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Applications of Flexible Manufacturing Systems in Industry: A Review

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Abstract: ***FMS and its adoption is a nuanced cradle technology in India and sees a limited implementation of its innovative technology and concepts. Our world today is a technologically sophisticated world, only characterized as fictional a few years ago. A lot today has transformed smart and technologists are striving to bring home new and innovative devices, homes, factories, and even cities. Scientifically proven is that these advanced technologies and concepts can boost an organization's overall performance. Many corporations, researchers, and institutions agree that automation and robotic systems are the foundation of industrial production and a key factor of the Industrial 4.0 revolution. There is an ongoing demand for increased output and manufacturing quality, as well as an urgent requirement to improve overall efficiency in manufacturing systems to withstand competitive pressure. Flexible Manufacturing Systems has added these advantages to organizations, due to its capabilities, capacity and advantages. The work of extensive research presented highlights the importance of FMS adoption and acceptance of various industrial automation technologies and techniques, as well as FMS potential.***
Keywords: Flexible Manufacturing Systems, Manufacturing, Industry 4.0, Industrial Production, Automation.

I. INTRODUCTION

The manufacturing industry is essential to a nation's economy. It remains vital as a key driver of growth and development. The sectoral focus is on manufacturing, increasing value proposition through the transformation of materials into products. Advanced technical advances in production and manufacturing are the goal of the next age industries, in which there is a thriving market and room for growth. Robots, NC machines, automation, CNC machines, and other new dynamic concepts, such as FMS, are pushing companies to develop these technical capabilities [1, 17]. Flexible Manufacturing Systems (FMS) is described as an interconnected complicated system controlled by the computer software for automation of material handling network and numerically controlled machinery that can handle small volumes of a variety of part types simultaneously [1]. A system capable of producing a broad variety of things by integrating a number of programmed machine tools integrated by an automated material management system [19]. The manufacturing technologies that comprise flexible manufacturing systems include computer or numerically controlled machines, conveyor systems (including roller, motorised roller), robotic systems, computers, automated guided vehicles and programmable electronic microcontrollers, among other things, are examples of numerical control or direct numerical control centres [2]. Flexible manufacturing can be understood as non-repeated mass production of multi-purposes due to changing client and market demand, production of different functions within the same period of the means of production made. Flexible manufacturing systems, providing macro operations planning and control with integrated control systems are computer-based systems and are capable of producing a wide range of goods or services quickly. Nowadays, flexibility entails developing competitively priced customized high-quality items that can be supplied to consumers promptly.

There is a vital significance and need to improve India's manufacturing efficiency and competitiveness. India's liberalization, globalization and privatisation strategies have mostly resulted in severe competition in the Indian sector. In contrast, the relative contribution of the manufacturing industry in general, as well as the sub-areas in particular, to India's overall GDP has remained dormant during the previous few decades. As a result, stakeholders and decision-makers are taking industrial competitiveness extremely seriously [2].

II. LITERATURE REVIEW

The acceptance of flexible manufacturing systems as an emerging technology has also been highlighted by Suresh et al. [3] in their presented work. The application of flexible manufacturing systems as an element of medium capacity, fairly diversified medium variety manufacturing has also been acclaimed. An attempt has also been made to describe FMS as a unified manufacturing facility comprising functional numerical controlled manufacturing units integrated with automatic material handling systems.

Flexibility within the systems is not a product of the capabilities of the equipment alone as argued by Gupta et al. [4]. It's really the result of multiple elements, including physical characteristics and functional decisions, consolidation of information, management approaches, etcetera. The effectiveness of flexibility in manufacturing process systems is quintessential under different operating environments. The vitality of advanced flexible manufacturing technology is also confirmed by Hammel [5]. Presented in his work is the capability of flexible manufacturing systems to increase system efficiencies, process flexibility and viability, and an end to end integration. It was also an observation that absolute transparency throughout the process chain at each stage can be achieved due to the ability of the systems to connect various departments and units together.

Bennett et al. [6] has further presented in their work aid to the development of impactful and efficient flexing manufacturing technology by virtue of critically important elements and attributes in literature.

Outlook	Definition of Flexibility
Manufacturing	➢ The capability of producing different parts without major retooling requirements. ➢ A measure of how swiftly the organization converts its processes from an old product line to a new one. ➢ The potential to change a production schedule to modify a component or handle multiple components.
Functional	➢ The ability to efficiently produce exceedingly customized and unique products.
Client	➢ The ability to utilize dimensions of delivery rate.
Strategic	➢ The ability of an organization to extend a diverse range of products to its customers.
Capability	➢ The ability to swiftly escalate or deescalate the production levels or rapidly switch the capacity from one product or service to the other.

Fig. 1 The flexibility concepts and diverse approaches

Additionally, Pandey et al. [7] analyzed the performing capabilities of flexible manufacturing technology in the context and setup of the manufacturing sector. The outcome provided the required evidence bringing to light the associated benefits including enhanced output and reduced lead times.

Dolage et al. [8] also considered the effects of the implementation of flexible manufacturing technology on the economic margins and synthesized that a significant relationship is present between both as per the research which makes it favourable for the organizations to adopt flexible manufacturing technologies at large.

Discussing the future trends of research, it was acclaimed by Chan et al. [9] that the advanced procedures on smart and intelligent flexible technologies will be critical in influencing research.

Fernandez et al. [10] presented the future of flexibility in manufacturing technologies in combination well with the industry's next-generation ready manufacturing areas. It was agreed that for supporting the next-gen manufacturing in an Industry 4.0 setup, the internet of things, cloud, and cyber systems are foundational blocks for advanced manufacturing activities to occur worldwide. These enhanced capabilities will be swift in scaling operations of production and will be attained with the help of emerging technology in material handling equipment, sensing, and integrating abilities.

It will therefore be equally important to consolidate the two dimensions of workspace namely virtual and physical in order to concentrate the required operational effectiveness of manufacturing as highlighted by Tao et al. [11].

It has also been agreed upon through the work presented by Tamimi et al. [12] that for elements of future research, it will be helpful to analyze flexible manufacturing technology through the use of models simulating the manufacturing systems as ascertained by measurement of performance of flexible systems in the carried out research.

Furthermore, the capabilities, limitations, and nuances of advancing and developing flexible systems and their utilization is a subject to be taken up for research in the near future as presented by Malhotra et al. [13] in his research. These avenues of research remain much less explored especially in the context of the Indian subcontinent. It has also been elucidated that the advancement and development of flexible manufacturing systems should be conforming with the ability to meet the demands while further boosting the manufacturing capability.

Blockchain technology assigns a unique identification to each part, allowing manufacturers to detect problems earlier and determine the source of the problem. Blockchain, for example, can track expiry dates, storage temperatures, and shipment information in the food business. Rather than recalling all of the merchandise, the food company may just remove the food that was affected in the one truck where the refrigeration system failed. The product may be recalled before it reaches to the customers [23, 26].

It is therefore clearly evident that the application of flexible manufacturing systems in the Indian scenario has a long way to go and is limited by a variety of influencing factors such as lacking advanced aspects considered essential for the success of these systems and also necessarily required in flexible cells and systems as mentioned by Rao et al. [14].

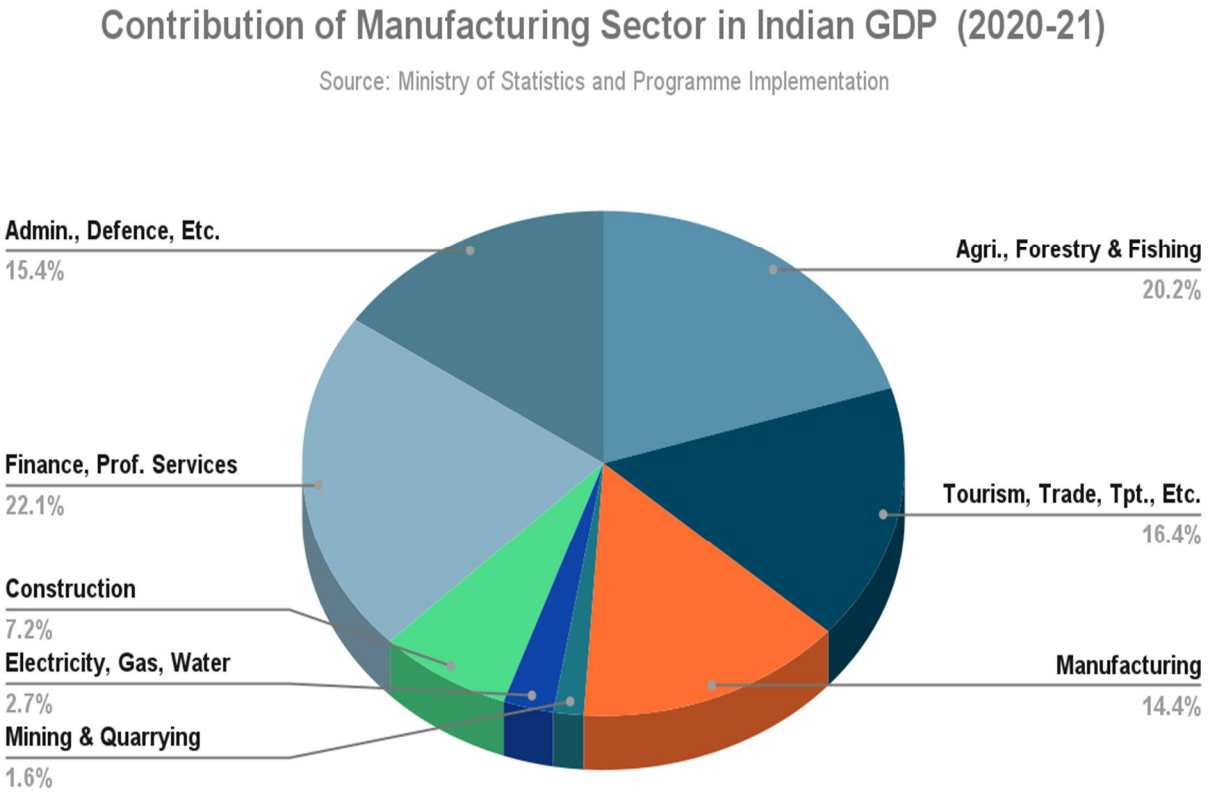

Fig. 2 The contribution of the manufacturing sector to Indian GDP (2020-21)

III. ACCEPTANCE AND IMPLEMENTATION CHALLENGES OF FLEXIBLE TECHNOLOGY IN THE INDIAN INDUSTRY

The fundamental stage in which the major crucial challenges are faced by flexible systems before any significant advancements can be initiated is the stage of design.

Not all the components that enter production can be suitably manufactured with flexible systems as the process might not be optimal. Therefore, it becomes essential to carefully select the components to be manufactured based on the potential of the system in terms of capacity, operational requisites, equipment, integration etcetera.

A conjunctional challenge is the amount of flexibility that is provided to each flexible system. Such a challenge arises because of the presence of a diverse set of requirements from each flexible unit due to variable operations purposes. An automated arm's flexibility and freedom in fabricating a mechanical component is an example of the challenge posed. Thus, design considerations have to be prioritized to eliminate the issue [16].

It also becomes important to address the ambiguity in the capability of each system for material handling including but not limited to roller conveyors, guided vehicles, tow trucks and tuggers, lifts, and robots at the fundamental stage.

At the early stage of design, blueprints of the factory floor highlighting the placement of each cell or unit aids the ultimate purpose of increasing the flexibility of the system through enhanced efficiency and effectiveness. The elements of such an objective would typically include and address queuing, vacant spaces, lead time optimization, congestion and traffic management etcetera.

An aspect closely related to computer-aided and integrated manufacturing is placing the control of the systems structurally considering the needs of multi-system and multi-element interaction. The decision pertaining to these elements such as control layout, equipment management, and production planning are needed to be taken at this point.

What follows the preliminary stages of design is the planning. Certain issues have been observed as a component of planning and essentially require resolution before the process of production starts.

It is an operational challenge to ascertain the components to be selected for the initiation of manufacturing of components. The decision of selection is based on a diverse range of factors that are determined.

The planning stage also includes the classification of the operations that need to be performed on the job on the numerical control machines using tools and equipment. Furthermore, the challenge is also to classify the machines to reduce lead times and the effectiveness of the flexible manufacturing systems.

As we now advance to the stage of scheduling, the challenges associated with sequencing and scheduling occur and are dealt with in real-time or instantaneously in flexible manufacturing systems. It demands ascertaining the right chain or set of events to be executed in the perfect order through advanced smart techniques of employing procedures or algorithms.

The performance of the entire flexible manufacturing system is also a function of the correct material handling systems put in place, hence the heedful selection of jigs, fixtures, conveyors, tuggers, trucks, lifts and pallets as per the requirements and capability of the systems is necessary.

As discussed earlier, each system operates under a set of constraints that limit its operation and performance. Thus, the system enjoys unique flexibility of operations including numerical control-related limitations, production capability related limitations etcetera. A flexible manufacturing system should, therefore, be considerate of the possibilities while operating [30].

Once the system is up and running, the process needs to be controlled and monitored, as a part of the control stage. It involves meticulous and strict adherence to the manufacturing schedule. Any errors or challenges that occur, such as those related to equipment and computer control, are dealt with by SOPs in place. It also involves periodic maintenance of systems underuse.

IV. APPLICATIONS OF FLEXIBLE MANUFACTURING SYSTEMS

A significant amount of literature has been researched and compiled on the use of flexible systems. The state and extent of its utilization and application in the real scenario differ and are also based on the industrial landscape and technological prowess of various nations and their individual sectors.

Hence, it becomes a tedious and challenging task to say with exactness quantitatively. Also, it can not be denied blatantly that the application and the extent to which these systems are put to use are constant across, therefore it becomes important to highlight the increase in difficulty in measuring and presenting statistics. However, attempts are being made to acing the challenge resolution [21].

Through means of research, it has been concluded that flexible systems are much more likely to thrive in the Indian industrial environment when the mentioned factors are predominantly present.

The systems and their performance should be backed by an adequately positive economic scenario. An absence can result in inferiority, high failures, and low confidence [23]. Also, some areas do struggle with inadequate capabilities to satisfy the requirements of the production of certain units or components in the Indian scenario due to varied reasons [25, 30].

A complete transformation in terms of the organization's composition and arrangement is required by a complete overhaul to make sure that it meets the standards of flexible systems under all encounterable conditions.

The synergy between the operating and functional components of the entire flexible ecosystem in various domains including but not limited to technology is of the essence.

The organization's stakeholders pay heed to the idea of flexible manufacturing which is deficient and imperfect without the presence of the right shareholder outlook, quality and performance measures, capital expenditure, and skill application, hence, remains the most critical aspect of the application of flexible systems in India. Moreover, data from complex manufacturing processes and systems may be examined and used to improve existing goods, processes, and services while also developing fresh offers [41,48].

Thus, in the manufacturing and production business, technologies such as data analytics, big data, and IIoT may be employed to assure quality, boost performance and efficiency, decrease costs, streamline supply chains and enhance flexible manufacturing systems [21, 27, 45, 50].

Influential Parameters	Indian Scenario
1. Market & Scenario a. Tough competition. b. Significant product diversity and differentiation. c. Induced confidence in high quality products.	a. Positive competition. b. Rich quality products are widely demanded. c. Positive market. d. Favorable tax regulations.
2. Governmental Policies a. Liberalized economy & policies. b. Technological reinforcement & assurance. c. Unhindered resource support. d. Liberal trade policies. e. Equity foreign participation.	a. Technological prowess present. b. Duty exemptions on certain products. c. Governmental financial aid. d. Foreign equity participation limited to 51%.
3. Investment Prospects a. Huge capital availability. b. Long term borrowing & low interest rates. c. Subsidized industrial inputs.	a. Capital raising prospects through markets. b. Governmental financial aid. c. Favorable governmental initiatives.
4. Resource Availability a. Unhindered resource support. b. Cheap & skilled workforce. c. Uninterrupted power availability.	a. Availability of skilled & cheap workforce b. Duty exemptions on certain products. c. Unhindered supply of certain resources.
5. Management Objectives a. Inventory minimization. b. Manufacturing cost reduction. c. Lead time reduction. d. Labor cost reduction. e. Rich quality products. f. Diverse product range.	Management Objectives are framed and maintained by individual organizations based on the organization's own interests.

Fig. 3 The scenario of flexible systems and their application in the Indian scenario

V. CONCLUSION

Flexible manufacturing systems are an integration of parts and processes. An essential component that finds its important mention is the computer or the process control unit which commands the operations involved. These flexible systems have changed the nature of manufacturing with limited human involvement and interference and huge production potential in today's world servicing and catering to swiftly evolving needs. This instils much-required confidence in the system. Such systems have thus claimed a special position in the global manufacturing industry. The work presented also highlights the scenario of limited contribution and adoption of flexible technological systems in Asia in contrast with the global scenario. It also stands by the fact that the utilization of this technology in the Indian subcontinent is also limited. However, owing to the fact that the adoption of smart and flexible technologies record performance enhancement in manufacturing, steps need to be taken towards its acceptance.

Furthermore, the future aspects of work regarding flexible systems need to be explored to incubate these systems out of their current nascent stage. Artificial Intelligence, Machine Learning, Deep Learning, Data Science, additive manufacturing technologies, and smart application of data will lead the way in research. With adequate evolution of these elements, we will be in a better position to embrace flexible manufacturing technology perfectly.

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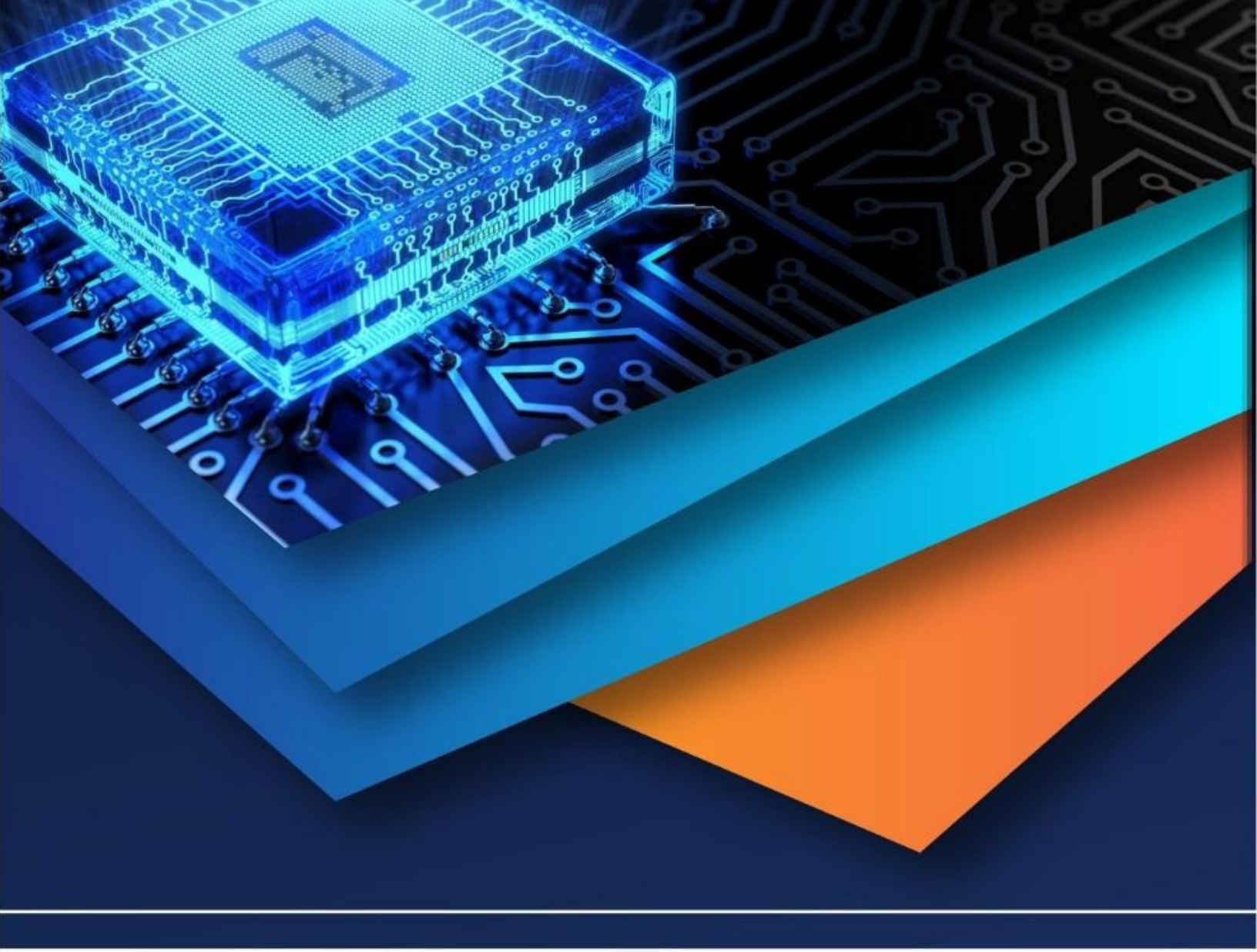

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