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A Research Paper on Flexible Manufacturing System Simulator for Technical Institutes

Vijay N. Kalbande[1*]; Ashish Fande[2*]; Santvan Jagtap[3]; Akash Shendre[4]; Rishabh Chikhale[5]; Anirudhh Sonkamble[6]
Satyendra Upawanshi[7]; Amar Pendram[8]
Department of Mechanical Engineering, NIT, RTMNU, Nagpur

Corresponding Author:- Vijay N. Kalbande[1*]; Ashish Fande[2*]

Abstract:- Today's scenario of manufacturing activities is toward automation. To provide practical exposure and better understand, there is need of automated machines in the technical institutes. Due to financial& space constraints, most of the institutes is not having automated machines for the demonstration. This comprehensive review navigates the landscape of Flexible Manufacturing Systems (FMS), dissecting scheduling rules, design, and simulation methodologies, and the integration of advanced technologies. The motor control systems, microcontroller applications, and robotic process automation contribute to a holistic understanding of FMS evolution. This synthesis serves as a roadmap for researchers and practitioners, fostering adaptability and responsiveness in modern manufacturing. FMS is the highest automation in manufacturing industry and work on group technology concept. In this project, the authors are planning to design and develop FMS Simulator for technical institute. This helps students to understand group technology concept, automated vehicle system, automated material handling system, working of automated transfer line, industrial robot and so on. This proposed initiative aligns with the broader goals of academics – to produce graduates who are not only well-versed in theoretical concepts but also equipped with the practical skills demanded by industry The utilization of an FMS with educational purposes started in the academic year 2011–2012 and still remains active. Here, the most illustrative FPs are expounded, and successful academic outcomes are reported. In addition, a set of initial considerations based on the experience acquired by the FMS is provided.

Keywords:- *Flexible Manufacturing System, Automation, Simulator, Industry 4.0, Robotics.*

I. INTRODUCTION

Flexible Manufacturing Systems (FMS) stand at the forefront of the contemporary manufacturing landscape, offering a transformative approach to production that aligns with the dynamic demands of modern industry. In a world characterized by rapid technological advancements, shifting consumer preferences, and a need for unparalleled efficiency, FMS emerges as a pivotal solution to enhance adaptability, responsiveness, and overall operational excellence. The core essence of FMS lies in its ability to dynamically reconfigure and optimize production processes, allowing manufacturers to respond promptly to changes in product specifications, order quantities, and market dynamics. This adaptability is particularly critical in an era where product life cycles are shrinking, customization is on the rise, and global competition is intensifying. FMS represents a paradigm shift from traditional, static manufacturing systems to dynamic, agile environments capable of seamlessly accommodating diverse production requirements. This comprehensive review embarks on a journey to dissect and synthesize the multifaceted realm of FMS, traversing through key dimensions that shape its evolution. Scheduling rules, a foundational aspect of FMS, are explored in-depth through the seminal works of Gelenbe and Guennouni (1991) and Sabuncuoglu (1998), which unravel insights into optimizing production schedules through sophisticated simulation approaches. Building upon this, the review navigates the terrain of design and simulation methodologies, examining the works of Um et al. (2021) and Daniyana et al. (2021) as they provide tangible applications and theoretical insights into the efficient design and simulation of FMS, with a particular focus on railcar sub-assembly operations.

As the manufacturing landscape continues its trajectory towards Industry 4.0, the integration of advanced technologies becomes paramount. Florescu and Barabas (2020) delve into the modeling and simulation of FMS as a foundational component of Industry 4.0, elucidating the role of technologies such as the Internet of Things (IoT) and data analytics in creating interconnected and intelligent manufacturing ecosystems. In parallel, Anglani et al. (2002) contribute a rule-based procedure for object-oriented modeling, offering a structured approach to unravel the intricacies of FMS and enhance decision-making processes. The integration of motor control systems, microcontroller applications, and advanced automation technologies further enriches the FMS landscape. Vinothkann (2020), Abebe et al., Thounaojam et al. (2014), Pinckney (2006), Louw et al., Costa et al. (2022), and Borisov et al. (2016) collectively present a panorama of how diverse technologies, from integrated motor drives to microcontrollers and robotic process automation (RPA), contribute to the flexibility, precision, and adaptability of manufacturing processes. In summary, this review embarks on a holistic exploration of FMS, providing a comprehensive overview of scheduling rules, design and simulation methodologies, and the integration of advanced technologies. By synthesizing

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insights from key papers, this review aims to contribute to a nuanced understanding of FMS, offering a roadmap for researchers, practitioners, and decision-makers navigating the dynamic landscape of modern manufacturing.

II. LITERATURE SURVEY REVIEW

This paper introduces FLEXSIM, a versatile simulation tool designed to evaluate specific classes of flexible manufacturing systems (FMS). The tool's originality lies in its separation of the data model, representing the entire FMS, from the simulation model by utilizing a relational database management system to define the simulated system. Consequently, FLEXSIM features a user interface incorporating a database management system tailored specifically for the FMS simulator. This methodology offers two significant advantages: the database interface can be directly linked to the manufacturing database of an actual FMS, and users can interact with the tool using terminology and data representation pertinent to the real FMS being simulated. Additionally, the relational database system ensures automatic verification of the system model's consistency and completeness during simulation. FLEXSIM operates on Unix Sys V and Unix Bsd4.3 operating systems, making it a portable tool [1]. This study investigates the impact of different scheduling rules on the performance of flexible manufacturing systems (FMSs). Various machine and automated guided vehicle (AGV) scheduling rules are evaluated based on the mean flow-time criterion. Scheduling rules are commonly used in practice, either as standalone scheduling schemes or as components of complex scheduling systems. In this paper, we compare these rules under different experimental conditions using an FMS simulation model. Our goal is to assess the sensitivity of the rules to changes in processing time distributions, varying levels of breakdown rates, and different AGV priority schemes. Additionally, the paper provides a comprehensive bibliography on the subject [2].

This paper focuses on the simulation design and analysis of a Flexible Manufacturing System (FMS) integrated with an Automated Guided Vehicle system (AGVs). To optimize the performance of FMS with AGVs, various parameters need to be considered, such as the number, speed, and dispatching rules of AGVs, types of parts, scheduling, and buffer sizes. Among the critical factors, we address the following three: (1) reducing congestion; (2) lowering vehicle utilization; and (3) increasing throughput. The paper employs systematic analysis methods that merge simulation-based analytic techniques with optimization methods, specifically Multi-Objective Non-Linear Programming (MONLP) and Evolution Strategy (ES). MONLP is used to determine the system's design parameters through multi-factorial and regression analyses, while ES verifies each parameter for simulation-based optimization. A validation test for these methods is conducted. This methodical approach to design produces accurate experimental results, ensures confidence in the specification of design parameters, and provides a robust framework for analysis [3].

Flexibility, intelligent coordination of the manufacturing processes, effective handling, and quality control are all encouraged by the railcar industry's manufacturing operations management system (FMS). The railcar industry faces a shortage of productivity due to certain production systems that are not adaptable in real time. As such, a flexible manufacturing system (FMS) is essential to meet the demands of manufacturing operations. An FMS that includes the assembly line, lean manufacturing, logistics, and quality assurance is proposed in this work. The components of the system include robotic welding, arrays of sensors and cameras, automated material storage and supply, standard interfaces like the internet of things (IoT) interface, robotic welding, and a strong intelligent control system. Radio Frequency Identification Technology (RFID) is used for component identification and process control. While the Anylogic 8.2 program was being used to simulate the designed system, a framework for the FMS's implementation was being developed. Based on the results obtained, there was an inverse relationship between the operating cycle time of the conveyor and the conveyor speed per cycle when the conveyor's performance was simulated at a speed of 3 m/s and 7 m/s. The results showed that the system can suitably perform the sequence of assembly and quality assurance operations during the manufacturing of railcar subassemblies with minimal interruptions and human intervention. This will promote production of component parts with high structural and dimensional integrity with significant reduction in the manufacturing cycle time and cost [4].

Recent years have witnessed a dynamic development trend in the field of Flexible Manufacturing Systems (FMS), which is now regarded as a foundation for digital manufacturing and an essential component of intelligent manufacturing systems. In an increasingly competitive industrial environment, creating the factory of the future will require managerial, technical, and creative efforts in addition to the study and analysis of certain FMS key elements. In order to determine the ideal architecture of the examined system, this paper offers a material flow design methodology for flexible manufacturing systems using a novel approach. A method for simulating and improving material flows in advanced manufacturing systems is provided by the research. The structure of the system can be established and specific technical and economic parameters for each processing and transport capacity can be determined by using specialized analysis and simulation software. Through virtual modeling and simulations, various processing scenarios will be assessed in an effort to improve the system's efficiency and performance. As a result, an interactive tool for industrial companies to use in the design and management of flexible manufacturing lines will be developed. This paper's primary application is in the development of intelligent manufacturing systems, where the control system will create and employ simulations to assess current parameters and forecast future events [5].

One of the most popular methods for the analysis and design of manufacturing systems is simulation using a software model. The object-oriented approach has proven to be a highly effective technique in the field of software

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engineering research, particularly when it comes to the design and implementation phases of complex software projects. Even though object-oriented programming has shown to be an effective technique, dependable software still requires the application of a systematic design approach, particularly when developing simulation models. This paper presents a new process for creating simulation models of flexible manufacturing systems (FMSs), based on the ARENA! simulation language and UML analysis/design tools. The definition of a systematic conceptual procedure to design FMS simulation models and a set of rules for the conceptual model translation in a simulation language are the two primary components of the proposed procedure. The objective is to increase the effectiveness of software development by using a rule-based methodology and to enhance the ARENA with some of the core object-oriented features! environment of simulation[6] When designing a control system, one of the most important factors to take into account is the availability of space. Space is needed for driver units, wiring connections, control circuits, and motors in the control system installation. By establishing wireless communication between the motor driver unit and control unit, this work aims to reduce the amount of space needed for a motor control system. The motor control system's overall space requirement is reduced thanks to the design. The control unit can be moved to any location in close proximity to the system because it is designed with wireless communication in mind. This enhances the system's accessibility during fault correction and precise operation times. The outcome shows the suggested system's dependability and effectiveness with a range of parametric assessments [7].

Integrated motor drives (IMD) present a potential answer to the growing demand for high power density, high efficiency, and high temperature capabilities in automotive and aerospace applications. The converter and the machine's close physical integration, nevertheless, might potentially raise the temperature of the individual parts. This necessitates meticulous IMD system design as well as mechanical, structural, and thermal analysis. This study examines the thermal impacts of current IMD technologies on the IMD system. Additionally examined are the impact of the power electronics location on the IMD system and related thermal management theories. Potential solutions are offered along with a discussion of the difficulties in designing and manufacturing an IMD and the effects that close physical integration has on the structure and mechanics. We also review possible converter topologies for an IMD, such as the matrix converter, multiphase full bridge converters, two-level bridge, and three-level neutral point clamped converters. Additionally covered are wide band gap devices such as silicon carbide and gallium nitride, as well as how they are packaged in power modules for IMDs. Packaging technologies and power module components are also showcased. [8]

The growth in demand for linear motors is principally driven by the replacement of traditional mechanical (ball screws, gear trains, cams), hydraulic, or pneumatic linear motion systems in manufacturing processes, machining, material handling, and positioning with direct electromechanical drives. The linear motor market heavily depends on the semiconductor industry (applications) and permanent magnet industry (linear motors manufacture). A recent market study1 shows that linear motors have impacted the linear motion market less than expected. The main obstacle that makes companies reluctant to replace mechanical, hydraulic, and pneumatic actuators with linear electric motors is the higher initial cost of installation of direct linear motor drives as compared to traditional mechanical drives [9]. This driving simulator study, conducted as part of the EU Adaptive project, investigated drivers' performance in critical traffic events, during the resumption of control from an automated driving system. Prior to the critical events, using a between-participant design, 75 drivers were exposed to various screen manipulations that varied the amount of available visual information from the road environment and automation state, which aimed to take them progressively further 'out-of-the-loop' (OoTL). The current paper presents an analysis of the timing, type, and rate of drivers' collision avoidance response, also investigating how these were influenced by the criticality of the unfolding situation. Results showed that the amount of visual information available to drivers during automation impacted on how quickly they resumed manual control, with less information associated with slower takeover times, however, this did not influence the timing of when drivers began a collision avoidance maneuver. Instead, the observed behavior is in line with recent accounts emphasizing the role of scenario kinematics in the timing of driver avoidance response. In specific, avoidance actions were started when the situation criticality was higher than an inverse time to collision value of about $0.3\ s^{-1}$. Our findings imply that take-over time, timing, and avoidance response quality appear to be largely independent. Moreover, kinematically late avoidance initiation was found to predict collision outcome, whereas long take-over time did not. Therefore, attaining kinematically early avoidance initiation should be the primary goal of system design, rather than short take-over times [10].

III. PROBLEM FORMULATION

A. *Problem Identification*

FMS have wide variety of application in both industries and other fields. Flexible manufacturing systems uses robot and other mechanisms to increase production as well as production quality. FMS along with robots are part of syllabus in various courses including ours. So to ensure brief study and hands on experience there was a significant gap between theoretical & practical knowledge , which was fulfilled previously by industrial visits .

B. *Existing System:*

- Automated manufacturing systems are very expensive and requires training to operate.
- They consume large floor space compared to other lab equipments .
- These system requires conditioned power source and hard to program and reprogram.

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- Installing a industry grade unit for educational purpose requires lots of resources.
- Maintenance is also expensive.

C. Proposed Solutions:

To solve all the above problems, development of a Arduino based flexible manufacturing system simulator, configured to perform sequential operation, can directly be operated by manual override, can perform actions like pick-n-place and assembly and can be reprogrammed to perform any action using manual assist programing. It will consist of two 5-DOF robotic arms, ASRS, AGVs and a conveyor belt as shown in figure below:

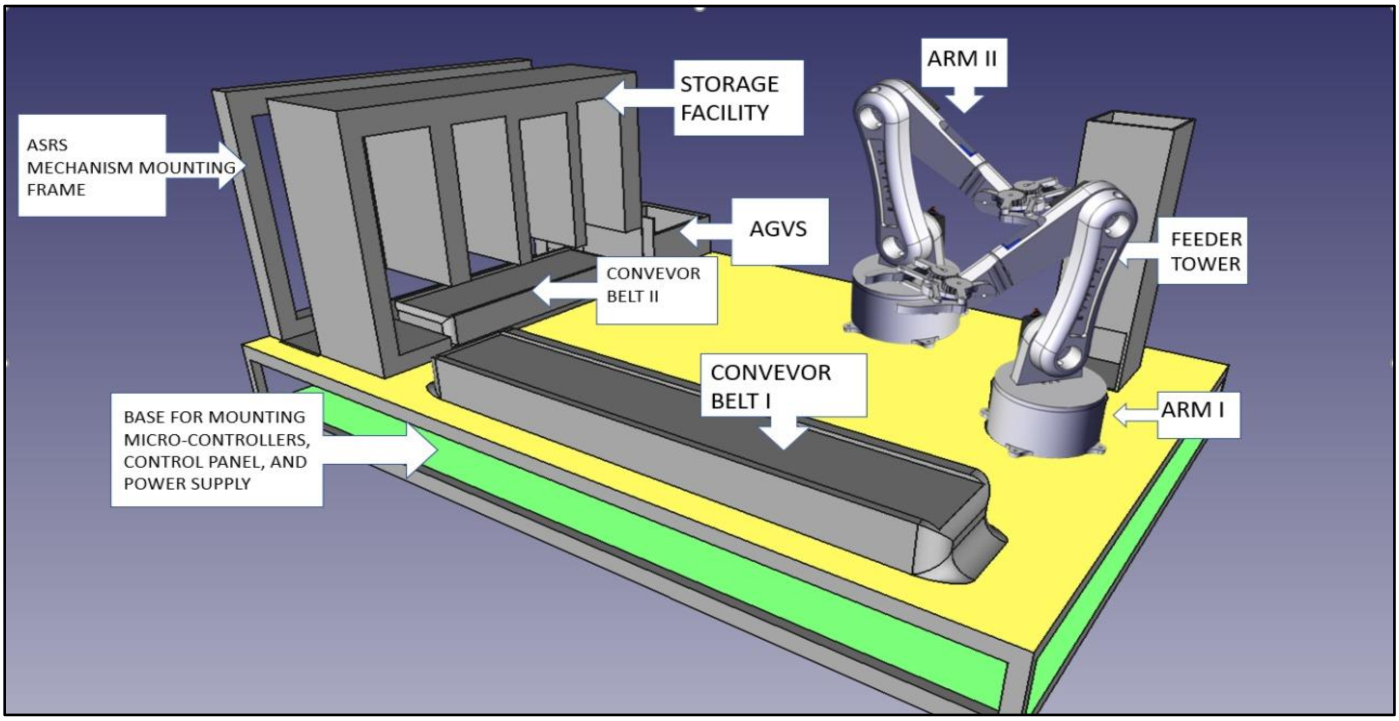


Fig 1 Project Layout

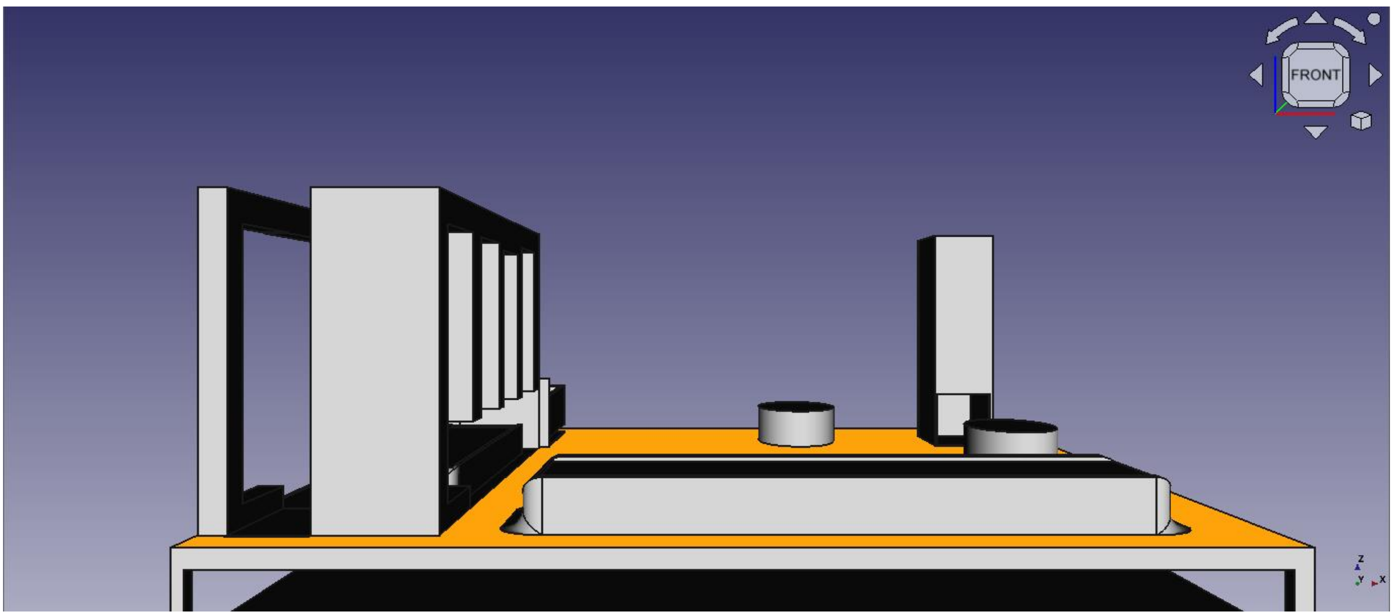
D. Project Aim and Objectives:

➢ *Aim:*

To design and develop a Flexible Manufacturing System simulator with robotic arms for Automation in Production lab for academic purpose.

➢ *Objective:*

- To develop a low cost a Flexible Manufacturing System simulator.
- To bridge the gap between academics and industry.
- To enhance learning with hands on experience on technologies like FMS, Robotics, ASRS, AGVs etc.



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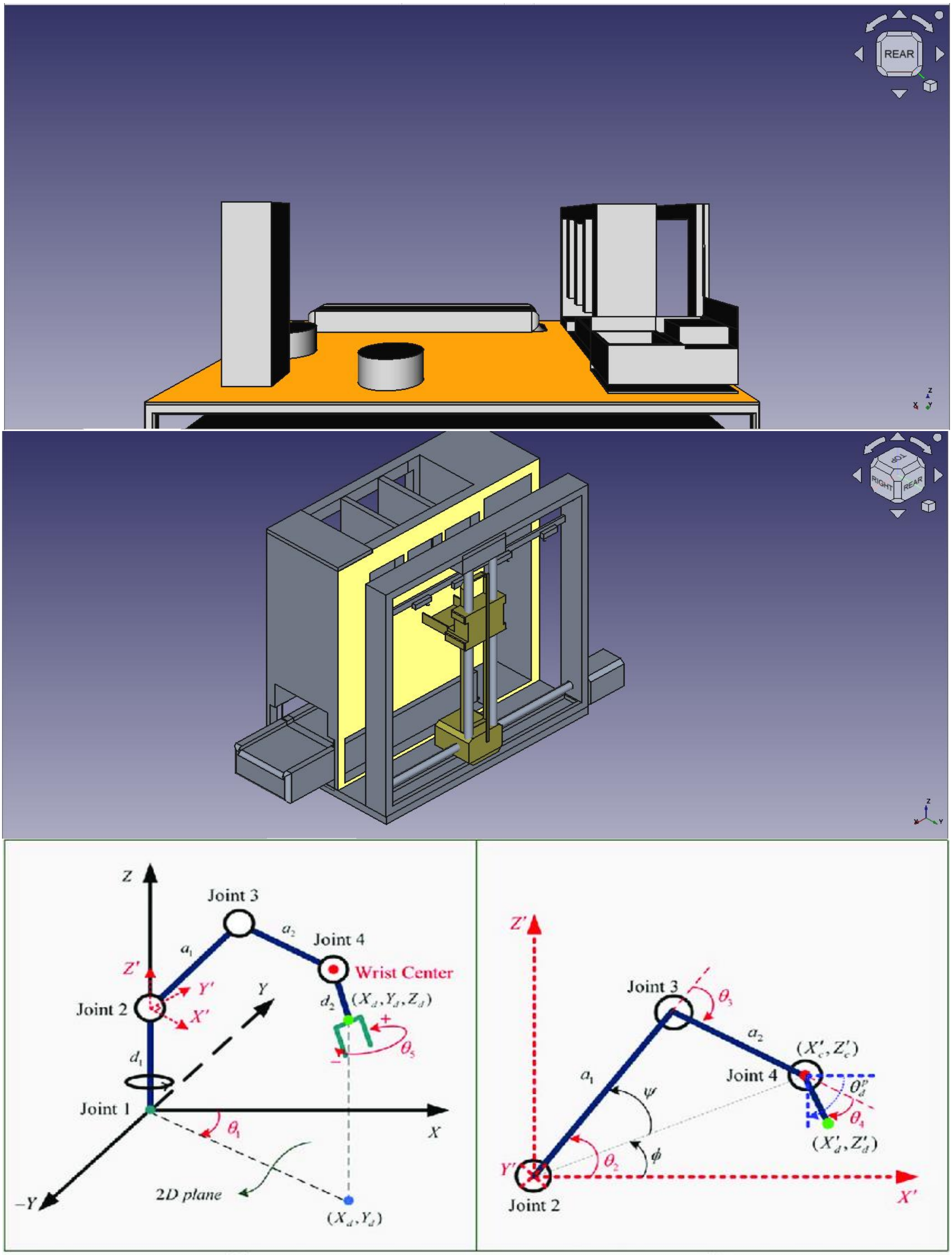

Fig 2 CAD Model and Orientation of robotic arms in 3-D space.

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E. Circuit Diagram and Flow Chart

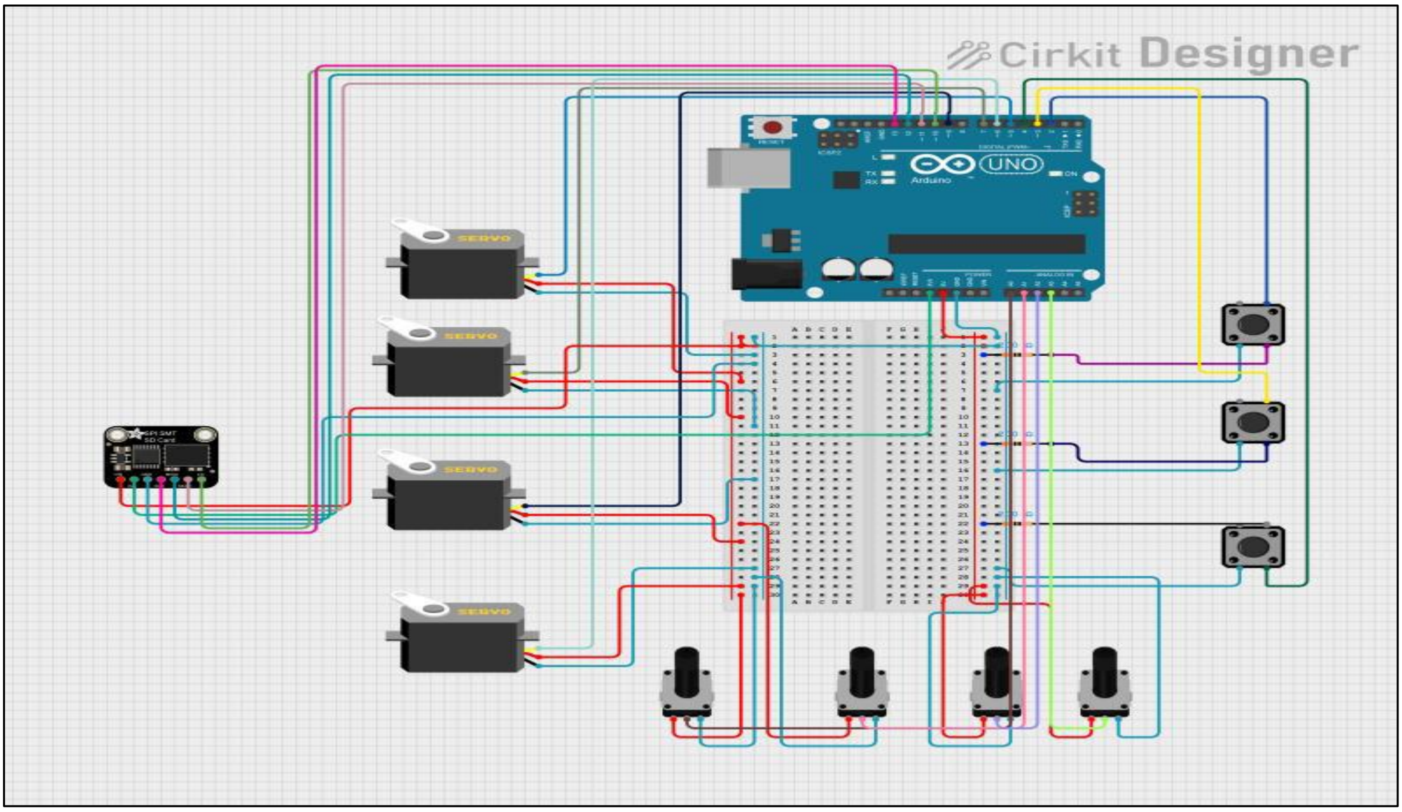

Fig 3 Circuit Diagram for Robotic Arms

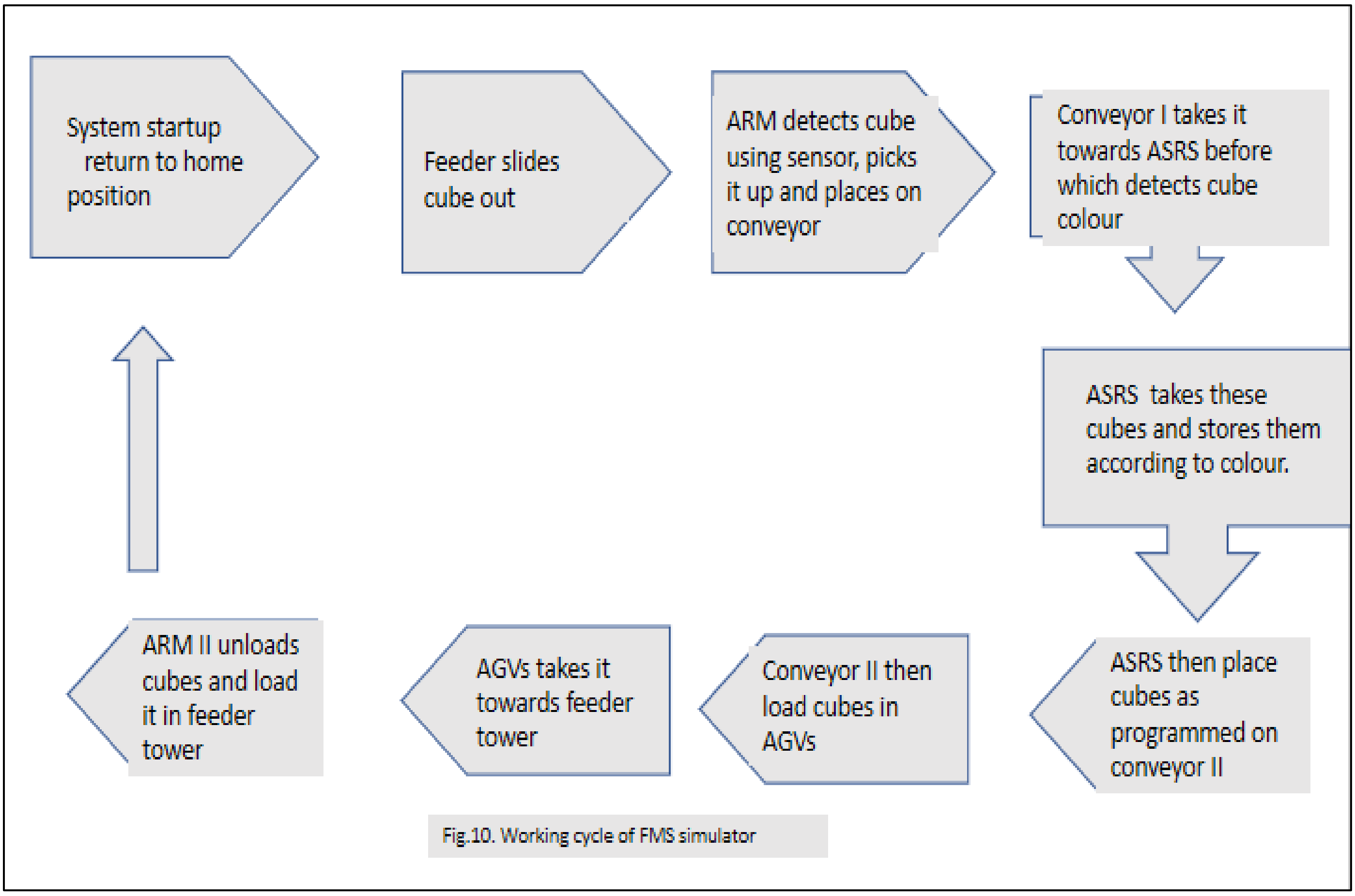

Fig 4 Work Flow Chart

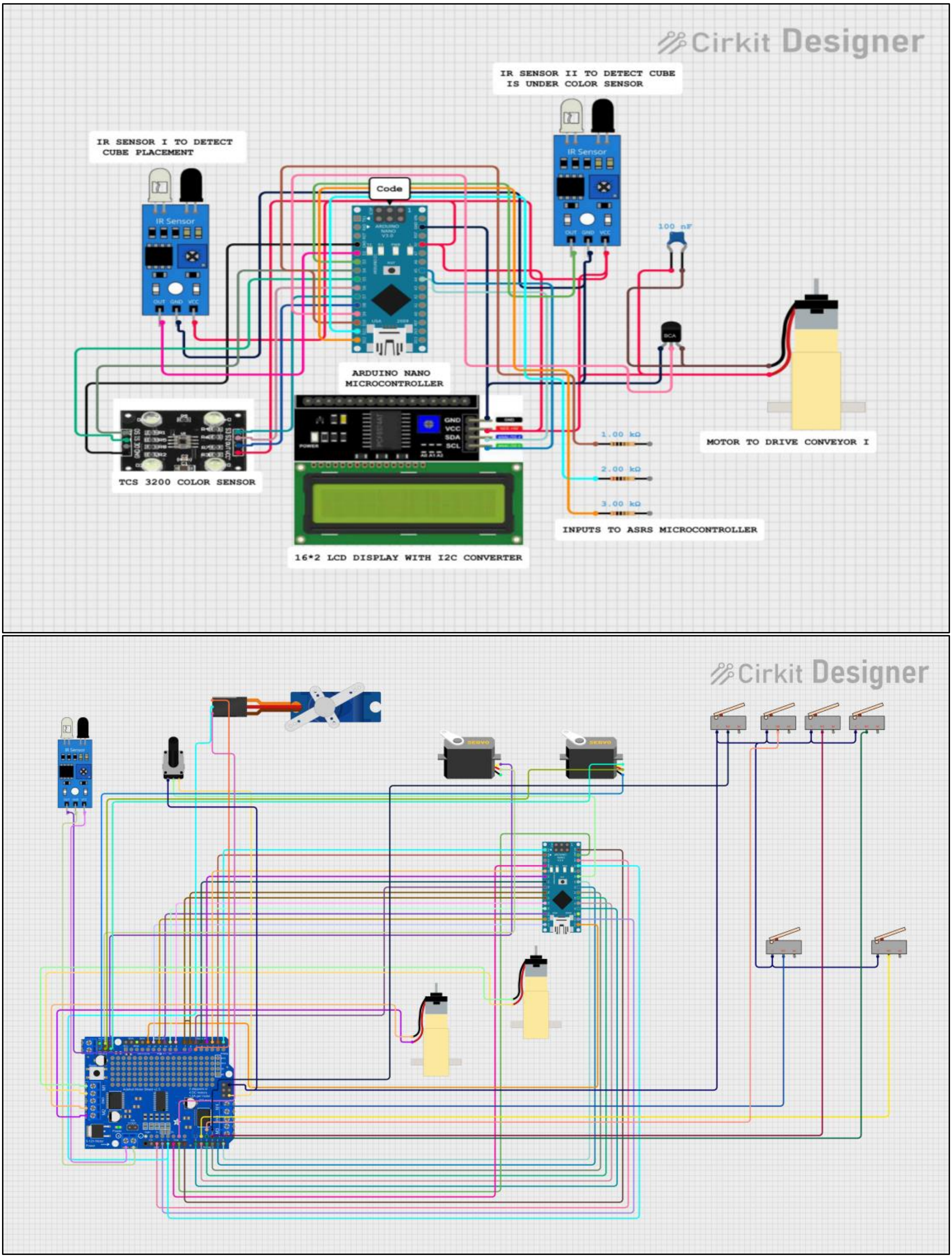

Fig 5 Circuit Diagram for Color Sorting and for ASRS System

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➢ *Advantages:*

- Hands- on learning.
- Cost effective training.
- Real time feedback.
- Enhanced problem-solving skills.
- Industry alignment.
- Accessible anytime, anywhere, safety and customization.

➢ *Disadvantages:*

- Technical issues.
- Dependency on technology.
- Lack of physical interaction.
- Skill transferability.

F. Facilities Required:

- Hardware: Arduino Mega micro controller, Sensors, MG995 servo motors, Conveyor Belt Assembly.
- Facility: 3-D printing , PCB milling, Acrylic Sheet cutting.
- Software: Arduino IDE, Tinker CAD, Free CAD.

IV. RESULTS AND DISCUSSION

Simulators provide a safe environment for students to learn and experiment without the risk of injury or damage to equipment, promoting a culture of safety in manufacturing education. Institutes can use simulators for research and development purposes, exploring new manufacturing techniques and processes in a controlled environment. flexible manufacturing system (FMS) simulator for technical institutes provides a valuable tool for students to learn and practice manufacturing processes in a controlled environment. Such a simulator offers a range of benefits, including hands-on experience, experimentation, and skill development. Here's an in-depth look at the results and implications of implementing an FMS simulator in technical institutes. A flexible manufacturing system simulator replicates the functions and processes of a real FMS within an educational setting. It typically consists of virtual or physical components such as workstations, robots, conveyor belts, and control systems. Students interact with the simulator to understand various aspects of manufacturing, including production planning, scheduling, operation sequencing, and machine programming. The primary objective of incorporating an FMS simulator into technical institutes' curriculum is to enhance students' understanding of modern manufacturing practices. By engaging with simulated production environments, students develop practical skills and theoretical knowledge that are vital for success in the manufacturing industry. The learning outcomes include: Hands-on Experience: Students gain practical experience by operating virtual or physical machinery, troubleshooting issues, and optimizing production processes within the simulated environment. Through simulated scenarios and challenges, students learn to identify problems, analyze root causes, and implement effective solutions, thereby honing their problem-solving abilities. Understanding of Automation: FMS simulators demonstrate the integration of automation technologies such as robotics, PLCs (Programmable Logic Controllers), and CNC (Computer Numerical Control) machines, allowing students to grasp the principles of automated manufacturing.

Collaborative projects and group activities within the simulator foster teamwork and communication skills among students, mirroring real-world manufacturing environments where cooperation is essential for success. Students are exposed to decision-making scenarios involving resource allocation, production scheduling, and inventory management, preparing them to make informed decisions in industrial settings. An effective FMS simulator for technical institutes should encompass a range of technical features and capabilities to provide a comprehensive learning experience: The simulator should allow for the integration of various modules representing different manufacturing processes, enabling customization based on specific learning objectives and curriculum requirements. The simulator should accurately replicate the behavior of real-world manufacturing systems, including machine dynamics, material flow, and system responsiveness, to provide an immersive learning experience. Students should have access to programming interfaces for controlling and configuring simulated machinery, facilitating learning in areas such as robot programming, PLC programming, and CNC machining. The simulator should provide real-time monitoring of production metrics, performance indicators, and system status, allowing students to assess the impact of their actions and decisions. Instructors should be able to create custom scenarios and exercises within the simulator, tailored to specific learning objectives and competency levels, to accommodate diverse student needs. To maximize the educational value of an FMS simulator, technical institutes can employ various pedagogical approaches and instructional methods: Encourage hands-on exploration and experimentation within the simulator, allowing students.

In the exploration of Flexible Manufacturing Systems (FMS) in this comprehensive review underscores the dynamic nature of modern manufacturing and the crucial role FMS plays in meeting its evolving demands. As we progress further into an era dominated by Industry 4.0 technologies, object-oriented modeling, and advanced automation, it becomes evident that the integration of theoretical knowledge with practical applications is paramount for academic and industrial success. To bridge the gap between theoretical understanding and hands-on experience, there is a pressing need for the establishment of low-cost Arduino-based FMS facilities in academic settings. Such facilities would not only empower students with practical skills but also serve as incubators for innovation and problem-solving in manufacturing. Arduino, known for its accessibility and versatility, can democratize access to FMS technology, fostering a new generation of engineers and researchers well-versed in both theoretical principles and real-world applications. This proposed initiative aligns with the broader goals of academics – to produce graduates who are not only well-versed in theoretical concepts but also equipped with the practical skills demanded by industry. Arduino-based FMS

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facilities have the potential to transform learning environments, creating a symbiotic relationship between academics and industry that nurtures creativity, adaptability, and a deep understanding of the intricacies of modern manufacturing.In concluding the discussion on implementing a flexible manufacturing system (FMS) simulator in technical institutes, it's essential to recap the significant points, analyze the implications, and outline recommendations for successful integration. The primary goal of introducing an FMS simulator in technical institutes is to enhance students' understanding of modern manufacturing processes and technologies. Through hands-on experience and experimentation, students develop practical skills, problem-solving abilities, and decision-making competencies vital for success in the manufacturing industry. An effective FMS simulator should possess a range of technical features and capabilities, including modular design, realistic simulation, programming interfaces, monitoring and feedback mechanisms, and scenario creation tools. These features enable a comprehensive learning experience and facilitate customization based on specific learning objectives and curriculum requirements. Various pedagogical approaches can be employed to maximize the educational value of an FMS simulator, including experiential learning, problem-based learning, simulation-based training, guided discovery, and assessment and feedback mechanisms. These approaches promote active engagement, critical thinking, skill development, and continuous improvement among students. The integration of an FMS simulator has a profound impact on student learning and skill development, leading to improved engagement, mastery of manufacturing skills, readiness for the industry, stimulation of innovation and creativity, and cultivation of a mindset of continuous improvement. By bridging the gap between academic knowledge and industry requirements, the simulator enhances students' employability and adaptability in industrial settings. Despite its benefits, the implementation of an FMS simulator presents certain challenges and considerations, including cost and infrastructure requirements, curriculum integration complexities, technical challenges, accessibility and equity concerns, and the need for robust evaluation and assessment methods. Addressing these challenges requires careful planning, pedagogical innovation, and ongoing support from stakeholders. Technical institutes should engage in strategic planning to assess the feasibility and potential benefits of integrating an FMS simulator into their educational programs. This process involves evaluating the institution's goals, resources, infrastructure, and stakeholder needs, as well as conducting cost-benefit analyses to justify investment decisions. Collaboration with industry partners and leveraging external funding sources can help mitigate financial barriers and facilitate the acquisition and maintenance of simulator equipment and software. The successful integration of an FMS simulator into the curriculum requires collaboration among faculty members, curriculum developers, instructional designers, and industry experts. Technical institutes should revise existing curricula to incorporate simulation-based learning modules, aligning them with industry standards and accreditation requirements. Faculty development programs should be implemented to train instructors in simulator operation, curriculum design, pedagogical strategies, and assessment methods, ensuring effective utilization of the simulator as an educational tool. Technical institutes must ensure equitable access to the FMS simulator for all students, regardless of background or resources. This involves providing adequate access to simulator facilities, scheduling flexibility to accommodate diverse student needs, and offering technical support services to address any issues or challenges encountered during simulation activities. Additionally, initiatives to promote inclusivity and diversity in technical education should be implemented to ensure that underrepresented groups have equal opportunities to benefit from simulator-based learning experiences. Technical institutes should adopt a culture of continuous improvement and quality assurance to enhance the effectiveness of FMS simulator integration. This involves soliciting feedback from students, instructors, and industry partners to identify areas for improvement and innovation in simulator design, curriculum delivery, and assessment practices. Regular evaluation of student learning outcomes and performance metrics can inform data-driven decision-making processes and facilitate evidence-based improvements in educational practices. Technical institutes should encourage research and innovation in the field of FMS simulation to advance the state of the art and address emerging challenges and opportunities. This involves conducting research projects, collaborations with industry partners, and participation in professional development activities such as conferences, workshops, and seminars. By staying abreast of the latest developments and best practices in FMS simulation, technical institutes can maintain their competitive edge and prepare students for the evolving demands of the manufacturing industry.

V. CONCLUSION

In conclusion, the integration of a flexible manufacturing system simulator in technical institutes represents a significant opportunity to enhance student learning, skill development, and readiness for the manufacturing industry.

- By providing a realistic and immersive learning environment, the simulator enables students to acquire practical experience, problem-solving abilities, and technical competencies essential for success in modern manufacturing settings.
- While challenges exist, strategic planning, curriculum integration, faculty development, student support services, continuous improvement, and research and innovation can help technical institutes leverage the full benefits of FMS simulation technology.
- By embracing simulation-based learning approaches and fostering collaboration with industry partners, technical institutes can play a pivotal role in preparing the workforce of tomorrow to meet the challenges and opportunities of the global manufacturing landscape.

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