Machining
Keep Calm and Continue Grinding

Brought To You By Norton Abrasives | Jul 10, 2019

In a production-grinding operation, waviness on the part surface is a potential clue that the machine or process has developed a vibration problem. The effect might be seen in inspection, or if there is a lapping or polishing step, the effect might be seen in the increased time spent removing the waves. According to Saint-Gobain Abrasives, manufacturer of Norton grinding wheels, this is the point at which shops almost always attempt to solve the vibration problem by making some simple change to the process. And that simple change might be a pretty good approach.

Indeed, those waves on the surface, often called chatter, could indicate the appropriate fix. On a part machined on a surface grinder, for example, vibration frequency (cycles per minute) is equal to the work speed (inches per minute) divided by the distance between two consecutive chatter marks (inch). Find the vibration frequency using this relationship, and if it matches the rotation speed of the grinding spindle, then this indicates that the grinding wheel, wheel flanges or the grinding spindle is a likely culprit. Change the wheel, tighten the flange bolts, or perhaps just change speed, and that much might be enough to cure or control the vibration problem.
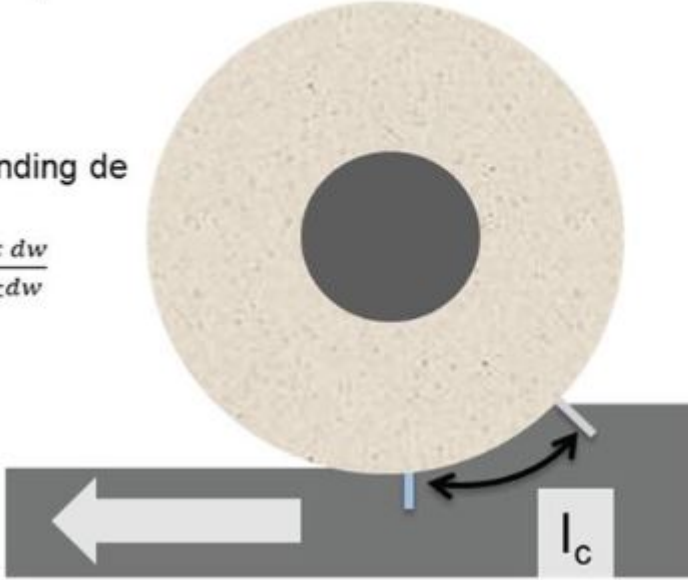

Contact Length $= l_c = \sqrt{a_e \cdot d_e}$

a_e = Depth of Cut
d_e = Equivalent Diameter

For Surface and Creepfeed Grinding de equals the wheel diameter

For cylindrical grinding $de = \dfrac{ds \times dw}{ds \pm dw}$

Outside Diameter (OD)+
Internal Diameter (ID) -

dw = workpiece diameter
ds = wheel diameter

l_c

How to calculate the contact length for contact-length filtering.

But in other cases—some involving other parts of the machine, some involving the natural frequency of the system—a simple fix is not enough to sufficiently address the problem. In these cases, the very best response is to have the machine serviced, repairing whatever failing machine element is allowing vibration to affect the workpiece. But service takes time and it means taking the machine out of production. For shops that need to keep going for the short term, researchers have proven out a process for overcoming vibration's effects without compromising productivity and without stopping the machine for the time being.

Contact-Length Filtering Case Study

This study was designed to show the effect contact-length filtering can have on reducing chatter due to vibration. The grinding test was performed at the Saint-Gobain Higgins Grinding Technology Center near Boston, Massachusetts. The test machine was an Elb creep-feed/surface grinder. The operation was slot grinding using an 8-inch-diameter, ½-inch-wide conventional abrasive wheel. The material ground was 4340 hardened steel. The wheel was intentionally thrown out of balance by adding weights to one side of the wheel hub. The vibration due to wheel unbalance was measured at 0.00019-inch displacement. The first test involved grinding three slots at "Condition 1". The feed rate was 120 inches per minute, and depth of cut was 0.001 inch. Six passes were made for each slot to achieve a total depth of 0.006 inch. The material removal rate was 0.12 cubic inch per minute per inch of wheel width. The chatter amplitude measured on the workpiece at these conditions was significant.

The second part of the test involved grinding three slots at "Condition 2". Here, the feed rate was reduced to 20 inches per minute, and the total depth was achieved in a single pass at a depth of cut of 0.006 inch. The wheel imbalance remained the same at 0.00019 inch. The material removal rate also remained the same. Yet the vibration amplitude observed on the workpiece at these conditions was greatly reduced, measured at 8 microinches versus 79 microinches when grinding at the first set of conditions.

Again, the imbalance remained the same. But grinding at conditions consistent with contact-length filtering produced a smooth surface despite the imbalance, without any reduction in productivity.

The technique has its limitations, the researchers stress. The case study represents an ideal scenario. It won't be possible in every process to achieve the condition of twice the contact length being larger than the vibration wavelength, let alone without any loss to material removal rate. But in the right applications, this technique is potentially a powerful option. It is a way to keep going, and to continue realizing an acceptable surface through production grinding, until the right moment comes when the valuable machine can be taken offline for repair.

What follows is derived from a paper about a technique called "contact-length filtering" written by Saint-Gobain corporate applications engineers John Hagan and Mark Martin. By reducing the work feed rate while increasing the depth of cut, the effects of severe vibration can be eliminated without any net effect on overall productivity.

Large Wheel-to-Work Ratio

The aim of contact-length filtering is to get the wheel-to-work contact length very large relative to the wavelength of the surface affected by vibration. When the former is high enough relative to the latter, the wheel effectively removes vibration-related peaks from the workpiece, smoothing out the surface even though vibration is still occurring. When the depth of cut is increased by the same multiple that feed rate is decreased, material removal rate (and therefore productivity) can remain the same.

The depth of cut controls contact length. Obviously, the contact length's increase needs to avoid unfavorable effects such as material burn, workpiece deflection and so on. The wheel's depth of cut is increased to a level that is heavy compared to standard cutting conditions but still avoids these ill effects.

Meanwhile, the feed rate (or work speed) controls the wavelength of the vibration marks in the part. A slower work speed shortens the wavelength.

Contact-length filtering begins to achieve a smooth surface when double the wheel-to-work contact length surpasses the wavelength of the chatter, or surface waviness. In other words, the condition required for chatter amplitude reduction is...

2 x Contact Length (*lc*) ≥ Chatter Wavelength (ξ*chatter*)

...where the two figures above define Contact Length (*lc*) and Chatter Wavelength (ξ*chatter*).

The technique won't always work, the researchers say. It won't be possible in every process to get the vibration wavelength low enough or the contact length high enough. In these cases, the only remaining solution is the one that needs to be performed anyway, namely, take the time to identify and correct the vibration's underlying cause. See the sidebar for a case in which contact-length filtering was effective for machining a smooth surface in spite of extreme vibration.

*This article was written by Peter Zelinski, Editor-in-Chief of **Modern Machine Shop** and originally appeared in the December 2018 **edition**. It was reproduced with permission.*