Data Driven Performance Metrics for Smart Manufacturing

### Introduction & Motivation

- Engineers play a vital role in sustainability. Incorporating correct performance metrics, big data, and smart manufacturing gives us the ability to improve the effectiveness and efficiency of manufacturing processes.
- Conservation efforts have been working, but improvements are still needed. Engineers have a responsibility to design, manufacture, and process materials and products in an ever more effective and efficient manner in order to better use our limited resources and reduce negative impacts.

### Objective

- Understand how effective current standard manufacturing performance metrics are in analyzing smart manufacturing processes.
- Smart performance metrics require continuous improvement while maintaining the integrity of the process.
- Reacting and adapting to external and internal process changes such as an increase in production rate.
- Analyze energy performance metrics for a subtractive manufacturing process.

### Performance Metrics

- All three sustainability pillars should be reviewed, and their subsets, to understand what aspects need to be considered during analysis.
- According to prioritized concerns, performance metrics are chosen for evaluation and improvement.
- Functional units are used to frame the performance metrics in relative and comparable terms.

### Methodology

- How to evaluate the *smartness* of performance metrics.
- Define the system for evaluation.
- What quality and quantity of relevant variables are required.
- Evaluate performance metrics.
- Subject performance metrics to an internal or external change.
- Can the performance metrics guide the system to a decision which improves the performance metrics while maintaining the integrity of the process.

### Case Study

- Machine: Mori Seiki NVD 1500 DCG.
- Tool: 5/16” solid carbide center cutting end mill.
- Internal/External change: Increase in production from 10 to 12 and 17 parts per day.
- Priority: maintain daily processing schedule
- Trial 3 is the business as usual case (BAU)

### Implementation and Conclusion

- The machine load, in conjunction with the specific energy and energy intensity performance metrics, gives the smart manufacturing system the ability to improve the energy performance while maintaining the integrity of the process.
- Energy intensity trends lower with an increase in load. Highly volatile which is were smart manufacturing excels.
- To evaluate and improve the energy performance of the process only a small amount of very detailed data is required: Energy use, material removed, process time, and the machine load.
- A limiting factor is required for effective use of performance metrics in a smart manufacturing system.

### Chosen Energy Performance Metrics

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\text{Energy Intensity} = \frac{\text{Process Energy}}{\text{# Produced Part}} \quad \text{units of Wh/Part}
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### Performance vs Load for Identical Processes Across Aluminum and Steel

![Graph showing Performance vs Load for Identical Processes Across Aluminum and Steel](image)

### Processing Time vs Energy Intensity for 10, 12, and 17 Parts with Changing Chip Load

![Graph showing Processing Time vs Energy Intensity for 10, 12, and 17 Parts with Changing Chip Load](image)