Pertanika Proceedings 1 (1): 67 - 72 (2025)

PERTANIKA JOURNALS

PERTANIKA PROCEEDINGS

Journal homepage: http://www.pertanika.upm.edu.my/

Application of Intelligent Manufacturing Technology in the Ceramic Industry: Innovative Practices to Improve Efficiency and Environmental Performance

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ABSTRACT

This study takes the ceramics industry as its object to improve production efficiency, reduce resource waste, and reduce environmental pollution. It explores the application of intelligent manufacturing technology in the ceramics industry. The ceramics industry is a significant part of China's traditional manufacturing industry. However, it has low production efficiency, causes serious resource waste, and causes severe environmental pollution. In the era of Industry 4.0, intelligent manufacturing has become a meaningful way to address these issues. This paper uses a combination of literature reviews, case studies, and other methods to evaluate and analyse intelligent manufacturing technologies' actual effects on the ceramics industry's transformation, upgrading, and sustainable development. The research shows that intelligent manufacturing technologies represented by the Internet of Things, artificial intelligence, and robotics have begun to show clear advantages in the ceramics industry. Improving production efficiency and reducing resource waste also positively affect environmental protection.

Keywords: Ceramic industry, environmental protection, intelligent manufacturing technology, production efficiency

ARTICLE INFO

Article history:
Received: 9 January 2025
Published: 17 February 2025

DOI: https://doi.org/10.47836/pp.1.1.014

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INTRODUCTION

Currently, China's ceramics industry has high energy consumption, severe environmental pollution, outdated equipment technology, insufficient innovation, low labour productivity, and a severe problem of overcapacity (Ding, 2022). As China enters

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the later stages of industrialisation, there is increasing emphasis on resource conservation and environmental protection, and the pressure on the ceramics industry to transform and upgrade is increasing, as is the gradual waning of the demographic dividend. The deep integration of the digital economy and the ceramics industry has opened new paths to address these issues. The integration of the digital economy and the ceramics industry is of great significance for reforming the development model of the ceramics industry and improving its added value and competitive advantage. This integration not only improves industrial performance but also promotes the optimisation of the industrial structure and promotes the industry's transformation towards a high-efficiency, energy-saving, and low-carbon model (Zhang, 2023). This study aims to evaluate the effectiveness of intelligent manufacturing in China's ceramics industry and formulate corresponding promotion recommendations accordingly. This study will be based on the theory of industrial integration and the techno-economic paradigm. It will comprehensively use research methods such as literature reviews and case studies to analyse the application of Internet of Things (IoT) and artificial intelligence (AI) technologies in the ceramics industry.

MATERIALS AND METHODS

This paper is based on the theory of industrial integration and the techno-economic paradigm and comprehensively uses research methods such as literature study and quantitative analysis. The literature study obtains data and information and determines the research objectives. Scholars' historical and current research status on the digital economy and industrial integration are understood. Quantitative analysis is used to research and analyse information such as enterprise production efficiency, and a comparative analysis is made of the KPI data before and after the introduction of IoT and AI technologies.

RESULTS AND DISCUSSION

Case 1: Application of IoT Technology in Ceramic Production

An in-depth study of a ceramics company with successful IoT technology applications. In ceramic manufacturing, IoT-based ceramic manufacturing is gradually realising the efficient use of resources. In practical application, the enterprise improves the manufacturing efficiency of the factory by using IoT technology (Wu et al., 2024).

On this basis, the introduction of Internet of Things (IoT) technology has greatly improved the production efficiency of ceramic enterprises (Liu, 2021). Data show that productivity can be improved by 18% by reducing downtime through real-time monitoring and predictive maintenance by introducing IoT technology. Accurate kiln temperature control and combustion efficiency through IoT technology can save 15% of energy consumption and lower scrap rates. Intelligent energy management systems with

IoT technology can reduce energy consumption by up to 15%. Real-time monitoring of process parameters can help reduce reject rates and improve product pass rates to over 99%. RFID tags and other tracking technologies can reduce inventory inaccuracies to less than 1% while increasing inventory turnover to 4. With IoT technology, companies can reduce supply chain response times by more than 20% and increase on-time delivery of orders by 10%. Predictive maintenance can reduce maintenance costs by 5% compared to planned maintenance. We compared the KPI data before and after the introduction of IoT technology, as shown in Figure 1.

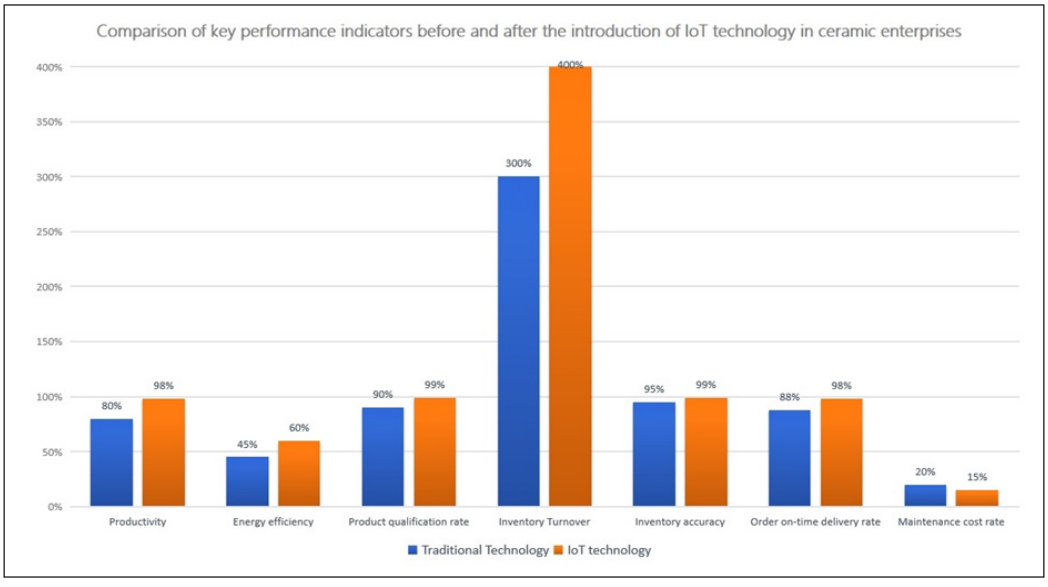

Figure 1. Comparison of KPI data before and after the introduction of IoT technology in ceramic enterprises

Case Study 2: Application of Artificial Intelligence Technology in Ceramic Quality Inspection

An in-depth study of a ceramics company with successful AI technology applications was conducted. In recent years, artificial intelligence has been increasingly used in industrial testing. Due to the complexity of the production process of ceramic products and the diversity of product characteristics, higher requirements are imposed on product quality inspection (Mao et al., 2020). The porcelain manufacturing company proposes to apply AI technology to automate the checking of ceramic products.

In ceramic production enterprises, with AI technology, the efficiency and precision of product quality inspection are greatly upgraded. Compared with traditional manual inspections, we can analyse vast quantities of pictures in a much shorter period (Gu, 2024). It is what makes rapid inspections of ceramic products possible. After testing, the

testing efficiency is improved by about 30%, and the testing time is reduced by 25%. The company's internal data shows that the AI testing system's false alarm and omission rates have been greatly reduced, and the accuracy rate has increased by 20%. In addition, the use of AI technology has led to a significant reduction in scrap rates. Checking and eliminating defective products can effectively avoid the inflow of defective products into the market, protect the enterprise's brand image, and reduce the cost of raw materials and production. The data shows that after adopting this system, the scrap rate is reduced by 15%, saving the enterprise a huge amount of money. The detection rate of products has been reduced by 10%, and the leakage rate has been reduced by 12%. We compared the KPI data before and after the introduction of AI technology, as shown in Figure 2.

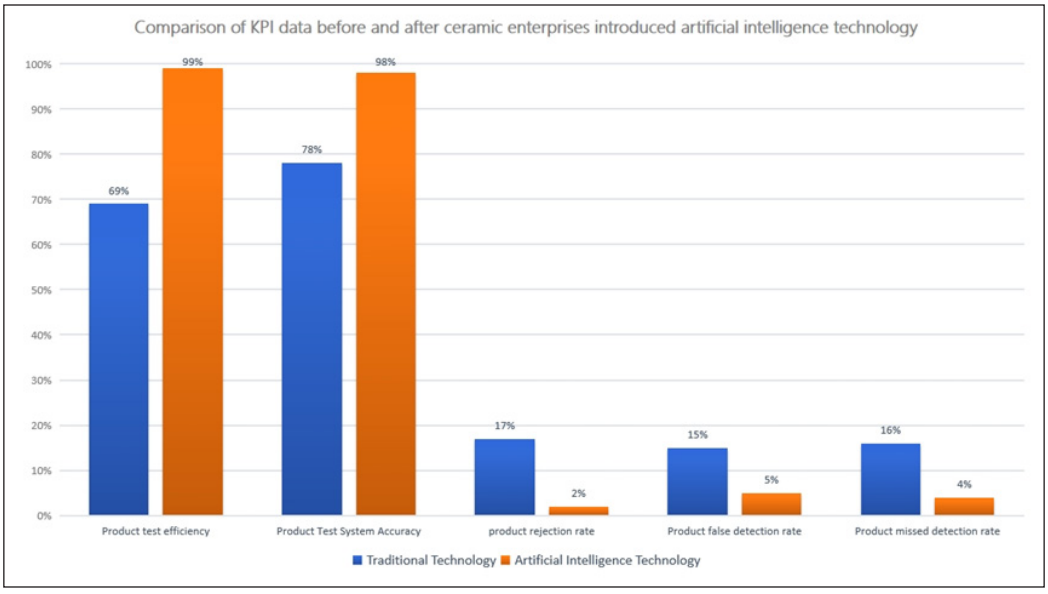

Figure 2. KPI data comparison between AI technology and traditional technology

Simultaneously, increased product output, energy savings, and reduction of environmental pollution are key priorities for the development of the ceramics industry. By comparison, a contemporary ceramic production enterprise might sometimes not look like a factory. It often combines large state-of-the-art plants with small office areas where design work is done and sales staff is accommodated, which is natural handicraft. It greatly accelerates production efficiency, reduces energy consumption, reduces manpower, reduces production costs, and simultaneously reduces environmental pollution. Strengthening support for enterprises in terms of policies and regulations, the government has introduced important incentives such as financial subsidies and tax incentives (Sakhaii et al., 2016)—enhancement of technological research and development and innovation in the firm. The

company needs to invest more in technological research and development—increased research on new processes (Zhang et al., 2018). Strengthen the cooperation between industry, academia, and research to accelerate the transformation and popularisation of scientific and technological achievements. Strengthen joint scientific research with institutions of higher learning, research institutes, and research institutes. Strengthening the talent training program and cultivating talents is the key to achieving sustainable industrial development. In higher vocational education, vocational literacy education must be strengthened, and based on this, additional relevant courses are set up so that students' theoretical knowledge and practical skills can be comprehensively improved. A group of competitive and capable high-quality talents can be cultivated, thus promoting the long-term development of China's industrial enterprises.

CONCLUSION

By analysing examples, people can see how intelligent manufacturing technology reduces business production costs and their environmental impact. The production process has automation and intelligence, making enterprises implement production management more accurately, eliminating human errors, and raising productivity. Intelligent manufacturing systems can also rationalise resource distribution and reduce waste on raw materials and fuel. It will reduce production costs. From the standpoint of environmental protection, energy conservation and environmental protection can be made even more successful by monitoring and data analysis in real-time to reduce pollution. The national government should give priority to enterprises in terms of policies and rewards and encourage enterprises and related research institutions to innovate through technology research and development.

ACKNOWLEDGEMENT

The authors sincerely thank the literature providers, reviewers, and editors on artificial intelligence in the ceramic industry who contributed to this article.

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