Data Analytic Framework for University - Industrial Collaboration for Implementing Industry 4.0 in Metal Manufacturing Sector

Hongbiao Dong*, Maryam Khaksar Ghalati, Jianbo Zhang
School of Engineering, University of Leicester, Leicester, UK
*Corresponding e-mail: hd38@leicester.ac.uk

Abstract: The metals industry is facing many challenges, from productivity, capital investment cycle, margin squeeze, and the global challenge of decarbonization. The revolution in digital manufacturing, from the concept of Industry 4.0 is a key enabler in meeting these challenges and ensuring companies remain fit for the future. Recent advances in information technologies and data sciences enable data-driven-decision-making in metal manufacturing, which can significantly improve their operations and profitability. Most of the large manufacturing enterprises now start to benefit from this as they can collect more data that can be utilized to enhance their decision-making processes. Universities, and small and medium enterprises (SMEs) have limited data and resources, thus reducing the possible gains. In this work, we propose a shared data analytic framework for university and industry to collaborate and share data, the data will be then jointly analyzed, feasibility and quality of data analytics and decision-making processes could be significantly enhanced.

Keywords: data sharing framework; digital manufacturing; metal manufacturing

1 Introduction

The metal industry is undergoing digital transformation due to challenges like productivity, capital investment cycles, margin squeeze, and the global push for decarbonization [1, 2]. Industry 4.0, which promotes the seamless integration of digital and physical systems, is key to meeting these challenges by leveraging artificial intelligence (AI) and vast data generated throughout manufacturing processes [3]. In 2023, global spending on digital transformation reached 2.15 trillion USD and is expected to grow to 3.9 trillion USD by 2027 [4]. Large enterprises typically lead in digital transformation due to advanced IT capabilities, optimizing operations through big data analytics. While big data analytics also advance university research and benefit SMEs, these smaller entities often face limitations in data and resources. A shared data analytic framework is needed to help these institutions fully leverage digital transformation.

2 Challenges in industrial-academia collaboration

Figure 1 illustrates the complex intersections between AI, academia, and the metal industry, highlighting the multifaceted challenges and opportunities in fostering effective industrial-academic data collaboration.

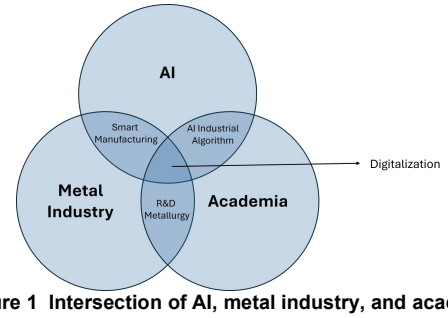

Figure 1 Intersection of AI, metal industry, and academia

Data nature and storage strategy in the metal industry. In the metal industry, data is generated from various sources such as sensors, ERP systems, and automated processes, leading to a mix of structured and unstructured data. This data is characterized by its high volume, velocity, variety, and variability, particularly in processes like BOF steelmaking, where real-time data on temperature, chemical composition, and emissions is crucial for maintaining product quality [5]. However, the fragmented legacy systems typically in place within metal-producing companies limit the accessibility and integration of this data. To address these challenges and fully leverage the insights offered by such diverse data, a comprehensive digital transformation is needed. This involves creating a unified data platform that enhances data storage, accessibility, integration, and analytics capabilities, thereby optimizing operational efficiency and decision-making across the organization.

Data confidentiality. Data confidentiality is a major concern in industry-academia collaborations, as industrial partners fear intellectual property theft or losing their competitive edge (Brettel et al., 2014). Effective data governance, such as those used in healthcare under HIPAA or in banking under Basel III standards, ensures that sensitive data is managed securely. The proposed framework emphasizes data governance solutions like anonymization, secure transfer protocols, and clear usage

agreements. Centralizing data management within academic institutions can simplify data access for research while ensuring industrial partners retain control over data usage—critical for protecting proprietary processes in the metals industry.

Standards for AI and industry 4.0. Adopting AI and machine learning in the metal industry can greatly enhance efficiency and innovation, but the implementation is challenging due to the complexity of metallurgical data and the need for specialized expertise. Developing models for predicting equipment failures or optimizing production processes requires deep integration of data science with metallurgical engineering. Effective data governance is crucial to ensure data quality, consistency, and regulatory compliance. Additionally, scalable data infrastructure is needed to manage growing data volumes and support real-time processing, enabling successful Industry 4.0 initiatives.

3 Data sharing and analytics framework

The shared data analytic framework facilitates seamless data integration and analysis across universities, SMEs, and large manufacturing enterprises. Its modular design allows flexible data input and processing, integrating data from various sources into a centralized, secure database. This database is protected with robust security measures, including encryption, access controls, and secure transfer protocols, ensuring confidentiality throughout the process.

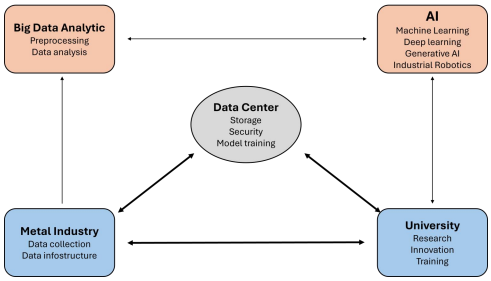

Figure 2 Data sharing and analytics framework

This secure database serves as the foundation for data analysis activities, including training machine learning models to predict outcomes, optimize processes, and generate actionable insights. The framework also incorporates advanced data visualization tools, making complex analyses accessible and particularly valuable in processes like casting, where precision is crucial. By integrating real-time data, the framework allows dynamic production adjustments, enhancing efficiency and reliability.

Additionally, the framework promotes industry-academia collaboration, accelerating technology development and innovation. This exchange benefits both sectors: universities gain access to real-world data for impactful research, while industry partners gain access to cutting-edge research and a skilled talent pipeline. Figure 2 illustrates this framework.

4 Conclusion

This paper discusses the characteristics and challenges of industrial data in the metals industry, focusing on the complexities of analyzing such data and the importance of secure data sharing between universities and industry. Embedding standards for data science and Industry 4.0 in future research is crucial for advancing the sector. The proposed shared data analytic framework facilitates the integration of experimental and modeling data from various laboratories and partners into a unified workflow. This integration enables advanced processes such as training machine learning algorithms to improve data-driven decision-making. The framework holds significant potential to enhance the reliability, availability, and efficiency of manufacturing processes, particularly in areas like casting. By fostering collaboration between academia and industry, the framework not only supports innovation but also strengthens the overall competitiveness and sustainability of the metals industry.

5 Acknowledgment

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