Use of Environmental Assessment and Techno Economic Analysis (TEA) to Evaluate the Impact and Feasibility of Coatings for Manufacturing Processes.

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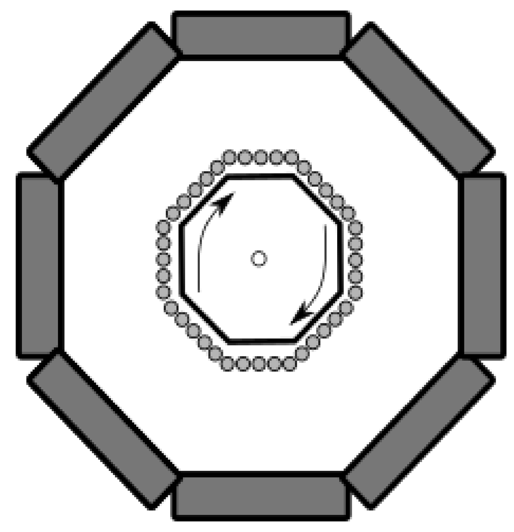
Introduction

The decision to use one technology over another depends on many factors and the decision-making process can be aided with assessment methodologies. Such methodologies include the use of TEA for cost assessment and the evaluation of Greenhouse Gases (GHG) emissions. As high-performance coatings on cutting tools for the machining of steel which have been demonstrated to improve tool life and productivity[1], two similar Physical Vapor Deposition (PVD) technologies are compared using the given methodologies: High Powered Impulse Magnetron Sputtering (HiPIMS) and Direct-Current Magnetron Sputtering (DC-MS)



Coatings assessment

Coatings of TiAlN deposited by HiPIMS and DC-MS are assessed. The main differences between the two processes are:

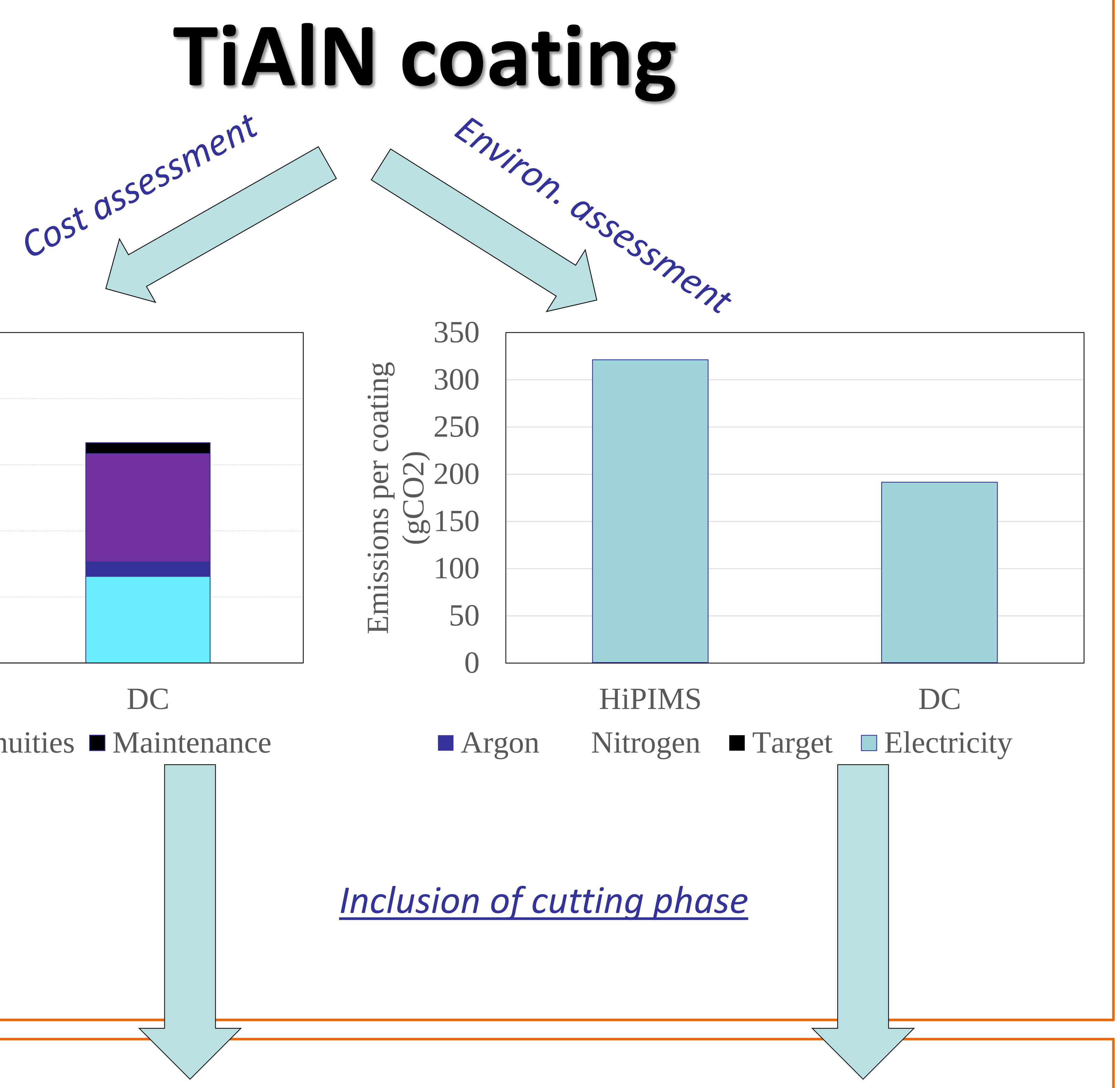
- A slower deposition rate for HiPIMS (133 min per batch compared to 67 min)
- A higher capital cost for HiPIMS (1.3M€ vs 1.2M€)
- A longer tool life for HiPIMS (75 min of cutting vs 50 min)

Carbon emissions evaluated through:

- Metal target production
- Gaz production
- Energy usage

Cost evaluated through:

- Capital costs
- Operating costs (consumables, energy and labor)



As expected, costs and CO2 emissions are higher for HiPIMS due to the lower production rate. However, if normalized to the tool life, it is more economically viable to use HiPIMS compared to direct-current magnetron sputtering.

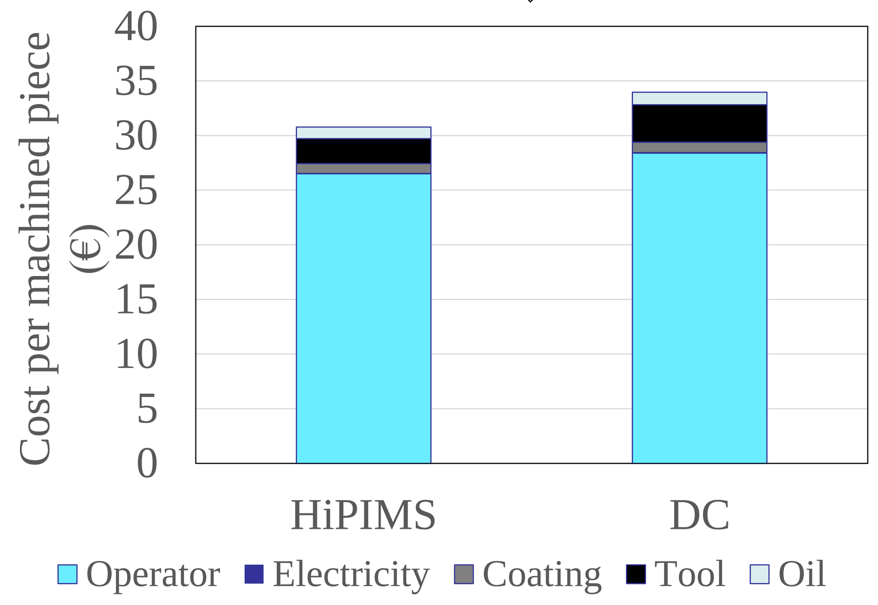
Cutting phase assessment

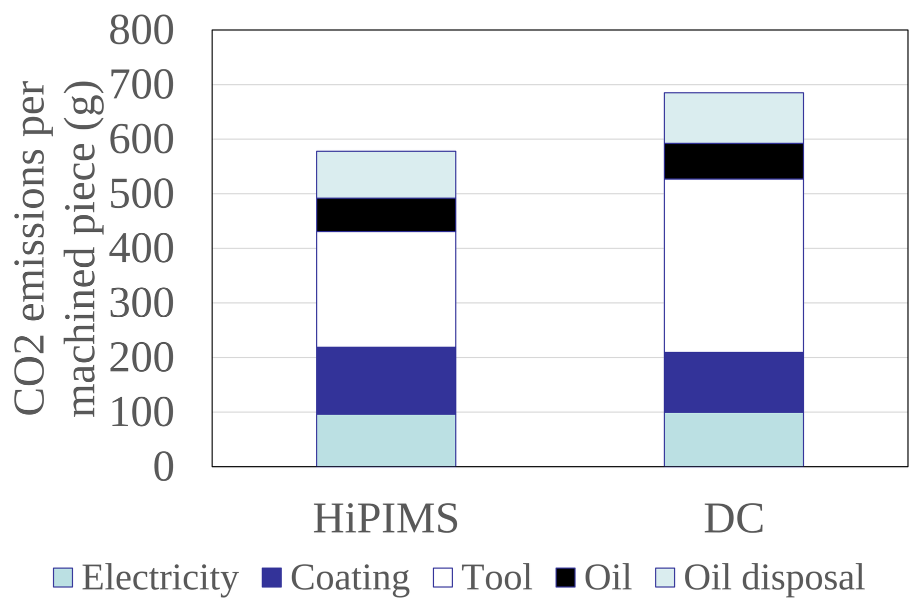
The choice of the coating, and by extension the tool life, has impacts beyond the coating itself. Indeed, with a higher tool life:

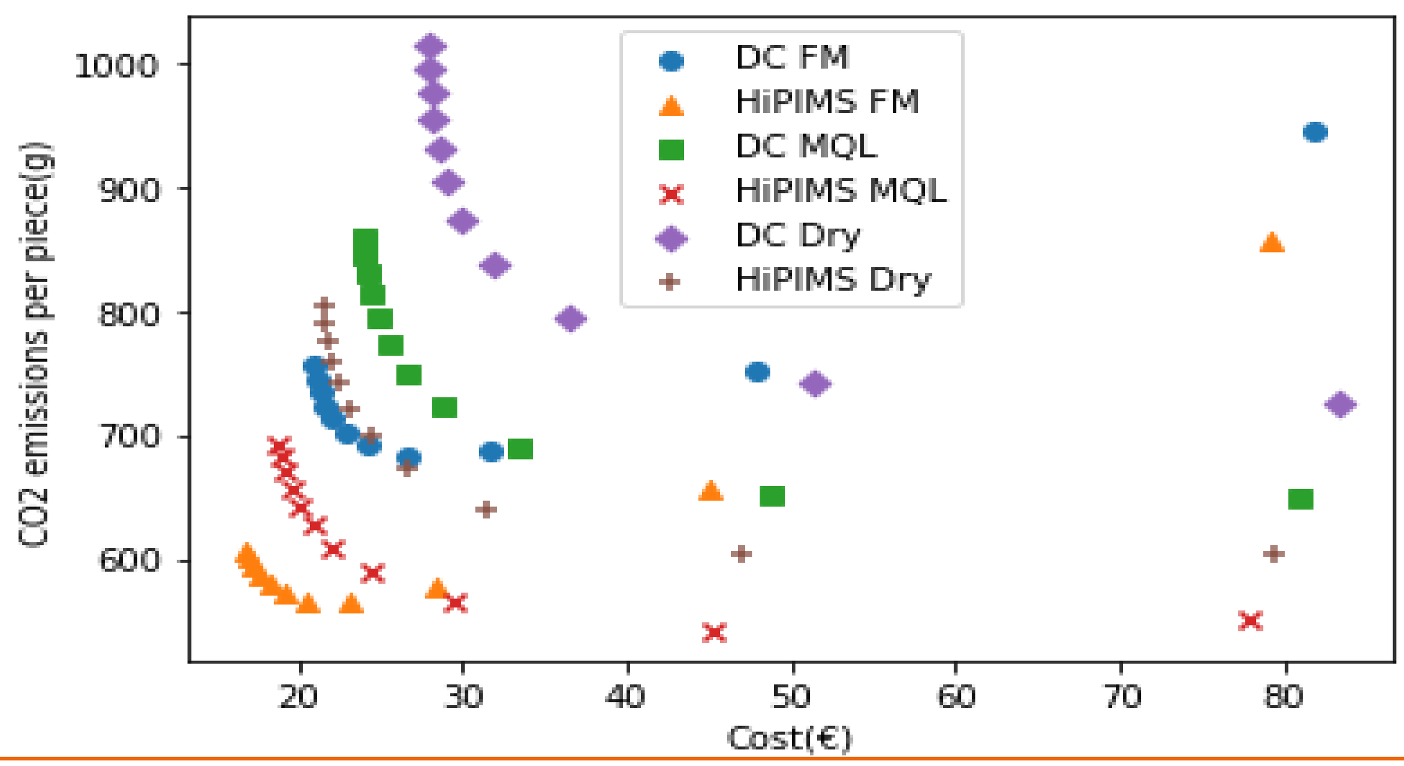
- Higher cutting speeds are possible
- Less tool replacement time is needed
- Less substrates are used
- Less lubrication is required

This leads to a clear advantage per machined piece in using HiPIMS coatings, both for cost (**~10% less cost**) and environmental impact (**~15% less CO2 emissions**).

Cutting speeds can also be varied, and pareto fronts of optimal cost vs. CO2 emissions can be put plotted with different lubrication scenarios.







Conclusions

Environmental and economic assessment can be applied to coatings and manufacturing technologies in order to evaluate their sustainability. Moreover, the inclusion of more steps of the life cycle into the study allows to give a wider picture for comparing different technologies. In the present case, HiPIMS appears to be more interesting in terms of cost and environmental impact only if the use phase is considered.

In future works, the methodology can be extended to other technologies such as CVD or even compare additive manufacturing to machining as well as it can be developed to include social impacts, for instance by estimating risks to the workers. The inclusion of other phases such as recycling may also improve the overall assessment.

References: [1] Fritz Klocke, Christoph Nobel & Drazen Veselovac (2016) Influence of Tool Coating, Tool Material, and Cutting Speed on the Machinability of Low-Leaded Brass Alloys in Turning, Materials and Manufacturing Processes, 31:14, 1895-1903, DOI: 10.1080/10426914.2015.1127944