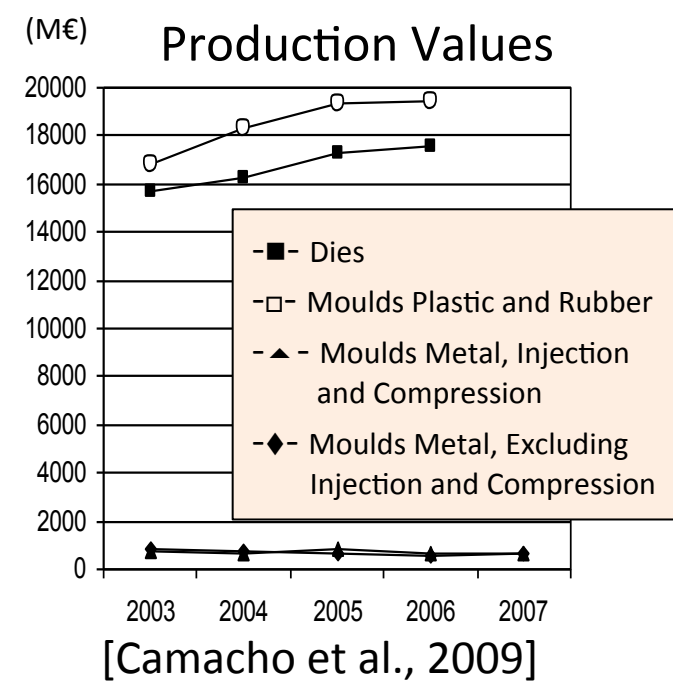


Environmental impact estimation of molds & dies manufacturing

Funding Sources: Industrial Affiliates of LMAS

Importance of molds & dies

- For product developers
 - Increasing environmental concern
 - Regulations and customer needs
- For mold makers
 - Global market of €65B in 2008 [ISTMA]
 - Influence on various products (Injection molding product in EU €42.6B 2009)



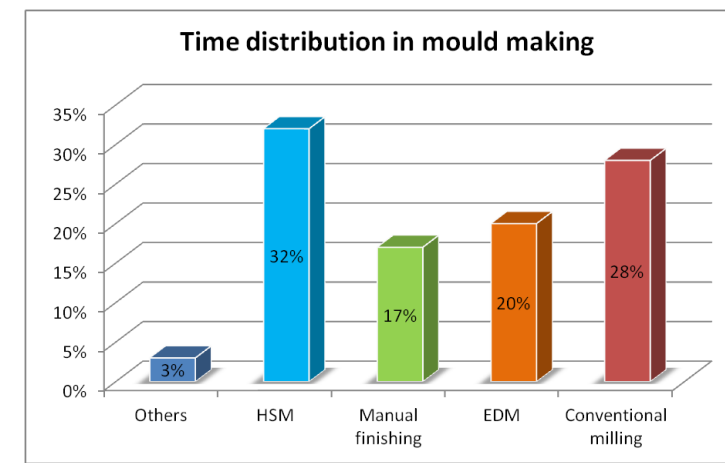
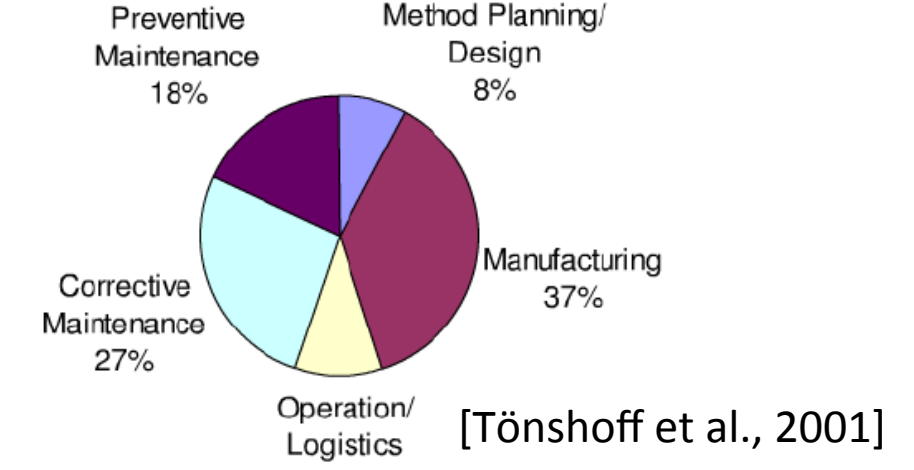
Product	Share of Mold/Die	Product	Share of Mold/Die
Vehicles	5%	Computer	5%
Electronics	5%	Telecom	8%
Semiconductor	5%	Mechanics	3%

[Korea mold industry roadmap (Bizhospital.co.kr), 2012]

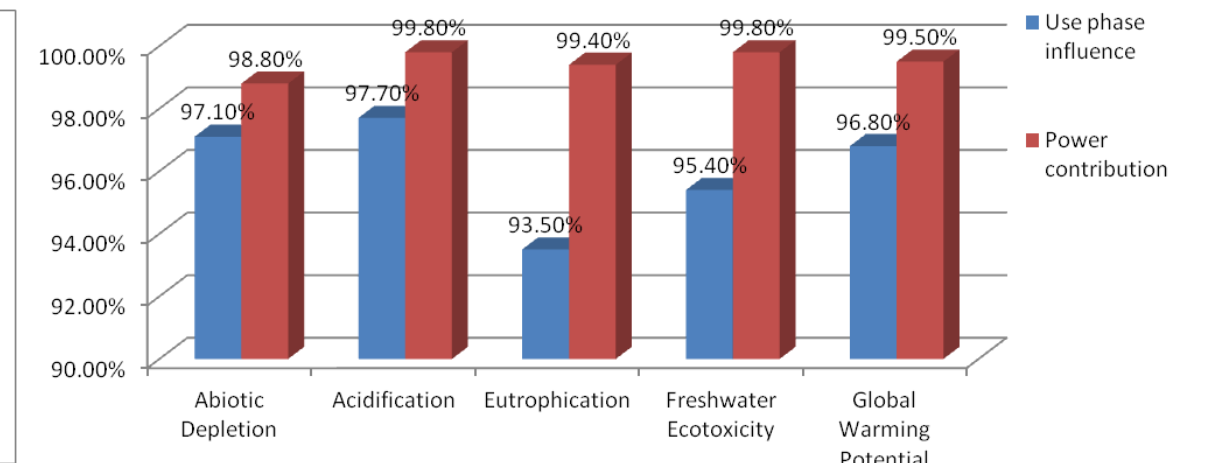
Key impact factors

- Manufacturing contribution
 - Dominant in life cycle cost
 - Milling and EDM are the biggest time consumers
 - Use phase electricity consumption

Life cycle cost of progressive die



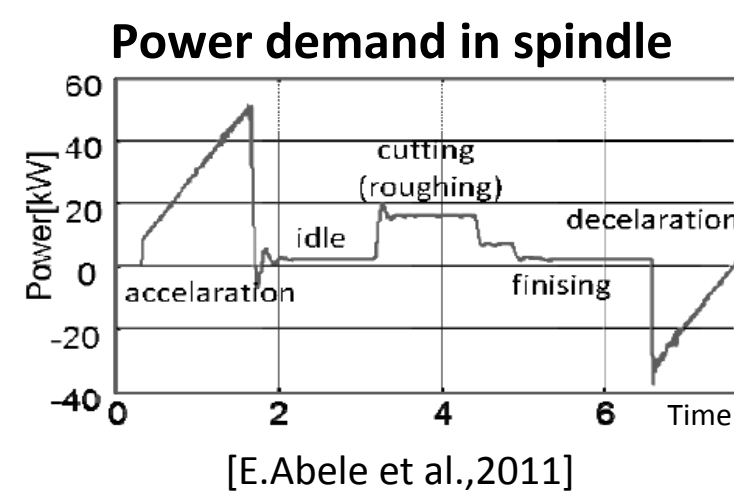
[P. Peças et al., 2009]



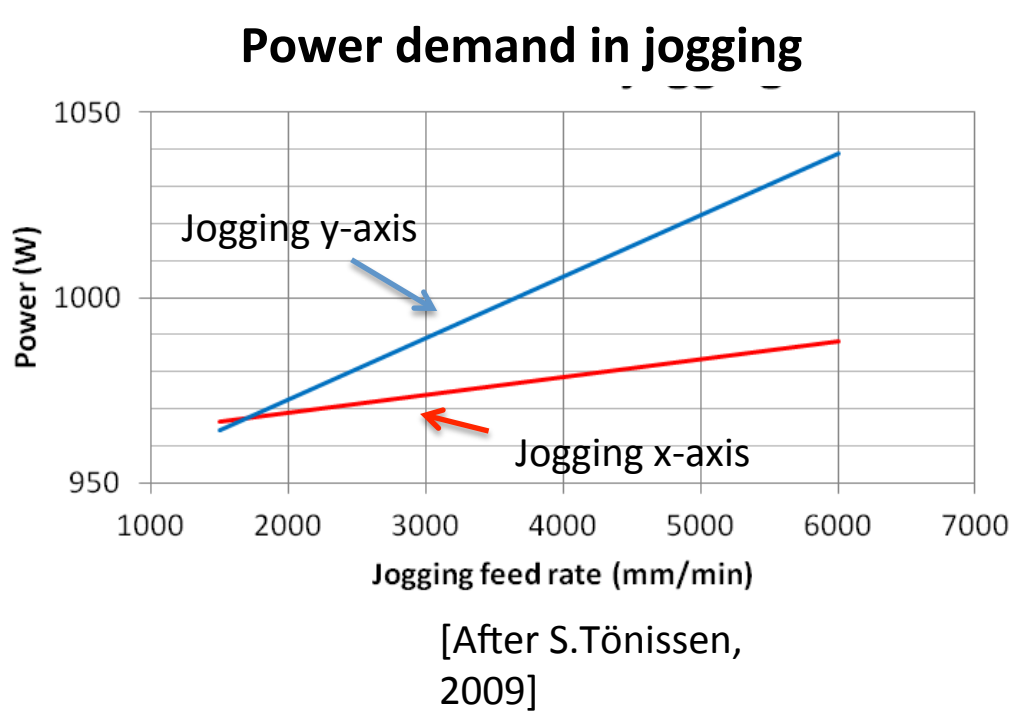
[LCA results of machine tool use phase CECIMO, 2009]

Limitations in the milling operation

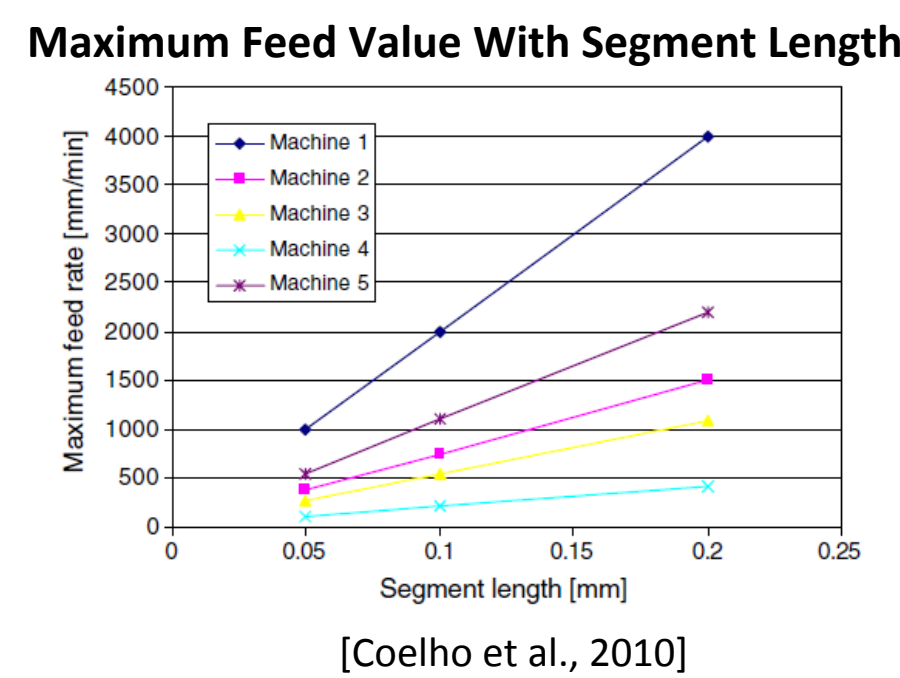
- Mechanical constraints
 - Finite acceleration/deceleration capacity
 - Different energy consuming characteristics
- Tool path constraints
 - Limited feed speed availability



[E.Abele et al., 2011]



[After S.Tönissen, 2009]

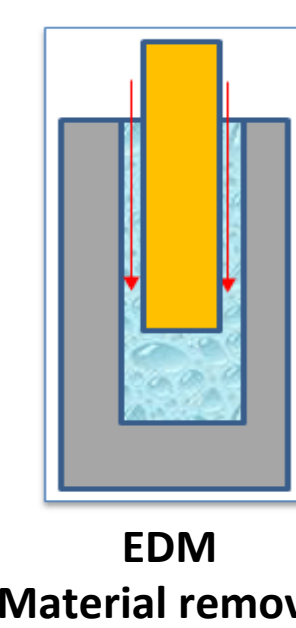


[Coelho et al., 2010]

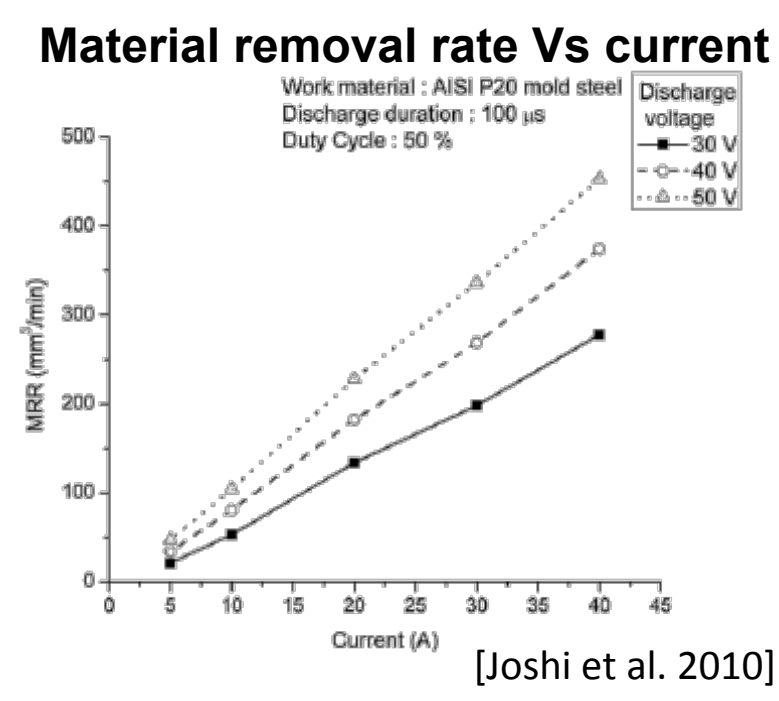
Limitations in the EDM operation

- Electric constraints
 - Discharge current defines removal performance
 - Machining performance is inconsistent to machining depth

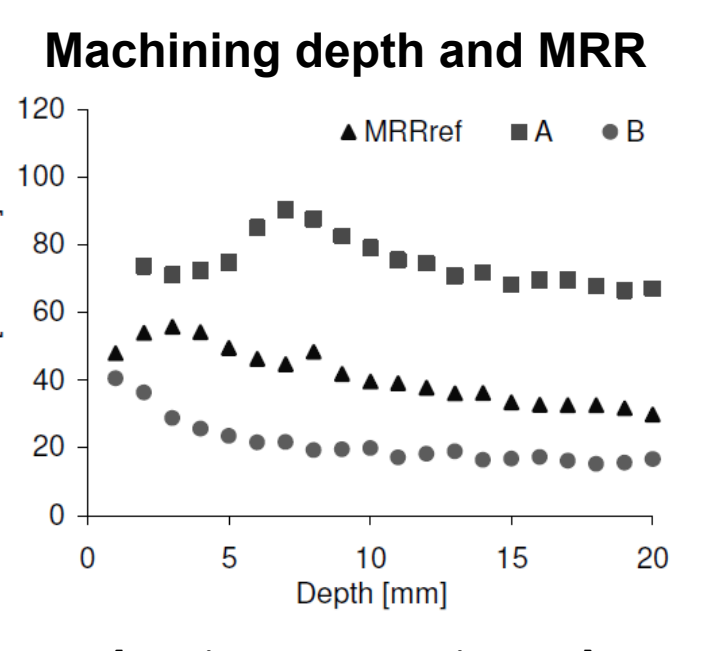
$$MRR = 6.64 \times 10^{-7} \times \frac{\text{discharge current}}{\text{point}} \times \left(\frac{\text{Melting}}{\text{point}} \right)^{-1.23} \times \frac{\text{PulseOnTime}}{\text{PulseOnTime} + \text{PulseOffTime}}$$



Material removal



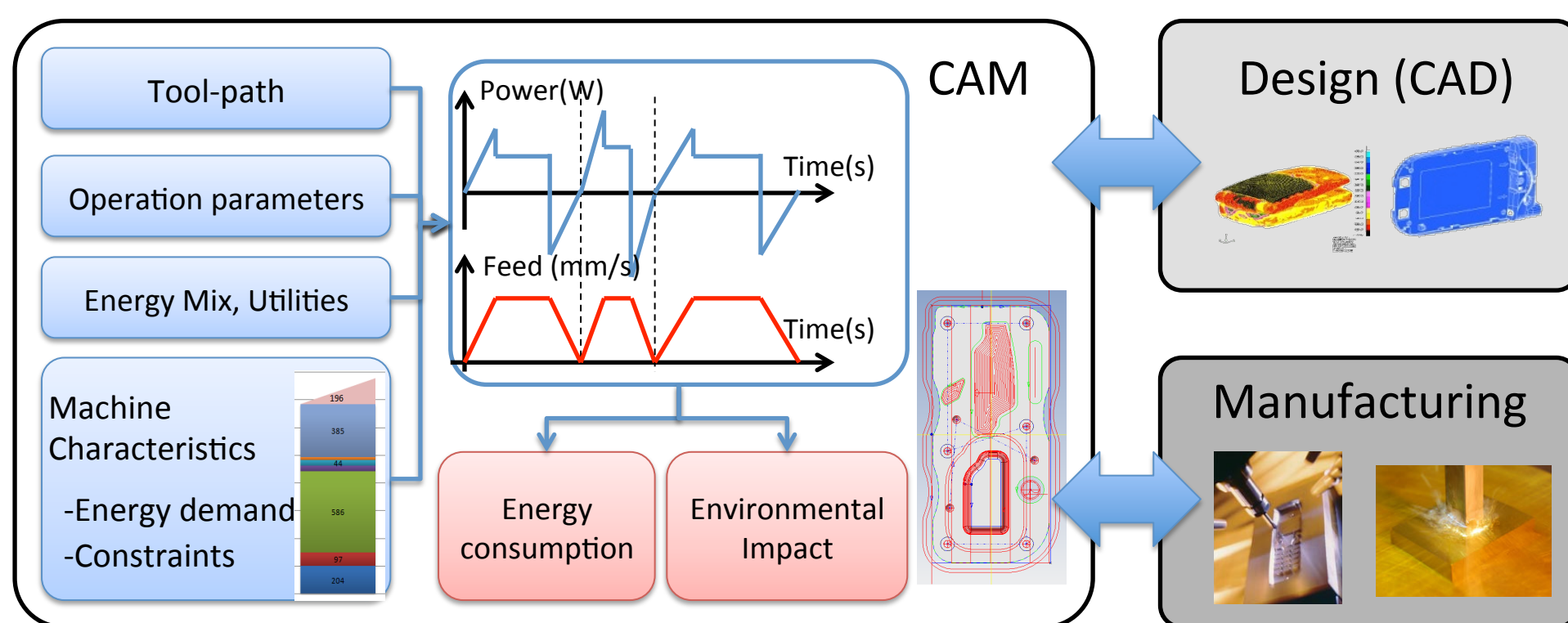
[Joshi et al. 2010]



[Vanderawera et al., 2010]

Approach

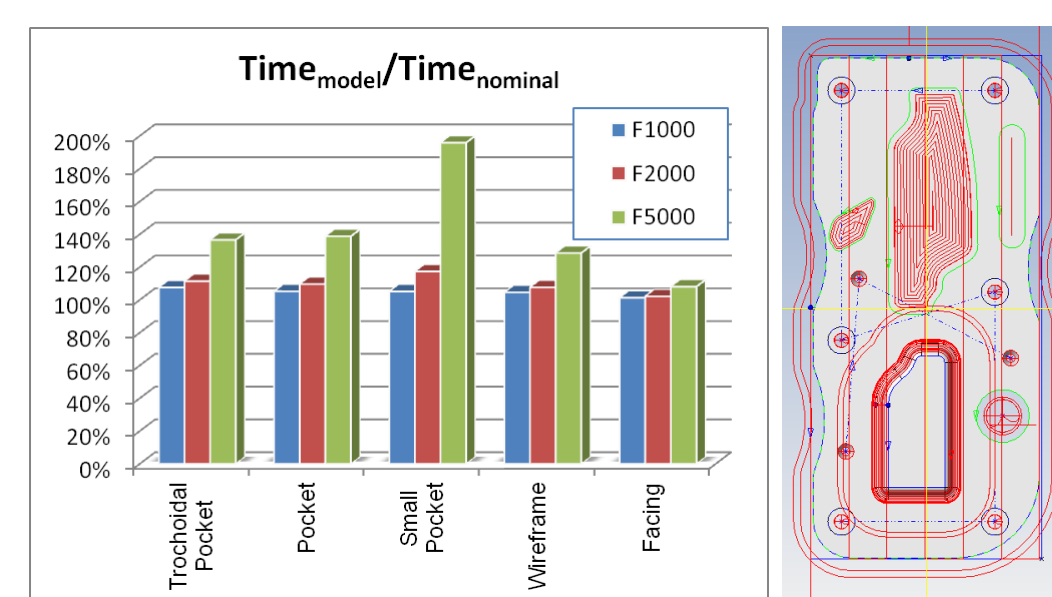
- CAM-based information management
- Inventory for machine tools and process data
- Process characteristics with operation parameters
- Data driven analysis of environmental impact



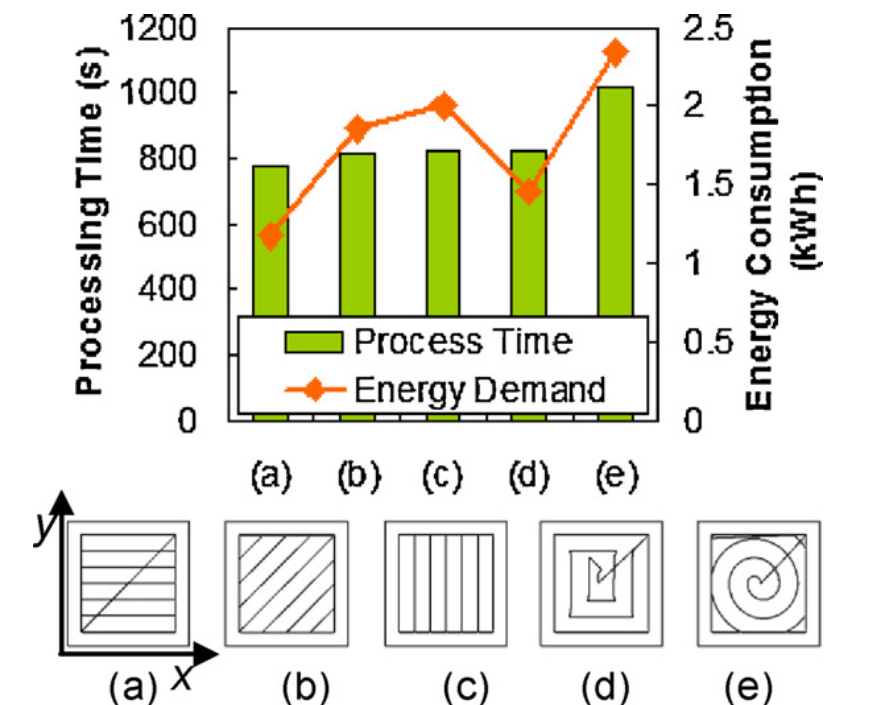
Analysis of milling impact

- Tool-path based estimation
 - Short tool paths cause more time and energy consumption.
 - Machine structure affects energy consuming characteristics.

Tool path Influence on processing time

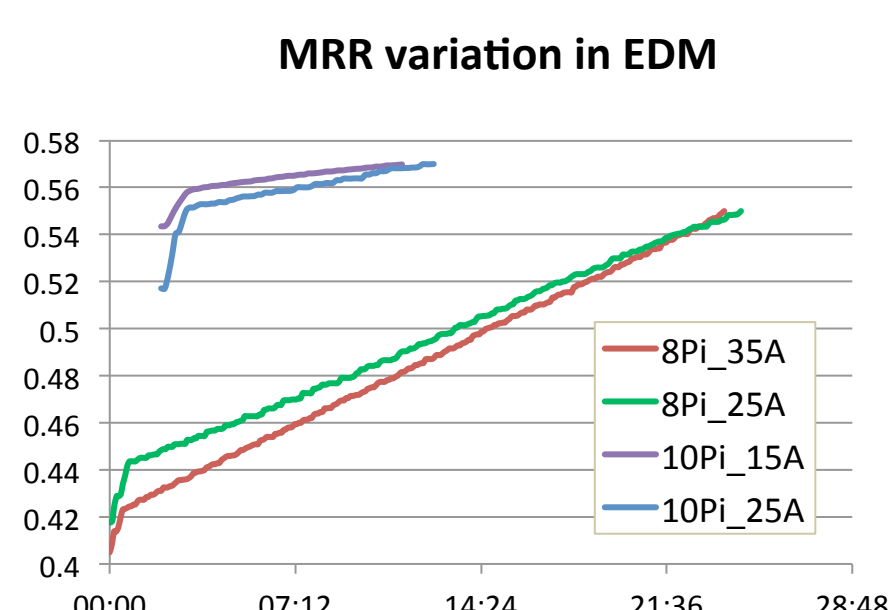


Tool path Influence on energy consumption



Analysis of EDM impact

- Discharge condition considered estimation
 - High depth/area ratio increases time and energy consumption.
 - Two distinct ranges with different M.R.R.s exist.
 - Optimal flushing condition minimizing energy consumption exists.



Jump Height		0.35	0.75	1.35	2.35
Depth 30mm	Time (min)	-	830	410	180
	Ratio (%)	-	461%	228%	100%
	Energy (kWh)	-	21.1	10.7	4.8
Depth 20mm	Time (min)	1300	360	120	120
	Ratio (%)	1090%	300%	100%	100%
	Energy (kWh)	32.4	9.2	3.1	3.2

Summary

- Operation-level energy consumption
 - CAM-based simulation can provide more reliable environmental impact analysis of milling and EDM processes.
 - Mold making impact can be estimated and reduced by mold engineers.
- Future works
 - More processes like grinding and w-EDM will be included.
 - Factory level utilities need consideration.