Advantages of ASPRO™ Treated Alumina Ceramics for Cutting Tool Applications

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Manufacturing efficiency is critical in today's world economy. Manufacturers are under intense competitive pressure to produce higher quality parts at ever-faster production rates. In the field of metal machining there is an increasing demand for high-technology cutting tools that can cut metals with unprecedented levels of speed and precision. The use of ceramic cutting tools offers significant advantages in cutting speed, quality, maintenance requirements and longevity. High-speed machining elevates the temperature at the tool/workpiece interface and, therefore, the thermal shock resistance of tool materials would be expected to play a more important role in the tool life [1]. Silicon nitride, silicon carbide cutting tools show a greater strength, wear resistance, and fracture toughness than the traditional aluminum oxide (alumina) cutting tools. However, silicon nitride and silicon carbide are not recommended for the machining of irons and steels, because they are considerably more soluble in iron. On other hand, aluminum oxide has a very low degree of chemical solubility in iron and cost significantly less and, consequently, is more suitable for machining iron and steel components. Currently, the dominant factor that limits the widespread use of alumina cutting tools in the metal cutting industry is their lack of adequate thermal shock resistance, which may result in catastrophic tool failure. Therefore, it is desirable to improve performance for existed ceramic cutting tool inserts.

In response to the increase demands of higher performance materials for industrial applications, a novel patented materials process - **ASPRO™ Conversion Technology** [2] has been developed at ATS Spartec – AHCS Inc. (a division of ATS Spartec Inc.) to produce new advanced ceramics with superior properties. The process transforms highly dense monolithic ceramic components to a new state by applying a particular combination of temperature and pressure. The ASPRO™ treated ceramic is the result of the Material–Process–Property–Application relationship development. Potentially, the ASPRO™ Conversion Technology can be applied to any solid materials with near full density, including materials with nanostructure, and improve their properties.

The ASPRO™ conversion technology is able to modify the atomic structure and chemical bonds in the treated materials leading to the unique combination of properties [3, 4]. These include high density, high thermal shock resistance, high level of toughness, hardness, chemical and wear resistance, and modified thermal and electrical properties required by structural and electronic applications. Successful experimental trials of the ASPRO™ treated alumina liners in internal combustion engines and castings of molten aluminum have provided important evidence of the effectiveness of this technology in responding to extreme thermal shock. As it was shown in our recent work [5] using the laser photothermal radiometry (PTR), the improvement in thermal shock behavior of ASPRO™ treated ceramics is the result of the reduction of thermal resistance between ceramic grain boundaries under transient conditions, as occurring in thermal shock experiments. It reduces the applied stress intensity by adsorption and quick distribution of the applied energy. Therefore, the ASPRO™ process can provide a higher performance ceramic and expand the envelope of their applications, as ceramic cutting tool inserts.

The objective of this work was to improve the performance of commercially available alumina based cutting tool inserts using the ASPRO™ Conversion Technology. The ceramic cutting tool inserts have been tested by a face milling, as an interrupted cutting operation, which subjects the inserts to thermal shock, as opposed to a continuous turning operation [6]. The tests were accomplished in the down milling and dry modes. The ceramic cutting tool inserts are presented in Fig. 1.

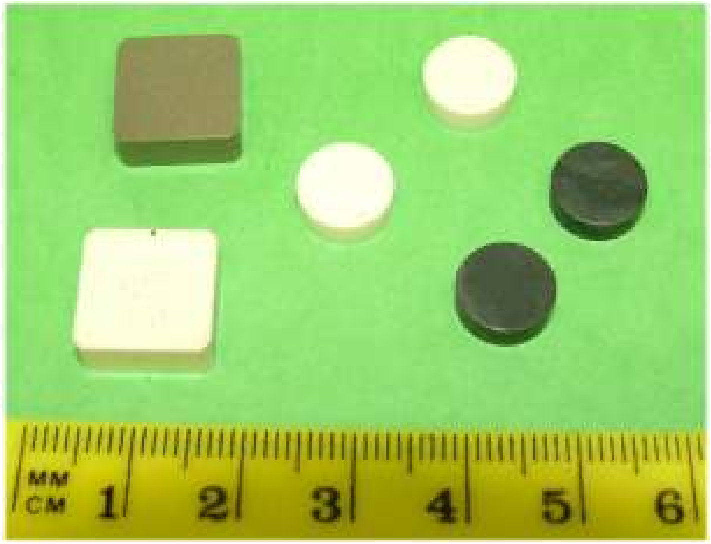
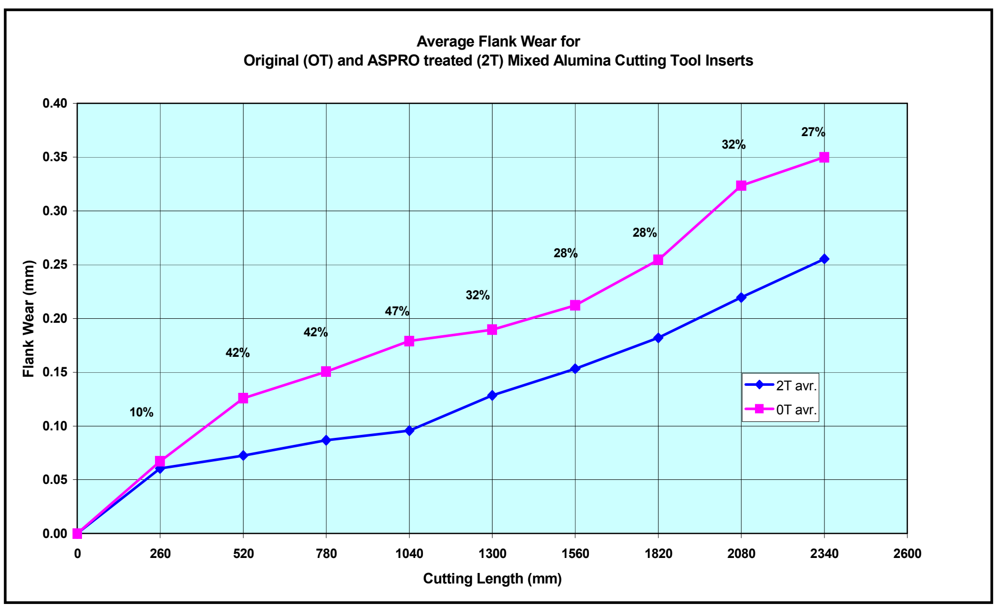


Fig. 1. The ceramic cutting tool inserts.

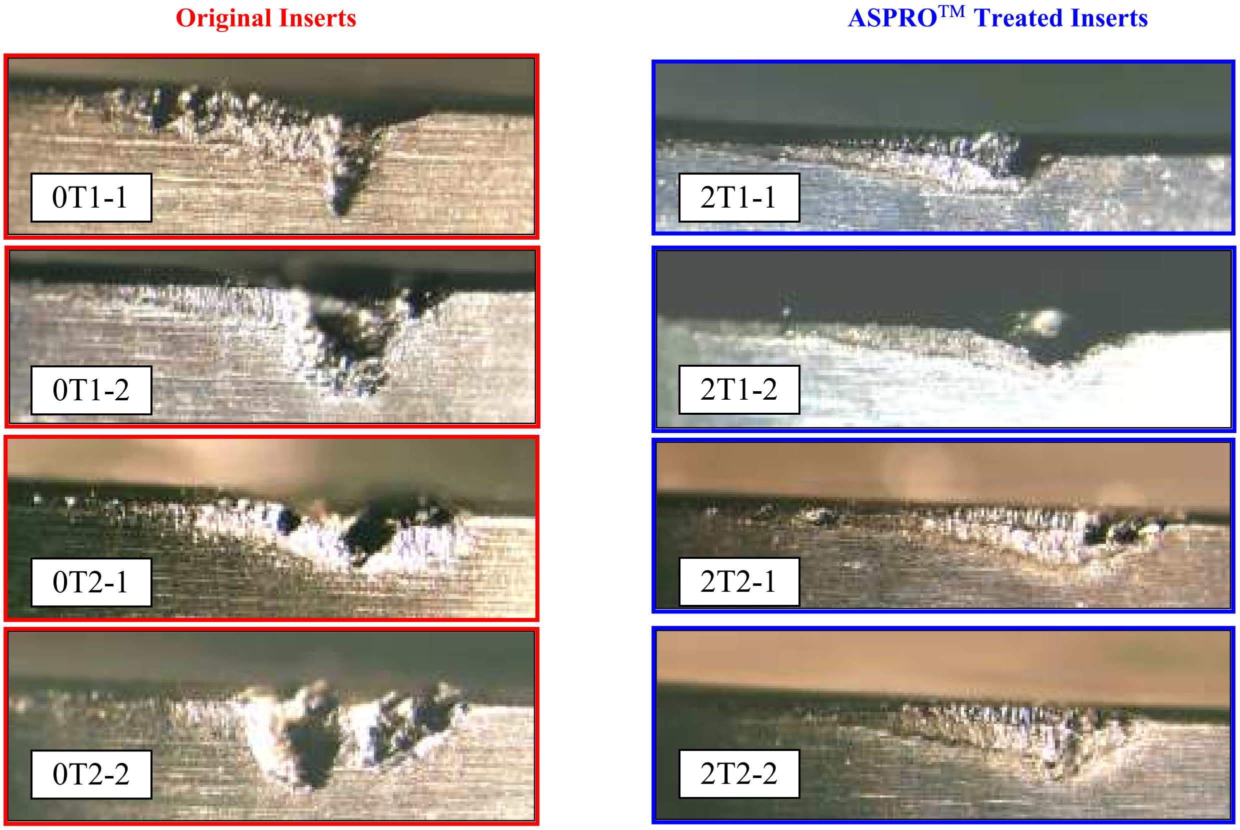
The machining tests are presented for Original and ASPRO™ treated ceramic cutting tool inserts are presented in Fig. 2. The following cutting conditions have been applied: cutting speed – 600 m/min, feed rate - 0.12 mm/tooth, depth of cut – 0.2 mm, work material – H13 steel, inserts – Mixed Alumina (Al_2O_3+TiC).



Remarks: *Percentages indicate overall improvement in Flank Wear of ASPRO ™ treated inserts vs. original inserts at corresponding cutting length.*

Fig. 2. Average Flank wears for Original (OT) and ASPRO™ treated (2T) mixed alumina ceramic cutting tool inserts.

Flank wears for Original and ASPRO™ treated Mixed Alumina cutting tool inserts after 2340 mm cutting length are presented in Fig. 3.



Remarks: *Original inserts are marked as 0T1-1, 0T1-2, 0T2-1, 0T2-2 and ASPRO™ treated inserts are 2T1-1, 2T1-2, 2T2-1, 2T2-2.*

Fig.3. Flank wears for Original and ASPRO™ treated Mixed Alumina cutting tool inserts

The wear measurements and micrographs showed overall improvements in Flank wear of ASPRO™ treated inserts vs. original inserts. These test results indicate that the ASPRO™ Conversion Technology can be applied to enhance the required properties for ceramic cutting tools, and as a result the ASPRO™ treated ceramic cutting tool inserts can offer significant advantages in machining hard materials and distinguish them from traditional steel, tungsten-carbide and ceramic cutting materials:

- Higher corrosion and oxidation resistance
- Higher abrasive wear resistance
- Higher hardness
- Increased thermal shock resistance
- Increased heat dispersion

Together, these properties permit to increase the rate of metal removal while obtaining longer tool life. Reduced operating time to produce a finished part, and reduced machine downtime through less frequent insert indexing and replacement result in an overall improvement in productivity and part cost reduction. It is deemed that the ASPRO™ treated ceramic inserts, on account of their increased thermal shock resistance, could therefore potentially capture a significant share of the market, by providing a cost-effective solution. The further development of improved ceramic cutting tool inserts will pave the way for laying the foundation towards developing an innovative technology for machining hard materials.

The ASPRO™ Conversion Technology exhibits the potential to extend the performance of advanced engineering ceramic materials far beyond traditional limits in cutting tools, engine components, materials processing, etc. The advances made through this technology now overcome the traditional technical shortcomings of ceramic components and enable the use of low-cost alumina ceramics.

ATS Spartec Inc. is interested in licensing the ASPRO™ Conversion Technology and collaborating with manufactures and research institutions to enhance the ceramic applications.

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Acknowledgements

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