GPS CASE STUDY

To improve the productivity in Grinding Process

Introduction

Grinding is the common name for machining processes that utilize hard abrasive particles as the cutting medium. In brief the entire grinding process can be viewed as input-transformation-output system. The inputs to the grinding process include grinding machine, process parameters, work materials and tooling. On the other hand the output deals with technical and system outputs. Form, dimensions, finish and part integrity are technical outputs whereas productivity and cost are system outputs. To improve the technical and systems output to meet the growing requirement of the industry, it is essential to understand what is exactly happening in the process. In-process diagnostic tools are very effective in this process. Grind-Trak™ is one of the process monitoring tools that helps us to understand the grinding process. [1]

This work focuses on the achievement of the productivity improvement in grinding process by application of Systems Approach and in-process diagnostic Grind-Trak™. It is presented as a case study for Grinding Process Solutions (GPS) – a collaborative effort between MGT, STIMS Institute and the customer.

Project Background

Our Customer is one of the leading auto parts manufacturer in India. In one of their Production line, grinding operation was the bottleneck operation. Production department was facing difficulty to achieve the actual output due to part rejection, part rework, and frequent taper corrections.

In this production line there are two individual lines, each producing a complimentary set of parts. In each line the production requirement (parts per day) is being achieved on two grinding machines.

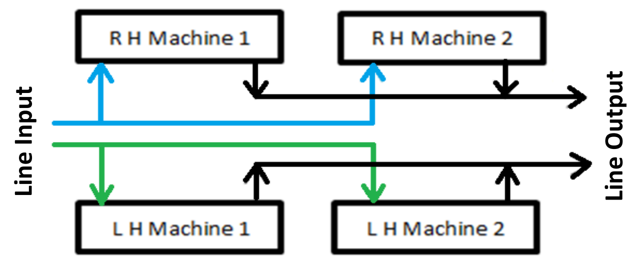

Figure 1 : Schematic Layout of Production line

Objective of the Project

Based upon the system inputs, the main objectives are

Technical Output:

i. Reduce part rework and rejection, taper correction
ii. Productivity improvement.

System Output:

i. Stabilize the Grinding Process with reduced rejections and re-work.
ii. To achieve the required production

Systems approach for Problem Solving

To achieve the required technical and system output, the study of actual grinding process is necessary. The study the grinding process was carried out by,

1. Aggregation of information received in a System Document
2. In-Process Monitoring [Capturing Power and displacement v/s time signal]
3. Measurement and Analysis of the In-process signals
4. Measurement of the quality of the actual parts produced from the grinding machines

Systematic Analysis of the problem

During the execution of the project the following activities were carried out.

1. Analyzing the Initial Cycle

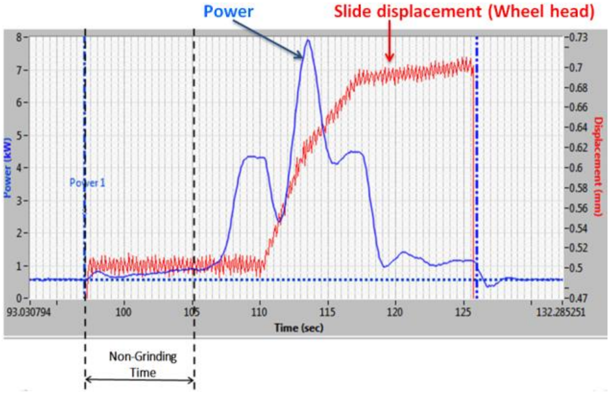

Figure 2: Initial Cycle

Following are the inferences to reduce cycle time by observing the In-process signal.

1. Non grinding time was more at the beginning of the cycle
2. Machine has capacity for high feed rates.
3. Finishing and spark out cycles are long.
4. The grinding power during the roughing cycle was exceeding the motor power limits.

Based upon the inferences, the grinding cycle was modified.

2. Reducing the Cycle Time:

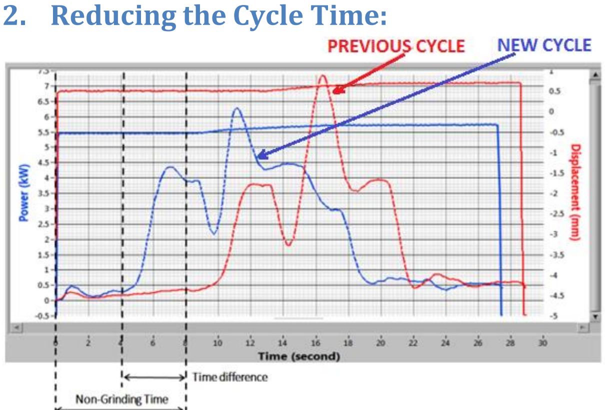

Figure 3: Initial and Modified cycles - Overlapped Signals

Figure 3 shows the overlapped process signals of the initial and the modified cycle. A cycle time reduction of almost 20% was achieved by making the following modifications:

1. Minimizing Non-Grinding time
2. Reducing the finishing cycle and spark-out time.

3. Part quality (Roundness)

Root cause for Roundness in the component can be any one of the reason indicated in Figure 4.

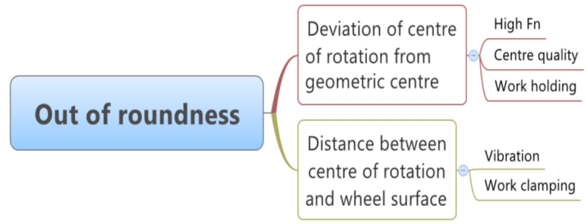

Figure 4 : Chart for the reason for Out of roundness

But Machine's Centre quality, Work holding and work clamping was in good condition. With reference to the above chart, either High normal forces (fn) or Vibration during grinding may be among the reasons for out of Roundness.

Generally high normal forces will be generated during grinding due to grain sliding or chip friction effects from the dressing process. Hence we decided to check the dressing process parameters.

	Day 1	
Dressing Parameters		After Modification
	Cycle 1.1	Cycle 1.2
Infeed (mm/min)	120	200
Lead (mm)	0.05	0.08
OLR	**18.4**	**11.1**

Table 1: Overlap ratio (OLR)

In dressing parameters, after calculating the Overlap ratio (OLR) as indicated in the above table, it was observed that the OLR of the initial cycle (Cycle 1.1) was very high. But for this kind of application the recommended OLR is 8 to 11. Hence, it was decide to reduce the overlap ratio by increasing dressing feed.

$$\text{Over lap Ratio (OLR)} = \frac{(Bc)\ X\ (Ns)}{(Df)}$$

Where, Bc = Diamond width,

Ns = Wheel rpm

Df = Dress Infeed (mm/min)

By increasing the dressing feed from 120 to 200min/min the OLR was reduced and as indicated in figure 3, the max. grinding power decreased by almost 1.0 kW confirming our hypothesis about the dressing being too fine. As a result, the part quality was achieved within the required limit and also it resulted in Size consistency and reduction in Part rejection and rework.

But when the new wheel was mounted, the size inconsistency, frequent taper correction re-appeared! Once again we decided to observe the process parameters. It was observed as indicated in table 2, with change in wheel diameter the wheel speed (Ns) has been decreased to maintain constant wheel velocity. Since OLR has relationship with wheel RPM, it was decided to recalculate the OLR.

	Wheel Dia (mm)	Wheel Speed	
		Vs (m/s)	Ns (rpm)
Day 1	350	45	**2455**
Day 2	550	45	**1465**

Table 2: Wheel Speed (Ns) calculation

	Day 1		Day 2	
Dressing Parameters		After Modification	New Wheel	After Modification
	Cycle 1.1	Cycle 1.2	Cycle 2.1	Cycle 2.2
Infeed (mm/min)	120	200	200	150
Lead (mm)	0.05	0.08	0.13	0.1
OLR	**18.4**	**11.1**	**7.0**	**9.4**

Table 3: Overlap ratio (OLR) Calculation

Table 3 indicates that, the OLR for the new wheel (i.e. Cycle 2.1) has been reduced, which implies that for the new (larger) wheel diameter the dressing is very coarse. Hence it was decided to increase the overlap ratio. By decreasing the dressing feed from 200 to 150 mm/min the OLR was increased and the part quality was achieved within the required limit. It also resulted in Size consistency, Part rejection and rework reduction.

Maintaining OLR in a controlled (small) range through suitable dressing parameters a stabilized grinding process can be achieved through the entire wheel life. He CNC controls in the machine were programmed to utilize the dressing feed Vs. wheel diameter to maintain the OLR between 9 and 11.

The grinding cycles in Figure 3 represent a set of Material Removal Rate (MRR) and the corresponding power consumed. This can be graphed as P Vs. MRR graph (Figure 5). The threshold power and the specific cutting energy (SCE) extracted from these graphs are noted in Table 4. The effect of OLR and its effect on part quality can be understood through these derived parameters and their interpretation using the microscopic interactions that occur during the grinding process (Figure 5). As indicated in table 4 the threshold power is high in the initial cycle compared to the modified Cycle. We can observe in figure 6, the higher threshold power implies glazing phenomenon i.e. 1.2, 1.3, 1.4 interactions. SCE has also been reduced in the modified cycle, i.e. interaction 2.3 has been reduced, which suggest that the cutting efficiency in the grinding process has been improved.

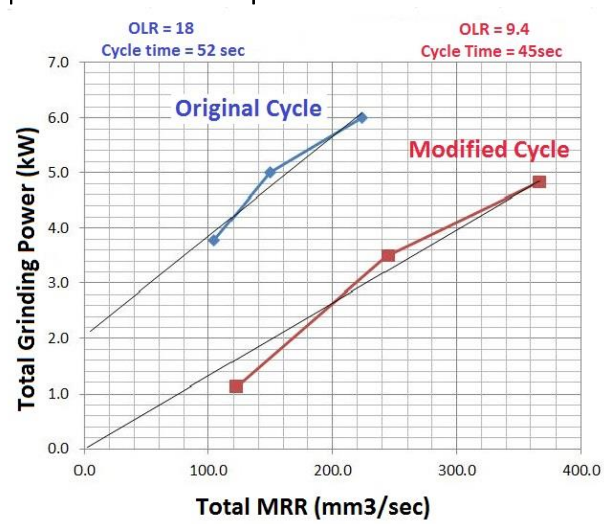

Figure 5: Grinding Power v/s MRR graph

	Original Cycle	Modified Cycle
Threshold Power (kW)	2.1	0.0
SCE (J/mm3)	18.1	15.2

Table 4: Threshold power & SCE values

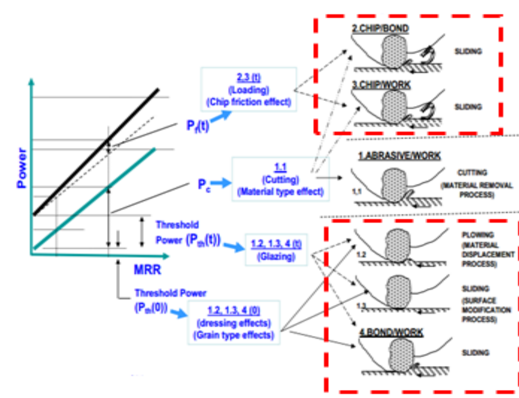

Figure 6: Microscopic interactions during grinding process

Size holding, taper, surface finish and their consistency are influenced by the threshold power and the SCE. Improvement in these parameters resulted in improved part quality and reduction in rejection and re-work.

4. Increasing Consumable life

To analyze the wheel behavior in the grinding process, the grinding power was observed for one dressing frequency (25 parts). As indicated in the graph (Figure 7), the grinding power was constant from 1st part to 25th part. This indicates that wheel behavior was consistent for the entire production process between the dressing operations. Later, dressing frequency was increased to 40 parts and all the part quality was within the specified limit. Hence, by increasing the dress skip, grinding wheel and dresser life was improved.

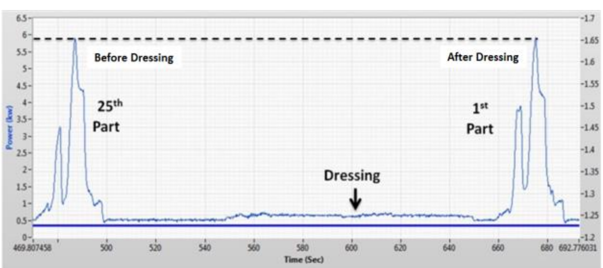

Figure 7: Grinding Power at the end of the dressing frequency and the power after dressing are nearly constant.

In order to achieve required production rate both the machines in the line cycle time and dressing frequency should be similar. To improve the production on RH machine 2, In-process signal was captured and Grinding Process and Dressing parameters were modified similar to LH machine. As a result cycle time was reduced by 10% and dressing interval improved by 33%. The process consistency was also improved to a Cpk of 1.67.

5. Measurement of actual parts produced

After the cycle time improvement production was monitored for an entire shift. But the number of units produced was lower than the expected number. It was hypothesized that this was due to improper machine utilization due to operator unavailability. To corroborate the hypothesis, the Machine utilization was measured:

1. Original Setup: (1 operator for 4 machines)
2. Modified Setup: (1 Operator for 2 machines

6.1 Actual machine utilization (4 machines)

In this test one operator was dedicated for operating 3 machines, since LH m/c 1 was switched off. Operator movement & actual machine utilization percentage is indicated in figure 8. Actual machine utilization was 45 % and 35 % on RH M/c 1 and 2, whereas 75 % on LH M/c 2. The results confirm our hypothesis that improper utilization of machines due to operator unavailability.

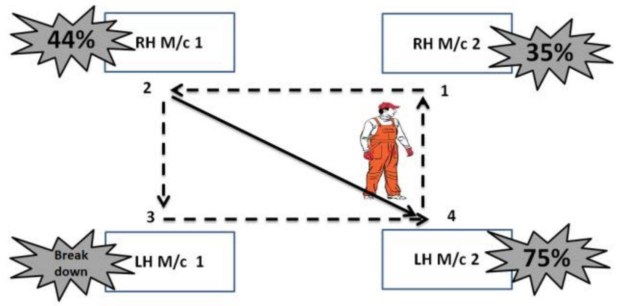

Figure 8: Operator line movement for 4 machines

6.2 Actual machine utilization (2 machines)

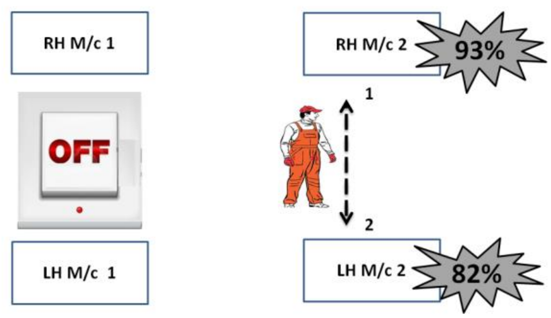

Figure 9: Operator dedicated for 2 machines only.

With one machine from each line switched off, the actual machine utilization increased to 82% & 93% in RH m/c LH m/c respectively (Figure 9).

The above results indicate that cycle time optimization also requires modifications in supply chain management to truly achieve an increase in productivity. Through this test it was also confirmed that with further optimization in cycle time the entire production can be achieved in only one grinding machine in each line.

7. Benefits from the Project

Through the grinding process optimization as detailed above benefits were achieved in terms of technical and economic outputs.

Technical Output:

	LH M/c	RH M/c
Cycle Time reduced	-18%	-10%
Skip dress increased	33%	33%
Dressing infeed reduced	-50%	---
Wheel life increased	14%	---
No. of Taper corrections reduced	-50%	---
Part Rejections reduced	-81%	---
Parts re-work reduced	-68%	---

Productivity Improvement

	LH M/c	RH M/c
Production (Parts/ Year)	+25%	+14%

Economic Output:

	LH M/c	RH M/c
Abrasive cost/Year reduced	-63%	-25%
Dresser cost /Year reduced	-25%	-25%
Rejection cost/Yr. reduced	-84%	---
Re-work cost /Yr. reduced	-77%	---
Total Cost saved / Yr.	**-58%**	**-15%**
Power and Machine cost saved	-89%	-86%

8. Conclusion

By viewing the entire grinding process as Input – Transformation – Output system, as illustrated in Figure 10, the production grinding process was

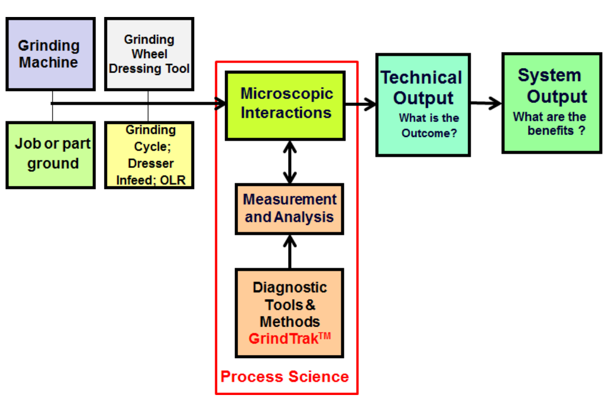

Figure 10: System approach employed in this study

improved significantly. By using the Diagnostic tool (GrindTrak™) original cycle was measured and analyzed leading to an understanding of the microscopic interactions. We call this as the manufacturing process science. Based upon the analysis the modification in process parameters was made leading to substantial improvements in the Technical as well as System Outputs. Sometimes they are called as the "Checking" and "managing" points respectively.

Through this case study, we have illustrated that to achieve the required output from the system a proper balancing of all the inputs is very important rather than focusing or modifying only one area in the input at a time. Also every solution requires understanding the process and its transformation (Science), using such process science effectively to achieve the desired results (Engineering) and also a constant focus not only on the technical outputs but also on the system outputs (net value / benefits).

Future Work

Further, study of machine behavior to be carried out to achieve actual requirement using only one grinding for each line.

References

[1] R. B. b. R. B. R.Vairamuthu, "Performance analysis of Cylindrical Grinding Process with a Portable Diagnostic tool," *All India Manufacturing Technology, Design and Research Conference (AIMTDR 2014),* 2014

Acknowledgement:

We would like to acknowledge the opportunity, collaboration and all the support from the customer engineers and their management. This opportunity demonstrates the possibilities for knowledge integration through system thinking and bringing science to shop floor manufacturing process improvement.