Project Case Study
Hybrid Modeling for Energy Efficient CNC Grinding

CESMII (The Clean Energy Smart Manufacturing Innovation Institute) invests in Smart Manufacturing innovation through projects with funds awarded by the U.S. Department of Energy (DoE). The objective of these projects is to develop emerging technologies, drive research and innovation, and deliver on their mission to democratize Smart Manufacturing.

ITAMCO (Indiana Technology and Manufacturing Companies) and the University of Buffalo were awarded the opportunity to develop "Hybrid Modeling for Energy Efficient CNC Grinding." The Project Lead is West Virginia University.

PROJECT OBJECTIVE

The principal goal is to reduce the extremely high energy consumption of grinding processes for gear manufacturing by at least 15% through hybrid modeling of the grinding system holistically.

The US demand for gears is expected to grow by 6.4% to $40 billion in sales. Grinding will remain the core technology to produce large-scale, high-quality gear components. The novel, scalable, and generalizable hybrid modeling approach and its deployment in the CESMII Smart Manufacturing Innovation Platform (SMIP) environment will provide a blueprint for other manufacturers to reduce the energy consumption of the US grinding industry.

The project showcases rapid recovery of Smart Manufacturing adoption cost through energy savings and productivity increases in an industry with energy intensive processes. The project creates an opportunity to scale its impact for other interested CESMII members across industries (automotive, aerospace, medical) and applications (milling, turning, etc.) within the larger CESMII network.

TECHNICAL APPROACH

To achieve this goal, novel hybrid modeling methods that combine multi-physics equation-based models with data-driven machine learning models will be developed. The hybrid model's output provides grinding process parameters (wheel speed, depth of cut, infeed duration) as well as grinding tool reconditioning schedule and parameters (dressing and sharpening) that reduce the overall grinding system's specific energy consumption.

The prototype model will be implemented in the industrial testbed and located on-premise at ITAMCO, a leading US gear manufacturer.

Article's Source: Case Study at www.cesmii.org.

ACCOMPLISHMENTS

- Created a unique hybrid model to optimize the grinding process energy consumption combining the physics model with the Deep Neural Network (DNN).
- Validated a hybrid model approach based on quantitative analysis of the physics model assumptions and boundary conditions. Pushing limits within boundary conditions can aid optimization.
- The pretrained hybrid model is used to develop a Jupyter Notebook that can now easily acquire minimal grinding time/energy usage with the optimal grinding settings.
- Developed a white paper that will serve as a practical guide on developing hybrid models for manufacturing use cases.

DELIVERABLES

- Delivered complete data model template for machine tool messages
- Collected and validated grinding manufacturing process sample data set
- Documented generalized hybrid model for grinding
- Documented development framework for hybrid model
- Hybrid model Smart Manufacturing App source code submitted to CESMII GitHub repository
- Functional Hybrid model Smart Manufacturing App implemented at ITAMCO

REUSABLE OUTCOMES

- Smart Manufacturing profile for CNC grinding made available for reuse by the broader CNC grinding community.
- Data-driven and physics-based predictive models for CNC grinding.
- Hybrid model analytics for generic grinding applications.

RESULTS

- 41% decrease in processing time equal to 222 minutes per part.
- $6.9k potential savings with a 37% decrease in energy consumption per year.
- $107k per year in potential cost savings per manufactured part due to decrease in part processing time.

FOR MORE INFORMATION

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