

AI-Driven Innovation: Transforming Industries and Enhancing Material Performance through Advanced Surface Engineering

Praveen Kumar¹ Ruby² Priyanka Garg³ Rakshit Mehta⁴ Navneet Kaur⁵

^{1,2,3,4}Student ⁵Assistant Professor

^{1,2,3,4,5}Department of Computer Science and Engineering

^{1,2,3,4,5}CGC-College of Engineering, CGC, Landran, Mohali, Punjab, India

Abstract — Artificial intelligence (AI) is rapidly revolutionizing industries across various sectors, driving innovation in areas ranging from automation and data analytics to the development of novel materials and processes. This paper explores the transformative potential of AI-driven innovation, highlighting its impact on diverse fields. While examining the broad spectrum of AI applications, a specific focus is placed on the critical challenge of material degradation due to corrosion in industrial systems. To illustrate AI's indirect yet significant role in advancing solutions to such challenges, this paper delves into the application of thermal spray coatings for combating corrosion in boiler steel. By optimizing coating design, deposition processes, and predictive maintenance strategies, AI can contribute to the enhanced performance and longevity of materials in demanding environments. This exploration demonstrates how AI, even when not directly controlling the coating process, can be instrumental in improving material selection, process efficiency, and ultimately, the resilience of critical industrial infrastructure. The insights presented underscore the pervasive influence of AI in fostering innovation and addressing long-standing engineering challenges through advanced material science and surface engineering principles.

Keywords: Artificial Intelligence, Use Cases, Advantages, Future Outlook, Potential Challenges, Emerging Trends, Industry Impact, Thermal Power Plant, Thermal Spray Coatings

I. INTRODUCTION

Artificial Intelligence (AI) denotes the capacity of machines or systems to execute tasks that typically necessitate human-like intellect, encompassing problem-solving, language understanding, experiential learning, reasoning, and generalization. Since the advent of the digital computer in the 1940s, machines have demonstrated the ability to perform intricate functions, such as proving mathematical theorems and achieving remarkable proficiency in games like chess [1].

Over time, AI has evolved into a pivotal force driving innovation across a multitude of industries. It underpins critical functionalities like visual and symbolic reasoning, task management, autonomous learning, and action recognition. The integration of diverse AI technologies has significantly enhanced the efficiency and cost-effectiveness of predictive analytics. As these technologies continue their rapid advancement, they are becoming increasingly integrated into our daily lives, pushing the boundaries of human cognitive abilities and enabling systems to simulate human intelligence across various domains.

AI is characterized by its potential to synthesize human-like cognitive processes with machine-based capabilities, including language processing, attention,

memory, perception, and planning. The past decade has witnessed substantial progress in AI development, initially rooted in computer science but now extending into fields such as cognitive science. The swift emergence of novel AI technologies has broadened the scope of its potential and applications across diverse sectors [2].

Today, AI is widely recognized as the ability to replicate or augment human cognitive functions within machines, finding applications in fields as varied as healthcare, education, agriculture, industry, and national security. Machine learning, a key subset of AI, often lies at the core of these operations, empowering systems to continuously refine their performance. The overarching aim of AI is to elevate the intelligence of machines, enabling them to perform complex tasks effectively and predictably within their operational environments. Research suggests that leveraging AI to support decision-making, reimagine traditional business models, and enhance customer experiences will be crucial for the success of digital initiatives by 2025. Furthermore, projections indicate that a significant majority of businesses will have adopted AI strategies, with many already making considerable strides in incorporating AI solutions across various sectors [3, 4].

This paper explores the transformative potential of AI-driven innovation across industries. While examining the broad spectrum of AI applications, we will also highlight how AI principles can indirectly contribute to advancements in seemingly unrelated fields through optimization and enhanced understanding. To illustrate this, we will delve into the critical area of material degradation due to corrosion in industrial systems. Specifically, we will examine the application of thermal spray coatings as a vital surface engineering technique for combating corrosion in boiler steel. By considering how AI-driven analytics and optimization strategies could enhance the selection, application, and maintenance of such coatings, this paper aims to demonstrate the pervasive influence of AI in fostering innovation and addressing long-standing engineering challenges through advanced material science. This exploration underscores the potential for AI to contribute to enhanced material performance and the longevity of critical industrial infrastructure through sophisticated surface engineering solutions.

II. UNDERSTANDING THE ROLE OF AI

Artificial Intelligence (AI) within the realms of computer science and engineering refers to the capability of machines or robots to exhibit intelligence similar to that of humans. The key applications of AI involve enabling machines to mimic human cognitive functions such as learning from past experiences, understanding and processing language, making decisions, and solving complex problems. When discussing AI, we typically focus on this concept and ask, "What

constitutes artificial intelligence?” A program is considered to be “artificially intelligent” if it is capable of performing tasks that would typically require human-level intellect. Often, the definition of AI is centered around the tasks it can successfully carry out. While intelligence was once seen as a uniquely human trait, today nearly 90% of computational work involves mathematical calculations, which are not always categorized as AI [5, 6]

AI functions as a versatile tool—similar to how mathematics or language is used—that is woven into various facets of modern society [2]. This tool is not restricted to specialists; it is increasingly accessible to a diverse array of users, many of whom apply AI in innovative and unexpected ways. Just as not all written content globally is produced by professionals in languages such as Chinese or English, AI is also utilized by people outside of expert circles. In recent years, AI has garnered widespread public interest and has been integrated into traditional fields like operations management and research. This development is significant, as it demonstrates how AI is progressively merging with and enhancing the functionality of well-established industries and sectors.

A. Why AI is in High Demand

While AI tools have been in existence for many years, their widespread adoption and use have dramatically increased in recent times. Several key factors have played a significant role in the growing importance and demand for AI technologies. These factors include: [3]

Computational Power and Cost Reduction: AI algorithms and methodologies offer businesses the ability to leverage exceptional computational power. When integrated with the Internet of Things (IoT), the generation of large volumes of data further enhances AI systems' performance, enabling them to process and analyze vast datasets more effectively [7].

Development of Large Datasets: The advent of big data technologies has facilitated the creation of massive datasets. As the volume of available data increases, AI models become increasingly adept at learning from this data and processing it more efficiently. Additionally, the increasing availability of AI-driven tools has made it more accessible for individuals and organizations to implement AI, helping bridge the gap between cutting-edge technology and society. AI developers continue to refine their models by focusing on intricate details and using neural networks to build advanced systems that learn and improve continuously, delivering reliable results. Beyond military applications, AI has been successfully applied across various industries, spurring progress in multiple sectors [8].

The economic and societal impact of AI has been significant. By 2030, AI is expected to contribute approximately \$15.7 trillion to the global economy, a figure that mirrors the combined GDP of China and India today. Many companies predict that AI could boost business productivity by up to 40%. Since 2000, the number of AI startups has expanded significantly, and AI is now being utilized across diverse domains—from tracking asteroids and celestial objects to predicting diseases, combating terrorism, and creating new technologies.

Computational Power: One of the significant obstacles in the widespread adoption of AI and deep learning is the high computational power required for these technologies to function effectively. Both AI and deep learning are foundational to artificial intelligence, but they demand substantial computational resources, particularly GPUs, to operate at optimal levels. Several industries, such as asteroid tracking, healthcare, and large-scale object monitoring, already possess the data and conceptual frameworks necessary for implementing deep learning models. However, these fields require immense computing power, often necessitating large-scale computing systems. While cloud computing and other similar platforms have made it easier to run AI systems, challenges persist with regard to the scalability and efficiency of these platforms in meeting the demanding computational requirements of deep learning.

Limited Understanding: Despite the growing market opportunities where AI can outperform traditional systems, one of the most significant challenges is the limited understanding of AI itself. Apart from technology enthusiasts, students, and professionals, only a small proportion of people truly grasp the potential of AI. For example, small and medium-sized enterprises (SMEs) stand to gain significantly from AI in areas such as streamlining operations, product development, resource management, online sales, and understanding consumer behavior to better meet market demands. Yet, many of these businesses are unaware of critical service providers, such as Google Cloud, Amazon Web Services, and other major technology companies, which could greatly facilitate their adoption of AI solutions [9-11].

Achieving Human-Level Performance: Reaching human-level performance in AI continues to be one of the greatest challenges researchers and startups face. Although some AI systems claim accuracy rates exceeding 90%, humans still outperform these systems in many tasks. For instance, in a simple task like determining whether an image depicts a dog or a cat, humans can make this decision with over 99% accuracy. However, replicating this level of performance with deep learning models requires significant investment, fine-tuning of hyperparameters, large datasets, advanced algorithms, and powerful computational resources, all while engaging in continuous training and testing. This process is considerably more intricate than it appears. Companies can bypass much of the complexity by utilizing pre-trained deep learning models offered by service providers. These models, which have been trained on millions of images, are highly efficient, but they still have limitations and are yet to reach the level of human-like performance.

Data Privacy and Security: A critical component that deep learning and machine learning models depend on is the collection and processing of data. While vast amounts of data are readily available, much of it is generated by millions of users worldwide, raising concerns about the potential for misuse or exploitation for malicious purposes. For instance, if a healthcare provider serving one million patients in a city experiences a cyberattack, leading to the leakage of sensitive personal data onto the dark web, the consequences could be severe. This exposed data might include private health information, medical conditions, and other sensitive details.

Compounding this issue is the sheer scale of global datasets. With data flowing from countless sources, the risk of breaches becomes significantly higher. In response, some organizations have started processing data directly on smart devices, ensuring that only processed models are sent back to central servers. This approach helps mitigate the risks associated with exposing sensitive personal information [12-14].

Bias in AI Models: The performance of an AI system, whether successful or flawed, is largely determined by the quality of the data on which it is trained. High-quality data is essential for building effective AI systems. However, the data collected daily often suffers from issues of quality and bias. It frequently reflects the characteristics of specific groups, influenced by factors such as religion, race, gender, or geographical location, inadvertently perpetuating social and racial biases. To advance AI development in a meaningful way, it is crucial to design algorithms that can better address and mitigate these biases. Ensuring that the data used to train AI systems is diverse and representative of all groups is essential for promoting fairness and inclusivity in AI technology.

III. AI-DRIVEN INNOVATION ACROSS SECTORS: LESSONS FROM COVID-19 AND APPLICATIONS IN MATERIAL SCIENCE

This section will explore the transformative power of Artificial Intelligence across various sectors, drawing initial examples from its critical role in managing the COVID-19 pandemic. Following this, it will broaden the scope to illustrate how AI principles and methodologies can be applied to seemingly unrelated fields, such as advanced material science and surface engineering, using the case of corrosion mitigation in boiler steel as a compelling example.

A. AI-Powered Model for COVID-19 Patient Management

To address the growing number of COVID-19 cases, an AI-based system can be developed to manage patient care efficiently. Patients exhibiting common symptoms, such as fever and cough, should undergo immediate testing. If they test positive, they must be isolated and quarantined for a duration of 14 days. Tracking the total number of infected individuals is essential. AI-driven geotagging can support contact tracing by identifying potential exposure points. "Infection investigators" can visit households, using tools such as CCTV and identification systems to monitor compliance with home isolation protocols. Once the number of quarantined individuals and confirmed positive cases exceeds a specific threshold, automated treatment protocols will be triggered. Continuous monitoring will be performed to track patient recovery progress and adjust care as necessary. Due to Covid there was a negative impact on various sectors [14-17].

B. AI-Powered Fever Detection System

The Athena Fever Detection System is an AI-based solution designed for quick, accurate, and mass screening of elevated body temperatures. It is a non-invasive, contactless technology that eliminates interference from heat sources like overhead lights or objects such as mobile phones and hot drinks. The system works by focusing on the hottest areas of the face, particularly near the eyes and the inner canthus, to

detect fever. Athena is typically used as part of a two-step screening process, with clinical thermometers used for fever confirmation. The system utilizes infrared imaging and handheld thermometers to gather temperature readings from various points. The remote fever detection system is capable of measuring body temperature from a distance of up to 5 meters.

C. AI for Virus Detection and Epidemic Forecasting

Artificial Intelligence (AI) is increasingly being applied in healthcare to prevent, monitor, and predict the spread of infectious diseases. During pandemics like COVID-19, AI has proven essential in predicting viral outbreaks. For instance, even before COVID-19 was officially recognized globally, Blue Dot, a Canadian AI company, issued early warnings about the spread of the virus. AI plays a crucial role in predicting epidemics and understanding disease transmission patterns. By analyzing global flight data, Blue Dot predicted potential spread to cities such as Tokyo, Bangkok, Seoul, and Taipei. Blue Dot leverages AI and natural language processing to process vast amounts of data from various sources—health organizations, media, and global airlines—allowing for real-time analysis, conducted every 15 minutes around the clock.

D. AI-Based Patient Screening System

Efficient screening of large groups of suspected patients is critical in ensuring proper isolation and treatment, especially in managing the rapid spread of COVID-19. Traditional laboratory tests for pathogens are often slow and can result in significant false negatives. AI, particularly deep learning techniques, can be employed to identify changes in CT scans of COVID-19 patients. By using deep learning models to analyze visual features from these scans, the system can support clinical decision-making and save valuable time in healthcare management. This AI-powered system employs both 2D and 3D deep learning models to enhance and optimize current diagnostic frameworks, seamlessly integrating these capabilities into clinical workflows to accelerate patient care.

E. Robotics and Drones Supporting Healthcare for COVID-19 Patients

Healthcare professionals have been forced to innovate and integrate technology in their efforts to combat the COVID-19 pandemic while providing timely and secure care. Drones, in particular, have proven beneficial in three key ways to help manage the spread of infectious diseases during large-scale outbreaks:

- Aerial surveillance to monitor the progression of widespread infectious diseases.
- Transporting essential supplies and medications to areas in need during epidemics.
- Post-pandemic analysis to track trends in infectious disease spread.

Surveillance drones have been deployed to observe individuals during lockdowns, monitor public gatherings, control traffic, supervise waste disposal, enforce social distancing measures, ensure compliance with mask-wearing, and identify individuals violating government-imposed regulations. Furthermore, robots have been utilized to

transport medical samples, quarantine materials, and assist in infection control during the spread of diseases such as COVID-19 [15].

F. The Impact of AI on Emotional Intelligence and Professional Roles

While machines excel in many tasks, it's essential to recognize their growing capabilities. Numerous skilled professions follow a similar pattern: (i) data collection, (ii) data analysis, (iii) interpretation of results, (iv) decision-making, and (v) action implementation. This framework can be applied across various sectors. For example, doctors diagnose, plan treatments, and interact with patients to provide effective care. Financial advisors collect and analyze client data, evaluate investment opportunities, interpret outcomes based on criteria like risk tolerance, suggest investment strategies, and guide clients in long-term planning. Business consultants similarly analyze problems and devise solutions for companies. These professionals shoulder significant responsibilities due to three critical skills: the ability to collect data swiftly and accurately, the use of experience and judgment to determine the best course of action, and the ability to navigate clients through the decision-making process [16, 17].

However, AI and machine learning are poised to surpass human proficiency in two critical areas—data processing and decision-making. This advancement will reshape the skill sets required for professionals aiming to remain relevant as their roles evolve in response to technological progress [16].

It is undeniable that digital systems play a vital role in data collection and analysis, and machines are undeniably proficient at performing these tasks. While some may argue that we should avoid allowing machines to make critical decisions, especially those affecting our lives or finances, such viewpoints are increasingly outdated. In today's world, where trusted, advanced technologies are integral to daily life, it becomes difficult to ignore the effectiveness of these systems. As automation continues to expand across industries, emotional intelligence is poised to become an essential skill for professionals looking to remain valuable in their careers.

In light of this, we propose three key actions to navigate the changing landscape:

- Embrace Technological Advancements: AI and machine learning have the capacity to significantly enhance outcomes and reduce costs. Rather than resisting technological progress, professionals should actively incorporate these innovations into their workflows, optimizing efficiency and productivity.
- Adapt to Evolving Changes in Your Field: To remain relevant, individuals must adapt to the ongoing shifts in their industries. This includes working toward improving processes and making them more efficient, reliable, and aligned with the latest technological advancements.

IV. EXTENDING AI PRINCIPLES TO MATERIAL PERFORMANCE: THE CASE OF CORROSION MITIGATION

This section will transition from the direct applications of AI during the pandemic to illustrate how the underlying principles of data analysis, optimization, and prediction inherent in AI can be leveraged to address challenges in other critical industrial domains. The focus will shift to the significant issue of corrosion in boiler systems and how advanced surface engineering techniques, potentially enhanced by AI methodologies, offer solutions.

A. The Challenge of Corrosion in Industrial Systems: Focus on Boiler Steel

The pervasive issue of corrosion in industrial settings carries significant economic and safety consequences, particularly within the demanding operational environments of boiler systems characterized by high temperatures, steam, and aggressive chemical exposures [18-21]. Commonly employed steel alloys in boiler construction exhibit inherent vulnerabilities to various forms of corrosion, including oxidation and sulfidation, underscoring the critical necessity for implementing robust and effective corrosion protection strategies to ensure the longevity, efficiency, and safe operation of these essential industrial assets, a challenge where AI-driven innovation can play an increasingly significant role in optimizing material selection and protective measures

B. Thermal Spray Coatings: An Advanced Surface Engineering Solution

Thermal spray coatings represent an advanced surface engineering solution. These versatile technologies offer a powerful method for depositing protective layers on materials, with various processes like flame spraying, arc spraying, plasma spraying, and HVOF tailored for specific applications, including the demanding environments of boiler systems [22-25]. Various researcher have used Ni-Cr and Ni-Al based coatings to combat corrosion of boiler steels in boiler system [26-30]. A diverse range of coating materials, encompassing metals, ceramics, high entropy alloy and cermets, are employed to combat high-temperature corrosion and related degradation mechanisms, ultimately enhancing the performance and extending the lifespan of critical boiler components [31-38]. However, there is an area where AI-driven optimization in material selection, process control, and predictive maintenance can further amplify their effectiveness.

C. The Potential Role of AI in Optimizing Thermal Spray Coating Applications

This subsection will explicitly connect the principles of AI to the application of thermal spray coatings. It can explore potential areas where AI can contribute, such as:

- Data-driven Material Selection: Using AI to analyze historical data on boiler environments and coating performance to predict the most effective coating materials for specific applications.
- Process Optimization: Employing AI algorithms to optimize the parameters of the thermal spray process (temperature, spray rate, powder feed, etc.) to achieve

coatings with superior adhesion, density, and corrosion resistance.

- Quality Control: Utilizing AI-powered image analysis and non-destructive testing data to automatically assess the quality and uniformity of applied coatings.
- Predictive Maintenance: Developing AI models to predict coating degradation rates based on operational data, enabling proactive maintenance scheduling and preventing costly failures.
- Robotics and Automation: AI-controlled robots in the precise and efficient application of thermal spray coatings.

V. APPLICATIONS OF AI IN DIVERSE SECTORS

Artificial neural networks serve as a fundamental tool for tackling a wide range of issues, such as machine translation, decision-making, visualization, clustering, and others [43]. Their adaptability makes them useful in a variety of domains.

AI enhances human life by offering personalized support for people with disabilities or the elderly, enabling real-time communication between different languages without the need to learn them, aiding in translation tasks, and much more. Its reach extends across multiple industries, including satellite management, neuromorphic computing, crowdsourcing, marketing, military operations, logistics, computer vision, plant design, nuclear management, education, reinforcement learning, machine learning, deep learning, social media, agriculture, e-commerce, surveillance, and beyond. The key areas where AI is significantly applied today are outlined below

- Healthcare: AI plays an essential role in diagnostics, patient care, and optimizing treatments. Machine learning algorithms can analyze medical imaging to detect diseases like cancer and cardiovascular conditions early. AI-assisted robots are utilized in surgeries, improving accuracy and reducing recovery times. Additionally, AI systems help predict patient outcomes, tailor treatment strategies, and efficiently manage healthcare resources [39].
- Agriculture: AI supports farmers by monitoring crop health, optimizing water usage, and forecasting weather to manage crop yields. AI-powered drones and robots carry out tasks such as planting, weeding, and harvesting, which reduces labor costs and boosts agricultural productivity. AI technologies also examine soil quality and pest populations, enabling precision farming that minimizes chemical usage.
- Finance: AI is widely used in the financial sector for fraud detection, algorithmic trading, and risk management. AI systems analyze large volumes of transaction data to spot irregularities and prevent fraudulent activities. AI also enhances customer service through chatbots that assist with inquiries, process transactions, and provide tailored financial guidance.
- Retail and E-Commerce: AI improves online shopping by personalizing product recommendations based on consumer behavior and preferences. AI-driven chatbots offer instant customer support, answering questions and processing orders. In addition, AI-driven analytics streamline inventory control and supply chain

management by predicting demand patterns and optimizing stock levels.

- Transportation and Logistics: AI is at the forefront of autonomous vehicle development, improving road safety and alleviating traffic congestion. In logistics, AI enhances delivery route optimization, cuts fuel consumption, and improves fleet management. AI-powered systems also streamline warehouse operations by using robots for efficient picking and packing.
- Education: AI offers personalized learning experiences by adjusting educational materials to fit the unique needs of each student. AI-powered virtual tutors provide immediate assistance with homework, exercises, and exam preparation. Moreover, AI helps with administrative functions like grading, scheduling, and tracking student performance, allowing teachers to focus more on instruction.
- Manufacturing: AI is revolutionizing the manufacturing sector by enabling predictive maintenance, improving product quality, and enhancing efficiency. AI systems continuously monitor equipment, identifying potential issues before they lead to breakdowns. Robotics and AI also play a role in assembly lines, reducing human labor in repetitive tasks and increasing overall productivity [40].
- Entertainment: AI has transformed entertainment through recommendation engines, such as those used by Netflix and Spotify. These systems analyze user behavior to suggest films, shows, or music. AI is also involved in content creation, from generating realistic CGI for films to creating personalized experiences in gaming.
- Energy: AI is crucial in energy management, from optimizing electricity distribution to predicting energy consumption patterns. AI-powered smart grids monitor real-time energy use and adjust to prevent outages and minimize waste. Additionally, AI aids the development of renewable energy, improving the efficiency of solar and wind power generation [41].
- Military and Defense: AI is employed in surveillance, threat detection, and autonomous weapon systems. AI algorithms process data from satellite images and drones to identify potential security risks. Additionally, AI-driven systems enhance military logistics, resource management, and strategic planning by analyzing vast amounts of operational data.
- Customer Service: AI-driven chatbots and virtual assistants have transformed customer service by providing 24/7 support. These systems can address frequently asked questions, resolve technical problems, and assist with billing and account management. AI improves the customer experience by delivering faster, more efficient service while reducing human error.

VI. CONCLUSION

In conclusion, artificial intelligence is undeniably a powerful engine of innovation, driving transformative changes across diverse industries. This paper has explored the pervasive influence of AI, not only in traditionally tech-centric sectors but also in its potential to revolutionize fundamental industrial challenges. By examining the critical issue of

corrosion in boiler steel and the application of advanced surface engineering techniques like thermal spray coatings, we have illustrated how AI-driven approaches can contribute to enhanced material performance and the longevity of critical infrastructure. While AI may not directly execute these material processes, its capabilities in data analysis, optimization, and predictive modeling offer significant opportunities to refine material selection, improve coating efficiency, and develop proactive maintenance strategies. As AI continues its rapid evolution, it is crucial to recognize its broad applicability in addressing complex engineering problems and fostering advancements in material science. Future research should continue to explore and leverage AI's potential to optimize industrial processes, enhance material resilience, and ultimately contribute to a more efficient, sustainable, and reliable future across all sectors.

REFERENCES

- [1] Adib Bin Rashid, MD Ashfakul Karim Kausik, AI revolutionizing industries worldwide: A comprehensive overview of its diverse applications, *Hybrid Advances*, Volume 7, 2024, 100277, ISSN 2773-207X, <https://doi.org/10.1016/j.hybadv.2024.100277>.
- [2] B. Li, B. Hou, W. Yu, X. Lu, C. Yang, Applications of artificial intelligence in intelligent manufacturing: a review, *Front. Inf. Technol. Electron. Eng.* 18 (1) (Jan. 2017) 86–96, <https://doi.org/10.1631/FITEE.1601885>.
- [3] M. Anagnostou, et al., Characteristics and challenges in the industries towards responsible AI: a systematic literature review, *Ethics Inf. Technol.* 24 (3) (Aug. 2022) 37, <https://doi.org/10.1007/s10676-022-09634-1>.
- [4] S.K. Jagatheesaperumal, M. Rahouti, K. Ahmad, A. Al-Fuqaha, M. Guizani, The Duo of artificial intelligence and big data for industry 4.0: applications, techniques, challenges, and future research directions, *IEEE Internet Things J.* 9 (15) (2022) 12861–12885, <https://doi.org/10.1109/IIOT.2021.3139827>.
- [5] I.H. Sarker, AI-based modeling: techniques, applications and research issues towards automation, intelligent and smart systems, *SN Comput. Sci.* 3 (2) (Feb. 2022) 158, <https://doi.org/10.1007/s42979-022-01043-x>.
- [6] M. Javaid, A. Haleem, R.P. Singh, R. Suman, Artificial intelligence applications for industry 4.0: a literature-based study, *J. Ind. Intg. Mgmt.* 7 (1) (Mar. 2022) 83–111, <https://doi.org/10.1142/S2424862221300040>.
- [7] N. Anantrasirichai, D. Bull, Artificial intelligence in the creative industries: a review, *Artif. Intell. Rev.* 55 (1) (Jan. 2022) 589–656, <https://doi.org/10.1007/s10462-021-10039-7>.
- [8] R.S. Peres, X. Jia, J. Lee, K. Sun, A.W. Colombo, J. Barata, Industrial artificial intelligence in industry 4.0—systematic review, challenges and Outlook, *IEEE Access* 8 (2020) 220121–220139, <https://doi.org/10.1109/ACCESS.2020.3042874>.
- [9] X. Xu, Y. Lu, B. Vogel-Heuser, L. Wang, Industry 4.0 and industry 5.0—Inception, conception and perception, *J. Manuf. Syst.* 61 (2021) 530–535, <https://doi.org/10.1016/j.jmsy.2021.10.006>. [53] A. Calabrese, M. Dora, N. Levaldi Ghiron, L. Tiburzi, Industry's 4.0 transformation process: how to start, where to aim, what to be aware of, *Prod. Plann. Control* 33 (5) (Apr. 2022) 492–512, <https://doi.org/10.1080/09537287.2020.1830315>.
- [10] D. Nahavandi, R. Alizadehsani, A. Khosravi, U.R. Acharya, Application of artificial intelligence in wearable devices: opportunities and challenges, *Comput. Methods Progr. Biomed.* 213 (2022) 106541, <https://doi.org/10.1016/j.cmpb.2021.106541>.
- [11] Z. Jan, et al., Artificial intelligence for industry 4.0: systematic review of applications, challenges, and opportunities, *Expert Syst. Appl.* 216 (2023) 119456, <https://doi.org/10.1016/j.eswa.2022.119456>.
- [12] A. Gilchrist, *Industry 4.0*, Apress, Berkeley, CA, 2016, <https://doi.org/10.1007/978-1-4842-2047-4>.
- [13] Soumia Zohra El Mestari, Gabriele Lenzini, Huseyin Demirci, Preserving data privacy in machine learning systems, *Computers & Security*, Volume 137, 2024, 103605, ISSN 0167-4048, <https://doi.org/10.1016/j.cose.2023.103605>.
- [14] B. Hashemian, et al., Clinical Deployment and Validation of a Radiology Artificial Intelligence System for COVID-19, 2020, <https://doi.org/10.21203/rs.3.rs61220/v1>.
- [15] Singh, M. and Kumar, S. (2021), “Impacts of novel COVID-19 on Various Sectors: A Study”, *I-manager's Journal on Future Engineering and Technology (JFET)*, Vol. 16 (4), pp. 17-25.
- [16] Singh, H, Kumar, S. and Kumar, R. (2021), “A Study on Novel CoronaVirus Disease (COVID-19)”, *Asian Journal of Engineering and Applied Technology*”, Vol. 10 (1), pp. 29-37. <https://doi.org/10.51983/ajeat-2021.10.1.2801>.
- [17] Singh, H., Kumar, S. and Kumar, R. (2020), “Impact of COVID-19 on Economy: A Critical Review”, *I-Manager's Journal on Humanities and Social Science*, Vol. 1 (3), pp. 39-45.
- [18] Kumar, S., Handa, A., Chawla, V, Grover, N.K and Kumar, R. (2021), “Performance of thermal-sprayed coatings to combat hot corrosion of coal-fired boiler tube and effects of process parameters and post coating heat treatment on coating performance: a review”, *Surface Engineering*, Volume 37 (7), pp. 833-860. DOI: 10.1080/02670844.2021.192450
- [19] Kumar, S., Kumar, M., and Handa, A., (2018), “Combating Hot Corrosion of Boiler Tubes- A Study”, *Engineering Failure Analysis*, Vol. 94, pp. 379-395. <https://doi.org/10.1016/j.engfailanal.2018.08.004>
- [20] Singh, H., Kumar, S. and Kumar, R. (2021), “Overview of Corrosion and its Control: A Critical Review”, *Proceedings on Engineering Sciences*”, Vol. 3 (1), pp. 13-24. DOI: 10.24874/PES03.01.002. <http://pesjournal.net/journal/v3-n1/2.pdf>.
- [21] Singh, T., Kumar, S., and Kumar, R. (2023). Study of Corrosion and its Preventive Measures. *i-manager's Journal on Future Engineering & Technology*, 19(1), 29-47. <https://doi.org/10.26634/jfet.19.1.20200>
- [22] Kumar, S, Kumar, R., Singh, S., Singh, H. and Handa, A. (2020), “The Role of Thermal Spray Coating to Combat Hot Corrosion of Boiler Tubes: A Study, *Journal of Xidian University*, Vol. 14 (5), pp. 229-239. <https://doi.org/10.37896/jxu14.5/024>

- [23] Kumar, R., and Kumar, S., (2018), "Thermal Spray Coating Process: A Study", *International Journal of Engineering Science and Research Technology*, Vol. 7 (3), pp. 610-617. DOI: 10.5281/zenodo.1207005.
- [24] Singh, S., Kumar, S., Prakash, C. and Khanna, V. (2025), "Thermal Spray Coatings, Fundamentals and Applications, Advanced Structured Materials, Springer Singapore, <https://doi.org/10.1007/978-981-96-3472-9> ISBN: 978-981-96-3471-2
- [25] Singh, S., Kumar, S., Prakash, C., Khanna, V. (2025). Overview of Various Surface Modification Techniques. In: *Thermal Spray Coatings. Advanced Structured Materials*, vol 232. Springer, Singapore. https://doi.org/10.1007/978-981-96-3472-9_1
- [26] Kumar, S., Kumar, M., Handa, A., (2020), "Erosion corrosion behavior and mechanical property of wire arc sprayed Ni-Cr and Ni-Al coating on boiler steels in actual boiler environment", *Material at High Temperature*, Volume 37 (6), pp. 370-384. <https://doi.org/10.1080/09603409.2020.1810922>.
- [27] Kumar, S., Kumar, M., Handa, A., (2019), "Comparative Study of High Temperature Oxidation Behavior of Wire Arc Sprayed Ni-Cr and Ni-Al Coatings", *Engineering Failure Analysis*, Vol. 106, pp. 104173 -104189. <https://doi.org/10.1016/j.engfailanal.2019.104173>
- [28] Kumar, S., Kumar, M., Handa, A., (2019), "High Temperature Oxidation and Erosion-Corrosion Behaviour of Wire Arc Sprayed Ni-Cr Coating on Boiler Steel", *Material Research Express*, Vol.6, pp. 125533. <https://doi.org/10.1088/2053-1591/ab5fae>
- [29] Kumar, M., Kant, S., Kumar, S., (2019), "Corrosion behavior of wire arc sprayed Ni-based coatings in extreme environment", *Materials Research Express*, Vol. 6 (10), pp.106427. <https://doi.org/10.1088/2053-1591/ab3bd8>
- [30] Sharma, V., Kumar, S., Kumar, M., Deepak, D., (2020), "High Temperature Oxidation Performance of Ni-Cr-Ti and Ni-5Al Coatings", *Material Today Proceeding*, Vol. 26 (3), pp. 3397-3406. <https://doi.org/10.1016/j.matpr.2019.11.048>
- [31] Kumar K. Kumar S. and Gill, H.S. (2025), "High-Temperature Oxidation Performance of HVOF and Plasma Sprayed Ni-20Cr, Ni-20Cr+TiC and Ni-20Cr+TiN coatings on T22 boiler steels, *Surface Review and Letters*, <http://dx.doi.org/10.1142/S0218625X25501306>
- [32] Kumar, K., Kumar, S. and Gill, H.S. (2024), "High-temperature erosion-corrosion performance of Plasma and HVOF-sprayed TiC and TiN enriched Ni-20Cr coatings in an actual boiler environment", *Journal of Material Engineering and Performance*, <http://dx.doi.org/10.1007/s11665-024-10465-y>
- [33] Kumar, K., Kumar, S. and Gill, H.S. (2024), "Role of Carbide-Based Thermal-Sprayed Coatings to Prevent Failure for Boiler Steels: A Review", *Journal of Failure Analysis and Prevention*, doi: 10.1007/s11668-024-01974-y
- [34] Kumar, S. (2024), "Comprehensive review on high entropy alloy-based coating, *Surface and Coatings Technology*, Volume 477, pp. 130327, <https://doi.org/10.1016/j.surfcoat.2023.130327>.
- [35] Kumar, K., Kumar, S. & Gill, H.S. Role of Surface Modification Techniques to Prevent Failure of Components Subjected to the Fireside of Boilers. *J Fail. Anal. and Preven.* 23, 1–15 (2023). <https://doi.org/10.1007/s11668-022-01556-w>.
- [36] Kumar, S. (2022), "Influence of processing conditions on the mechanical, tribological and fatigue performance of cold spray coating: A Review", *Surface Engineering*, Vol. 38 (4), pp. 324-365. <https://doi.org/10.1080/02670844.2022.2073424>
- [37] Kumar, S. and Kumar, R. (2021), "Influence of processing conditions on the properties of thermal sprayed coating: a review", *Surface Engineering*, Vol. 37 (11), pp. 1339-1372. <https://doi.org/10.1080/02670844.2021.1967024>.
- [38] Maleki Varnosfaderani S, Forouzanfar M. The Role of AI in Hospitals and Clinics: Transforming Healthcare in the 21st Century. *Bioengineering (Basel)*. 2024 Mar 29;11(4):337. doi: 10.3390/bioengineering11040337. PMID: 38671759; PMCID: PMC11047988.
- [39] Kumar, S., Kumar, R. A Comprehensive Study on Additive Manufacturing Techniques, Machine Learning Integration, and Internet of Things-Driven Sustainability Opportunities. *J. of Mater Eng and Perform* (2025). <https://doi.org/10.1007/s11665-025-10757-x>
- [40] Jindal, H., Kumar, D., Ishika, Kumar, S. and Kumar, R. (2021), "Role of Artificial Intelligence in Distinct Sector: A Study", *Asian Journal of Computer Science and Technology*, Vol. 10 (1), pp. 1-12. <https://doi.org/10.51983/ajcst-2021.10.1.2696>