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Digital Twin Based Online Material Defect Detection for CNC-Milled Workpieces

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Abstract

Achieving reliable lot size one compatible and adaptable online quality monitoring for CNC-milled workpieces remains elusive yet. To address this challenge, our approach aims to bridge the current gap in research by developing a cost-effective and reference-independent monitoring concept for material defect detection in CNC-machined parts. This paper presents a novel digital twin-based method, utilizing machining vibrations and a g-code-based encoding of the cutting process. The objective is to detect material defects, such as blowholes, without the need for individual workpiece references. The proposed method aims to reduce barriers to entry, minimize waste, and enhance machine productivity by enabling automated early online quality control. To develop and validate the model, we generate a new dataset combining machining vibration with technological context data such as chip-shape. We demonstrate the feasibility and potential of the approach in a job shop setting on a 3-axis CNC mill.

Keywords: Monitoring; Machining; Material defects; Vibrations; Lot size one

1. Introduction

The manufacturing industry is undergoing a paradigm shift, transitioning from a focus on 'responsiveness' to a 'market-of-one', deemed 'Mass Individualisation' [1] or 'Mass Personalisation' [2]. This entails the production of custom-made products while maintaining the low unit costs traditionally associated with mass production. In response, there has been a global push towards smart manufacturing characterized by autonomous operations enabled by advanced sensing, data processing, and decision-making technologies. [3, 4].

Within this context, reducing lot sizes in job shop settings becomes imperative, and additive manufacturing (AM), particularly 3D printing, emerges as a promising solution due to its autonomy and versatility. However, despite its advantages, AM still falls short compared to traditional techniques like CNC milling in aspects such as dimensional accuracy, mechanical properties, material variety, and surface quality [5, 6, 7]. CNC milling, therefore, remain pivotal, presenting not only significant potential but also high necessity for optimisation due to its complex nature of underlying processes that result in lower process resilience and robustness compared to AM.

Nomenclature

CNC	Computerised Numerical Controled (machine tool
AM	Additive Manufacturing
CCC	...

A monitoring system that utilises deep process context (e.g. technological, geometric, or material property data) to generate reference agnostic (= lot size one capable) process status insights, would ready CNC mills for the Mass Personlisation paradigm shift.

Such a workpiece centered monitoring system which detects material defects or user (=operator) error (e.g. wrong wrong

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material, or part clamping error) during normal machining can increase process efficiency & reliablity, reduces waste, and enables higher product quality.

To achieve economic efficiency and general market accessibility such a system must be easy to integrate, be machine agnostic, and be relatively low cost.

2. Related work

state of the art (1,5seiten)

Most monitoring systems focus on tool wear or machine maintenance, holistic process specific monitoring especially of the workpiece is rarely employed on todays shop floors or in current research. The only availabe enterprise monitoring product for workpiece and process monitoring is the Qass.

3. Aproach

(vorgehen + prinzipielle aufbau/Konzept)
- welche physikalische grsse? vibration
- kontext architektur (feature)
- schaubild design

4. Implementation

- full design from Aproach transform to proof of concept
- in python, auf emco, DoE...
- experimental setup

5. Validation

...and evaluation

6. Conclusion

and futere recommendation (halbe seite)

Zitiertest...
[8, 9, 10]
[9]
[10]
[11]
[5]

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