**DOMAIN**

Three-dimensional rapid prototyping and manufacturing (3DRPM) involves using interconnected technologies to create physical objects directly from CAD data. Unlike traditional machining, which removes excess material, 3DRPM builds objects layer by layer horizontally. These systems are also called solid freeform fabrication and layered manufacturing, offering advantages over conventional methods like milling or turning (Pérès & Noyes, 2006).

1. Objects can be produced with intricate geometric complexities without requiring complex machine setups or final assembly.

2. Objects can be constructed using multiple materials, including composites, and materials can be varied in a controlled manner at any location within the object.

3. Solid freeform fabrication systems simplify the construction of complex objects, making it a manageable, straightforward, and relatively fast process.

4. The use of jigs and fixtures becomes unnecessary in this approach

Predictive Maintenance (PM) is a method used to monitor the status of machinery to prevent costly failures and perform maintenance only when necessary. It has a long history, evolving from the earliest form of visual inspection to automated techniques that utilize advanced signal processing. In traditional maintenance practices, there is a trade-off involved, where one must choose between maximizing the lifespan of a component and risking machine downtime (run-to-failure) or maximizing uptime by replacing parts early, even if they are still functional (time-based PM). However, it has been demonstrated that this time-based approach is ineffective for most equipment components, as they are flawed and unreliable in recent years (Mobley, 2022). PM aims to minimize maintenance by forecasting it ahead of time, allowing companies to maximize the useful life of assets. This is achieved by reducing maintenance frequency, avoiding unplanned breakdowns, and eliminating unnecessary preventive maintenance. As a result, substantial time and cost savings are realized, along with improved system reliability (Traini et al., 2019).

To implement a PM strategy, a Condition Monitoring (CM) system is required. CM involves monitoring one or more machine parameters to detect potential faults at an early stage. Specifically, in machining operations like milling and turning that utilize cutting tools, monitoring tool degradation is crucial. Worn-out tools can negatively impact workpiece quality and potentially cause damage to the machining system (Traini et al., 2021). Accurate tool condition assessment prevents the use of degraded tools, which can lead to lower work quality, increased costs, and longer production times due to excessive preventive replacements. Industry 4.0 emphasizes machine digitization and connectivity, enabling more effective condition monitoring. This is achieved through sensor data analysis, providing better insights into the tool's status (Żabiński et al., 2019). From the various descriptions, it can be understood that PM is highly necessary for milling machines as it serves to prevent more severe damage to the machine and avoid incurring larger costs.