An Analytical Model of Rotary Diamond Dressing

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Abstract

Rotary dressing exhibits complex phenomena. An analytical model of rotary diamond dressing is developed to see the effect of a dressing-grit on the grinding wheel. Using this model, systems can be developed to know before-hand the effect of various dressing conditions and grit geometry/orientations on grinding wheel topography.

Nomenclatures

r_d	Radius of curvature of grit envelop of dresser (mm)
r_g	Radius of grinding wheel (mm)
w_d	Rotational speed of dresser (rad/s)
w_g	Rotational speed of grinding wheel (rad/s)
VR	Velocity ratio
v_d	Velocity of dresser (m/min)
v_g	Velocity of grinding wheel (m/min)
d	Depth of cut (mm)
β	Grit envelop angle (rad)
α	Angle of attack for dresser (rad)
γ	Angle of attack for grinding wheel (rad)
T	Engagement time (s)
x_d	*x*-coordinate of center of dresser (mm)
z_d	*z*-coordinate of center of dresser (mm)
x_g	*x*-coordinate of center of grinding wheel (mm)
z_g	*z*-coordinate of center of grinding wheel (mm)
$l_{(.)}$	dressing length of (.) (mm)

1. Introduction

To keep the material removal ability of a grinding wheel (GW), it is important to perform dressing [1-3]. Diamond grits are often embedded on the circumferential surface of a rotary dresser (RD) [2]. Both RD and GW rotate and an overlap (depth of cut) is maintained while dressing. This motion creates a specific topography. Many authors have studied the topography of grinding wheel after dressing and developing systems for dressing analysis [4-6]. However, to design a dresser for a particular dressing operation, it is important to set the pitch and orientations of dresser-grits and the underlying dressing conditions. The objective is to minimize the dressing time without hitting the same location of grinding wheel again and again.

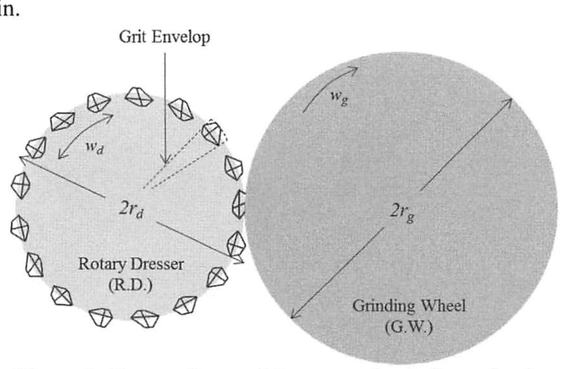


Figure 1. Rotary diamond dresser and grinding wheel.

Therefore, an analytical model is needed that provides the effect of dresser-grit on wheel topography for various dressing conditions and grit geometry and orientations. This study develops an analytical model for the above mentioned purpose. The remainder of this section is organized as follows. Section 2 describes dressing scenarios and provides analytical relationships among angles of attack and contact period. Section 3 describes trajectory of RD and GW. Section 4 shows results and discusses the findings. Section 5 concludes the study.

2. Dressing Scenarios, Angles of Attack, Contact Period

There are two scenarios of dressing called *down-cut* and *up-cut*. In down-cut, the velocities of RD and GW at points of contacts are in the same direction, whereas it is the opposite in case of up-cut (see Fig. 2). Figure 2 shows the relative positions of a grit of RD and GW for down-cut and up-cut, respectively. When a dressing-grit first attacks GW, it creates two angles of attack, α (on the RD), γ (on the GW). The relationships between these two angles are given below:

$$r_d \cos\alpha + r_g \cos\gamma = r_g + r_d - d \quad (1)$$
$$r_d \sin\alpha = r_g \sin\gamma$$

When the angles are very small, the following approximation can be applied:

$$\sin\alpha = \alpha \quad \sin\gamma = \gamma$$
$$\cos\alpha = 1 - \frac{\alpha^2}{2} \quad \cos\gamma = 1 - \frac{\gamma^2}{2} \quad (1.1)$$

As such, the following relationships hold:

$$\gamma = \frac{1}{r_g}\sqrt{\frac{2d}{\left[\frac{1}{r_d}+\frac{1}{r_g}\right]}} \quad (1.2)$$

$$\alpha = \frac{1}{r_d}\sqrt{\frac{2d}{\left[\frac{1}{r_d}+\frac{1}{r_g}\right]}} \quad (1.3)$$

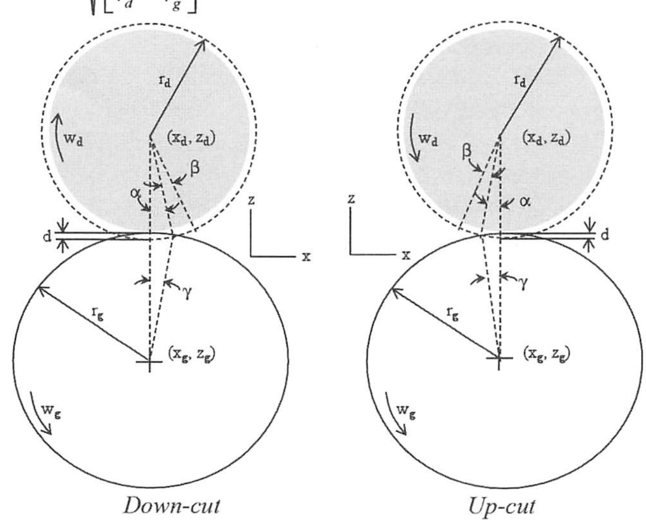


Figure 2. Angles of attack.

A grit of RD rotates an angle $2\alpha+\beta$ during the contact period. Therefore, the period of contact (T) is as follows:

$$T = \frac{2\alpha + \beta}{w_d} \quad (2)$$

3. Trajectory of RD and GW during Contact Period

The trajectory of RD and GW during the contact period is an important issue. It is different for up-cut and down-cut scenarios. However, the relationship between the center of RD and GW are the same for both cases, as follows:

$$\begin{aligned} x_g &= x_d \\ z_d &= z_g + r_g + r_d - d \end{aligned} \quad (3)$$

3.1. Down-cut

For down-cut, a point $(x_g(t),z_g(t))$ on the GW during T is given by:

$$\begin{aligned} x_g(t) &= x_g + r_g \sin(\gamma - w_g t) \\ z_g(t) &= z_g + r_g \cos(\gamma - w_g t) \\ t &= [0,T] \end{aligned} \quad (4)$$

Similarly, a point $(x_d(t),z_d(t))$ on the RD during T is given by:

$$\begin{aligned} x_d(t) &= x_d + r_d \sin(\alpha - w_d t) \\ z_d(t) &= z_d - r_d \cos(\alpha - w_d t) \\ t &= [0,T] \end{aligned} \quad (5)$$

Since the directions of motions of RD and GW are the same, the dressing length can be determined as follows:

$$l_{down} = r_g w_g T \quad (6)$$

If the relationship in (2) and the relationships among VR, angular and linear velocities are used, then the expression of dressing length can be rewritten as follows:

$$l_{down} = \frac{2\alpha + \beta}{VR} r_d \quad (7)$$

3.2. Up-cut

For up-cut, a point $(x_g(t),z_g(t))$ on the GW during T is given by:

$$\begin{aligned} x_g(t) &= x_g - r_g \sin(\gamma + w_g t) \\ z_g(t) &= z_g + r_g \cos(\gamma + w_g t) \\ t &= [0,T] \end{aligned} \quad (8)$$

Similarly, a point $(x_d(t),z_d(t))$ on the RD during T is given by:

$$\begin{aligned} x_d(t) &= x_d - r_d \sin(\alpha - w_d t) \\ z_d(t) &= z_d - r_d \cos(\alpha - w_d t) \\ t &= [0,T] \end{aligned} \quad (9)$$

Since the directions of motions of RD and GW are not the same, the dressing length can be determined as follows:

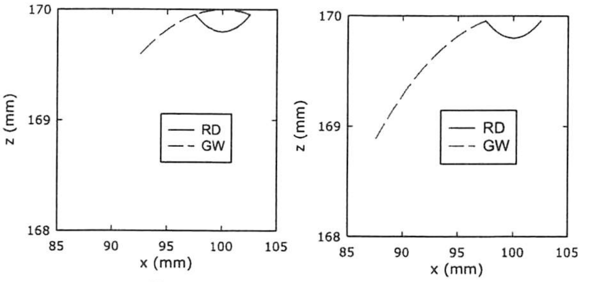
$$l_{up} = r_g w_g T + 2\gamma r_g \quad (10)$$

If the relationship in (2) and the relationships among VR, angular and linear velocities are used, then the expression of dressing length can be rewritten as follows:

$$l_{up} = \frac{2\alpha + \beta}{VR} r_d + 2\gamma r_g \quad (11)$$

4. Results and Discussions

Typical trajectories of RD and GW are shown in Fig. 3 wherein VR = 0.5, r_g=70mm, r_d=20mm, v_g=20m/min (v_g=$w_g r_g$), v_d=$VR.v_g$=0.5*20 m/min, d=0.2mm. As seen from Fig. 3, the trajectory of RD is included in the trajectory of GW for down-cut. This is the opposite for the case of up-cut. This justifies the extra dressing length for up-cut compared to down-cut (compare equations (6) and (10)). The dressing length for VR = [0.05,0.1,...,1.2] and β=0 are also determined as shown in Fig. 4. As seen from Fig. 4, the dressing length remains almost constant after VR=0.7 and down-cut dressing length remains shorter than that of up-cut for all VR.



Down-cut　　　　Up-cut

Figure 3. Trajectories of RD and GW during contact period.

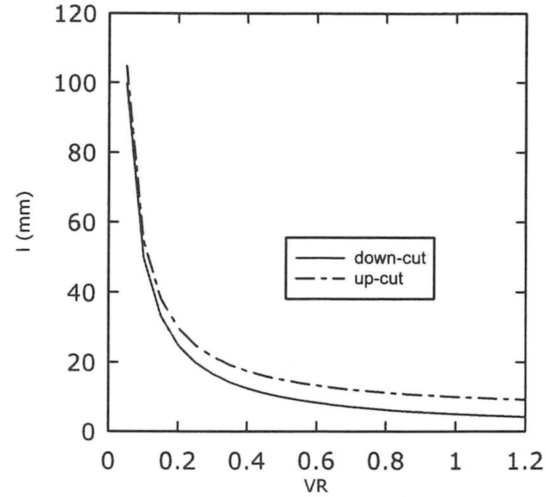


Figure 4. Dressing length for different VR.

5. Concluding Remarks

An analytical model is developed to know the effect of a dressing-grit (embedded on the circumferential surface of a rotary diamond dresser) on the grinding wheel. The analytical model is helpful in determining dressing length, engagement time, etc. for up-cut and down-cut for various dressing conditions. A computerized system will be developed for dressing performance analysis based on the presented analytical model.

References

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