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Automatic material handling for machining process using 6 DOF of robot

Prof. V. G. Galande[1], Nikita Ahire[2], Kanchan Pangavhane[3], Ashwini Avhad[4]

Professor, Dept. Of Robotics and Automation,

K. K. Wagh Institute of Engineering Education and research, Nashik, India[1]

Dept. Of Robotics and Automation, K. K. Wagh Institute of Engineering Education and research, Nashik, India[2,3,4]

Abstract: Most of the manufacturing industries perform batch-wise production where different jobs undergo various machining operations. More number of the machining operations at different machining stations requires scheduling in order to minimize the cycle, delay time and energy consumption. There are various solutions available with different combinations, such kind of problems are termed as “NP Hard Problems”. Various algorithms and software’s are available for solving this type of problems in manufacturing industries, but it provides solution by using traditional algorithms and are expensive too for medium-scale industries. Therefore, there is need of technique which will provide global, unique and feasible solution for complex scheduling problems. Solutions provided by the algorithms are automatically generated, they can be executed by the automatic system like Robotics. Robotics System itself consist of multiple path planning combinations.This project focuses on the automatic material handling and scheduling of machining processes using a six-degree-of-freedom (6-DOF) Kawasaki robot in an industrial setup with two CNC machines. The robot loads a job into the first CNC machine, flips the job, places it into the second CNC machine, and finally unloads it into the finished pallet. The proposed system improves workflow efficiency, minimizes delays, and ensures consistent job handling accuracy. This also enhances worker safety by minimizing human interaction in hazardous areas. The case study conducted in the industrial setup demonstrates the effectiveness of robotic automation in material handling and scheduling, making it adaptable for various manufacturing applications while offering a cost-effective solution for reducing labor expenses. The use of robots for loading and unloading jobs in industries offers significant advantages in terms of reducing labor costs and increasing productivity. By automating the loading and unloading process, industries can reduce dependency on manual labor, minimizing the risk of human errors, inconsistencies and workplace injuries associated with repetitive tasks. Robots ensure precise and accurate placement of jobs, preventing misalignment issues that could lead to defects or machine downtime. Additionally, robotic systems can work in hazardous environments, reducing the need for human workers to be exposed to high temperatures, heavy loads, or sharp tools. With improved efficiency and reduced labor costs, industries experience higher throughput, lower operational expenses, and increased overall profitability. The reliability and speed of robotic loading and unloading contribute to a streamlined manufacturing process, making automation an essential investment for modern industries aiming for higher productivity and consistent quality.

Keywords: CNC machine, Material Handling, labor expenses, productivity.

I. INTRODUCTION

In the technology driven era of manufacturing, the integration of Robotics and Automation has proven to be a great evolution in increasing efficiency, productivity and precision. Manufacturing industries in India holds up to 17 percent GDP of nation. Generally manufacturing industries try to reduce the expenses and utilize the resources in optimized manner. Industries are attempting to stay competitive and meet the growing variable demands of customers, flexible manufacturing may be the solution to fulfill requirements but, in that case, scheduling plays an important role for optimization, to counter idle time of machines and utilize the potential of each resource, as cycle time and energy consumption are the two conflicting criteria. Scheduling is done manually as it is difficult when there is complex structure or ways. Automated robotic systems are providing solution for scheduling and optimization but they are on the basis of traditional or conventional methods. Also, the overview of manufacturing industrial sectors. This project focuses on the development and implementation of an Automatic Material Handling and Scheduling System using a 6-DOF Kawasaki Robot in an industrial setup with two CNC machines. The primary objective is to automate the loading, flipping, unloading, and scheduling processes to enhance production efficiency while maintaining accuracy and safety. In this system, the robot picks up a job and loads it into the first CNC machine for machining. Once the process is complete, the robot flips the job and places it into the second CNC machine for further operations. After machining in the second CNC, the finished product is unloaded and placed into the finished pallet. This automation not only ensures precise handling of

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the workpiece but also eliminates the need for manual job flipping and handling, thereby reducing dependency on human labor. One of the significant advantages of integrating robotic automation in material handling is the reduction of cycle time and operational delays. Unlike manual handling, where workers take time to adjust, inspect, and align jobs, robots perform these tasks swiftly and with high accuracy. This results in optimized machine utilization, reduced idle time, and improved throughput. Moreover, robotic systems are programmed to follow pre-defined paths and sequences, ensuring consistent placement of jobs in CNC machines, which significantly reduces the chances of misalignment and machining defects. Another critical aspect of this project is workplace safety. Manual job handling in CNC machining environments involves potential risks such as injuries from sharp tools, exposure to high temperatures, and physical strain due to lifting heavy components. To mitigate these risks, a fencing system has been installed around the working area of the robot and CNC machines, restricting human intervention in hazardous zones. This setup ensures operator safety while allowing the robot to execute material handling tasks efficiently. Overall, this project demonstrates the feasibility and advantages of using robotic automation for material handling and scheduling in CNC-based manufacturing setups. The integration of a 6-DOF Kawasaki Robot with CNC machines ensures smooth workflow execution, reduces production delays, enhances precision, and improves workplace safety. The case study conducted within the industry validates the effectiveness of this system in achieving high efficiency, cost savings, and enhanced productivity. With the growing demand for automation in manufacturing, the proposed system serves as a scalable and adaptable solution for industries aiming to implement smart robotic automation for material handling applications.

II. LITERATURE SURVEY

Most of the manufacturing companies perform Batch-wise production where different operations are carried out. The most common processes are carried out on various workpiece are turning, drilling, grooving, etc. Various researchers have worked on optimization of cutting parameters of the turning process. Genetic algorithm has been used as an optimal solution finder to find the optimal cutting parameters during turning process [3]. Some other researcher used multi-objective optimization technique to optimize cutting parameters in turning processes: speed, feed and depth of cut [4]. Usually, the industrial robot is used to perform various operations due to its flexibility and efficiency. Most of the machining operations required scheduling in order to minimize cycle time and energy consumption and increase the productivity. To perform the scheduling of the robotic system, various methodologies are available which provides solutions to such problems. Some researchers have used Travelling salesman algorithm with some improvements by considering only minimization of cycle time [5]. Along with cycle time, few researchers have considered energy consumption as an important aspect for cyclic scheduling [6]. Genetic algorithm is one of the most popular approaches used by previous researchers to optimize robotic tasks. This method has a wide task point space. However, this research is limited to 2–3 degrees of freedom manipulators [8]. However, "Elastic net method" is used for the scheduling purpose of non-redundant and redundant robots and research on optimal configuration of robot [9]. Mainly m-machine cells are used for the scheduling of the robotic system by researchers [6][7]. Moreover, Researchers have attempted evolutionary optimization methods such as heuristic algorithm to find the pareto efficient solutions for minimizing the considerations. [7]. Researchers have used the traditional algorithms for optimization problems which provides them the local solutions as results[6].To conclude, it is noticed that mainly research is carried out scheduling on the m-machine cells and have used traditional algorithms which provides local solutions to the given problem. This report presents the automatic scheduling carried on the robot centered cell which uses metaheuristic algorithms and provides global solutions with better results.

III. MOTIVATION

Manufacturing industries rely on efficient material handling and scheduling to reduce cycle time, labor dependency, and production costs. Manual operations often lead to inconsistencies, delays, and safety risks, affecting overall productivity. This project automates job loading, unloading, and scheduling using a 6-DOF Kawasaki Robot with two CNC machines. Robotics ensures precision, reduced errors, and optimized workflow, leading to higher efficiency and lower operational costs. Additionally, automation enhances worker safety by minimizing human intervention in hazardous environments. By implementing robotic automation, the project demonstrates a cost-effective and scalable solution for industries, aligning with Industry 4.0 trends to improve production quality and process reliability.

IV OBJECTIVE

The objectives are as follows:

1. Minimize labor dependency and costs.
2. Enhance workplace safety by reducing human risks.
3. Automate material handling using a 6-DOF Kawasaki Robot.

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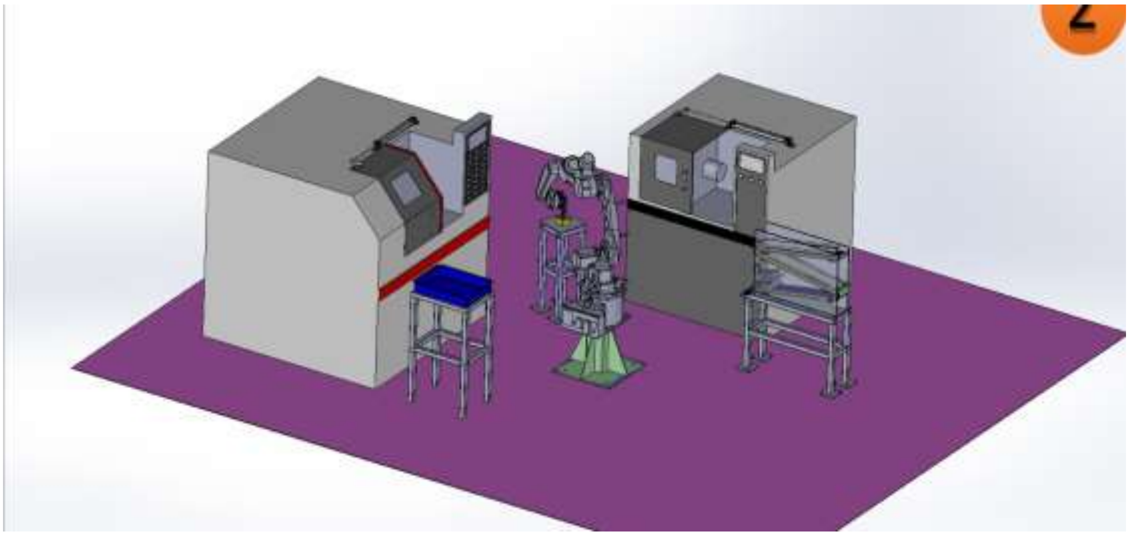
4. Optimize scheduling to reduce cycle time.
5. Improve accuracy and consistency in job placement.

V SYSTEM ARCHITECTURE



VI METHODOLOGY AND SCOPE

Methodology:
The proposed system aims to automate the material handling and scheduling process in a machining setup using a 6-DOF Kawasaki RS020N robot integrated with four CNC stations. The methodology involves designing a seamless workflow where the robot efficiently picks, places, and loads raw materials into CNC machines, reducing manual intervention and optimizing cycle time. The robot programming is carried out using the Kawasaki teach pendant, ensuring precise motion planning and accurate placement of materials. To enhance automation, a Programmable Logic Controller (PLC) is used to control the entire system, coordinating the robot's movements with the CNC machine operations. The system undergoes extensive simulation using RoboDK to test performance before real-world implementation. The cycle time, accuracy, and efficiency of the automated process are compared with manual CNC operations to quantify the benefits. Experimental validation is performed by testing the robot's repeatability, response time, and overall system effectiveness in an industrial environment. This methodology ensures a fully automated workflow, reducing human errors, improving productivity, and optimizing resource utilization in machining processes.

Following are the main steps to follow the methodology :
Part Loading :

Unfinished part into the machine.
A part loader places a raw metal job onto a conveyor belt leading to the CNC machine.

Part Flip Unit :

To position the part correctly for processing.
After loading, the part moves to a part flip unit where it is rotated to the required orientation for machining.

Robot Operation :

To manage the handling and movement of parts between different stages.
A robotic arm picks up the part from the flip unit and places it into the CNC machine for processing. After machining, the robot retrieves the finished part.

Cycle Repeats :

To ensure continuous operation by handling new and finished parts. Once the robot removes the finished part from the CNC machine, it places it on a designated tray. Then, a new unfinished part is placed onto the conveyor belt, and the cycle starts again.

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Scope :
Automation of Material Handling and Scheduling: Uses a 6-DOF Kawasaki RS020N robot to automate pick-and-place operations across four CNC stations, reducing manual effort and errors.

Optimized Workflow and Reduced Cycle Time: Enhances efficiency by minimizing cycle time and ensuring smooth, precise, and consistent robotic movements.

Integration with CNC and PLC-Based Control: A PLC system synchronizes robot and CNC operations, improving scheduling and reducing machine idle time.

Performance Validation and Industrial Application: Robo DK simulation ensures system efficiency before real-world implementation, making it suitable for industrial automation. Future Scope and Expansion: Can be enhanced with AI-based scheduling, IoT monitoring, and machine vision for a smarter, fully automated machining process.

VII SPECIFICATIONS

Specifications of robot:
Brand: Kawasaki
Model: RS20N
Type: Robot Arm
Axes: 6
Payload: 20 kg
Reach: 1725 mm
Repeatability: 0.04 mm
Weight: 230 kg

Kawasaki robot

Kawasaki E01 controller:
For small and medium sized industrial robots
Compact and space-saving design.
High-speed, precise servo control.
User-friendly touch screen interface.
Multi-tasking with simultaneous control.
Advanced safety features and emergency stop.
Ethernet and fieldbus connectivity.
Durable in industrial environments.
Energy-efficient, low power usage.

Kawasaki controller

VIII ROBOT PROGRAMMING

90% industries use online programming to teach robots.
•User friendly interface
•Ease to use
•Safety features
•Real time monitoring
•Precise control
•Increase accuracy

Online programming:

Step	Action	Command	Description
1	Home position	CALL HOME_POS	At home position
2	Move to autoloader	JOINT 5 1 0 1	Move to loading position

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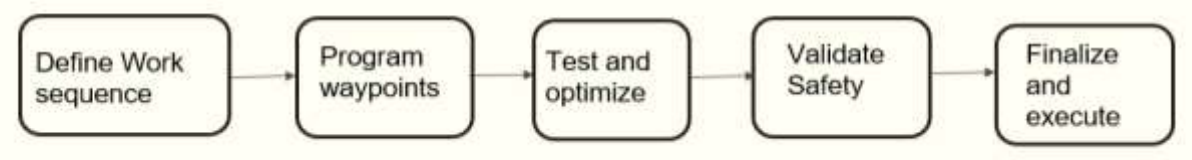
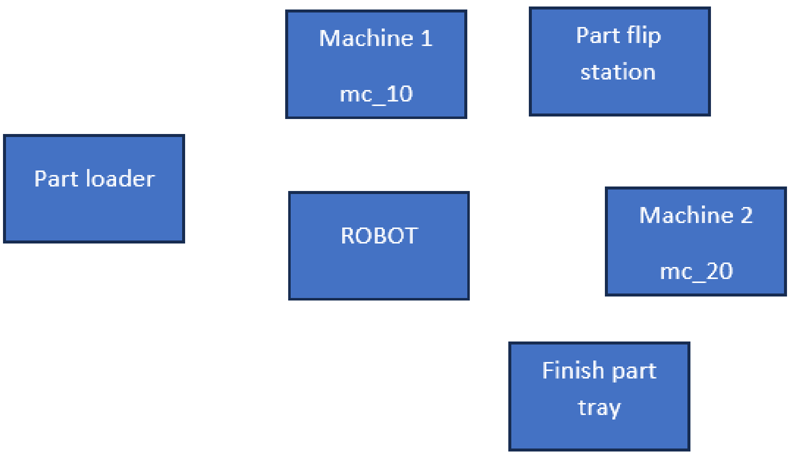
3	Pick job	CALL GRIPPER2_CLOSE	Close gripper to pick job
4	Move to CNC	JOINT 5 1 0 1	Position robot at CNC
5	Wait for CNC door	PULSE 33, 2	CNC door open signal
6	Remove previous job & place new job	CALL GRIPPER_CLOSE 2, CALL GRIPPER_OPEN1	Swap jobs
7	Move to home position	CALL HOME_POS	Home position
8	Move to pallet	JOINT 5 1 0 1	Approach pallet
9	Unload finished part	CALL GRIPPER1_OPEN	Open gripper to unload part
10	Return to home	JOINT 5 1 0 1	Return to initial position

Flow of system:





Robot centered cell

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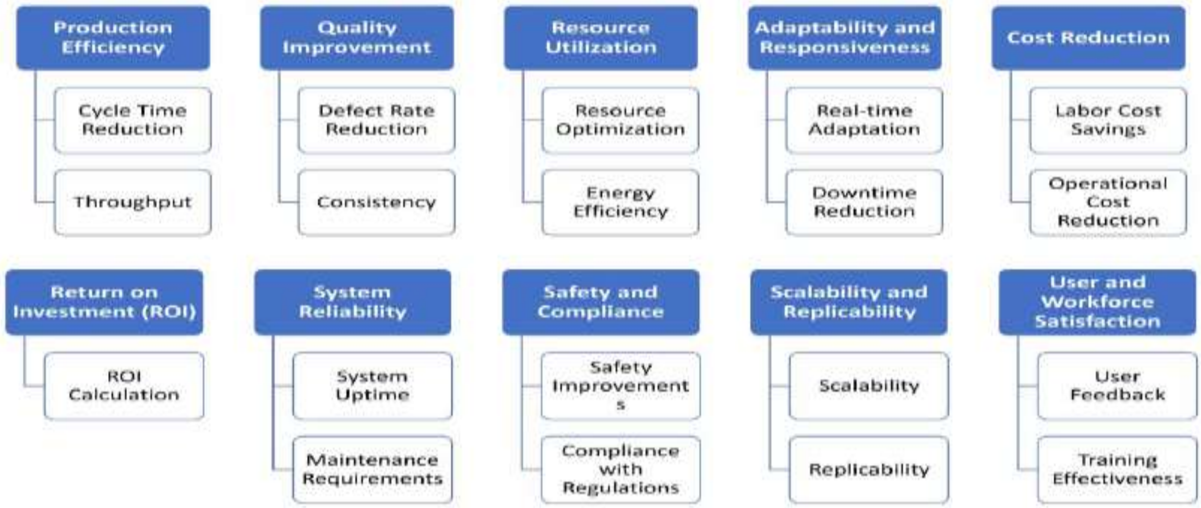
COMPARISION TABLE

Challenges	Traditional Manual system	Robot load-unload system
Labor cost	Training needed	Lower operational cost
Human errors	Handling mistake	High precision
Safety	Risk of injuries	Minimal human interaction
Productivity continuity	Downtime issues	Minimal downtime

IX PERFORMANCE PARAMETER



X CONCLUSION

The implementation of a robotic system with automatic scheduling for material handling in manufacturing has demonstrated significant improvements in efficiency, cost reduction, and process reliability. This project successfully integrated a 6-DOF Kawasaki robot into an industrial setup with two CNC machines, streamlining the workflow by automating the loading, flipping, and unloading of jobs.One of the most notable advantages of this system is the reduction in labor costs. By automating repetitive and physically demanding tasks, the need for manual intervention is minimized, allowing human workers to focus on more complex and value-added activities. Additionally, the system enhances workplace safety by reducing human exposure to hazardous environments, such as high temperatures and heavy machinery.The robotic system also improves overall productivity by maintaining consistent job handling accuracy and eliminating operator fatigue-related errors. Unlike manual handling, where inconsistencies in positioning may lead to defects or rework, the automated process ensures precision in job placement, reducing material wastage and optimizing machine utilization.While the cycle time of manual and robotic operations remains similar, the automated system offers superior reliability and repeatability, eliminating variations caused by human inefficiencies. This results in smoother production flow, reduced machine downtime, and better synchronization between machining stations.Furthermore, the reduction in material handling time has a direct impact on increasing throughput. By integrating scheduling algorithms, job transitions between CNC machines are optimized, leading to a more synchronized and efficient production cycle. The fenced working area for the robotic system ensures safety compliance while allowing uninterrupted operations.In conclusion, the implementation of robotic automation for material handling and scheduling presents a viable and scalable solution for modern manufacturing industries. It not only reduces labor dependency but also enhances productivity, ensures process stability, and improves overall operational efficiency. The findings from this project highlight the potential for further advancements in robotic automation, paving the way for smarter and more adaptable manufacturing systems in the future.

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