Analytical and Numerical Study of Root Canal Instrumentation

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Faculty:
Jun Ni

Objectives

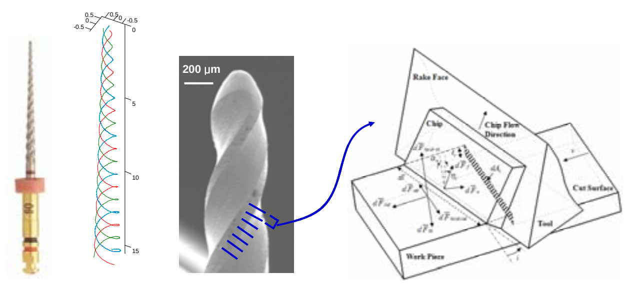
- Predict cutting forces in endodontic instrumentation using rotary NiTi files
- Characterize fatigue behavior of NiTi endodontic files
- Improve endodontic instrument design with fewer tool failure and reduced post operation sensation

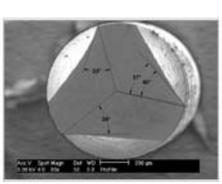
State-of-the-Art

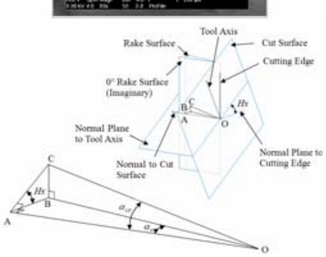
- Model the complex helical geometry of rotary files
- Quantify the impact of design parameters on the structural behavior of endodontic instruments
- Analyze the canal instrumentation as a material removal process with engineering methods

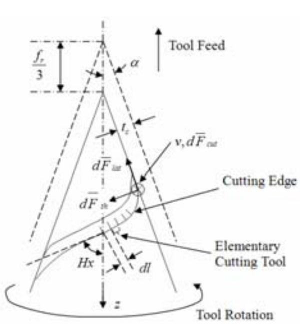
Approaches

- Simulate the mechanical behavior of rotary files with finite element method
- Model cutting forces on the basis of oblique cutting theory
- Utilize design of experiment method to characterize the fatigue behavior of rotary files



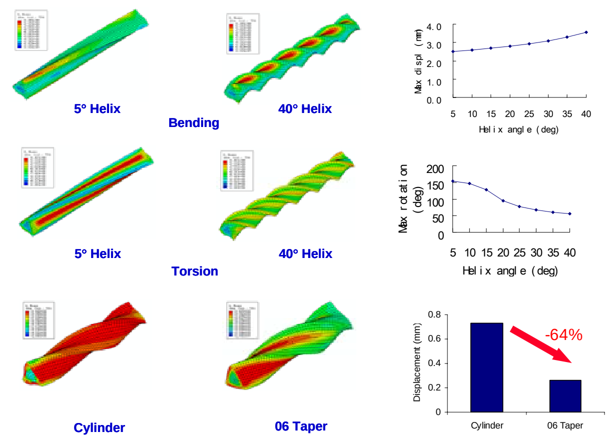




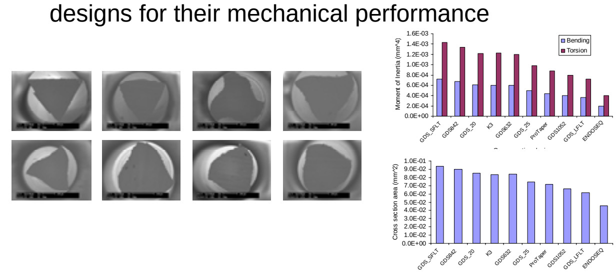


Accomplishments

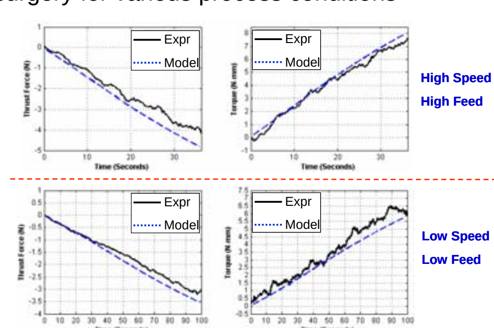
- Identified the impact of design parameters on the bending flexibility and torsional stiffness of endodontic files



- Evaluated the designs of commercial instrument designs for their mechanical performance



- Developed a generalized force model that accurately predicts the axial and torque forces in root canal surgery for various process conditions



Benefits

- Empower the advancement in medical device design
- The methodology can be utilized to research a variety of surgical processes

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Improvement of Gundrilling Processes for Crankshaft Oil Holes

Research Assistants/Staff
W. Zhang, J. Jung, X. Lin

Faculty:
J. Ni

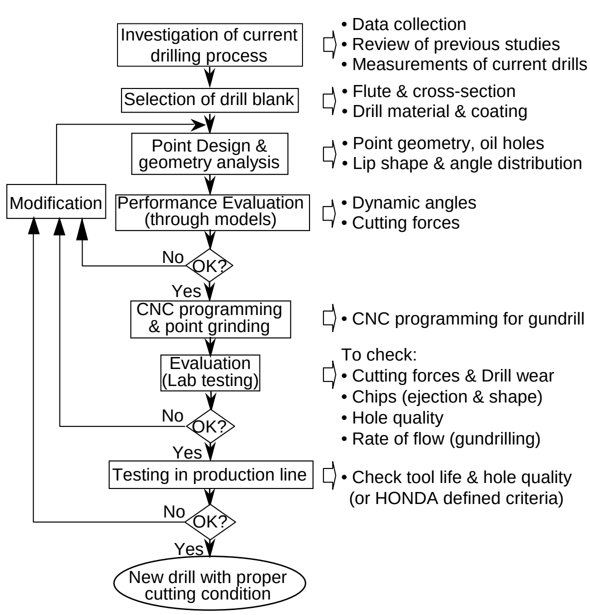
Objectives

To develop new gundrills and corresponding cutting conditions for drilling crankshaft oil-holes. When drilling holes in crankshafts composed of S48CM forging alloy steel (with manganese), an improvement of 20% is the project target, i.e. from 60 pcs per drill to 72 pcs per drill.

State-of-the-Art

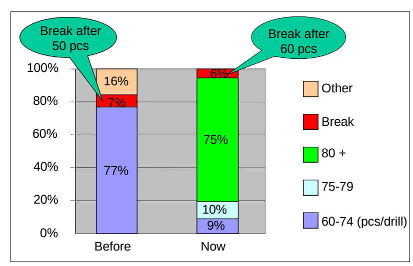
The most frequently encountered problems in drilling with gundrills are unsatisfactory tool life and poor hole quality. These problems are caused by improper drill geometry design, poor manufacture and tool material, and unsatisfactory cutting conditions, among others. These problems become even worse as the holes get deeper. Furthermore, new workpiece material, such as S48CM alloy steel, which was designed to have good mechanical properties, has very poor machinability. In drilling of S48CM, the tool life dropped 50% as compared with drilling of S48C that composed of lower manganese.

Approaches



Accomplishments

- Reviewed the previous studies on gundrilling performed by the Honda team
- Measured and analyzed the gundrills currently used in the production line
- Created geometry models for gundrills
- Completed the lab tests of gundrills composed of C5, C6 and C7 grade carbide and revealed some effects of the gundrill material on the gundrill wear in drilling S48CM
- Completed the lab tests of gundrills with Hardlube, TiAlN and TiN coatings and found some influences of the coating material and coating process on the tool life in drilling S48CM
- Carried out the lab and production tests of the newly designed gundrills, which are modified only in the gundrill geometry. An improvement of about 30% or higher (up to about 40,000 mm deep per drill) has been reached



Improvement of gundrill life

Future Work

- Continue to work on geometry modification to obtain even greater improvement (up to 100 pcs per drill) in the tool life
- Study the effects of the carbide grade on gundrill crater wear and find a method to reduce flank wear
- Further investigate the effects of gundrill coating on tool life
- Optimize the coolant pressure and flow rate to increase tool life

Sponsors

Honda of America Manufacturing, Inc.

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Deep hole Drilling of Aluminum

Research Assistants/Staff

F. Ke   X. Lin

Faculty:

J. Ni

Objectives

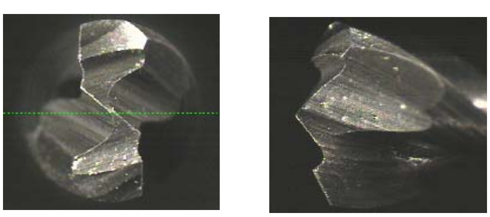
- To develop new drill geometry for deep hole drilling aluminum alloys.
- To improve the manufacturing efficiency by reducing pecking times and increasing feed rate.

State-of-the-Art

- Chip evacuation is the major problem in deep hole drilling, due to the confined cutting space and poor cutting conditions.
- Chip evacuation smoothness is directly influenced by drill chip.
- Specially designed drill point geometry can improve the chip properties and thus improve chip evacuation process.

Approaches

Small and well broken chips are preferred in small deep hole drilling. And how to break the chips to smaller pieces by drill point modification is important to obtain smooth chip evacuation process.



New drill point design

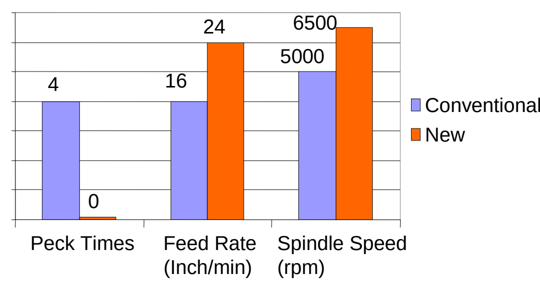
Drill with conventional point

Drill with new point

Chip comparison

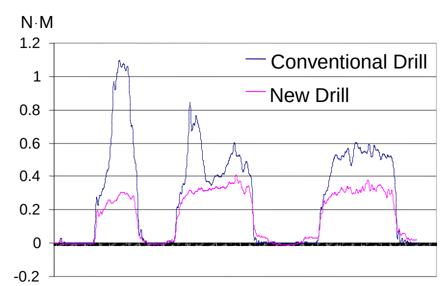
Accomplishments

- Drill pecking time is dramatically reduced. Current design, when drilling a hole of 3 mm in diameter and 37.5 mm deep on aluminum alloy, requires 4 pecks. When drilling with the new drill, no peck is necessary.



Drill Comparison

- Drilling torque is reduced by new point drill, and thus increased drill life



Torque Comparison

Future Work

- Further investigating drill point geometry for deep hole drilling.
- Investigate the effect on drill point on material build up on the flute, and how to reduce it.

Sponsor

NSF-I/UCRC, Delphi Automotive Systems

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Tool Geometry Measurement System

Research Assistants/Staff
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Objectives

To develop a new non-contact 3-D drill geometry measurement system which will measure:

- Drill bit geometry
- Drill flute cross section profile
- Drill wear

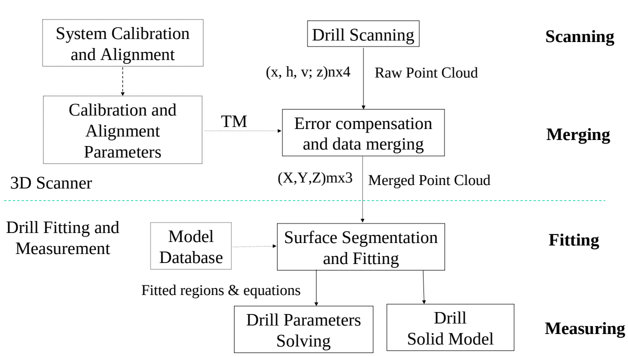
The system will greatly impact drill design, drill quality control, performance analysis, and reverse engineering.

State-of-the-Art

Drilling performance is significantly affected by drill geometry properties. Due to the complexity of drill geometry and wear, it's difficult to measure effectively and accurately. Current drill measurement devices, such as PG1000 Cutting Tool Inspection Systems, can only get geometric parameters from 2-D silhouette images. With the 3-D Tools Geometry Measurement System, all the parameters can be obtained automatically and efficiently. 3-D scanner with the TriCam laser sensor can quickly measure the surface of a drill. 3-D scanner with the new ConoProbe laser sensor can accurately measure all the surface of a drill even with very small and very complex areas.

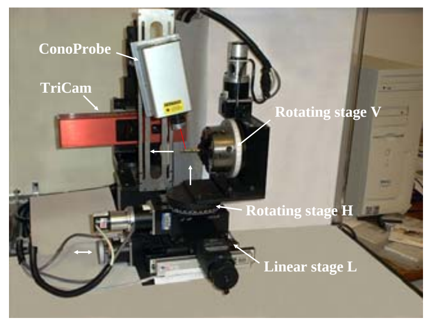
Approaches

A new laser sensor, Optimet ConoProbe, is used to develop a new 3-D scanner to obtain both higher measurement accuracy and the ability to measure very small complex areas. Using special system configuration and new algorithms, the system can measure any design of drills and get all the geometry parameters. The following flowchart describes the approaches of drill scanning and measurement.

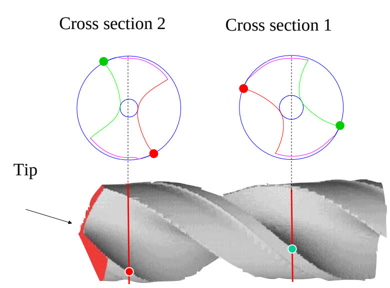


Accomplishments

- Developed a new laser sensor 3-D scanner (non-contact, automatic, high accuracy, true 3-D, full 3-D)
- Developed all the algorithms (path planning, surface scanning; data filtering, merging, segmentation, fitting; parameter measurement, etc.) for measuring drills



System with two laser sensors



Drill scanning and fitting

Future Work

- Implement and optimize all the software for current system
  - •System calibration
  - •System alignment
  - •Data merging
  - •Interactive path planner
  - •Modeling and fitting

Sponsors

NSF-I/UCRC

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High Throughput Deep Hole Drilling

Research Assistants/Staff
J. Jung, X. Lin

Faculty:
J. Ni

Objectives

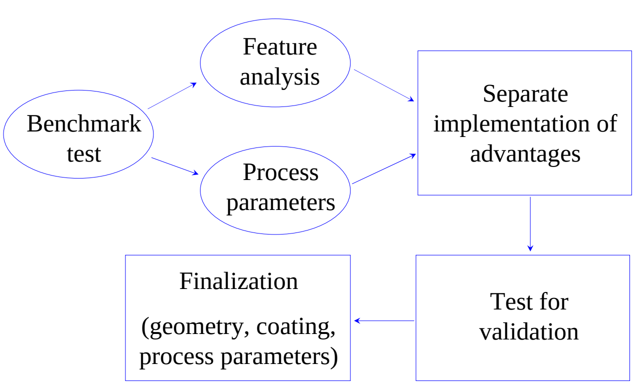
- To perform the benchmark study of commercial gundrills designed for deep hole drilling in such materials as gray cast iron, aluminum, nodular iron, steel, forged steel and compacted graphite iron
- To obtain pros/cons of each drill required to make an aspect ratio of 20 under a much higher penetration rate than used in the current automobile production line
- To apply empirical findings to developing appropriate drills in terms of geometry and process parameters through iterations of implementation and validation

Problem Statement

- Gundrills can experience premature failures due to chipping, excessive wear at the corner and inner edge, and inefficient chip evacuation.
- Significant factors related to the failures include clearance angle, inner/outer cutting angle, the sizes of coolant annuli, feed rate and surface footage.
- Coating process is an issue for gundrills from the viewpoint of the strength of the brazing joint and the distortion of the long shank.

Approaches

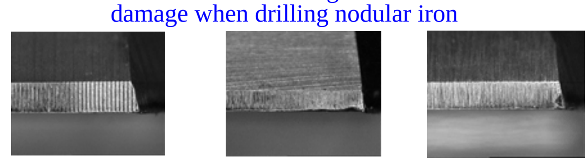
- The benchmark test is performed for a group of gundrills under the same cutting conditions.
- The drills are measured based on drilling forces, wear, cutting noise, coolant volume flow rate, chip morphology, the number of holes made.
- Drill features and process parameters are analyzed, and advantages are applied to improving geometry and process



Accomplishments

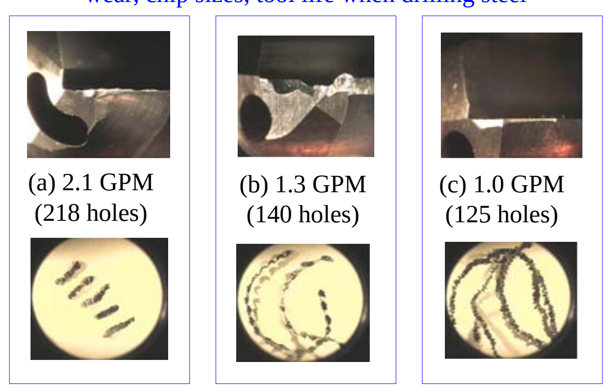
- The benchmark tests were finished for 5 materials: gray cast iron, aluminum, nodular iron, steel, and C.G.I.
- Dominant features for failure modes were analyzed based on the types of work materials (abrasive and non-abrasive) and new process parameters were proposed for steel and C.G.I.

The effect of outer angle on corner damage when drilling nodular iron



(a) 40° (undamaged) (b) 30° (damaged) (c) 30° (damaged)

The effect of coolant volume flow rate (GPM) on wear, chip sizes, tool life when drilling steel



(a) 2.1 GPM (218 holes) (b) 1.3 GPM (140 holes) (c) 1.0 GPM (125 holes)

Future Work

- Advantageous features will be implemented and validated for optimization of geometry and process parameters.
- Coating materials and process will be further studied to improve wear resistance and tool life while maintaining tool strength and dimension.

Sponsors

NCMS-HTHM Consortium (Ford, GM, DaimlerChrysler, StarCutter, Ionbond, Kennametal/Greenfield, Caterpillar)

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Ultrasonic Assisted Dry Drilling of Aluminum

Research Assistants/Staff
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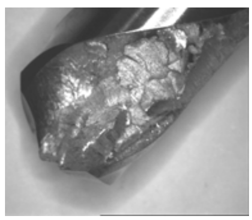
Faculty:
J. Yuan J. Ni

Objectives

- To analyze the cutting mechanism of ultrasonic drilling
- To investigate the effect of ultrasonic drilling on drilling forces, chip evacuation, and hole quality when dry drilling aluminum

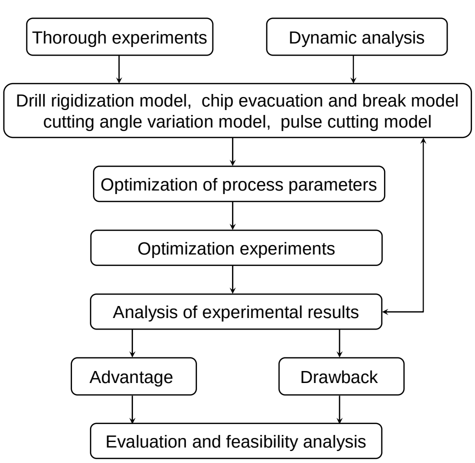
State-of-the-Art



- A rough flute surface, caused by adhering chip deposits, and severe build-up in the drill flutes are the main factors that prohibit dry drilling from being used for aluminum alloys.
- Ultrasonic machining has proven to be an effective method for machining materials with low ductility and high hardness, such as ceramics, inorganic glass, Ni/ Ti alloys, etc.
- The use of ultrasonic machining for dry drilling of aluminum alloys is a relatively recent, emerging technology.

Approaches

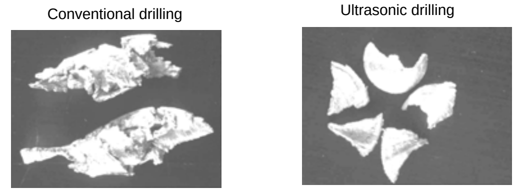
A self-tuning ultrasonic generator and a rotatable ultrasonic drilling head, which vibrates axially, are utilized to conduct the dry drilling tests. The following flowchart describes the approach for investigating the effectiveness of ultrasonic drilling.



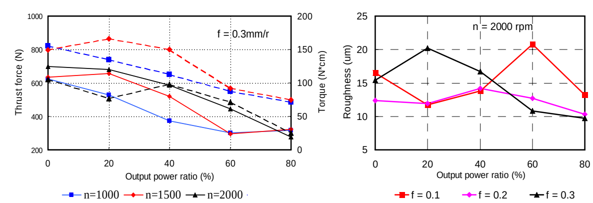
Accomplishments

- The models describing the cutting angle variation, drill rigidization, chip evacuation, and pulse cutting process were developed. Thus, the effect of ultrasonic drilling on the drilling process and hole quality can be well understood.
- Thorough experiments were carried out to investigate the effectiveness of ultrasonic dry drilling of aluminum.

Conventional drilling   Ultrasonic drilling

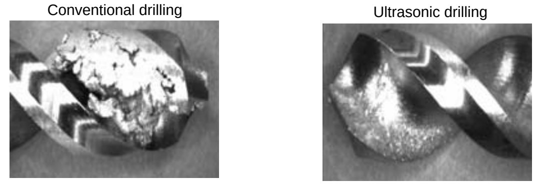


Chip forms



Drilling forces and surface roughness

Conventional drilling   Ultrasonic drilling



Drill flute after drilling 60 holes

Future Work

- Modify the joint structure between the drill and the ultrasonic head to reduce or eliminate heat generation.
- Investigate the effectiveness of ultrasonic drilling under more severe drilling conditions.

Sponsors

Ford, General Motors, DaimlerChrysler, TRC
(Through the Dry Machining of Aluminum Consortium)

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Investigation on Core Drilling of Ceramic Materials

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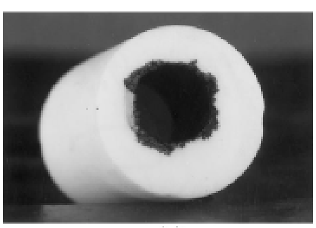
Faculty:
J. Ni and A. Shih

Objectives

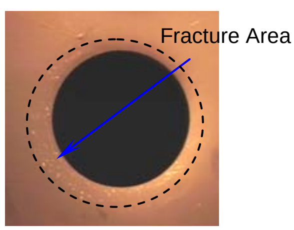
- Investigate the feasibility to use conventional CNC machines to drill holes on ceramic with high quality
- Improve the design of conventional core drill to minimize fracture area in ceramic drilling process

State-of-the-Art

- Drilling holes in ceramic with high quality is very difficult and expensive due to high hardness, wear resistance and brittleness of ceramic
- Ultrasonic core drilling and manually controlled core drilling are the main methods to drill holes in ceramic right now, however, both of them have the problem of fracture at hole exit in drilling process



Exit of the hole on Alumina, drilled by ultrasonic core drilling process



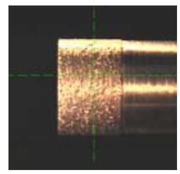
Exit of the hole on Zirconia, drilled by manually controlled core drilling process

Approaches

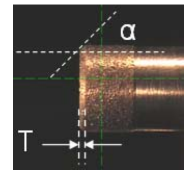
- Axis symmetric finite element modeling of core drilling process has been used to study the effect of core drill geometry on stress distribution in core drilling of ceramic
- A series of manually controlled core drilling tests are conducted on Zirconia work pieces with improved core drill
- Drilling tests of Zirconia using improved core drill on conventional CNC machine

Accomplishments

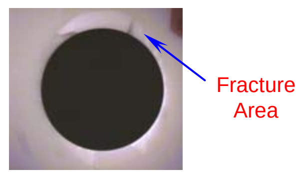
- Performance evaluation of conventional core drill and improved core drill on a conventional CNC machine



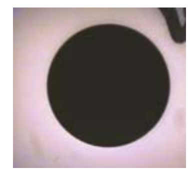
Conventional Flat Core Drill



Improved Core Drill

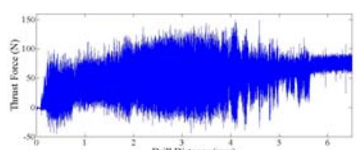


Exit of the Hole, Drilled by Conventional Flat Core Drill on CNC Machine

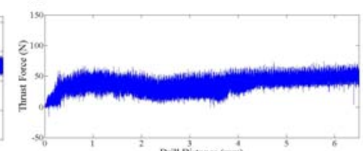


Exit of the Hole, Drilled by Improved Core Drill on CNC Machine

- Measurement of thrust force in core drilling process



Thrust Force, Drilled by Conventional Flat Drill on CNC Machine



Thrust Force, Drilled by Improved Drill on CNC Machine

Future Work

- Optimization of ceramic core drilling process using improved core drill on conventional CNC machine

Application

- Fabrication of ceramic micro-engine components

Intake cap

Swing arm

Sponsors

- Powerix Technologies Inc

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