ACOUSTIC-BASED EVALUATION AND MONITORING OF MILLING TOOL WEAR IN CNC MACHINING.

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Annotatsya: Ushbu tadqiqot RDB dastgohlarida ishlov berish jarayonida frezalash asboblarining yeyilishini baholash uchun ovozga asoslangan mexanizmni o'z ichiga oladi. Rezonans chastotalarini olish uchun maxsus LabVIEW tovushni aniqlash dasturi ishlatilgan, bu esa eskirish bilan bog'liq takrorlanishda real vaqtda tasniflash imkonini beradi. Tizim, shuningdek, tezlashuv, tebranish, harorat va kuchlanishni kuzatish uchun bir nechta sensorlarni o'z ichiga olgan bo'lib, metall, yog'och va keramika kabi turli materiallarda ishlov berish dinamikasining keng qamrovli ko'rinishini ta'minlaydi.

Kalit so'zlar: FIR va IIR filtrlari, Ovoz kuchini aniqlash, ICP 4030 CNC mashinasi

Аннотация:В данном исследовании представлена основанная на звуке методология оценки износа фрезерного инструмента во время операций обработки на станках с ЧПУ. Для извлечения резонансных частот использовалась специальная программа обнаружения звука LabVIEW, что позволяет классифицировать закономерности, связанные с износом, в режиме реального времени. Система также включала несколько датчиков для контроля ускорения, вибрации, температуры и напряжения, обеспечивая комплексное представление о динамике обработки различных материалов, таких как металлы, дерево и керамика.

Ключевые слова: КИХ- и БИХ-фильтры, обнаружение звуковой мощности, станок с ЧПУ ICP 4030.

Abstract. This study presents a sound-based methodology for evaluating milling tool wear during CNC machining operations. A custom LabVIEW sound detection program was used to extract resonant frequencies, enabling real-time classification of wear-related patterns. The system also incorporated multiple sensors to monitor acceleration, vibration, temperature, and voltage, providing a comprehensive view of machining dynamics across various materials such as metals, wood, and ceramics.

Keywords—FIR and IIR filters, Sound power detection, ICP 4030 CNC machine.

Introduction

The experimental procedure was illustrated through a block diagram that outlines the setup and workflow. Auditory signals generated during CNC milling

ISSN 3030-3907

were captured using a microphone and subsequently processed and classified via FlexLogger, Dadem, LabVIEW, and NI MAX software tools. The experiment, including the integration of the microphone with sound power detection systems.
To acquire hardware data, a sound detection program developed in LabVIEW was employed to extract the resonant frequencies produced by the CNC machine during operation. Acting as a transducer, the microphone converts airborne acoustic vibrations into electronic signals or stores them digitally. In this study, a compact tabletop PC microphone was used to facilitate computer-based audio recording. To minimize environmental noise and suppress unwanted background interference, a high-sensitivity microphone was selected.

The LabVIEW-integrated CompactRIO and NI DAQ 9174 systems enabled real-time evaluation. These multifunctional platforms support tasks such as measurement, data acquisition, and dynamic frequency analysis. Their rapid response capabilities make them particularly suitable for CNC machining environments, where immediate feedback and efficient workflow are essential.
Block Diagram of the Experimental Process

The initial phase of the investigation involves careful selection of appropriate equipment and the execution of essential analyses using National Instruments hardware and software. This setup includes configuring multiple data acquisition channels to support various sensors—such as measuring acceleration, vibration, temperature via thermocouples, and voltage input/output.

This integrated system enables the collection of comprehensive data during machining operations, facilitating a deeper understanding of the acoustic characteristics generated when processing different materials, including metals, wood, and ceramics. The block diagram presented below outlines the sequential flow of the experimental procedure, illustrating the relationships between hardware components, sensor inputs, and data processing modules.

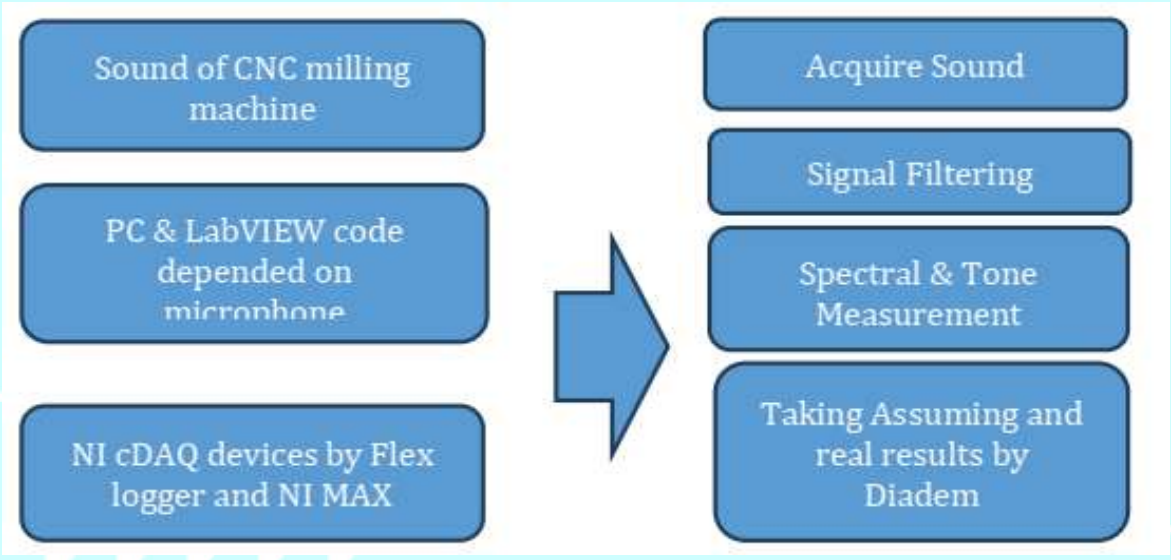


Figure 1. Project diagram.

ISSN 3030-3907

Flex Logger, a creation like no other in the constellation of software marvels, the genius of electromechanical system validation. In addition, the opportunity of a virtuoso, the symphony of sensor optimization and data logging. Regarding sanctuary of lofty efficiency uncorrupted by the fetters of programming taste the ambrosia that is synchronized electromechanical creativity. The crucible of validation where the literary sensitivity of the integrated data logger constructs a beautiful arrangement of verification through sensor-specific configuration and optimal signalization.

Given information about the NI 9215 provides ±10 maximum input voltage range, NI 9232 provides Acceleration & Vibration range Moreover Measurement value we've chosen *meter/secund*^{2} or *Gravity* and IEPE sensor class, NI 9213 provides Thermometer range Moreover measurement value we've chosen *Celsius or Farad and* Thermocouple sensor class.

That's a typical scenario of CNC acceleration and deceleration. Upon initiating motion along a given axis, the system does not instantaneously attain its designated rapid traverse speed (e.g., 20 meters per minute). Contrary to intuitive expectations, no physical entity, whether mechanical or biological, can achieve peak velocity instantaneously. Instead, the axis undergoes a controlled acceleration phase, gradually increasing its velocity in accordance with predefined motion profiles. This progression resembles the dynamic buildup of a symphonic composition, steadily gaining momentum toward its peak. As the axis approaches its target position, a deceleration phase is triggered. This ensures that the system reduces speed smoothly and predictably, ultimately reaching zero velocity precisely at the intended endpoint. The resulting velocity-time graph exhibits a characteristic S-curve, reflecting the elegant transition between acceleration and deceleration phases. Such motion profiles are essential for minimizing mechanical stress, enhancing positional accuracy, and ensuring operational safety.

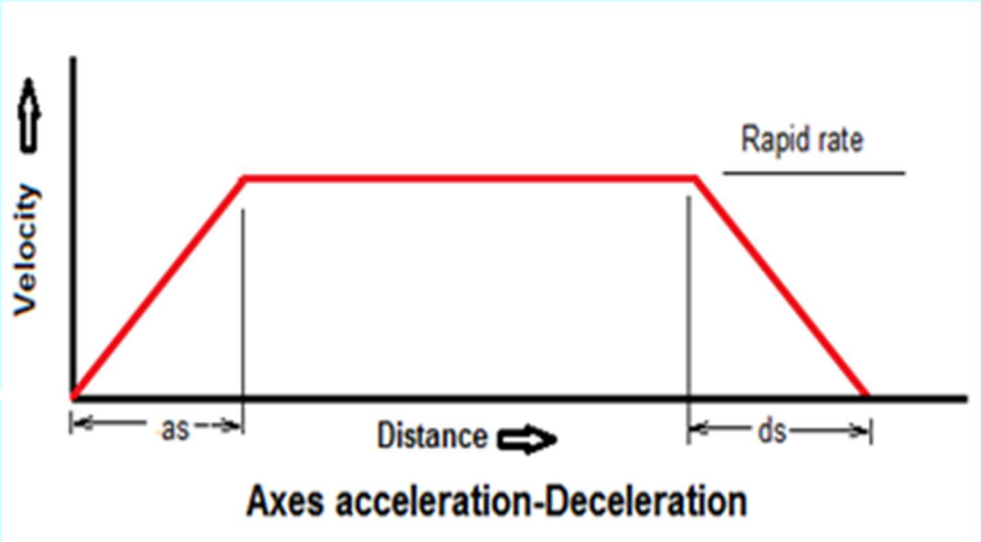


Figure 4. example diagram

ISSN 3030-3907

To streamline the configuration of data acquisition channels, users are not constrained to default naming conventions; instead, they are encouraged to assign contextually appropriate and descriptive labels. The customization process extends beyond nomenclature—it encompasses adjustments such as selecting the preferred temperature unit, calibrating measurement ranges, choosing an optimal thermocouple type, configuring the cold junction compensation (CJC) source, and applying linear transformations to refine signal interpretation. FlexLogger further enhances this setup by offering advanced features, including configurable alarms. These alarms can be programmed to trigger notifications when a monitored parameter exceeds or falls below a predefined threshold. Although this functionality was not utilized in the present study, it exemplifies the software's capacity for real-time monitoring and responsive control. Unlike previous configurations that required manual parameter input before displaying any data, the current thermometer interface provides immediate visualization of live temperature readings. This improvement facilitates more efficient observation and analysis during experimental procedures.

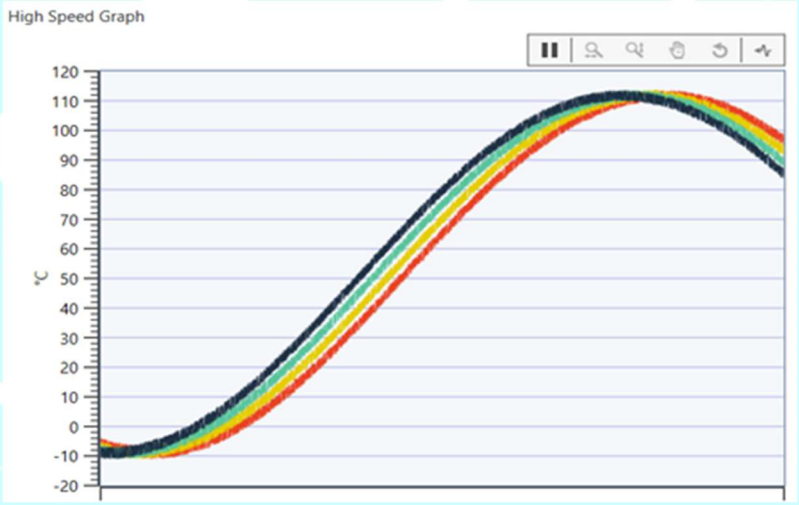


Figure 5. Thermocouple range

The sensors are not just attached there; they are lurking filtering accelerations for sure. But here's the best part: so that these signals could also be analyzed and divided into two dissimilar realms, they are subjected to some signal analysis. But that's only the beginning. From the first realm – mechanical displacements – we move around using a model-based avenue to ascertain cutting forces; and from the second – high-frequency vibrations – we explore the circumstance of spindles, gauging the magnitude of the situation. Progressively understanding the milling circumstance one lecture at a moment. Now let's proceed to the second matter. The sensors aren't attached there either; moreover, they perceptibly delve into the spindle's fastening structure to monitor its acceleration. But here's the most rewarding aspect: these sensors don't just persist as unreactive factors in the progress.

ISSN 3030-3907

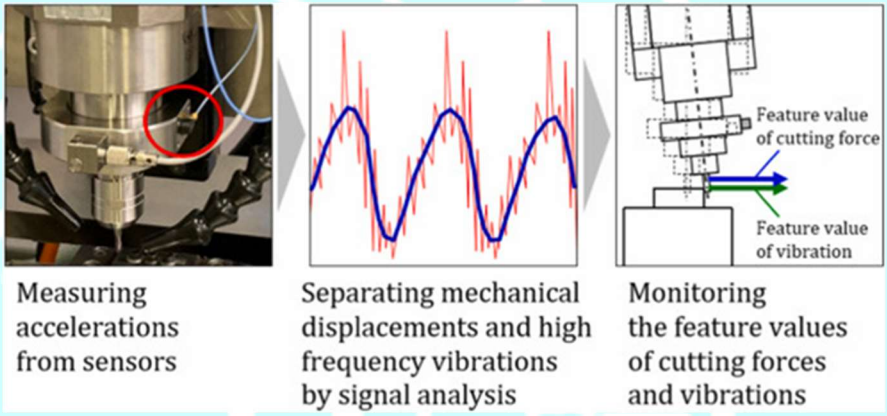


Figure 8

We are dealing with a tool of small diameter – that is, a thin one which lacks much rigidity closer to the central point. This implies that the signals of acceleration we consider are all over the place. For one, this is the set of vibrations of high frequency due to self-excited and forced vortical whipping; for two, high-frequency components of signal come from mechanical displacements because of cutting force. And that's the most concise way I can put it – as each of them is, basically, a spectrum. However, we've also got a little trick up the sleeve – you know, spaghetti against the wall. Sequential quadratic regression approximation helps us to do exactly that – distinguish one component from the other.

Conclusion: This study demonstrates the viability of using acoustic signal analysis as a non-invasive method for monitoring milling tool wear. By integrating high-sensitivity microphones with advanced data acquisition systems such as LabVIEW, CompactRIO, and NI DAQ 9174, the experiment successfully captured and processed the resonant frequencies generated during CNC machining. The use of FIR and IIR filters, alongside real-time signal classification via FlexLogger and Dadem, enabled precise identification of wear-related patterns.The experimental setups supported by thermocouples, vibration sensors, and voltage channels—provided a multidimensional view of the machining environment, revealing correlations between mechanical displacements, spindle dynamics, and high-frequency vibrations.. This approach not only enhances the understanding of tool behavior but also opens pathways for predictive maintenance and smarter machining strategies in industrial applications.

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ISSN 3030-3907