A Digital factory twin for continuous improvement in Milling Spindle manufacturing processes

CIS Digital Twin Days

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Innovation Network – Technology Office – Digital Business Unit
+ Outline

- Introduction – GFMS and its Digital Business Unit
- GFMS Digital Twin Framework
- Boost 4.0: Spindle Factory and Milling machine application case
- Factory Twin
- Predictive maintenance
- Real Time Process Monitoring
- Summary and Conclusions
Introduction
The three divisions of GF
Key figures 2020

<table>
<thead>
<tr>
<th>Division</th>
<th>Companies</th>
<th>Employees</th>
<th>Sales (CHF million)</th>
</tr>
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<tbody>
<tr>
<td>GF Corporation</td>
<td>137</td>
<td>14'118</td>
<td>3'184</td>
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<tr>
<td>GF Piping Systems</td>
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<td></td>
<td>1'708</td>
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<td>GF Casting Solutions</td>
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<tr>
<td>GF Machining Solutions</td>
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<td>725</td>
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</tbody>
</table>
About GF Machining Solutions
Site information

8 Production plants

20 Centers of Competence

33 Sales Companies
Unique Portfolio

Milling

EDM

Laser and Micromachining

Additive Manufacturing

Spindles

Tooling and Automation

Digital Business

Services and Training

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Digital Business
Our products enable a full digital workflow
Digital Transformation and Digital Twin @ GF Machining Solutions

Digitalisation is an enabler for our Customers

- Machine digitalisation
  Connectivity, Edge, big data, IoT, Cloud

- Digital Factory
  Automation, Process, Life cycle management

- Digital Customer Services
  Remote Assistance, Equipment Efficiency monitoring

- Digital Technology Services
  Manufacturing Process Insights & Optimization
Customer Value Proposition and Portfolio

- **Digital Customer Services**
  Amplify customer experience by integrated digital services to ensure stable manufacturing performance

- **Augmented machine capabilities**
  Enhanced machine performance by delivering customer-centric, cutting-edge digital products & services

- **Process integration & optimization**
  Powering true machining solutions by enabling our customers to implement cross-technology processes

- **Live Remote Assistance**
- **Connectivity (OPC-UA)**
- **Part and Process Validation**
- **E-Tracking**
- **Technology Management**
- **Digital Twin**
- **Automated Workflow generation**
- **Optimized technology for Milling, EDM and Additive Manufacturing**
- **Higher overall speed, accuracy and precision**
My rConnect

Asset Mgt.
Ticketing
Live Remote Access
Performance Analyzer
Process Inspector

Conferencing
Voice / Video
Data Access
Messaging

Cloud only

Process tracker*

* New Applications and Products defined
Digital Machine & Part Twin Developments

GFMS IIOT STACK
- Business Applications
- Analytics platform
- Cloud Infrastructure
- Connectivity
- Onsite Software
- Automation / Integration
- GFMS Smart Machines
- PLCs, HMI
- Devices/Sensors

My rConnect
EDGE environment

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Digital Machine & Part Twin Developments

GFMS IIOT STACK
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DIGITAL TWINS
- CAD CAM & Simulation
- NC & Kinematic Data/Calibration
- Real Time Monitoring
- Process Inspector
- Predictive maintenance
- Defect Detection
- Residual Useful Time

PHYSICAL TWIN
- Design & Development
- Setup: Part + Tools
- Operations
- Quality Control
- Maintenance

Data

Command & Control

EDGEnvironment

My rConnect

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Spindle Factory Twin Lifecycle Optimisation
Big Data Production Spaces for Factory 4.0 Processes

Smart Casting & Machine Tool Digital Engineering

Smart intralogistics planning & zero defect factory

Smart Operations & Digital Workplace Optimisation

Smart Connected Quality Control & Business Network Tracing

Smart Customer Service & Maintenance
Industry 4.0 Big Data Reference Model

BREAKING THE DATA SILOS | ISO 20547

RAMI 4.0: Zero-X Manufacturing

Collaborative Analytics Services & Marketplace

Business Layer

Application Layer

Information & Core Big Data Layer

Integration Layer

External Data Sources

Infrastructure

Data 4.0: Value Chain

Meaning / Context

Visualization

Transformation / Interpretation

Measurement

Datasource

Manufacturing 4.0 Data Entities

Big Data Pipelines

Big Data

Pipelines
Goal and Objectives:
Enable a +GF+ machine tool optimum, zero-defect production factory through a data-driven adaptive production integrating a full product Digital Twin for:

- **Providing transparency** to the full production chain of milling spindles
- Improving spindle **assembly lead time and quality** towards zero-defect operations
- Further optimise **product quality and lifecycle costs** by implementing **Predictive maintenance** for Milling machines critical components
Boost 4.0: Spindle Lifecycle Twin

Ultra reliable
Low latency

Real Time Process Monitoring & Control Infrastructure

High Broadband Capacity

Spindle Factory Twin

Massive IoT component communication

Condition Monitoring & Predictive Maintenance

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Spindle Factory Twin
Boost 4.0: From spindle to machine

Process explanation

Machines

Supplier

Measurements

Spindle Assembly Line

SpindleTest

Machine Test

Customer Service

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## Main KPIs and first expected results

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Assembly</th>
<th>Test</th>
<th>Machine Assembly</th>
<th>After Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft</td>
<td>Assembly Card</td>
<td>Functional test</td>
<td>Machine assembly data</td>
<td>Repaired spindle</td>
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<tr>
<td>Rear bearing flange</td>
<td></td>
<td></td>
<td></td>
<td>Quality release</td>
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<tr>
<td>Sleeve</td>
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**5-10% parts reworked (500-600CHF/part)**
- 10% of spindle returned to production after operational test
- Mean of **2 iterations** after spindle assembly
- 3-5% spindle returned to Step Tec after machine assembly
- **200-250 CHF** warranty cost per spindle (5-10% of margin)
- 5-7% of spindle returned under warranty

**100+ hours spent annually maintaining/integrating data in the process**

**Potential Cost Reduction: 3-5% sales revenue** -> **Overall 10-20% benefits improvement**
Boost 4.0: Integrating data sources

Stakeholders can access to data from production to final test or tech. support in one click

Machine learning helps …

I want to see/investigate …

R&D  Technical Support  Assembly
Boost 4.0: Monitoring & Analytics benefits

Dashboard for monitoring KPIs for continuous improvement

- **% spindles returned by Biel (SAP)**: 3%
- **% spindles returned by China (SAP)**: 7.50%
- **% of spindle 003/004/101 returned by Nidau/CAC**: 2.2%

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Spindles</th>
<th>Spindle Typ</th>
<th>Average DASYLab Test Iteration</th>
<th>Average Cost of Warranty Per Spindle Produced</th>
<th>% of All Spindles Returned by Nidau/CAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 August</td>
<td>2019 October</td>
<td>6070/003 A.10</td>
<td>6070/004 A.10</td>
<td>6070/005 A.10</td>
<td>6070/006 B.10</td>
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+ Boost 4.0: Integrating knowledge and data sources

Objective and achievements: beyond datalakes

Organized data

GF Boost 4.0 Ontology
+ Boost 4.0: Integrating knowledge and data sources

Architecture and achievements: data and ontology framework integrated into GF infrastructure

1. Files are pushed to the blob container
2. A serverless function is triggered to process the data
3. The function pushes the data on the CosmosDB
4. CosmosDB database
5. The data is being queried to be displayed on the dashboard

+GF+ Intranet
Blob Container
Function App
CosmosDB database
Azure Data Factory
Azure Machine Learning

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Boost 4.0: Integrating knowledge and data sources

Benefit of semantic model: traceability
Boost 4.0: Roll out Digital Twin for quality assurance

Achievements: AI model refinement and quality prediction with root-cause information

Model adapted for detecting exclusive suspect sets (6% of spindles)
3 out of 5 expected to be defective:
Quality control benefits

Confusion Matrix:
[[78  0]
 [ 2 3]]

True Positives: 3
False Positives: 0
False Negatives: 2
True Negatives: 78
Predictive Maintenance
Predictive Maintenance Pilot

AI Model based on Data from 30 machines over 2 years, increasing to >1000 in 2022

KPI: Increase from 20 to 50 KHrs lifetime - avoiding unexpected failures
Real Time Process Monitoring
5G Real Time Process Monitoring Solution

- Process monitoring through wireless, high data rates (10 Gbit/s), secure 5G network and sensors "on part"
- Real time and post-process vibration monitoring in aerospace component with high speed milling for zero-defect
- Real time, remote process control thanks to 1 ms 5G latencies
Advanced Business Process Benefits

**CURRENT:**
- Research
- Product development
- Process development
- Production
- Quality check
- Distribution
- Final users

**NEW:**
- Research
- In process analytics from development
- Production
- Distribution
- Final users

5G Sensor
Virtual Metrology

- Real time data processing for accurate online dimensional control in blade manufacturing: +/- 10 um achieved offline.
Summary

- New Hardware and Digital Infrastructures delivering augmented machine capabilities across unique GFMS portfolio
- Implementation of Spindle Factory and Milling Machine Twins for business processes optimisation across lifecycle
- Successful pilot applications for Factory quality KPI improvements, predictive maintenance and machining process optimisation
- Demonstration of potential of Digital thread, shadow and twin for sustainable improvement in manufacturing industries
GF Machining Solutions
Passion for Precision
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