CYCLE TIME REDUCTION IN CRANKSHAFT PIN GRINDING

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ABSTRACT

Crankshaft pin grinding was a bottleneck operation at an Australian automotive manufacturing company. A novel technique to reduce the cycle time and optimize the process was developed at the plant. A GCM (Grinding cycle Monitor) was used to optimize each crankshaft pin, and then the full cycle on each of the crankshaft pin grinding machines was optimized. The technique developed is suited for an Industrial environment and removes the expert skill usually required for optimizing the crankshaft pin grinding process. The optimized process resulted in a reduction in cycle time and grinding wheel consumption without any deterioration in the surface finish.

Keywords: Crankshaft, Grinding, Cycle times, Optimizing

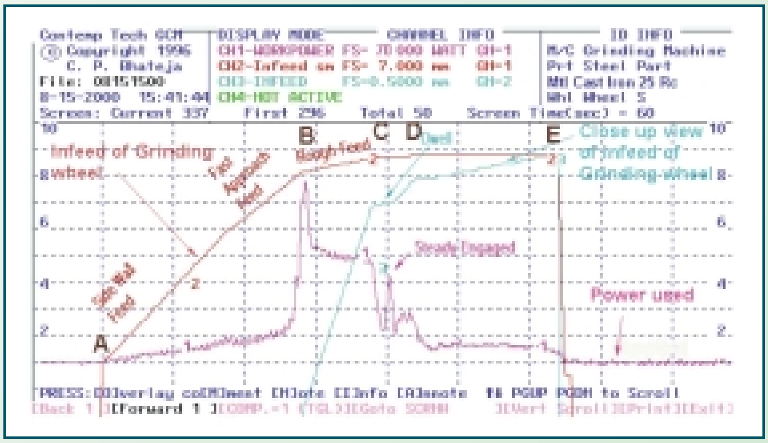

Figure 1 GCM output of a full crankshaft pin grinding cycle

INTRODUCTION

Grinding is a very important finishing process in the automotive industry and often requires close tolerances and high surface finish. Material removal rates in grinding are limited because of chatter [1-5] and other problems such as thermal damage [6-16]. Cycle time reduction then often depends on the skill of the operator running the grinding machine. In order to understand the process it is necessary to measure the grinding forces. The literature [17, 18] reveals that grinding forces have been measured for surface and cylindrical grinding. In the latter case, the studies have been limited to grinding of round components where contact takes place on a plane lying in the plane containing a line joining the headstock and tailstock centers. A recent study of forces on off-round components, such as in a square cross-sectioned punch (contact not taking place as above), reported the difficulty of using direct measurements of grinding forces [19]. Crankshaft pin grinding is a cylindrical grinding operation, but the throw of the pin causes the axis of the crankshaft pin to be offset from the axis joining the headstock and tailstock centers. This makes it difficult to measure the grinding forces using commonly used devices such as a strain gauge or a dynamometer. Consequently it was decided to measure the grinding power. A Grinding Cycle Monitor was used to understand the grinding process and optimize the crankshaft pin grinding process. Using a GCM did not require any elaborate setup that is required when connecting dynamometers in an Industrial environment.

GCM EXPERIMENTAL SETUP

A grinding cycle monitor (GCM), as the name denotes is a device that can be used to monitor a grinding cycle. [20-23] This device is capable of measuring the grinding wheel power consumption, the infeed of the grinding wheel and then displaying it graphically. Figure 1 shows a typical output of a GCM cycle while data logging a full crankshaft pin grinding

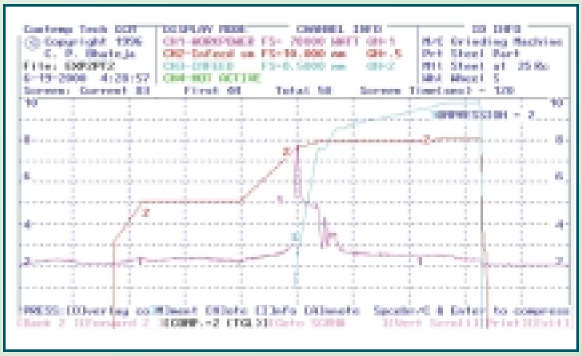

Figure 2 GCM output of crankshaft pin 1

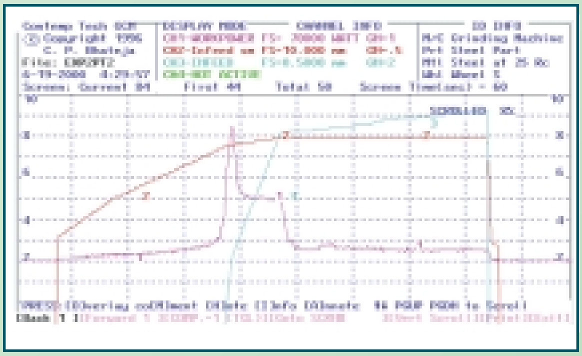

Figure 3 GCM output of crankshaft pin 6

Figure 4 GCM output of crankshaft pin 5

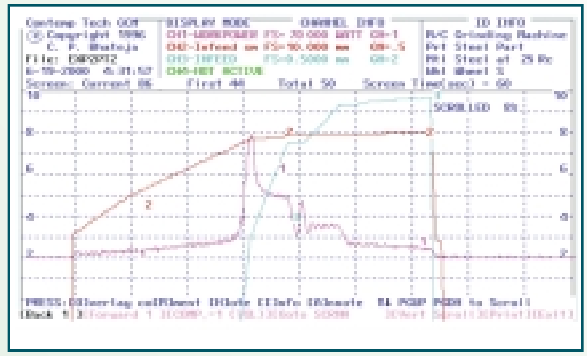

Figure 5 GCM output of crankshaft pin 2

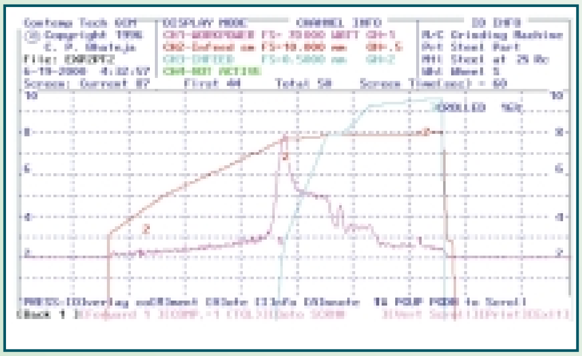

Figure 6 GCM output of crankshaft pin 3

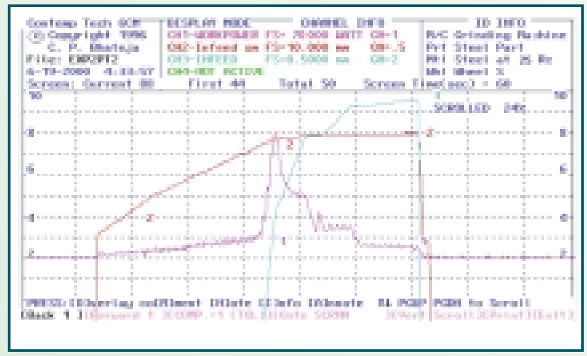

Figure 7 GCM output of crankshaft pin 4

cycle data. A Landis crankshaft pin (cylindrical) grinding machine was used for the experiments.

The grinding wheel power consumption data was logged on channel 1 of the GCM. This is represented by the numeral "1" in Figure 1. The units used to record data are Watts. Channel 2 of the GCM was used to record the linear displacement of the grinding wheel. The line marked with "2′ in Figure 1 represents this. Channel 3 was used to record the final 1 mm travel of the grinding wheel head. This is represented by the "3" in Figure 1.

In Figure 1, point A represents the beginning of the infeed of the grinding wheel head as it grinds the crank pin shoulder wall. Point B represents the end of the shoulder grinding and beginning of the rough grinding of the crankshaft pin diameter. The slope of the infeed (0.5 mm range) shows that the infeed rate is still high. At Point C the rough feed has finished and Point D represents the engagement of the steady [24], microfeed starts followed by a "spark out" stage [25]. In the next section the results of the experiments are presented for a full set of 6 crankshaft pins using the same representations as in Figure 1.

EXPERIMENTAL RESULTS AND ANALYSIS

SIGNATURE COMPARISON OF SINGLE GRIND CYCLES

Figures 2 to 7 show the GCM output for a full set of 6 crankshaft pins ground on a six-cylinder crankshaft Landis Crankshaft pin grinding machine in order of grind sequence.

Examination of the sparkout stage in Figures 2 and 3 indicates that the time taken for this stage for crankshaft pins 1 and 6 is appreciably more than for the crankshaft pins 2 to 5. The higher stiffness near the clamping supports would suggest that the flexing of the component would be the least at these sections. Thus the spark out stage should be shorter rather than longer. Consequently the spark out stage time was reduced for crankshaft pins 1 and 6 and brought in line with the other center pins. This resulted in a uniform cycle, and also a reduced cycle time. Examination of the quality of the crankshaft pins 1 and 6 ground with the reduced sparkout stages did not indicate any change in the surface finish quality.

An examination of the grinding power and the material removal rate

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during shoulder grinding indicated that there was scope for the grinding infeed to be increased. Almost 50% of the cycle time was being spent on grinding the shoulders, even though material removed in that stage is much lower than the diameter grinding. Accordingly this feedrate was increased, resulting in further reduction in cycle time without any deterioration in shoulder surface finish. Figure 8 shows the output of the GCM for the optimized crankshaft pin cycle. Using this technique all 3 crankshaft pin grinding machines were optimized for individual crankshaft pin grinding cycle times

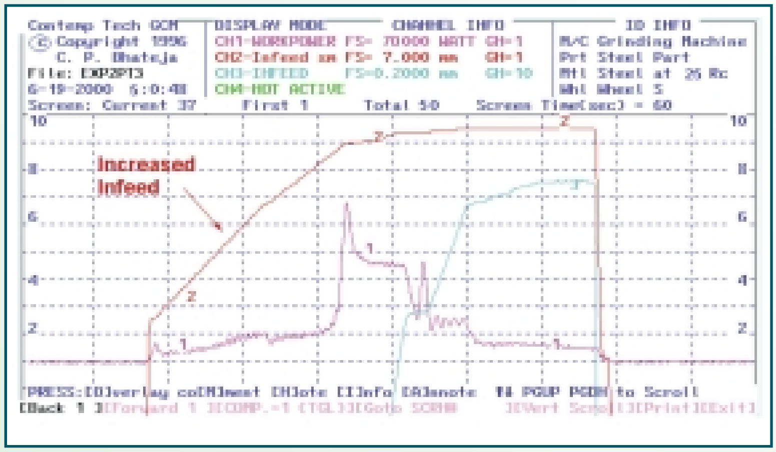

Figure 8 Pin 4 with increased infeed and shorter cycle times

SIGNATURE COMPARISON OF MULTIPLE GRIND CYCLES

After each of the individual crankshaft pin grinding cycles was optimized on each of the three machines, the "signature patterns" of each of the machines were compared. The signature pattern is a graphical output of a series of crankshaft pin grinding cycles captured on a single GCM frame. These are shown in Figures 9 to 12. Interestingly the signatures varied. Figure 9 shows that there is a delay of around 21 seconds due to an interruption in grinding on crankshaft pin grinding machine B. This is indicated by a horizontal line when the wheel infeed stops. A similar delay was found on crankshaft pin grinding machine C (Figure 10). Figure 11 shows that no such delay occurred in the case of crankshaft pin grinding machine A. In order to investigate this phenomenon, the GCM output of crankshaft pin grinding machine C was studied in more detail (Figure 12).

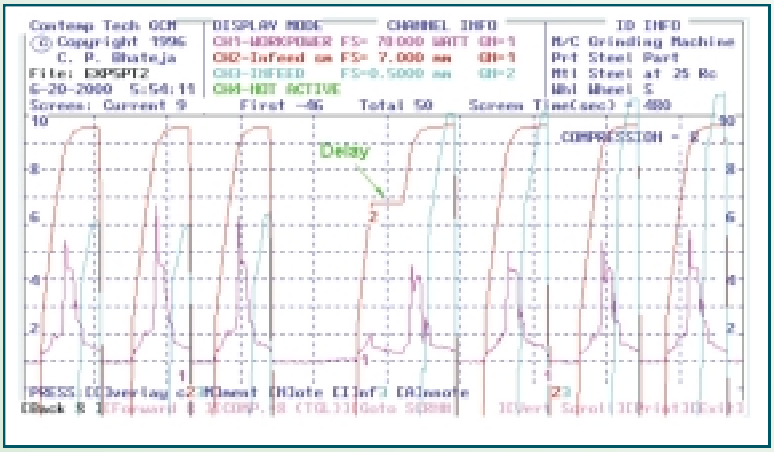

Figure 9 GCM signature output for crankshaft pin grinding machine B

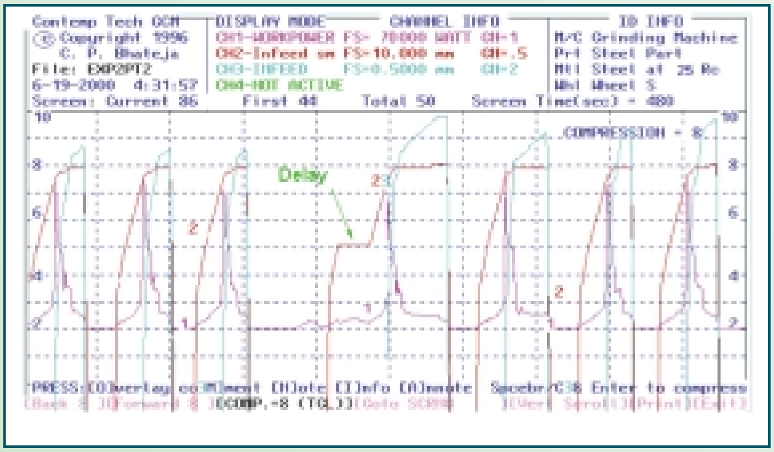

Figure 10 GCM signature output for crankshaft pin grinding machine C

Investigation of machine C indicated that the infeed of the grinding wheel head stopped because the finish dressing of the wheel had been completed. This was because the diameter grinding cannot be started till the grinding wheel dressing is complete. Further investigation revealed that this did not happen on machine A because a smaller grinding wheel at that point in time ran with a higher rotation speed (to maintain constant surface speed). This

	Pin Grinding machine A	Pin Grinding machine B	Pin Grinding machine C
Cycle times before improvements	6.7	7.0 – 7.1	6.9 – 7.0
Cycle times after improvements	6.2	6.2 – 6.3	6.0 – 6.2
Cycle time reduction(%)	8.2	12.8	13.9

Table 1. Crankshaft Grinding Cycle times

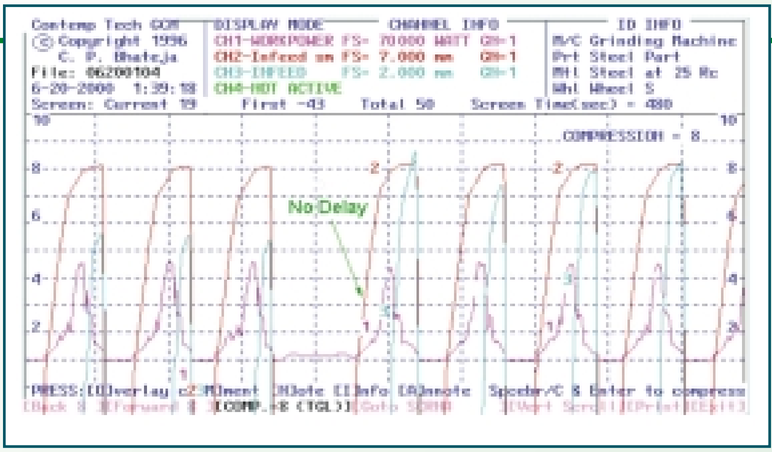

Figure 11 GCM signature output for crankshaft pin grinding machine A

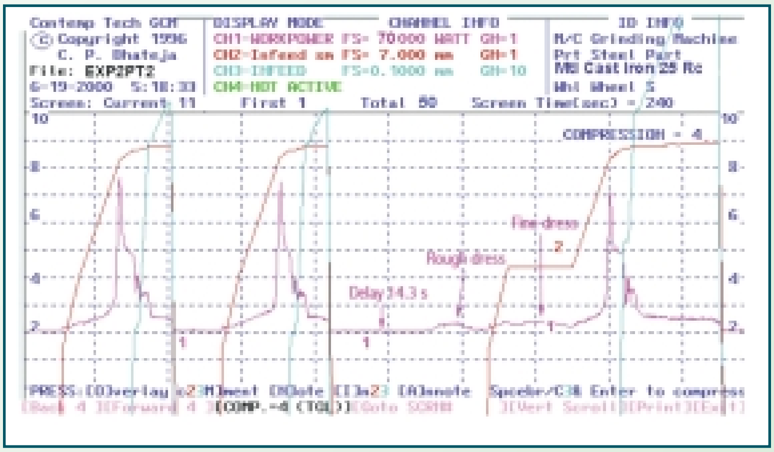

Figure 12 Magnified GCM output display for crankshaft pin grinding machine C.

caused the dressing cycle to complete on time. This investigation also led to questioning the current dressing feed rates. The dressing feed rate was subsequently increased, resulting in a better grit cutting action and more importantly it over came the problem of delays occurring when a new grinding wheel was mounted. The freer cutting wheel also reduced the time in the sparkout stage because of the ease of cut of the grinding wheel, which attributes to less deflection in the crankshaft and higher material removal rates using the same amount of power [26]. Table 1 below shows the overall improvement in cycle times using the combination of both the single and multiple grind analysis techniques.

CONCLUSION

A crankshaft pin grinding machine can be optimized using a GCM. A two-stage process is recommended. In the first stage each pin is optimized. This is followed by the optimization of the full crankshaft pin grinding cycle. The technique developed in this study is suited for an industrial situation and removes the expert skill requirement out of the optimization process. The study led to a reduced cycle time without any deterioration in the surface finish. This study also showed that a device such as a GCM can be rapidly connected to a grinding machine and the process understood without having to spend time in setting up a dynamometer, especially in an Industrial environment.

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