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A Role of Ergonomics in Advanced Manufacturing Systems: A Harmonious Blend of Human and Machine

Darshan H. Bhalodia[1,*], Rishabh D. Makwana[1], Parth M. Lakum[1], Heena M. Patel[1], Rohit R. Raval[1]

Abstract

The integration of human and machine elements in advanced manufacturing systems (AMS) necessitates a careful consideration of ergonomic principles to ensure the well-being and performance of the workforce. This paper explores the critical role of ergonomics in AMS, focusing on physical, cognitive, and organizational aspects. By optimizing the interaction between humans and technology, ergonomics aims to reduce musculoskeletal disorders, improve worker satisfaction, and enhance overall system efficiency. The paper delves into specific ergonomic considerations in AMS, such as workstation design, tool and equipment selection, work organization, and training. Furthermore, it discusses the potential benefits of incorporating ergonomic principles into AMS, including reduced injuries, improved quality, and increased worker morale. By striking a balance between technological advancements and human well-being, ergonomic design can contribute to the sustainable development of advanced manufacturing systems. The research highlights how ergonomics can improve the interface between operators and machines, ensuring that both human skills and machine capabilities are maximized for productivity and safety. Through an exploration of practical case studies, the paper illustrates the tangible benefits of ergonomics in advanced manufacturing settings, including reduced error rates, improved system adaptability, and increased operational efficiency. By fostering an ergonomic approach, advanced manufacturing systems not only improve worker well-being but also contribute to the sustainability and long-term success of manufacturing operations in the face of technological transformation. This work underscores the need for interdisciplinary collaboration between engineers, designers, and ergonomics experts to create manufacturing environments that are both technologically advanced and human-centered.

Keywords: Ergonomics, advanced manufacturing system, Industry 4.0, workstation, Human-machine interface design

***Author for Correspondence**
Darshan H. Bhalodia
E-mail: darshan.bhalodiya@atmiyauni.ac.in

[1]Assistant Professor, Department of Mechanical Engineering, Atmiya University, Rajkot, Gujarat, India.

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INTRODUCTION

The rapid evolution of manufacturing systems, driven by technological advancements, has led to the emergence of advanced manufacturing systems (AMS). While these systems offer significant benefits in terms of efficiency, productivity, and quality, they also introduce new challenges for workers.

The integration of human and machine elements in AMS necessitates a careful consideration of ergonomic principles to ensure the well-being and performance of the workforce.

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This paper explores how important ergonomics are to innovative industrial processes. It explores the fundamental concepts of ergonomics, its application in various manufacturing settings, and the specific challenges posed by AMS. Additionally, it examines the benefits of incorporating ergonomic principles into AMS design and implementation, including improved worker health, enhanced productivity, and reduced costs.

LITERATURE REVIEW

According to Arto Reiman, Jari Kaivo-oja and Elina Parviainen, a maturity paradox was identified highlighting the need to pay attention to the simultaneous development of technological HF/E capabilities in the manufacturing context [1].

Martina Gasova, Martin Gaso and Andrej Stefanik had given advanced industrial tools of ergonomics based on Industry 4.0 in which they suggested that operators in production/montage should not be only ones discussed but also support actions of production. Those are logistics and other indirect working activities. This is the only way it will be feasible [2].

According to Johannes Labuttis, human resources are a crucial component of success for those working in Siemens AG's factory production and process consultancy. In this situation, ergonomics are crucial. Experts analyze and appraise workstations using scientifically established evaluation techniques, drawing on ergonomics knowledge acquired through scientific trainings [3].

Priscila Rodrigues Fernandes and Ana Lucia Berretta Hurtado proposed that an ergonomics program must implement proactive measures to ensure sustainability, as only by anticipating negative events can prevention be fostered. Businesses have aimed to establish such initiatives, as they can enhance workplace quality of life while simultaneously decreasing expenses associated with treatments, employee turnover, legal claims, production errors, and absenteeism due to health issues among workers [4].

Ozlem Kaya evaluated the work environments of garment enterprises in Istanbul, Bursa and Corum provinces in terms of ergonomics. The quality control, fabric cutting, warehouse and manufacturing departments of 10 different establishments, which are active in 2015, were observed and these departments were evaluated by taking their photos. In this context, ergonomically suitable and unsuitable features of working environments of these establishments were determined and suggestions were made [5].

UNDERSTANDING ERGONOMICS

Ergonomics, the study of adapting the job to the worker, seeks to enhance the relationship between people and their work surroundings. It includes a broad array of elements, such as physical, cognitive, and organizational factors. By considering the capabilities and limitations of human beings, ergonomics seeks to create workspaces that are safe, efficient, and comfortable.

Key Principles of Ergonomics

- *Physical ergonomics:* Focuses on the physical demands of work, such as posture, force, and repetition.
- *Cognitive ergonomics:* Deals with mental processes involved in work, including decision-making, problem-solving, and information processing.
- *Organizational ergonomics:* Addresses the organizational and social factors that influence work, such as work design, job satisfaction, and stress management.

ERGONOMICS IN TRADITIONAL MANUFACTURING

Before delving into the specific challenges and opportunities of AMS, it is essential to understand the historical application of ergonomics in traditional manufacturing settings.

Traditional Manufacturing Ergonomics

- *Workstation design:* Traditional manufacturing often involved fixed workstations, leading to poor posture and musculoskeletal disorders. Ergonomic interventions included adjustable workstations, ergonomic seating, and proper tool placement.

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- *Tool and equipment design:* Tools and equipment were often designed without considering human factors. Ergonomic design principles were applied to reduce the physical demands of tasks, such as reducing force, minimizing repetitive motions, and optimizing tool handle design.
- *Work organization:* Traditional manufacturing often involved repetitive and monotonous tasks. Ergonomic interventions focused on job rotation, task redesign, and work-rest schedules to reduce fatigue and boredom.

ERGONOMICS IN ADVANCED MANUFACTURING SYSTEMS

AMS, characterized by automation, robotics, and digital technologies, present unique ergonomic challenges. The swift advancement of technology frequently surpasses the creation of ergonomic standards, creating possible hazards for employees.

Ergonomic Challenges in AMS

- *Human-robot collaboration:* The integration of robots into the workplace requires careful consideration of human-robot interaction. Ergonomics is vital in creating collaborative workspaces that reduce the likelihood of accidents and enhance productivity.
- *Virtual and augmented reality:* Utilizing virtual and augmented reality technologies in manufacturing may cause eye strain, fatigue, and motion sickness. Guidelines for ergonomics are essential to enhance the design and application of these technologies.
- *Remote and teleoperated systems:* Remote and teleoperated systems can lead to prolonged periods of sedentary work, eye strain, and musculoskeletal disorders. Ergonomic interventions, such as adjustable workstations and frequent breaks, are essential.
- *Data-intensive tasks:* The increasing reliance on data analysis and decision-making in AMS can lead to cognitive overload and stress. Ergonomic interventions, such as clear and intuitive user interfaces and effective task design, can mitigate these risks.

Ergonomic Opportunities in AMS

- *Personalized workstations:* AMS can enable the customization of workstations to individual worker preferences and needs, reducing the risk of musculoskeletal disorders.
- *Real-time monitoring and feedback*: Wearable technology and sensor-based systems can monitor worker posture, movement, and physiological parameters in real-time, providing immediate feedback to prevent injuries [6].
- *Predictive maintenance:* By analyzing data on equipment usage and worker performance, predictive maintenance can identify potential ergonomic issues before they lead to injuries or breakdowns.
- *Cognitive ergonomics:* AMS can be designed to reduce cognitive workload by automating routine tasks, providing clear and concise information, and minimizing distractions.

ERGONOMICS IN INDUSTRY 4.0

Ergonomics, the discipline focused on creating workspaces and tools that suit the individuals using them, is a crucial element of Industry 4.0. This is because Industry 4.0, with its focus on automation, robotics, and artificial intelligence, can significantly impact the way people work and interact with technology (Figure 1).

The Importance of Ergonomics in Industry 4.0

- *Prevention of musculoskeletal disorders (MSDs):* MSDs frequently occur in the workplace due to repetitive activities, uncomfortable positions, and lifting heavy items.
- In Industry 4.0, where automation can lead to repetitive tasks and new types of work, ergonomics can help prevent these injuries.
- *Improving worker productivity:* Ergonomic workplaces can reduce fatigue, increase comfort, and improve overall worker well-being, leading to higher productivity and job satisfaction.

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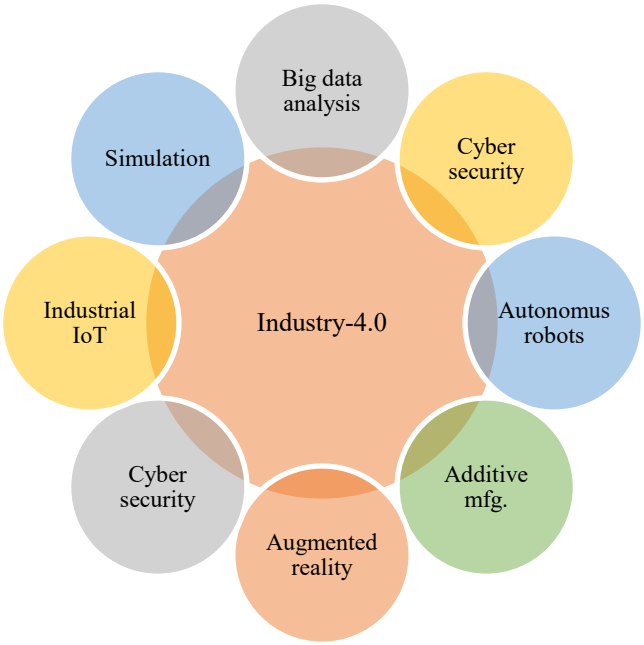

Figure 1. Impact of ergonomics in industry 4.0.

- *Reducing errors and accidents:* Proper ergonomic design can help reduce errors caused by fatigue or discomfort and can also help prevent accidents caused by poorly designed equipment or workspaces.
- *Adapting to evolving workplaces:* Industry 4.0 is constantly evolving, with new technologies and work processes emerging all the time. Ergonomics can help ensure that workplaces and equipment are designed to adapt to these changes, keeping workers safe and productive.

Ergonomic Considerations in Industry 4.0

- *Human-machine interface design:* Ergonomics plays a crucial role in designing intuitive and user-friendly interfaces for machines and software. This includes factors like screen size, font size, and layout, as well as voice commands and touchscreens.
- *Workplace design:* Ergonomics can help create workspaces that are adaptable to different tasks and workers. This includes adjustable workstations, ergonomic seating, and proper lighting.
- *Training and education:* Workers need to be trained on how to use new technologies ergonomically. This includes proper posture, techniques for avoiding repetitive strain injuries, and how to recognize and report ergonomic issues [7].
- *Data-driven ergonomics:* Industry 4.0 generates vast amounts of data, which can be used to analyze worker performance, identify potential ergonomic risks, and optimize work processes.
- *Collaborative robotics:* When working alongside robots, ergonomics is crucial to ensure safe and efficient collaboration. This involves creating robots that are simple to engage with and that do not threaten the safety of employees.

Challenges and Opportunities

While Industry 4.0 offers many opportunities for improving workplace ergonomics, it also presents challenges. For instance, the swift pace of technological advancements can hinder the ability to stay current with ergonomic best practices. Additionally, the increasing use of automation can lead to new types of ergonomic risks that need to be identified and addressed [8].

However, Industry 4.0 also offers opportunities for innovative solutions to ergonomic challenges. For instance, wearable tech can help track employee posture and offer immediate feedback. Virtual and augmented reality can simulate and evaluate various workplace layouts.

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BENEFITS OF ERGONOMICS IN AMS

As technology progresses, the significance of ergonomics will continue to grow. By emphasizing human factors, we can leverage the possibilities of AMS to develop a future where technology and human abilities operate in unison (Figure 2).

Enhanced Employee Health and Wellness

- Decreased fatigue and stress
- Decreased musculoskeletal issues
- Enhanced job satisfaction and morale

Enhanced Output and Effectiveness

- Decrease in rate or errors and accidents
- Improved product quality
- Faster task completion times

Reduced Costs

- Lower healthcare costs
- Reduced absenteeism and turnover
- Improved product quality and reduced waste

CASE STUDIES: EFFECTIVE APPLICATION OF ERGONOMICS IN AMS

Case Study 1: Automotive Manufacturing

- Implementation of ergonomic workstations with adjustable seating and tool holders.
- Use of exoskeletons to reduce physical strain during assembly tasks.
- Training courses aimed at instructing employees on correct posture and work methods.

Case Study 2: Electronics Manufacturing

- Design of ergonomic assembly lines with reduced reach distances and minimized repetitive motions.
- Utilization of ergonomic hand tools and devices to alleviate hand and wrist strain.
- Implementation of job rotation and work-rest schedules to prevent fatigue [9, 10].

LIMITATIONS OF ERGONOMICS IN ADVANCED MANUFACTURING SYSTEMS

While ergonomics is a crucial aspect of advanced manufacturing systems, it does come with certain limitations.

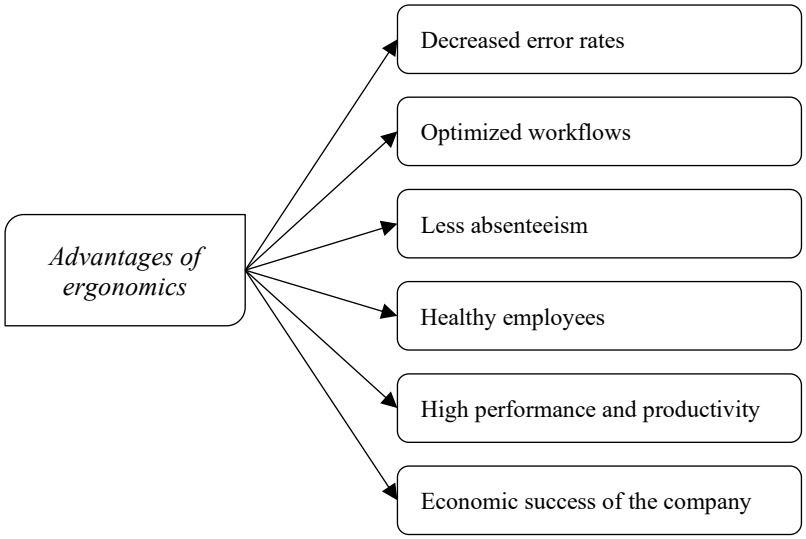

Figure 2. Advantages of ergonomics in advanced manufacturing system.

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Initial Investment

Implementing ergonomic solutions often requires significant upfront costs, including:

- Ergonomic assessments and consultations
- Purchasing ergonomic equipment (chairs, keyboards, workstations)
- Training employees on proper ergonomic practices
- Modifying existing workstations

Resistance to Change

- Workers may be resistant to changes in their work routines and workstations, especially if they have become accustomed to their current setup.
- Overcoming this resistance requires effective communication, training, and ongoing support.

Complex Work Environments

- Advanced manufacturing systems often involve complex and dynamic work environments, making it challenging to apply ergonomic principles consistently.
- Factors like frequent task changes, shift work, and varying work demands can hinder the effectiveness of ergonomic interventions.

Individual Variability

- People have different body sizes, strengths, and preferences, making it difficult to design a one-size-fits-all ergonomic solution.
- Tailoring ergonomic solutions to individual needs can be time-consuming and costly.

Technological Limitations

- While technology can enhance ergonomics, it can also introduce new challenges. For example, poorly designed or configured computer workstations can lead to musculoskeletal disorders.
- It's essential to ensure that technology is used in an ergonomic manner.

Long-Term Effectiveness

- The long-term effectiveness of ergonomic interventions can be compromised if workers don't consistently adhere to ergonomic principles.
- Ongoing monitoring and reinforcement of ergonomic practices are crucial to maintain their benefits.

Subjectivity of Comfort

- What feels comfortable to one individual might not feel comfortable to someone else.
- It's important to involve workers in the ergonomic design process to ensure their needs and preferences are considered.

To address these constraints, it's crucial to:

- *Involve workers in the design process:* Seek their input and feedback to ensure solutions are practical and effective.
- *Perform detailed ergonomic evaluations:* Recognize particular ergonomic hazards and customize solutions as needed.
- *Provide ongoing training and support:* Educate workers on proper ergonomic practices and encourage them to report any discomfort or pain.
- *Invest in high-quality ergonomic equipment:* Choose equipment that is adjustable and designed to support good posture.
- *Assess and evaluate the efficiency of ergonomic implementations:* Routinely examine the effects of ergonomic modifications and modify as necessary.

By addressing these limitations, organizations can create more ergonomic and productive work environments in advanced manufacturing systems.

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FUTURE DIRECTIONS AND RESEARCH NEEDS

- *Advanced human-machine interfaces:* Developing intuitive and user-friendly interfaces that minimize cognitive load and optimize human-machine interaction.
- *Wearable technology and biometric monitoring:* Utilizing wearable devices to monitor worker performance, fatigue, and stress levels in real-time.
- *Cognitive ergonomics in AMS:* Investigating the impact of cognitive factors on worker performance and designing systems that support optimal cognitive function.
- *Ergonomic design for diverse workforces:* Considering the needs of workers with disabilities and diverse physical abilities.

CONCLUSION

Ergonomics plays a vital role in ensuring the success of advanced manufacturing systems. By integrating ergonomic principles into the design, implementation, and operation of AMS, organizations can create work environments that are safe, efficient, and conducive to human well-being. As technology progresses, the significance of ergonomics will continue to grow. By emphasizing human factors, we can leverage the possibilities of AMS to develop a future where technology and human abilities operate in unison.

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