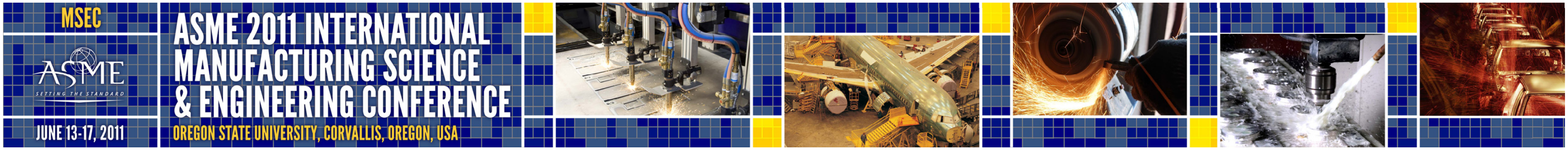

Life Cycle Management of Abrasive Tools and Effects on Sustainable Grinding

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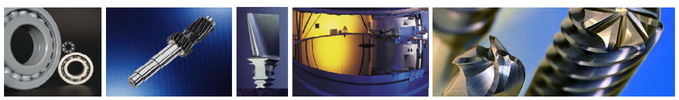
Motivation

Machining with geometrically undefined cutting edges, i.e. grinding, polishing, lapping and honing amongst others, represent key technologies with high process performance, high process stability, and high quality tolerances. They act also as core technologies supporting the development of high-end products, energy systems, and efficient machines. Nevertheless, sustainability aspects in abrasive machining is a growing concern and is gaining recognition in the industry.

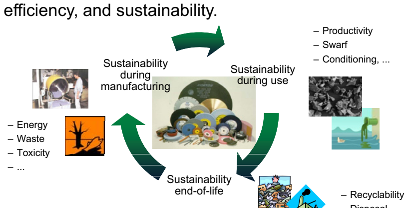
Abrasive tools are enablers for optimum processes and are the focus of the following analyses.



Source: MTU, Junker, Franke, Cerobear, Walther Trowal, Siemens, Schott Glas

Objectives

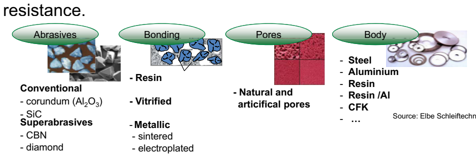
For the first time a holistic view on the life cycle of abrasive tools will be done encompassing manufacturing, use phase and end-of-life. Special emphasis is given to energy, resource efficiency, and sustainability.



Source: Rappold Winterthur, Saint-Gobain Abrasives

Abrasive Tool Design

Abrasive tools are complex products consisting of abrasive grits in a bonding or a slurry paste. The selection of the abrasives affects chip formation, effectiveness, process heat generation and convection. The bonding has to hold the grits until they are blunt and relieve them to apply new sharp grits. Pores in a bonded or coated tool are important to supply cooling lubricant and remove chips from the contact zone. Grinding tools with the superabrasives diamond and cubic boron nitride (CBN) consist of only a thin abrasive layer on a body to limit the high material costs and to utilize the higher wear resistance.



Source: Elbe Schleiftechnik, Tyrolit, Semung Diamond Tools

Tool design defines the process performance essentially through productivity and tool life. Workpiece quality emerges from the chip formation mechanisms, process forces and heat.

Source: Werner, VDS, 2004

Abstract:

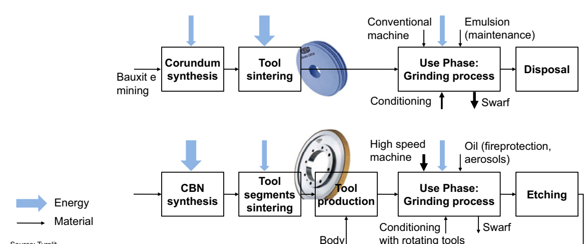
The world-wide trend to environmental awareness is accompanied by a rising need for manufacturing technologies that spare energy and resources. The sustainability of products and processes becomes more and more a main competitive edge. However, the very essential aspect of abrasive tool design and its impact on process eco-efficiency have not been examined in a holistic view yet. Therefore this work evaluates the whole tool life from manufacturing to use phase and end-of-life.

Abrasive tools have a huge variety in specifications, manufacturing steps and ingredients. Therefore a framework has to be set up to evaluate tool manufacturing with a thorough investigation of main and auxiliary ingredients, emissions, waste and energy. Tool design affects the abrasive machining process in terms of productivity, workpiece quality and tool life. Relevant mechanisms of impact are discussed, evaluated and included into a suitable holistic life cycle management of abrasive tools. Not only the improvement of the single abrasive process, but moreover the process chain and leveraging effects on product performance are considered. Different scenarios for the end-of-life of abrasive tools conclude the life cycle management. Abrasive tools are not only complex products, but moreover important enablers for green manufacturing.

Abrasive Tool Production

The system boundaries are important for the quality and relevance of life cycle considerations. The production of abrasives and vitrified bonds is characterized by mining and processes emitting greenhouse gas; resin and electroplated bonds include chemical production steps. Manufacturers are pressed to substitute pore builders based on naphthalene. New chemicals, however, change the manufacturing robustness.

The choice of abrasives, e.g. CBN vs. corundum, implies not only different production chains for the abrasive tool (e.g. abrasive layer on steel body vs. full-body), but also an appropriate process layout for the use phase. For example, a high-speed machine and oil are needed to gain the intrinsic advantages of superabrasives. This affects the process sustainability by energy use, maintenance, worker education and health, etc.



Abrasive Tool Use By The Example Of Grinding

Research shows prospective results and ongoing developments to improve **grinding process sustainability**, by

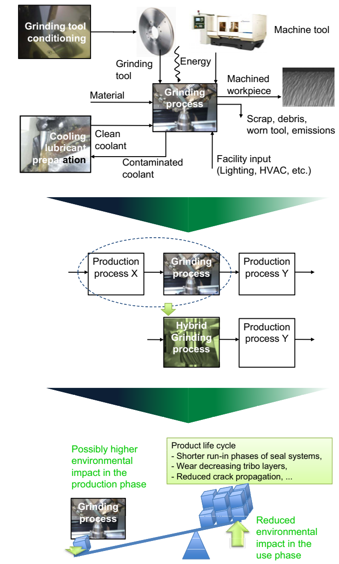
- Coolant reduction,
- Less energy consumption,
- Higher productivity, etc.

The energy savings of one machining process, however, often disappear in the energy considerations of an entire factory. Therefore, a larger view on the production chain is worthwhile (**greener process chain**). Examples are

- Avoiding tool change and adding value by the combination of hard cutting, grinding and hard roller burnishing,
- Avoiding the hardening process by grind-hardening, etc.

Leveraging abrasive processes becomes more and more the focus of attention, i.e. the trade-offs between production and improved product performance. Examples are

- Speed stroke grinding to induce compressive stress,
- Decreased product wear by tribo-layers,
- Shorter wear-intensive run-in phases of seal systems, etc.



Sources: after Dahmus, Gutowski, Helu, Dornfeld, Pictures from Tyrolit, Mikrosa, WZL RWTH Aachen

Abrasive Tool End of Life

Today, abrasive tools are often disposed via household waste or special waste leading to waste combustion or to the garbage dump. For different end of life scenarios, energy, emissions and toxicity are examined and evaluated. Nevertheless, in the case of grinding wheels with layers the bodies are often re-plated. The potential for recycling of superabrasive tools is discussed.

Conclusion and Future Work

Abrasive tools are complex products that enable high performance and high quality processes. Their life cycle is regarded in terms on energy and resource efficiency including their production and end of life. Moreover, their capability to enhance green manufacturing itself is discussed and evaluated in this project.

Future work will focus on abrasive grits in terms of the energy that is consumed during their production related to the productivity of the abrasive tool. The design of the grinding tool body (material and shape) affects process capability and machine power. Sustainability of grinding processes will be evaluated by machine power measurements as well as by analysis of grinding debris, emissions to air, or cooling lubricant. Tool conditioning leverages tool performance and tool life, which will be considered. Discussions with tool manufacturers will reveal how much research should be done in future on supply chain and packaging aspects.

Acknowledgments

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