Cobot Error Analysis and Motion Study Using SolidWorks and RoboDk Software

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***Abstract*—The rapid adoption of collaborative robots (cobots) in modern manufacturing environments has significantly transformed industrial automation by enabling safe human–robot interaction, flexibility, and improved productivity. However, achieving high accuracy and repeatability remains a critical challenge due to geometric inaccuracies, joint compliance, payload effects, calibration errors, and environmental influences. This paper presents a comprehensive motion study and error analysis of a collaborative robot using SolidWorks and RoboDK software platforms. A detailed three-dimensional CAD model of the cobot is developed in SolidWorks and subjected to motion analysis to evaluate kinematic behavior, joint constraints, velocity profiles, and mechanical feasibility. The validated model is then imported into RoboDK for offline programming, trajectory planning, workspace analysis, and error evaluation. Various sources of error—including geometric, kinematic, dynamic, tool-related, and control errors—are systematically identified and analyzed. The results demonstrate the effectiveness of simulation-based validation in predicting cobot performance, reducing deployment risks, and improving operational accuracy.**

***Index Terms*—Collaborative Robot, Cobot Error Analysis, Motion Study, SolidWorks, RoboDK, Kinematic Simulation, Industrial Automation.**

I. INTRODUCTION

Collaborative robots, commonly referred to as cobots, represent a significant advancement in industrial automation. Unlike traditional industrial robots that operate within isolated and safety-restricted environments, cobots are specifically designed to work safely alongside human operators. Their lightweight structure, integrated safety mechanisms, force-limiting joints, and intuitive programming interfaces make them suitable for applications such as assembly, material handling, inspection, packaging, and machine tending.

As manufacturing industries increasingly adopt Industry 4.0 principles, the demand for flexible and intelligent automation systems continues to grow. In such environments, the accuracy, repeatability, and reliability of cobot motion are crucial factors influencing productivity and product quality. Even minor deviations in end-effector position or orientation can lead to defects, collisions, or inefficient operations. Therefore, understanding and minimizing motion-related errors is essential for successful cobot deployment.

Physical experimentation on actual cobots is often expensive, time-consuming, and limited by safety and accessibility constraints. Consequently, simulation-based approaches using advanced software tools have become indispensable. SolidWorks enables precise mechanical modelling and motion analysis, while RoboDK offers powerful capabilities for robotic simulation, offline programming, and error analysis. This project integrates both platforms to conduct a detailed motion study and error evaluation of a collaborative robot, providing valuable insights into its performance characteristics.

II. LITERATURE REVIEW

Previous studies indicate that:
- Addition of fillers improves mechanical and tribological properties.
- Glass fibers enhance tensile strength and stiffness.

- MoS_2 acts as a solid lubricant reducing friction.
- TiO_2 improves hardness and wear resistance.

However, limited research exists on:

- Combined effect of TiO_2 and MoS_2 in PTFE
- Performance under low-speed, high-load conditions
- Use of distilled water-based lubrication systems.

III. PROBLEM STATEMENT

Conventional metallic bearings used in industries (e.g., sugar and food processing) face issues such as:

- Lubrication contamination
- Corrosion and wear
- Frequent maintenance

IV. OBJECTIVES

The primary objective of this work is to analyze and improve the motion accuracy and feasibility of a collaborative robot through simulation-based techniques. The specific objectives are:

To develop a detailed 3D CAD model of the cobot using SolidWorks.

- To perform motion analysis in SolidWorks to evaluate joint behavior, constraints, and mechanical feasibility.
- To import and configure the cobot model in RoboDK for kinematic simulation.
- To plan and simulate robot trajectories using RoboDK.
- To identify and analyze various sources of cobot errors.
- To compare motion behavior between SolidWorks and RoboDK simulations.
- To propose optimization strategies for improving accuracy and performance.

V. DESIGN CONSIDERATION

Design considerations play a crucial role in determining the performance and accuracy of collaborative robots. The following aspects were considered during the design and modelling stage:

- Mechanical Structure: Lightweight yet rigid link design to ensure safety and minimize deflection.
- Joint Configuration: Proper selection of revolute joints with defined limits to avoid singularities.
- Material Selection: Use of Aluminum HE30 (AA6082) for the pick head to achieve an optimal balance between strength and weight.
- Payload Capacity: TM20 cobot with a maximum payload of 20 kg, including a 12 kg pick head and 8 kg product load.
- Tool Center Point (TCP): Accurate definition of TCP to ensure precise end-effector positioning.
- Workspace Constraints: Consideration of reachability, obstacle clearance, and operator safety.

VI. METHODOLOGY

The methodology adopted in this study follows a structured and systematic approach integrating CAD modelling, motion analysis, and robotic simulation.

6.1 Literature Review.

A comprehensive literature survey was conducted to understand robotic kinematics, dynamics, error sources, and simulation techniques. Classical and modern robotics textbooks and handbooks provided the theoretical foundation for this work.

6.2. CAD Modelling in SolidWorks

Each component of the cobot was modelled in SolidWorks based on design dimensions and functional requirements. Joints were defined using appropriate mates, and material properties were assigned to simulate realistic mass and inertia effects.

6.3 Motion Study in SolidWorks

Motion analysis was performed by applying rotary motors at each joint, defining joint limits, and executing time-based simulations. Parameters such as velocity, acceleration, torque, and interference were analysed.

6.4 Trajectory Planning and Simulation

- Different robot paths, including joint, linear, and circular motions, were simulated in RoboDK. Collision detection, workspace feasibility, and cycle time estimation were carried out

VII. EXPERIMENTAL SETUP

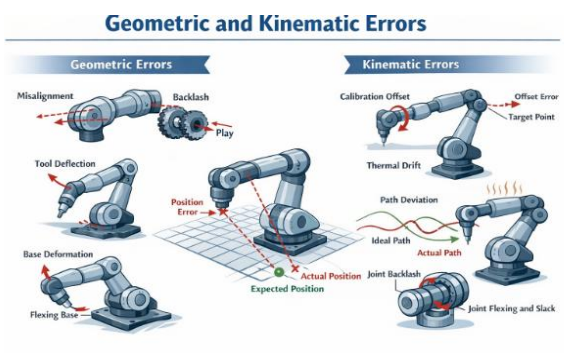
- The experimental setup for this study was developed to evaluate the motion characteristics and positional accuracy of a collaborative robot using simulation-based tools. The complete workflow consisted of CAD modelling in SolidWorks followed by robotic simulation and trajectory analysis in RoboDK.

VIII. RESULTS AND DISCUSSION

Cobot errors were classified into the following categories:

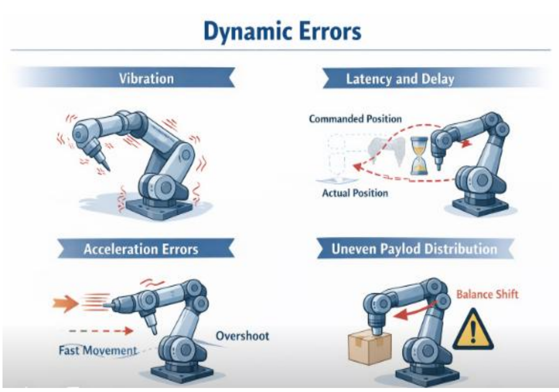
8.1. Geometric and Kinematic Errors

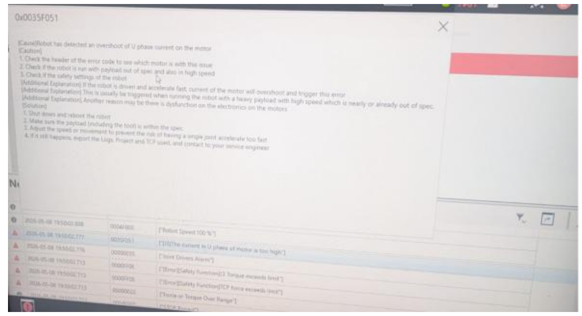
These include joint offset errors, link length deviations, axis misalignment, and manufacturing tolerances. Such errors directly affect forward and inverse kinematics, leading to positional inaccuracies.



8.2 Dynamic Errors

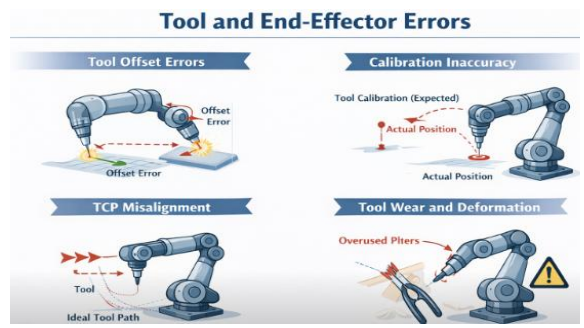
Dynamic errors arise due to joint backlash, servo lag, payload-induced deflection, vibration, and oscillation. These effects become more pronounced at higher speeds and near workspace boundaries.

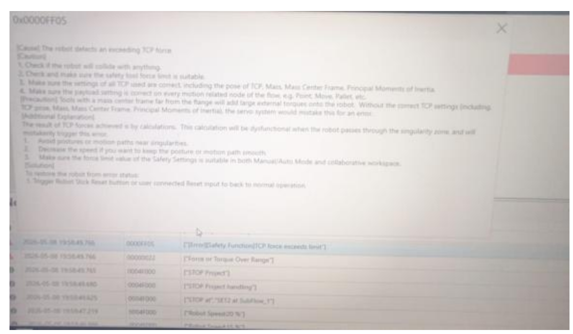




8.3 Tool and End-Effector Errors

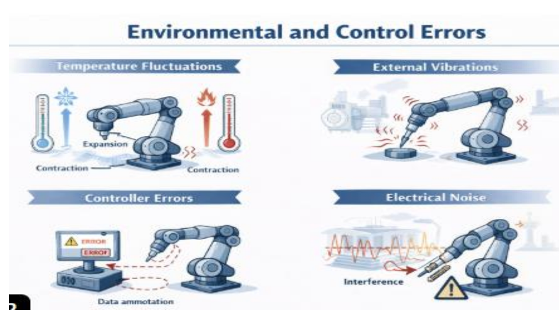
Incorrect TCP calibration, tool weight mismatch, and inconsistent gripping forces introduce systematic errors during pick-and-place operations.





8.4 Environmental and Control Errors

Temperature variations, floor vibrations, communication delays, and incorrect frame definitions contribute to reduced repeatability and accuracy.



IX. CONCLUSION

This study successfully demonstrates a systematic approach for conducting motion study and error analysis of a collaborative robot using SolidWorks and RoboDK. The integration of CAD-based mechanical modeling with robotic simulation enables early identification of design limitations and error sources. Simulation-based validation reduces deployment risks, improves accuracy, and enhances operational reliability. The methodology presented in this work can be effectively applied to various industrial cobot applications, supporting smarter and safer automation solutions.

X. FUTURE SCOPE

Future work may include experimental validation using physical cobots, machine learning–based error compensation techniques, multi-cobot coordination, and digital twin implementation for real-time monitoring and optimization.

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