



## Analysis of the environmental impact for a turning operation of AISI 1040 steel

G. Campatelli  
[gianni.campatelli@unifi.it](mailto:gianni.campatelli@unifi.it)

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- Development of a model to quantify the environmental cost of the machining processes
- Evaluation of the most relevant factors (cutting speed, depth of cut, feed, lubrication strategy) regarding the environmental cost of machining
- Optimization of the process using the model



In Europe (2005 data) about the 25% of the primary energy consumption is used by the industry and has been esteemed a margin of improvement of about the 30%.

Possible actions:

- the development of zero defect processes, → Relevant technology change relevant investment
- the implementation of net shape processes, → Relevant technology change relevant investment
- the use of reusable materials, → Technology optimization, reduced investment
- the reduction of the resources consumption of the production machines. → Technology optimization, reduced investment

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Reference standard:  
ISO 14040 - Life Cycle Assessment

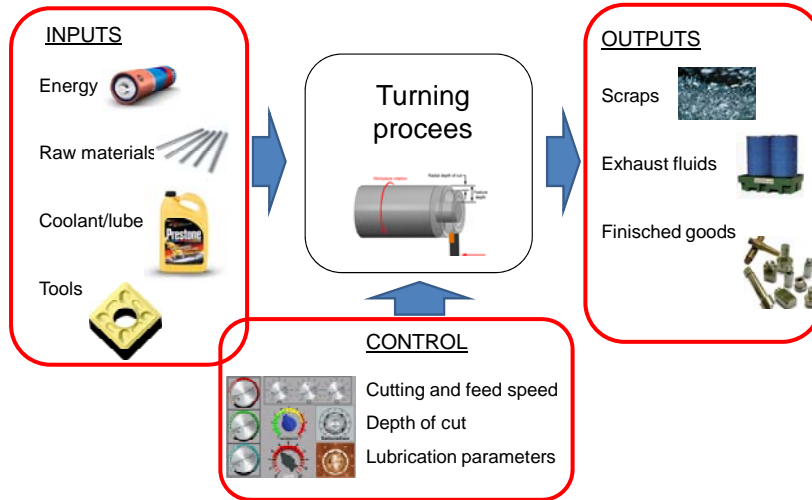
**From cradle to grave**

- Pre-production and sample product
- Production
- Distribution
- Use
- Recycling
- Final dismantle

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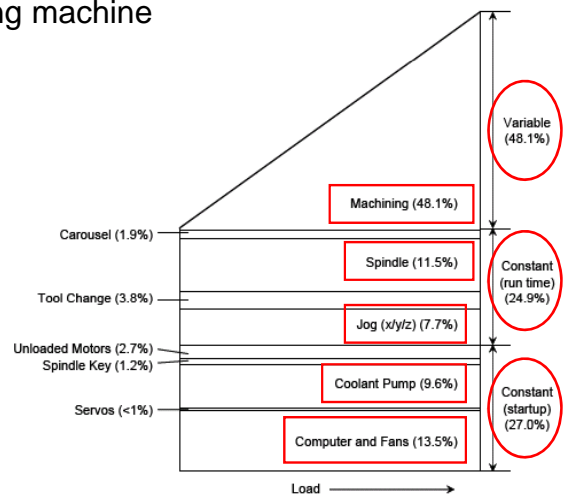
## Machining as a system



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## Energy data collection by Dahmus and Gutowsky for a 6 kW milling machine



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**Electrical consumption:** mainly the spindle (during machining) and coolant support system

**Lubrication:** both for the electrical power consumption of the lubrication system than for the treatment of the scraps at the end of the machining process

The most common lubrication strategies are:

- flooded lubrication,
  - dry machining,
  - MQL (Minimal Quantity Lubrication),
  - solid lubrication
  - air spray
  - cryogenic lubrication
  - water vapor lubrication
- Most common and considered in this study
- To be experimentally studied more in detail in order to be correctly assessed

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For the measurement of the environmental impact of the machining process has been used 4 Eco-indicators (Eco-indicators 99) that deal about many different aspects of the damage that the environment could suffer:

- Global warming potential (g eq. CO<sub>2</sub>)
- Acidification potential (g eq. SO<sub>2</sub>)
- Eutrophication potential (g eq. PO<sub>4</sub>)
- Photo-chemical oxidant formation potential (g eq. ethylene)

Actually there is not an unique proposal for standard indicators but the eco-indicators provide a good idea of the environmental impact of a general process

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Considered contributions:

- electrical energy



- processing of the scraps



Contributions that could be considered for further analysis:

- environmental impact of the insert



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3 different lubrication strategies has been considered

| Lubrication strategy | Lubrication power consumption | Scraps to be treated |
|----------------------|-------------------------------|----------------------|
| Flooded              | Oil pump                      | Oil soaked           |
| MQL                  | Air compressor                | Dry                  |
| Dry                  | None                          | Dry                  |

The condition of the scraps at the end of the cutting process define different approach for the treatment with different environmental cost

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**Material:** AISI 1040 steel

**Machine:** a 6 kW Tortona SAG 210 turning machine

**Tool:** TaeguTec PCLNR 2525 M12 with insert  
CNMG 432 MP TT 3500

**MQL lubricant:** Biocut 3000 (oil-alcohol emulsion)

**Flooded lubricant:** standard synthetic oil

**MQL system:** manufactured by Unijet

**Force acquisition device:** 3 axes piezoelectric cell  
Kistler 9257A

**Signal acquisition:** National Instruments 9215 @ 1000 Hz



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The experimental tests have been carried out with a full factorial approach that considered:

- Feed rate: from 0.04 to 0.16 mm/rev
- Depth of cut: from 1 to 2 mm
- Lubrication: dry, flooded, MQL

Other parameters:

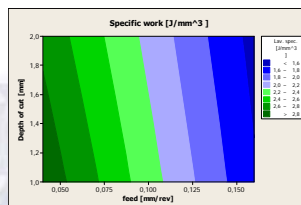
- Cutting speed: maintained constant to 200 m/s  $\pm$  5%
- Used MQL oil: about 60 ml/h



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The specific energy of cut has been obtained in order to assess the power consumption



Comparing the results of the 3 lubrication strategies

| Lubrication strategy | Mean reduction of cutting power | Energy needed for 1 kg material removal (kJ) |
|----------------------|---------------------------------|--|
| Dry                  | ----                            | 0,43   |
| Flooded              | - 10%                           | 0,39   |
| MQL                  | - 15%                           | 0,37   |

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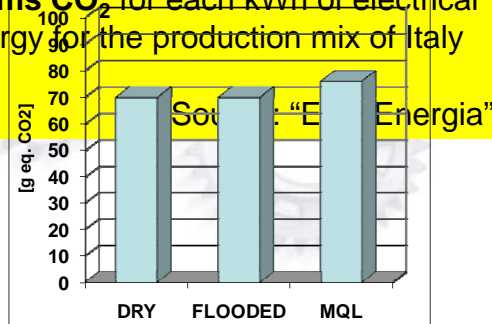


Support system energy consumption:

Oil pump (flooded): 0,04 kJ/kg material

Air compressor (MQL): 0,14 kJ/kg material

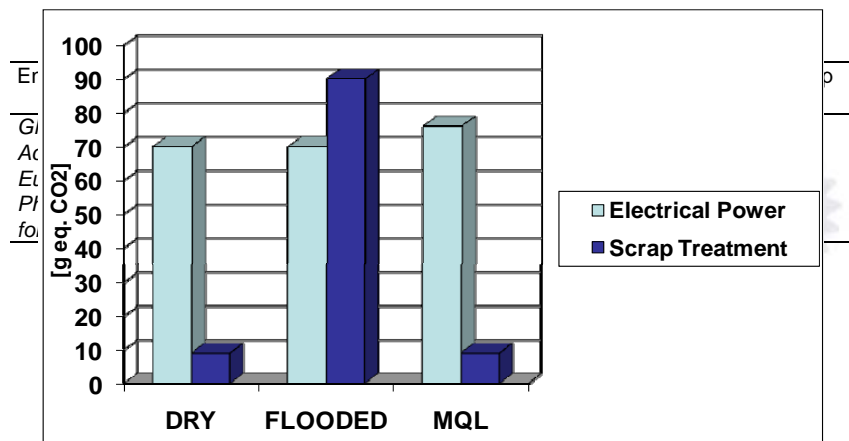
Comparison Considering a production of **470 grams CO<sub>2</sub>** for each kWh of electrical energy for the production mix of Italy



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The environmental impact of dry/soaked scrap has been evaluated using literature data



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- a significant reduction in environmental impact of a machining process it is possible with the correct choice of cutting parameters and lubrication strategy
- the specific power consumption could be reduced using more demanding cutting parameters
- this choice also affect positively the time/cost needed to produce a component obtaining a more sustainable production strategy
- MQL is the best compromise between environmental impact (the difference between MQL and dry lubrication are negligible) and production cost in spite of the longer tool life

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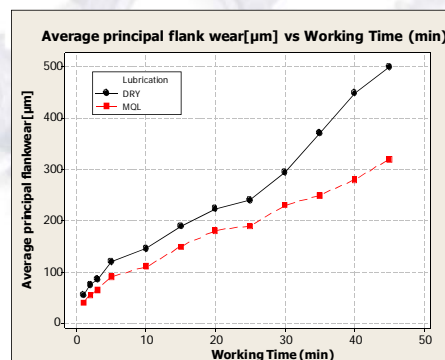


The assessment of the best lubrication strategy has been carried out only considering the environmental impact of the machining process (energy and scrap processing).

Moreover it is possible to evaluate the best solution considering also the cost of the process. Also in this case the **MQL results as winner** thanks to an increase of tool life (and so tool cost and tool environmental impact)



In order to include also this contribution a model to assess the improvement of tool life using MQL has to be developed. In our experimental tests the improvement range from 20% to 25% but more accurate (replicas) tests are needed for a more confident estimation



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TI**



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