Optimization of the parameters for the rotary diamond dressing of grinding wheels

Chin-Chia Liu, Dyi-Cheng Chen and Tsung-Ying Kuo

Department of Industrial Education and Technology, National Changhua University of Education, Changhua, Taiwan

ABSTRACT

The object of this study was the optimization of dressing parameters used with rotary diamond dressers. A grinding wheel was dressed using different dressing factors and levels and the results were evaluated by the examination of test pieces ground using the dressed wheel. The surface roughness value of the test pieces was measured to determine the optimal dressing parameters. The effect of five dressing factors on surface roughness and work efficiency was investigated – dressing speed ratio, cross feed rate, dressing depth, dressing count, and smoothing count. The ranking of the dressing tests was determined using an $L_{16} (4^5)$ Taguchi orthogonal array to evaluate the ground surface of the test pieces. The experimental data was analyzed and the signal/noise ratio was calculated. The quality characteristics were used to determine the optimal dressing parameters using principal component and Grey relational analyses. This approach allowed the optimal combination of factors and levels that would achieve a targeted grinding quality with favorable processing efficiency to be found.

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1. Introduction

The parameters used to dress a grinding wheel have a critical and direct influence on grinding quality. With use, a grinding wheel becomes dull due to wear. The surface porosity is also reduced by an accumulation of metal particles and other material. This greatly hinders grinding efficiency and may even cause burn or chatter on the ground surface of
a workpiece [1]. These wear-induced changes do not appear in a surface roughness measurement, but cause poor grinding quality and may even damage the surface of a workpiece and reduce its surface strength.

Advances in technology have resulted in better methods for the dressing of grinding wheels. One method uses a rotary diamond coated disc dresser. This causes little abrasion to the surface of the diamond disk and results in fast and effective dressing [2]. Dinesh et al [3] proposed a method for the prediction of the number of effective abrasive grains on the surface of a grinding wheel. This provided a theoretical basis for modeling the related grinding force, surface roughness and processing temperature. Jiang et al [4] established 2D and 3D predictive models, and the results indicated that the amount of feed per revolution is the most important factor affecting the surface topography of the grinding wheel. However, this equipment is considerably more expensive than traditional methods and not in general use. Few investigations have been made into the optimization of the dressing parameters of rotary diamond discs and further study was clearly warranted.

2. Dresser and Parameters [5, 6, 7, and 8]

The surface topography of a grinding wheel is mainly influenced by the dressing parameters. Topography has a profound influence on grinding ability. The use of a diamond dressing wheel is illustrated in Figure 1.

The relationship between a grinding wheel and dressing wheel is referred to as the dressing speed ratio; the

\[ q = \frac{V_d}{V_s} \]  

In Figure 1, \( V_d \) is the dressing speed ratio of the dressing wheel, \( V_s \) is the dressing speed ratio of the grinding wheel, \( a_d \) is the grinding wheel dressing depth, and \( A \) is the contact point between the grinding and dressing wheels. When the grinding wheel and dressing wheel are moving in the same direction, the dressing speed ratio is positive, when movement is in the opposite direction it is negative. This principle is illustrated in Figure 2.

The cross-feed rate refers to the feed distance, that is, the distance that the dressing wheel moves toward the grinding wheel per one revolution of the grinding wheel. Feed rate is measured in millimeters per revolution, and a slower feed rate indicates a higher dressing quality. However, a slower feed rate also means that dressing takes longer.

Smoothing refers to the use of a non-radial feed when dressing, and a higher dressing count results in a smoother grinding wheel. However, excessive smoothing can reduce the cutting ability of a grinding wheel and should be done sparingly.

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Figure 1. Diagram of dressing a grinding wheel.
3. Construction of the Taguchi Orthogonal Arrays \([9,10]\)

Five factors were selected in this study, and each factor had five levels. The factors were dressing speed ratio, cross-feed rate, dressing depth, dressing count, and smoothing count; the five factors and their four levels are listed in Table 1.

\(L_{16}(4^5)\) orthogonal arrays were selected, as presented in Table 2.

The goal of this study was a determination of surface roughness (Ra) and operating time. A shorter operating time was more desirable, and therefore the smaller-the-better characteristic was selected for operating time. A closer Ra to the target value was also more desirable, and therefore the nominal-the-best characteristic was selected for the Ra.

4. Experimental and Analysis

After each dressing the grinding wheel was used to grind a test piece (see Figure 3) and the Ra of the ground test piece was measured as shown in Figure 4.

The target value of Ra was 0.32\(\mu\)m. The signal–noise (S/N) ratio of the nominal-the-best characteristic was also measured and the results of the calculation are set out in Table 3.

After the grinding wheel was dressed, a test piece was ground. The operating time and S/N ratio of the smaller-the-better characteristic was calculated and the results are shown in Table 4.

The S/N ratio was normalized before principal component analysis, and the results are presented in Table 5.

Principal component analysis was conducted by calculating the eigenvectors of the normalized values. The eigenvectors were converted to independent linear
combinations. Normalized values were then substituted into the independent linear combinations to obtain the principal component points [11] as shown in Table 6.

The Grey correlation coefficient was calculated using the principal component points which were then converted to Grey relational grade. The rank of each group was then obtained after rearrangement according to grade [12] as shown in Table 7.

The seventh group in Table 7 had the optimal combination of factors and levels. To obtain this optimum the average coefficients of the correlation between each factor and level was calculated. The average correlation coefficients are shown in Table 8.

In Table 8, a higher coefficient indicates a better factor level. The optimal dressing parameter combination was A2, B3, C4, D1, and E2. This combination was similar to the seventh group in Table 4, having a dressing speed ratio of -0.12, cross feed rate of 0.06 mm/r, dressing depth of 0.2 mm, dressing count of 1, and a smoothing count of 1; the smoothing count being the most important factor.

The three optimal combinations with the highest S/N ratios were the thirteenth, seventh, and fifth groups. The thirteenth group had the highest S/N ratio; the Ra was 0.331μm and the operating time was 212 seconds. The
seventh group had the second highest S/N ratio; an Ra of 0.321 μm and an operating time of 106 seconds. The fifth group had the third highest S/N ratio; the Ra was 0.309 μm and the operating time was 276 seconds. The Ra of the seventh group was close to the target value of 0.32 μm, but the operating time of the group was shorter than that of the other groups. This indicated that the results of the analysis were valid.

5. Conclusion

The dressing parameters of grinding wheels have a critical direct influence on grinding quality. In this study, five dressing parameters were examined – dressing speed ratio, cross feed rate, dressing depth, dressing count, and smoothing count – and each factor had four levels. By integrating the Taguchi method, with principal component and Grey correlation coefficient analyses, the optimal parameter combination with multiple quality characteristics were identified. After experimental values were obtained through a grinding and dressing process, the values were analyzed to determine the optimal dressing parameters. The experimental values showed the identified optimal parameters to be valid.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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