Metal Cutting Process Challenges for LARGE PARTS & TOUGH MATERIALS

2019 JAN.

TOSHIBA MACHINE
Best Partner of Leading Industries
Building infrastructure is very important for Indian Socio economic growth.

Bogibeel Bridge

Chenani – Nashri Tunnel

Bandra – Worli Sea Link
Large Machine Tools are one of the key factors of infrastructure to do Machining of the Large Parts of CONSTRUCTION, MINING MACHINERY, POWER GENERATION, RAIL WAY, AIR CRAFT, OIL DRILLING EQUIPMENTS and so on.
LARGE MACHINERY – MAJOR PARTS as 1 PIECE CASTING

Bridge Machine – BED Weighs 55.4 Tons

DIE CAST Machine – PLATEN Weighs 56 Tons
What’s NEW with TOSHIBA MACHINE

NEW TECHnology of NEXt GENeration. MANUFACTURING

- 3D Metal Laminate technology
- Friction Stir Welding
- New Solutions for AIR CRAFT – LARGE Parts
- Machining Support by SENSOR LESS Monitoring
- IoT Integrated MODEL Machine Shop
3D Metal Laminate Technology

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Large size Laminate Molding Machine for **Inconel Laminating.**

- More than 600mm diameter laminate molding that is not achievable by current powder additive manufacturing.
- High Power laser (~6kW) **Max laminate molding speed** 500 cc/h
- High speed molding by **2 head**
- Taper shape molding by Tilt head

**High volume “500 cc/h × 2 = 1,000 cc/h”**
3D Metal Laminate Technology

Applications

- Material: INCONEL 718
- Size: Φ324mm x H314mm
- Molding weight: 9.1kg
- Molding time: 16.5 hour

Manufacturing process

- 3D laminate
  - Near net shape
- Heat treatment
  - Annealing
  - Aging treatment
- Machining
  - Machining
  - Grinding

Process

- Cylinder
- Rib
- Flange

Applicable into jet engines and other tough material.
We developed new welding technology (FSW: Friction Stir Welding)

What is Friction stir welding

Push rotating tool into workpieces, then frictional heat lets material soften and stirring

It is new welding technology instead of current welding methods

FSW Tool

Rotation

Bonding material

Stirring

Shoulder

Probe

FSW Tool
Friction stir welding (FSW)

- Environment friendly
- Energy saving

Make transport equipment more light weight

FSW for Aluminum material that was difficult for welding

Rocket
Jet air plane

Outer case of fuel tank
Bullet train
Automobile
Ship

Frame
Bonnet
MERITS - FSW TECHNOLOGY

◆ JOINING OF METAL WHICH RESISTS MORE

- Aluminium Alloys Which resists a LOT to JOIN

◆ LESS – DEFORMATION, NO CRACK AND PORES

- Process in 1/5th of Temperature Raise Compare to ARC Welding, Contraction and Expansion is Reduced, Normal Deformation is 1/10th Compare to ARC Welding

◆ JOINT STRENGTH – NOT MUCH CHANGE

- Grain Refinement Increases the Strength of Joint, Sometimes Strength is HIGHER Than BASE METAL

◆ COMPLEX HOLLOW STRUCTURE IS POSSIBLE

- Complete Hollow Structure is POSSIBLE in FSW Which allows More Flexibility in FLOW GROOVES of Liquid & Gas。

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MERITS - FSW TECHNOLOGY

- **Joining of HOMOGENEOUS & DISMILIAR Materials is POSSIBLE**
  - ALUMINIUM × ALUMINIUM
  - S.S × S.S
  - Steel × Steel

  Joining is Difficult due to HIGH Bonding Temp.  
  TOSHIBA MACHINE Develop SPL Tools with TOOL MAKER

- **JOINING OF COMPLEX SHAPES**
  - Joining Curves
  - Joining SQUARE Tubes → POSSIBILITY with ROTARY TABLE

  Proceed to NEXT OPERATION after JOINING ⇒ OPTIMIZED PROCESS
FSW Results ADVERSE Effect in Machine Tools  ⇒ HEAT & LOAD

< HEAT >  Processing HEAT Reaches 500~600℃  ⇒ Possibility of SPINDLE BEARING Failure。

<LOAD>  Z - Large Load Applied in AXIAL Direction。  ⇒ Bearing Load EXCEEDS Limit、 Bearing Fall into Disrepair。

FSW-TOOL Introduction

<HEAT>  Cooling Mechanism

⇒ FLOW COOLANT  
HEAT DISSIPATION HEAT

< LOAD > DISTRIBUTION MECHANISM

BEARING OF HEAVY LOAD
⇒ Distribute the LOAD by Receiving at SPINDLE HEAD
5-Axis Head with CHIP COLLECTION APPARATUS, Tandem Plate

- Machining time decrease 30% compared to conventional machine.
- Post process time decrease 40% by improving machining accuracy decrease.
High-speed machining of aluminum aircraft parts

High efficiency horizontal high-speed profiler

Basic machine and full-enclosure

Horizontal profiler application

APC
Set-up ST
Spindle speed: 30,000min⁻¹
Main motor: 120kW, Tool shank: HSK-A63/80

Rapid feedrate: 50m/min
Cutting feedrate: 30,000mm/min
X-axis is by Linear-motor drive and Y and Z axes are driven by twin-ball screw mechanism.
Robust feeding system and high rigid mechanism designed by CAE, high-speed cutting more than 10 times than the conventional machine. (Rough cutting operation)
Optimized shortest cutting time is suggested.
Toshiba Machine Developing ULTRA HIGH Pressure Coolant Systems

**CHALLENGES**

- Work Hardening, Shorter Tool Life
- Continuous Chips and Built Up Edges are the Factors Hinders the Machining Process.

**WHAT is ULTRA HIGH PRESSURE COOLANT**

By Supplying the Coolant at Cutting Edge with ULTRA HIGH PRESSURE, it Cuts the Chips and Increase the TOOL LIFE.

<table>
<thead>
<tr>
<th>Pressure Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW Pr.</td>
<td>0.7 Mpa</td>
</tr>
<tr>
<td>HIGH Pr.</td>
<td>10 MPa</td>
</tr>
<tr>
<td>Extra HIGH Pr.</td>
<td></td>
</tr>
</tbody>
</table>

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CHALLENGING – TOUGH to CUT Materials

- Processing by Ultra High Pressure
  - MACHINE: TUE-100(S)
  - Max Coolant Pr: 20MPa
  - Process by Through Coolant

- EXAMPLE
  - Material: Inconel718
  - Size: Φ500×100
  - Tool Tip: Cemented Carbide
  - Chip Breaking - IMPROVED
  - Tool Life - EXTENDED

Productivity 33% UP
CHALLENGES – Ultra Hi Pressure Coolant Technology

Improved Cutting Conditions – TOOL LIFE Extended

MANY RELATED PARAMETERS, DIFFICULT to FIND OPTIMUM PROCESS CONDITIONS
- Cutting Speed
- Feed
- Depth of Cut
- Coolant Pressure
- Method of Coolant Applying
- Process (Rough, Finish)
- Cutting Insert

Adapt to Machining Conditions, It is Necessary to Choose Parameters

Machining Test Considering QUALITY ENGINEERING

WHAT is QUALITY ENGINEERING
Method of Efficiently Realize the R&D, Product & Process Design

FEATURE
- Possibility of Achieving the Target in SHORT Period
- You can Know the Influence of Each Parameter
CHALLENGES – Ultra Hi Pressure Coolant Technology

Test by Quality Engineering

<table>
<thead>
<tr>
<th>Control Factor</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cs - V [m/min]</td>
<td>Small</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>Big</td>
</tr>
<tr>
<td>FEED [mm/rev]</td>
<td>Small</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>Big</td>
</tr>
<tr>
<td>DoC [mm]</td>
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</tr>
<tr>
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<td></td>
<td>Big</td>
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General Exam
No of Test = 43 = 64 Times

Quality Engineering
Introduced Experiment Design Method
⇒ To obtain optimum machining conditions, 12 times machining in actual machine

Process Condition: Roughing
Material: Inconel 718
Size: Φ500 × 100
Cutting Tool: Cemented carbide

Compared with recommended conditions of maker
Productivity 2.4 UP

TOSHIBA MACHINE WILL CONDUCT VARIOUS TEST TO SUPPORT THEIR CLIENTS

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Workpiece: Turbine Disk  
Machine: TUE-100 (S)  
Material: Inconel 718

**OD/End Facing 10MPa**

- Rough
- Cutting Tip ⇒ Ceramic

- Finish
- Cutting Tip ⇒ CBN

After Rough
After Finish
Sensor-less monitoring
Cutting force observer developed by Keio Univ. Generally to sense cutting force needs torque sensor, however, without any special sensor, NC will process to cutting force with motor current, encoder rotation and position and scale feedbacks.

During cutting, cutting force will be monitored at real-time. Assume force on cutting blades to work piece ⇒ Faulty cut detection
Not necessary for special sensor → Cheaper solution

「Faulty cut detection」 developing

(1) Tool breakage detection
Detected by the estimate cutting force

(2) Tool breakage detection
Detected by comparing with basic cutting force and monitored cutting force

No breakage
breakage

Machining support functions
Sensor-less monitoring
Detect vibration in boring operation

Now developing

To avoid detected vibration, spindle speed must be changed.

Detect vibration

Under Keio Univ. simulation, they found out to avoid vibration with cyclic operation

Avoid vibration

- Spindle speed must be changed in cyclic
- Synchronized feed F, vibration will be avoided.
# IoT at Machine Tools

<table>
<thead>
<tr>
<th>Items</th>
<th>Vibration data process and analyze to preview machine manage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>At our Technical Center in our Gotenba Plant, we will preview BM-1250(U) for vibration data process and analyze. Data will be sent in Cloud and/or Fact eye to server and will be observed to manage.</td>
</tr>
</tbody>
</table>

## Preview machine tools damage (Cloud・On-plemises)

- Preview machine tools damage using vibration data process and analyze.
- Data will be sent in Cloud and observed to manage.

## Remote diagnosis system

- Remote diagnosis and monitoring by peripheral devices.
- Through internet, MCW and BM-U at Technical Center will be always monitored during cutting and it will be displayed in NC screen. Edit data/program, sequence ladder, I/O and so on.
## IoT at Machine tools

<table>
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</thead>
<tbody>
<tr>
<td><strong>3</strong></td>
<td>Visible cutting process at factory</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>Visible assembling at factory</td>
</tr>
</tbody>
</table>

### Gotenba NO.2 Factory Layout
Assembling process will be displayed on the machine.
Sincere Thanks For Listening

ANY QUERIES or Clarifications !!!

(or)

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