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# Grinding and Super-Finishing Test Machine Project

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# Abstract:

A research project in The University of Akron to study grinding and super-finishing of silicon nitride ceramic was initiated by Dr. Siamak Farhad and sponsored by the Timken Company, with the assistance of undergraduate students Michael Simon, Ryan Hosso and Mathew Rozmajzl. The study required analysis of forces and scratches generated during grinding processes of silicon nitride samples. A testing assembly was designed and constructed to record the forces generated during grinding and super-finishing of silicon nitride samples in a computer-numerical-control machine. Silicon nitride samples were subjected to desired grinding and super-finishing operations and all forces generated during the process were recorded. The samples were then examined under an electron microscope to document, measure and study the material removal. All data was subjected to confidential analysis under direction of Dr. Siamak Farhad, and the Timken company and applicable analysis conclusions are being reached.

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# Introduction

Silicon nitride ceramic is used in a variety of engineering applications due to its high thermal resistance and hardness. Due to its ceramic nature, manufacturing of silicon nitride must account for its brittleness to achieve required quality. A process of interest is the grinding and super-finishing of ceramic silicon nitride using a grinding wheel. Although silicon nitride is brittle, when material removal occurs on a very small scale, the material removal can be plastic as well as brittle, providing an opportunity to study the material properties of silicon nitride. Study of these two modes of material removal during grinding under desired conditions will enable greater understanding of the material properties of silicon nitride, generating results which will be applicable both for Dr. Farhad's academic studies and for use by Timken Corporation.

# Testing and Data Elements of Interest

Grinding and super-finishing processes of interest were achieved by a CNC machine equipped with a diamond-tipped cutting wheel. CNC settings, such as spindle speed, for each test were determined in advance to achieve a desired range of test conditions. The silicon nitride samples were rectangular and identical to make the material a constant in the experiment. Analysis required all forces generated during grinding processes: forces normal to the silicon nitride surface exposed to grinding, and forces tangential and perpendicular to the rotation of the grinding wheel. It is also necessary to study the scratches generated in the silicon nitride samples. Both types of data will be processed, organized, and analyzed for the study.

# Testing Assembly Design and Creation

Development of a testing setup capable of meeting analysis needs was the first major goal of the project. To record forces during grinding processes, a Kistler type 9347c force sensor was acquired. The force sensor was selected based on its high sensitivity and accuracy, which is necessary due to the small scale of the grinding and degree of accuracy required for the materials science application. A custom mount assembly which held the force sensor, and a silicon nitride sample was designed and machined at Timken with the help of Joshua Campbell. During testing the mounting would hold the ceramic sample steady while all forces generated during the grinding process would be conducted through a metal plate and into the force sensor. The force sensor outputted signals to a Kistler 5073 amplifier, which was programmed using ManuWare software to convert signals from the force sensor into analog voltage signals. The analog voltage signals were recorded by a National Instruments Data Acquisition (DAQ) module and chassis, which converted the data into digital form which was entered into a computer via either an ethernet cable or wireless connection. The use of the amplifier was necessary to convert the low-magnitude, electronic signals outputted by the force sensor into voltage signals with a controlled scale which were readable by the DAQ. LabVIEW software was programmed and used to record the digital data and to convert it into a TDMS file for analysis in the future.

# Testing and Data Acquisition

Numerous silicon nitride samples were tested using the CNC machine and the testing assembly. For each test, a silicon nitride sample was mounted inside the CNC machine, which was programmed to preform several passes with its equipped grinding wheel, creating scratches in the sample. As the grinding wheel scratched each sample, forces recorded by the force sensor were recorded on LabVIEW. After each trial, LabVIEW created a TDMS file, which was then converted to a MAT file in MATLAB before being saved for use in later analysis. During testing, the CNC machine was operated by David Allen.

# Analysis

After data acquisition from testing was complete analysis was performed on the data.

Force data was filtered to reduce noise. It was then manipulated and measured in MATLAB and other programs according to confidential analysis developed by Timken company and Dr. Farhad.

Every scratch in the silicon nitride samples was assigned a number and photographed using an electron microscope supplied by The University of Akron. Each scratch was divided into regions based on whether the mode of material removal was ductile or brittle. Further confidential geometric and mathematical analysis was completed to study the material removal.

# Conclusion

The testing assembly was successfully designed, constructed, and verified to have sufficient accuracy, precision, and data acquisition rate for acceptable quality of measurements. Several successful tests were completed, and more will be completed in the future as part of the ongoing project. Analysis processes are being completed on data from the tests, and results have been verified as being useful to the aims of Dr. Farhad's and the Timken Company's research.

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This project was made possible by the work and support of several accomplices and professionals.

Dr. Siamak Farhad directed the project, helped utilize material science theory to execute the analysis and data acquisition, and secured support for the project from The University of Akron.

Joshua Campbell, a Timken Company employee, served as a liaison with Timken and coordinated their support for the project. He utilized Timken's expertise and his own professional skills in the field of material science to develop and utilize the theory behind the project and to correctly complete testing.

Mathew Rozmajzl and Ryan Hosso preformed tasks during every stage of the project.

University of Akron technicians Eric Pfiffner, Doug Noble and Associate Professor Daniel E. Kandray provided technical assistance in the use of the CNC machine, creation of the testing assembly and installation of computer software.

Kistler Employee David Allen provided technical support regarding the Kistler force sensor and amplifier used in the project.

# Appendix

Below is an example of an image of a scratch in a silicon nitride sample combined with a diagram displaying scratch depth.