The 6th Joint International Conference on Multibody System Dynamics and
The 10th Asian Conference on Multibody System Dynamics
October 16-20, 2022, New Delhi, India

Development of affordable Collaborative Robots for Engineering Education

Ranga Rakesh Ranganayakulu, Karanam Sreedhar Sai Thilak, Aditya Navghare Shridhar, Madhanagopal Manoharan, Senthilkumaran Kumaraguru*

Center for Smart Manufacturing,
Department of Mechanical Engineering,
Indian Institute of Information Technology Design and Manufacturing Kancheepuram,
Melakottaiyur, Chennai - 600127, India.
*skumaran@iiitdm.ac.in

Abstract

Collaborative Robots or CoBots are specifically designed for human interaction within a defined collaborative workspace and it plays a major role in the advanced manufacturing shop floor. Robot-Robot and Human-Robot collaboration are the primary characteristics of CoBots for context-aware and situation-aware applications. This paper proposes the design, kinematics, and dynamic analysis of open-source affordable industrial serial manipulators for their transformation into CoBots. The rigidity of the robot arms can be analyzed by performing static and transient structural analysis. The transient structural analysis on each joint angle of the open-source AR3 robot arm [1] is performed by cumulative iterations until force convergence maintains a stable value. Kinematics and dynamics of the robot arm are analyzed to check its feasibility for its operations. Hand guiding is implemented using two push buttons such as the teach button and the move button. Move button is used to move the robot freely. The teach button is pressed after moving the robot to the desired position. Human intrusion and touch are detected using visual and pressure sensors. These sensors are integrated with the robotic arms for Human Augmented Robot Intelligence [2]. The proposed dual-arm robots can execute both synchronous and asynchronous tasks. The asynchronous tasks require parallel execution of robot motion control trajectories, which can be achieved through multithreading and command streaming. Whereas the synchronous tasks require synchronization primitives like semaphores [3]. This embedded kinematic controller can execute tasks automatically and make decisions under the influence of external disturbances. Robot motion control trajectories are generated and simulated in RoboDK [4] to verify whether there are any collisions and singularities in the generated trajectory paths. On successful calibration, the accuracy of the fabricated robot arm is found to be ± 0.2 mm. Based on the Denavit Hartenburg (DH) parameters [5], the work volume of the robot arm is shown in **fig. 1. a.,** and its exploded view in **fig. 1. b.** with all its parts.

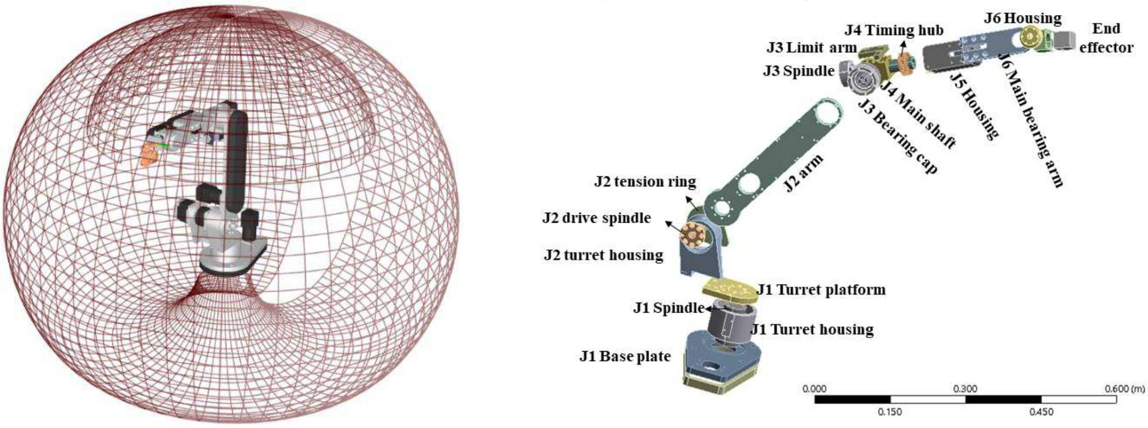

Fig. 1. a. AR3 robot workspace visualization, **1. b.** Exploded view of the assembled robot arm

Aluminium Alloy 5083 is used to fabricate the robot arm structure, and those material properties are considered for analysis. From the structural analysis results, it is found that the maximum deformation in the arm is 0.12607 mm. The maximum stress generated using the Von-Mises approach was 9.3844 MPa, which is significantly lower than the yield strength of 5083 Aluminium Alloy (276 MPa). The robot arm is analyzed with Newmark implicit time integration method by considering the joint angle rotation of 60°. Three robust FEA methods for analyzing forces with transient dynamics approach in ANSYS workbench are the full method, reduced method, and modal superposition method [6]. This implicit analysis uses the full method to study the transient forces on joint spindles [7]. The implicit solver uses the stiffness matrix and newton iteration to solve non-linearity. **Equation 1** provides the general governing relation [8] for transient analysis of structures, where $[M]$ is the mass matrix, $[C]$ is the damping matrix, $[K]$ is the stiffness matrix, and $\{F\}$ is the load.

$$[M].x''(t) + [C].x'(t) + K.x(t) = F \quad (1)$$

These collaborative robot systems are the emerging technology, which plays a key role in the implementation of Industry 5.0. A unified Collaborative Robots motion control software is developed to control the two robot arms through a Graphical User Interface (GUI) with communication (COM) ports.

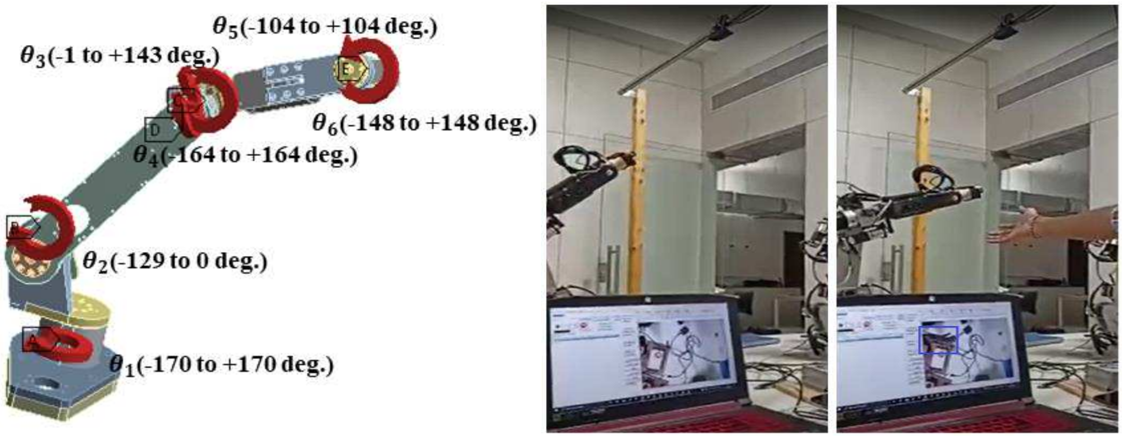

Fig. 2. a. Joint angle limits of the open source robot arm, **2. b.** Human robot collaboration

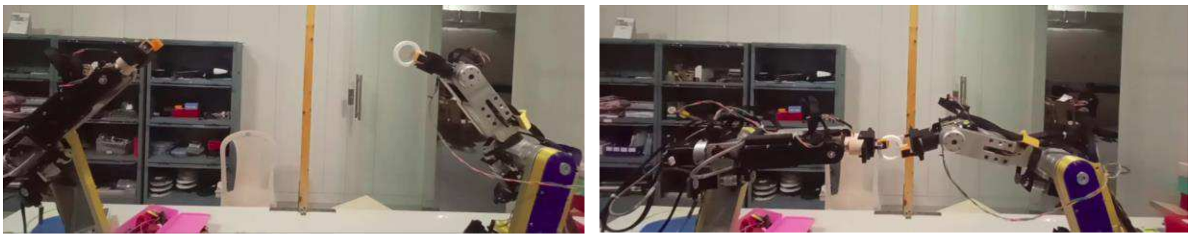

Fig. 3. a. Robot robot collaboration, 3. b. Automated object exchange mechanism

The proposed collaborative robotic systems can be used for applications such as pick and place, palletizing, painting, welding, machine tending, assembly operations, soldering, drilling, screw fastening, 3D printing, vision inspection, LASER engraving, deburring, and glue dispensing. The development of the Application Program Interface (API) for these applications using the proposed modular collaborative robot arms by students will be the major focus in the future. The entire robotic systems was assembled inside the laboratory, which makes the students to have hands-on in the intricates of robot fabrication.

Keywords: Collaborative robotics, Human Robot collaboration, Robot Robot collaboration, Affordable robotics technology.

REFERENCES

[1] Annin robotics – AR3 open-source six-axis serial manipulator (2019), Accessed on Nov. 15, 2019. Available: www.anninrobotics.com.

[2] Mruthyunjaya, V., & Jankowski, C. (2019). Human-Augmented Robotic Intelligence (HARI) for Human-Robot Interaction. *Advances in Intelligent Systems and Computing*. doi: 10.1007/978-3-030-32523-7_14.

[3] Hernandez, Carlos. Practical Model-Based Systems Engineering. United Kingdom, Artech House, 2019.

[4] RoboDK Software (2020), Simulate Robot Applications, Accessed on Jan. 15, 2020. Available: https://www.robodk.com/download.

[5] M. Manoharan, A. N. Shridhar, V. Y. Vinod, and S. Kumaraguru, "A novel volume decomposition methodology for multi-robots collaborative additive manufacturing," *4th IEEE Conf. Inf. Commun. Technol. CICT 2020*, vol. D, 2020, doi: 10.1109/CICT51604.2020.9312088.

[6] E. Ferhatoglu, E. Cigeroglu, and H. N. Özgüven, "A new modal superposition method for nonlinear vibration analysis of structures using hybrid mode shapes," *Mech. Syst. Signal Process.*, vol. 107, pp. 317–342, 2018, doi: 10.1016/j.ymssp.2018.01.036.

[7] S. N. R. Remala, "Nonlinear transient Finite Element simulations of beam parametric response including Quadratic damping," Uni. of Kentucky, 2005.

[8] R. Potter and M. Richardson, "Mass, stiffness, and damping matrices from measured modal parameters," no. 6, pp. 1–5, 1974.