommended by die manufacture.

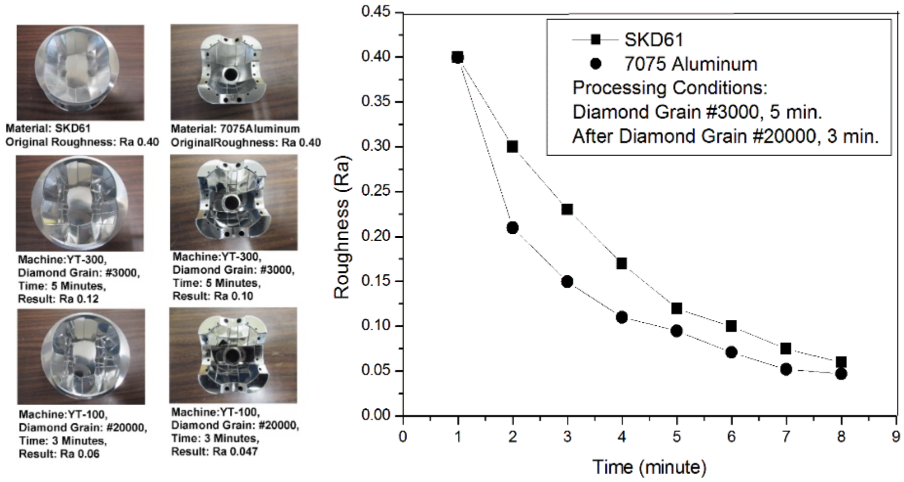



**FIGURE 5.** SKD61 and 7075 aluminum tool after using composite diamond abrasive sandblasting

## CONCLUSION

This novel adjustable-viscoelasticity abrasive infiltrated using by diamond particles is suitable for 3D surface sandblasting polishing. The Taguchi experiments result shows that it has very high polishing efficiency for the complex surface and it can even polish narrow inner angles to mirror surface roughness quickly. The polishing abrasives are adhered with diamond particles by physical interaction of collision and then gradually falling on the workpiece. The abrasive is finally recovered into the collector and its viscoelasticity will be readjusted again for circulation polishing. Through this recovery processing, it can achieve maximum economic benefits. It was found that for superabsorbent and polymer materials with low density, high viscosity and adjustable elasticity, when different concentration of water-based anti-rust solution is added to the abrasive, the optimal sandblasting polishing parameters can be determined using the Taguchi experiment method and performed on two different set of materials of car lampshade reflection plates. The obtained results are further compared with manual polishing and it was justified and concluded that this novel sandblasting give higher efficiency. Therefore, this innovative adjustable viscoelastic PA can be infiltrated with fine diamond particles. By using the optimized processing parameters, this abrasive will contribute significantly to three-dimensional precise polishing processing to achieve high efficiency and accuracy.

## ACKNOWLEDGMENTS

Thanks to Kun-yu Pan’s general manager of Cosmovac Industrial Co., Ltd. for providing the equipment and Chang Gung University Center for Reliability Science and Technologies (CReST) for providing the facilities for the test.

## REFERENCES

1. Jae-Hyun Jung, Hyung-Ki Park, Byoung Soo Lee, Jaeho Choi, Bosung Seo, Hyo Kyu Kim, Gun Hee Kim, Hyung Giun Kim, Study on surface shape control of pure Ti fabricated by electron beam melting using electrolytic polishing, Surface & Coatings Technology, 324 (2017) 106–110
2. Fengjun Chen, Hui Wang, Yu Tang, Shaohui Yin, Shuai Huang, Guanghua Zhang, Novel cavitation fluid jet polishing process based on negative pressure effects, Ultrasonics Sonochemistry, 42( 2018) 339-346
3. Soumen Mandal, Evan L.H. Thomas, Laia Gines, David Morgan, Joshua Green , Emmanuel B. Brousseau, Oliver A. Williams, Redox agent enhanced chemical mechanical polishing of thin film diamond ,Carbon 130 (2018) 25-30

4. John D. Ferry, JOHN WILEY & SONS. Viscoelastic properties of polymers, (1980) 12-14
5. Loan D. Marinescu. Handbook of Ceramics Grinding and Polishing, Elsevier Inc., Chapter 6, (2015)270-273