Prognostics and Health Management to Improve Resilient Manufacturing

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Abstract

Manufacturers need to be resilient to effectively mitigate substantial disruptions to manufacturing operations so they may remain competitive. Disruptions resulting from the COVID-19 global pandemic have caused manufacturers to experience new challenges, including 1) working with reduced in-person operations, 2) retasking workers into new roles, and 3) reconfiguring their equipment and processes to yield completely new product lines. Improved monitoring, diagnostic, and prognostic technologies and methods (collectively known as Prognostics and Health Management (PHM)) can help address these challenges and potential future disruptions.

Keywords: Prognostics and Health Management (PHM), Maintenance, Natural Language Processing (NLP), Resilient Manufacturing, Standards

Importance of PHM

PHM technologies can help to monitor production in real time, provide a rich history of the assets and facility, and predict potential future failures to reduce the time and cost of maintenance activities[1]. In 2016, U.S. manufacturers reported spending $50 billion on maintenance which was a significant portion of their total operating costs[2]. PHM can also increase asset availability, reduce scrap, and sustain process quality[3]. Effective use of PHM technologies enables manufacturers to determine the appropriate levels of reactive, preventive, and predictive maintenance to employ throughout their facilities. Small improvements in PHM implementation can help to optimize these strategies, decreasing unnecessary downtime and saving costs[4]. Likewise, PHM can enhance risk mitigation strategies by providing greater intelligence to better prepare for an impending disruption, minimize the impact of a disruption while it is occurring, and promote a faster recovery once a disruption has subsided. PHM can be

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[1] Vogl, G. W., Weiss, B. A., & Helu, M. (2019). A review of diagnostic and prognostic capabilities and best practices for manufacturing. Journal of Intelligent Manufacturing, 30(1), 79-95. doi:10.1007/s10845-016-1228-8.

[2] Thomas, D. S., (2018). *The costs and benefits of advanced maintenance in manufacturing*. US Department of Commerce, National Institute of Standards and Technology.

[3] Jin, X., Siegel, D., Weiss, B. A., Gamel, E., Wang, W., Lee, J., et al. (2016). The present status and future growth of maintenance in US manufacturing: results from a pilot survey. Manuf Rev (Les Ulis), 3, 10. doi:10.1051/mfreview/2016005.

[4] Chang, Q., Ni, J., Bandyopadhyay, P., Biller, S., and Xiao, G. (February 7, 2007). "Maintenance Opportunity Planning System." ASME. J. Manuf. Sci. Eng. June 2007; 129(3): 661–668. https://doi.org/10.1115/1.2716713

a critical tool to enhance scheduling operations since unplanned downtime can make it difficult for an organization to meet their production deadlines[5].

Ultimately, PHM technologies can help with the challenges posed by significant disruptions to the manufacturing ecosystem, including 1) reducing in-person staff, 2) shifting workers into roles they are not normally in, and 3) producing new product lines.

Reducing in-person staff

The 2020 COVID-19 global pandemic is forcing many factories to rethink and reduce their in-person staffing levels. Manufacturers must adapt operations to continue with fewer personnel while still maintaining necessary productivity. The effective implementation of PHM technologies increases an organization's ability to monitor, diagnose, and predict equipment states and process health. Advancing these capabilities often includes the generation of digital data including health state information. This data and information can be leveraged to enable remote operations including remote monitoring. PHM technologies for remote operations must feature sensors (to capture the data), algorithms (to process the data), networking infrastructure (to transmit the data), visualizations (to interpret the data), and cybersecurity (to secure the data).

With facilities operating with less in-person staff, Augmented Reality (AR) is also a valuable technology to promote remote awareness of equipment and process health. AR technologies allow more experienced staff to provide updates to less experienced staff with real-time audio and augmented visualizations overlaid on machines. Staff can work remotely, but still integrate their knowledge and expertise with onsite personnel during maintenance tasks.

Operating with reduced in-person staff can lead to less maintenance being performed on assets. Using PHM to optimize maintenance strategies can improve the efficiency of maintenance in the facility. As an example, with more automated monitoring and alerts, a maintenance technician or operator may be free to perform other tasks. Improved data analysis can lower time for various tasks in the maintenance work-flow, such as root cause analysis. Better component failure predictions from data can help optimize the maintenance schedule by reducing over-maintenance or under-maintenance.

While not every disruption will cause the same impacts as the pandemic, improved remote operations and optimized maintenance are invaluable for companies to remain competitive in the future. When staffing levels are increased again, the PHM methods and technologies will enable staff to work more efficiently and potentially spend more time on other activities in the facility.

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[5] Richards, R., & Ong, J. (2020) 'Leveraging PHM in Conjunction with Intelligent Scheduling to Improve Manufacturing Resilience' 2020 IEEE Aerospace Conference. IEEE, pp. 1-7.

Shifting workforce

Not only do these disruptions cause less in-person staff, they may force staff into new roles where the staff may not have previous experience. PHM technologies can provide employees with easy-to-understand, information access to help them fulfill their new roles. Asset monitoring solutions and visualizations can display health information to help operators on a new product line or working with machines with which they may have limited experience.

How-to-manuals are another important tool to help workers quickly get up to speed. While these are not new PHM developments, work with Natural Language Processing (NLP) of technical text has facilitated the automatic creation of how-to-manuals by processing multiple data sources and compressing them in an easy-to-understand format. Manufacturers, technology integrators and developers, and academics are working on NLP solutions for use in the PHM workflow[6].

Producing new products

During the 2020 pandemic, many factories pivoted to manufacturing essential products to support a country's pandemic response. While the magnitudes of these shifts may not be the same in the future, manufacturers can benefit from being agile and quickly adapting to consumer needs. PHM technologies can provide asset history and predict potential pitfalls of using that asset for a new product line. As discussed earlier, monitoring technologies can help provide important process information, which is invaluable for operators working with new products.

Moving Forward

PHM technologies and methodologies have been successfully deployed. However, widespread adoption has not yet been achieved, especially by Small-to-Medium Manufacturers (SMMs)[7].

Manufacturers may not be aware of the vast array of available PHM technologies. PHM adoption may face a cultural wall; personnel may view greater automation and digitization as taking over their jobs. If companies are aware and want to adopt PHM, PHM technologies can still have high costs. Likewise, some solutions require advanced technical understanding for implementation (i.e., the cost of integration can be much higher than the equipment cost). Technology integrators may be pushing their preferred solutions which could be less than ideal for their manufacturing customer. Several steps are needed to properly move forward with the integration of PHM technology for improving manufacturing resilience.

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[6] Brundage, M. P., Weiss, B. A., & Pellegrino, J. (2020). Summary Report: Standards Requirements Gathering Workshop for Natural Language Analysis.

[7] Helu, M., & Weiss, B. A. (2016) 'The current state of sensing, health management, and control for small-to-medium-sized manufacturers' ASME 2016 Manufacturing Science and Engineering Conference, MSEC2016.

Integration Technology Methods

One reason for the slow adoption of PHM technologies is the lack of methods to integrate this technology into existing maintenance workflows. Practical methods must be developed to improve technology integration with an emphasis on how the technology interacts with human actors on the floor. Once technology is integrated into the maintenance workflow, the workflow needs to be reevaluated to see if the workflow, itself, can be improved. PHM integration should be an iterative process.

It is also important for manufacturers that are not experienced with PHM to set reasonable expectations and find low-hanging fruit-type implementation projects. Achieving early successes while integrating PHM technologies can improve buy-in and allow for larger projects in the future.

Open Source Datasets

Manufacturers must provide open datasets and work with researchers to improve research efforts into real-world PHM technologies and methodologies. Real-world data helps researchers learn the problems of manufacturers and build applicable solutions and methods to solve these problems. If real data is used, it boosts researchers in addressing the practical issues with implementation.

Standards and Best Practice Guidelines

To help bridge the gap between research and industry, standards need to be developed. These standards, alongside less stringent guidelines and best practices, help companies implement PHM solutions in a structured way[8,9]. Once a company is successful in implementing PHM technologies, best practices and guidelines should be developed to help others do the same. Communities of interest and standard development organizations[10] help push forward research and documentation for PHM.

Conclusion

[8] Weiss, B. A., Alonzo, D., & Weinman, S. D. (2017) 'Summary Report on a Workshop on Advanced Monitoring, Diagnostics, and Prognostics for Manufacturing Operations'.
[9] Weiss, B. A., Brundage, M. P., & Pellegrino, J. (2020). Summary Report: Meeting of the ASME Standards Subcommittee on Advanced Monitoring, Diagnostics, and Prognostics for Manufacturing Operations Hosted at NIST.
[10] https://cstools.asme.org/csconnect/CommitteePages.cfm?Committee=102342234

The 2020 global pandemic has forced nearly every manufacturer to re-examine their operations to both maintain their competitiveness and the safety of the workforce amid a volatile landscape. PHM technologies and methodologies can help manufacturers respond to major disruptions. Investing in and utilizing PHM solutions provide benefits that will be seen even after the pandemic is over.

PHM can enhance an organization's ability to monitor, diagnose, and predict asset health states. In addition to increasing the efficiency of onsite maintenance operations, PHM technologies can promote remote monitoring and diagnostic activities thereby reducing onsite staff requirements. Likewise, the integration of PHM technologies can support the retasking and training of personnel on unfamiliar equipment and processes. Ultimately, PHM technologies exist to raise awareness and increase the intelligence of equipment and process health. The more informed a manufacturer is on their current and predicted future health states of their factories, the more efficient and cost-effective their operations.

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