GF Machining Solutions

Speed of Development: The Future of Machine Building

Sergei Schurov 23/06/2016
Machine Tools Industry: Journey Through the Time

Heritage
Swiss Trains are Picking up Speed!

Gotthard Story:
Travel time will be reduced up to 1hr vs. existing route

Gotthard Tunnel start to finish:
- Upper tunnel 1872 – 1882:
  - 10 years, 15 km
- Base tunnel 2004 – 2016:
  - 12 years, 57 km

Productivity gain: 320%

Saving: 25%
Technology Development Train is on the Fast Track

Technology pace accelerated

... and so has product cycle time

Source: Michael Mace “Map of the Future”, Talks at Google 2013

Machine Tools industry Makes no Exception

1954
One of the first EDM die sinking machines

1969
The first CNC WEDM machine

<table>
<thead>
<tr>
<th>WEDM Generator</th>
<th>1960</th>
<th>1975</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Efficiency (%)</td>
<td>7</td>
<td>70</td>
<td>85</td>
</tr>
<tr>
<td>Costs reduction (%)</td>
<td>100</td>
<td>70</td>
<td>&lt;30</td>
</tr>
<tr>
<td>Cutting speed (mm²/min)</td>
<td>7</td>
<td>20</td>
<td>500</td>
</tr>
</tbody>
</table>

2016 Today
Georg Fischer group are industrial pioneers for over two centuries

GF was founded more than 200 years ago and has taken quite a few steps to arrive where it is today. Since 1931 GF is listed on the Swiss Stock Exchange.
Georg Fischer Corporation in 2015

- Countries: 32
- Companies: 121
- Production plants: 45
- Centers of competence: 38

GF Piping Systems: 39% CHF 1 417 million
GF Automotive: 36% CHF 1 321 million
GF Machining Solutions: 25% CHF 902 million

Total sales in 2015: CHF 3 640 million, 14 400 employees worldwide
GF Machining Solutions
A complete solution provider

- GF Machining Solutions is a leading provider of Machines and Automation Solutions for high precision manufacturing technologies
- Global sales at 902 Mio in 2015
- HQ in Switzerland with 3,003 employees at 35 companies worldwide

- GF Machining Solutions is a premium brand in these core businesses:
Focus on EDM technology: **Electric Discharge Machines**

- A workpiece and tool are placed in the work position without touch.
- A gap remains, filled by the liquid "dielectric." The workpiece and the tool are connected to a power source.
- An electrical switch ensures pulsating current flows between power source, workpiece and tool.
- EDM process applies no mechanical force and is not sensitive to the hardness of the workpiece material.

**Operating Principle**

**EDM process is ideally suited for high precision machining requirements.**
EDM Process examples:

**Die Sinking EDM**

The required shape is formed negatively in the metal or another conductive material with a three-dimensional electrode.

**Wire EDM**

The machine under CNC control cuts the profile in conductive material by guiding moving wire along the programmed path.
EDM Process is notoriously difficult to control

- High energies involved, up to $10^7$ W/mm$^2$
- Can easily degenerate: welding or nothing
- Attempts were made to model the EDM process, however no comprehensive model of it exists to date due to complexity of phenomena
  + Thermal
  + Electrical
  + Electro-physical
- Non-linear behaviour: multivariable stochastic control problem

No surprise that EDM whole-heartedly embraced CNC opportunities from start
EDM technology progress is matching electronics evolution rate

From 1970 to 2006….. number of transistors in a PC processor has multiplied

\[ X \, 1,000,000 \, \text{Times} \]

Today EDM technology roughly at 20% of its theoretical potential – progress must continue

In just 10 years … EDM process has become

\[ 340\% \, \text{Faster !!!} \]
Early progress was achieved by using Numerical Control technology

Before

- Performance derived from dedicated hardware: control boards, drives, motors, sensors
- Handcrafted software assured optimised performance to compensate for hardware component limitations
- Hardware (electronics) based control algorithms or simple calculations heavily restricted by available computing power

Now

- Dedicated hardware still exists as ASIC’s, efficiently designed by specialist companies
- Standard operating systems and development libraries provided by mainstream suppliers of PC Software
- Processor speed evolution changed the rules by making it possible creating parallel real time control systems running on the same CPU

Development resources now focus on highly optimised control and customer applications
Wire EDM machine today is a sophisticated multi-technology product

- Mechanical systems
  - Stability and precision

- Liquid dielectric management
  - Suitable EDM erosion conditions

- EDM generator
  - Speed and performance

- Numerical control system
  - Machine programmability

- HMI
  - Man-machine interaction

- Automation systems
  - Productivity and autonomy

Future improvements will increasingly rely on cross-system design optimisation
Machine Tools Industry: Journey Through the Time

Model based design
Modelling applications for machine tools

- Data rendering and off-line algorithm development
  - Example: Wire path optimisation and protection strategies

- Modelling of physical processes or control events
  - Example: Dielectric level control system

- Iterative Learning Control
  - Example: Optimise process flow for repetitive control events

- System modelling of individual modules or sub-systems
  - Example: Machine tool changer optimised for speed and load
Wire CNC path Modelling: optimise CNC algorithms

- **Goal:** simulate EDM specific behaviour
  - With milling: feed forward mode, no feedback
  - With EDM: feedback mandatory
    - Gap piece-wire too small: short-circuit → no sparking
    - Gap piece-wire too big: open-circuit → no sparking
    - Gap piece-wire well controlled → correct sparking

- **Example:** wire is flexible
  - Simulate contour path deformation (wire trailing error)

**Benefit:** accelerate development by avoiding multiple experiments with real machine
Dielectric Level Control: Maximise system performance

System physical design

Closed loop mathematical model

Development process flow includes modelling phase

MATLAB Mathematical Model

SIMULINK System Model

SIMULINK Simulation

ANALYSIS Mechanical Rework

MACHINE Final Tests

Benefit: reduce number of mechanical design iterations and speed up validation
Iterative Learning Control
Optimise process flow

- In die sinking EDM, periodic flushing “jump” is applied to clear cavity from erosion debris

- After the jump, the process control is unstable due to particles still moving

- Solution: ILC
  Iterative Learning Control

- Tracking history of repetitive system behaviour allows optimising control parameters

**Benefit: improved system performance after initial adaptation period**
Automation model of a Tool Changer: Mathematical model to physical processes

Benefit: optimise parameters for reliable operation of mechanical system
Machine Tools Industry: Journey Through the Time

Outlook
Machines are using sophisticated control systems that are rapidly becoming development bottleneck

- Control software acts as a ‘glue’ joining together mechanics and applications
- For the first time allows to see limitations from user prospective
- Laborious process to get to the point where results are visible

*Control software development loop must become faster*
Machine design evolution: Challenges and opportunities

Response comes in several steps

- **Step 1:** Visual programming environment
- **Step 2:** Model based design approach in most functions
- **Step 3:** Use simulation modules as portable exchange media between teams for validation and interaction
- **Step 4:** ?

*Development tools and methods must advance to next level*
Are we \textit{smart} enough?

Two major market forces:

1. Production is increasingly concentrated in the areas with shortages of skilled labour

2. The intelligent skilled workers are increasingly moving into creative roles

Fulfilling customer demands using conventional development methods will be more and more restrictive and slow: engineering needs to become \textit{smarter}

\textit{Previously enough to invent – now need to continuously re-invent and at faster pace!}
What is next?

Step 4: Complete machine simulation

Deeply integrated systems
- “System in Silicon” – complete machine modelling
  + Physical systems, control processes, user applications
- Late decisions based on market feedback
  + Field test inputs ‘just in time’ to optimise at pre-launch phase

Industrial Internet: Industry 4.0
- Smart factories with
  + Automated production process flow optimisation
- Self learning machines
  + Eliminate process tuning from user prospective

The next station: Intelligent Machines
Smart engineering and accelerating development pace will ensure more Gotthard Tunnels will be built … … in less time