Process Parameter Optimization for Energy Consumption Reduction in Milling Machines

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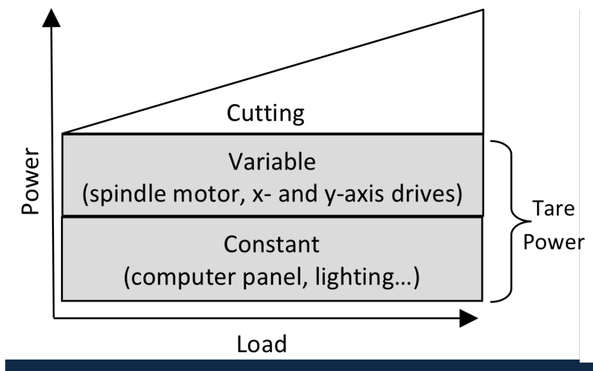
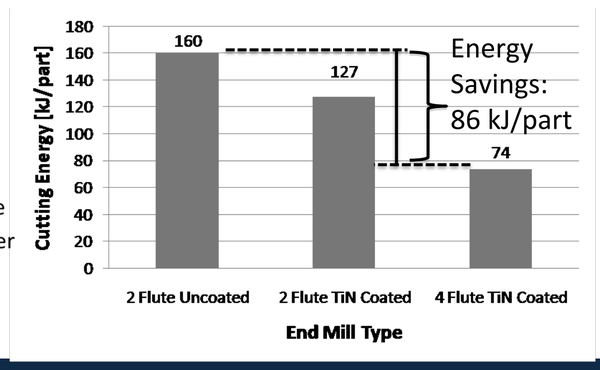
Motivation & Background

- What can operators do to reduce the environmental impact of machining?
- This study is concerned with reducing energy consumption of automated milling machine tools at the process level.
- Previous work shows that changing the cutting tool type to increase the material removal rate (M.R.R.) results in a significant reduction in energy consumption.

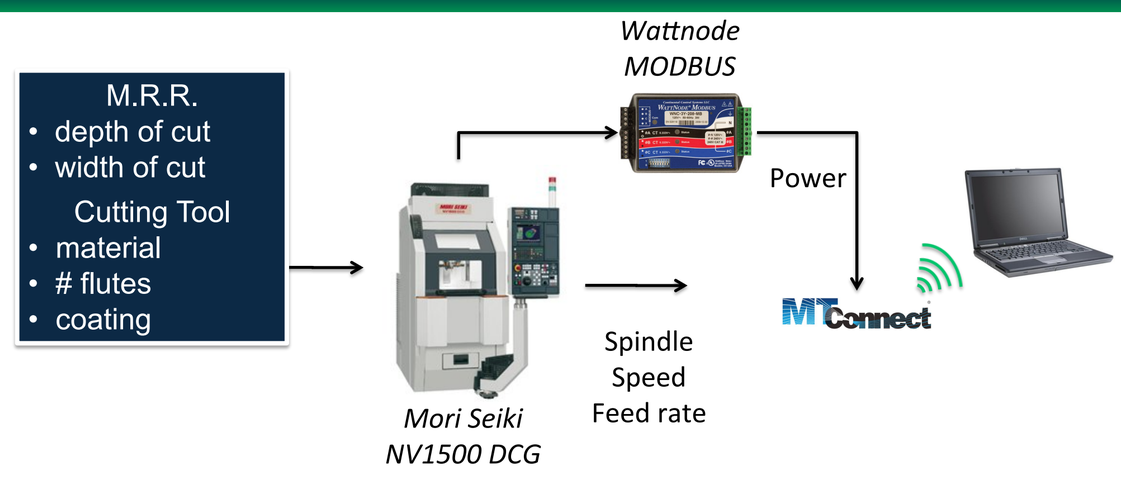
Power Breakdown of Machine Tools



Specific Energy of Mori Seiki NV1500 DCG



Power Demand Experimental Setup

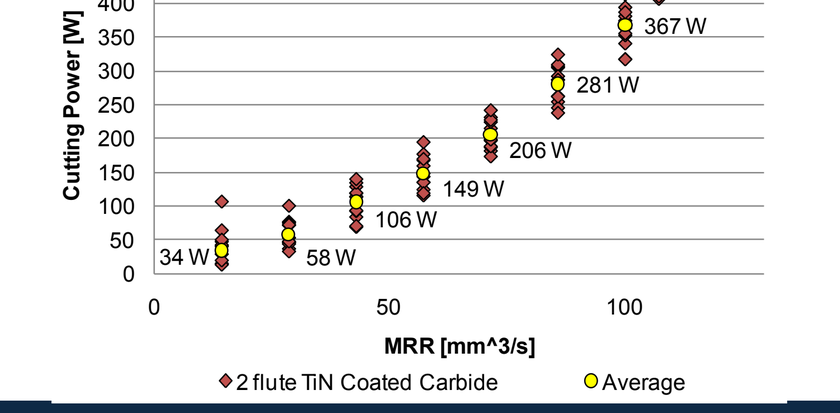


- Power data was obtained and correlated to the process parameters on the Mori Seiki controller using MTConnect
- The recommended feed rates and spindle speeds were maintained by varying the width and depth of cut, and the cutting tool type for the specific energy characterization.

Time and Power Trade-off

- In high tare machine tools, time dominates over power when optimizing for reduced energy consumption.

Energy and power demand as a function of M.R.R. for depth of cut experiments with 2 flute TiN coated end mill



Specific Energy Characterization

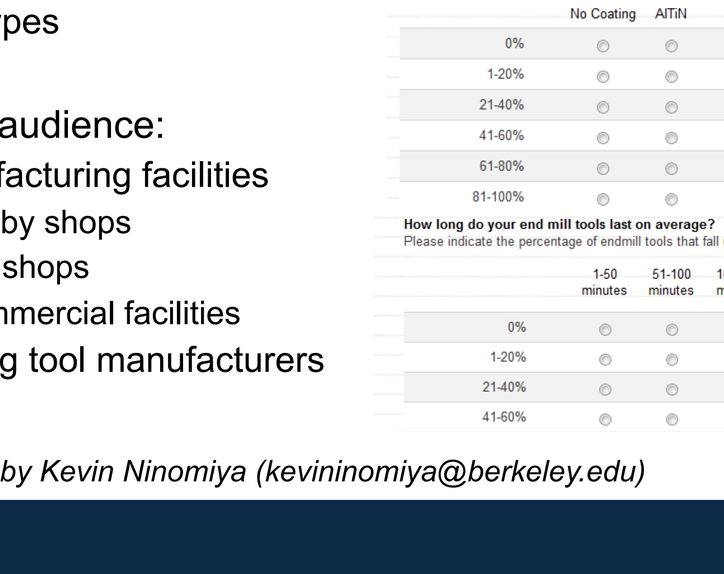
- The specific energy was found to be inversely proportional to the material removal rate (M.R.R.).
- The energy consumption of part production can subsequently be estimated.
- Advantages:
  - Fast – A test part doesn't have to be machined
  - Versatile – Method can be applied across a range of manufacturing processes
  - Accurate – The dependency on M.R.R. adds accuracy vs. using aggregate machining data

Specific Energy of Mori Seiki NV1500 DCG

Cutting Power Demand

- The cutting power demand for width of cut experiments are shown below using a 2 flute TiN coated carbide end mill.
- With an average air cutting power demand of 1510W, the cutting power demand of the machine tool accounted for as much as 22% of the total power.

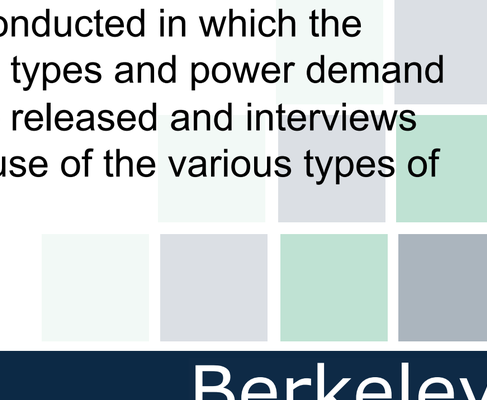
Cutting power demand for 1018 steel



Cutting Force and Power Demand by Tool Type

- A range of cutting tool types are available to vary the M.R.R. of a process for any given machining center, but how do these cutting tools differ in cutting forces and cutting power demand?
- A test part has been designed from which cutting forces across the x, y, and z axes will be measured.
- The objectives of the test part design were to maximize the length of cut
  - along the x and y axes individually,
  - and with simultaneous x and y axis feed for the purpose of interpolating.
- These forces will be correlated to the cutting power demand for a range of cutting tool types.

Test part for cutting force and power demand experiments



Contributions by Kevin Ninomiya (kevininomiya@berkeley.edu)

Cutting Tool Type Survey and Interviews

- Faster machining reduces energy consumption, but what type of cutting tools are actually being used by industry?
- Survey and Interview Goal:
  - Define market share of cutting tool types
- Survey audience:
  - Manufacturing facilities
    - Hobby shops
    - Job shops
    - Commercial facilities
  - Cutting tool manufacturers

Sample Cutting Tool Survey Questions

What type of coating do your end mill tools have?
Please skip if your answer to question above was 0%.

	No Coating	AlTiN	TiN	TiCN	Other
0%					
1-20%					
21-40%					
41-60%					
61-80%					
81-100%					

How long do your end mill tools last on average?
Please indicate the percentage of endmill tools that fall under each life span range.

	1-50 minutes	51-100 minutes	101-150 minutes	151-200 minutes	more than 200 minutes
0%					
1-20%					
21-40%					
41-60%					

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Conclusions and Future Work

- Process parameter optimization allows the environmental impact of the manufacturing phase of a product to be reduced at the operator-level.
- The specific energy model developed herein can be used by designers and manufacturers alike to estimate the energy consumption of a part's production.
- Furthermore, experiments will be conducted in which the cutting forces of various cutting tool types and power demand are correlated. A survey will also be released and interviews conducted to determine the actual use of the various types of cutting tools in industry.