Virtual Simulation of Machine Tool Operation

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RCMT introduction

- Research Center of Manufacturing Technology (RCMT) is an institute of Faculty of Mechanical Engineering, Czech Technical University in Prague
- RCMT was founded in 2000 by the Association of Engineering Technology with the support of the Czech Ministry of Education
- Three strategic tasks:
  - **Education** of young professionals in bachelor’s, master’s and doctoral programmes of study
  - **Research** in the field of production machines and manufacturing technology
  - **Support to companies** in the field of production machines and manufacturing technology
Everybody needs parts, elements and components

All producers of goods need machine tools and production technologies to produce their specific parts.
Basic manufacturing technologies

- material dividing
- material forming and casting
- material removing
- material adding

Basic requests on machine tools and technologies

- Accuracy
- Quality
- Productivity
- Reliability
- Efficiency
- Environmentally friendly

How can industry 4.0 support reaching of these goals with higher added value?
Traditional machine tool builders
Selected case: large part production systems

Typical scenario:
- large machine tools with skilled operators
- large parts with high price
- piece and low series production

How can industry 4.0 help in these specific manufacturing cases?
Understanding of companies to I4.0 concept

- survey of German manufacturing SMEs done by Fraunhofer IPA Bayreuth:
  - 79% of companies are newcomers in I4.0 concept
  - 76% of companies does not understand economical benefits
  - 85% of companies does not have knowledge of principles
  - (results for machinery industry companies only)

- positive real examples should be presented
  - semi industrial testbeds
  - specific industrial applications

- focus on relatively lower levels of the pyramid
  - intelligent production systems
  - digital twin of workpiece and machine tool

Source: ADDIXA CONTROL
Step 1: Intelligent production systems

- Example: Intelligent fixture

- Operator portable screen with SW for clamping device control and communication
- Machine tool control system
- Industrial PC with specific SW
- Technology planning and optimization

75% savings of idle time

- Part position checking
- Workpiece leveling
- Clamping
- Machining

Current situation (manual part setup)

Enabling technology (additional HW&SW)

System operation (semiautomatic)
Step 2: Machine tool models for virtual machining

- CAD data
- CAM processing
- FEM model of the structure
- joint model of the structure and feed drives
- structured data storage
- parallel check of running machine
- process proposal and virtual testing
- machine tool design and virtual testing
- virtual machining, data sharing with other systems
Example of virtual machining optimization

- comparison of various control system setting and NC functions to quality of the workpiece surface
Cyber physical approach to identify machining errors

- CAM simulation
Cyber physical approach to identify machining errors

- CNC system interpolation

NC data visualization
Cyber physical approach to identify machining errors

- CNC system interpolation
- Machine tool dynamic model

CAD

CNC

MT structure + feed drives

Machine Tool Digital Twin

Workpiece Digital Twin

Complete virtual machining
Example of part production optimization

- Machine tool: Kovosvit MAS MCU 700V – 5X
- Workpiece: compressor wheel Ø 240 x 120 mm, finishing machining

- Original NC program:
  - machining time of 6 min
  - surface accuracy of 0.04 mm (predicted and also measured)

- Optimized NC program
  - machining time of 2.5 min (-58%)
  - the same surface accuracy of 0.04 mm (machined and measured)
Step 2+: Decision making support

- **machine tool user**
  - **workpiece**
    - size, material, technological operations
    - surface quality, accuracy, productivity
    - price of the workpiece
    - acceptable market price

- **machine tool producer**
  - cutting tool and machine tool
    - stiffness, accuracy, performance
    - machine tool price, running costs

Point of success of the whole production chain

Digital twins can decrease the decision risk
Step 3: Digital Twin (MT/W) as an universal data collector

- Weakness of the current manufacturing control systems
  - imperfect data collection and connection
  - low integration level and synergic use of the data
- We do not use existing data efficiently: **data from virtual and real sources** are used only partial; they are **not combined**; the **feedback is missing**.

[Diagram showing the relationship between real and virtual machine tools and data collection for maintenance and quality control, with the source credited to Fraunhofer IPT.]
Conclusion

- Industry 4.0 has potential significantly improve production system usable value in terms of accuracy, quality, productivity, reliability, efficiency and environmentally friendliness.

- **Intelligent production systems** is one of keystones of Industry 4.0, but still they are not an industrial standard in many specific production sectors.

- Expansion of **digital twin of machine tools** and **workpieces** will be next step for collection and connection of all types of existing data for manufacturing process control.

- We need **positive real examples** to boost up decision of companies (especially SMEs) in direction of Industry 4.0. This needs realization of **testbeds** and **pilot studies**.
Thank you for your attention

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