Chapter 15
Cycle Time Optimization in Automatic Screw Tightening Machines

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ABSTRACT

The increasing adoption of mechatronics in the automotive industry has transformed manual operations into automated systems for improved efficiency, quality, and safety. Among these, Automatic Screw Tightening Machines (ASTMs) are widely used in lamp assembly to fasten body and extension parts. However, these machines often face increased cycle times under varying conditions, reducing production throughput. This study addresses cycle time optimization by analyzing the machine's construction, programming, and workflow, followed by a cycle time study to identify bottlenecks. Benchmarking revealed screw feeding as a major contributor to delays. To resolve this, the Anti-Tumble Unit was redesigned with a feed-while-drive mechanism, enabling screw feeding and tightening simultaneously. This improvement reduced cycle time from 45 to 33 seconds, achieving a 26.7% reduction. The findings show that targeted design modifications can significantly enhance automated assembly performance and can be applied to optimize cycle time in other industrial processes.

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1. INTRODUCTION

The automotive industry has increasingly adopted mechatronics-based automation to improve productivity, quality, and safety. Traditional manual operations such as welding, screwing, and testing are progressively being replaced by automated systems that ensure consistent performance, reduce human error, and meet the growing demand for high-volume production. In India, lamp assembly lines in particular employ a wide range of automated solutions including impulse welding machines, auto-screwing machines, and light and leak testing units. Robotic fastening systems have been widely studied in the context of torque accuracy and control strategies, but relatively little attention has been given to cycle time optimization (Hossain et al. 2016, Boys et al. 1977).

Several works have focused on precise torque control during screw tightening. For example, Liu et al. (2020) proposed a fuzzy algorithm for thread tightening torque control, while Miao et al. (2020) reviewed methods for measuring bolt tightening force and loosening detection. Qiu et al. (2023) developed a multi-objective mathematical model for screw tightening optimization. These studies emphasize fastening reliability and error reduction, but they do not address the temporal efficiency of screwdriving operations. Recent works highlight the role of predictive maintenance in improving system reliability. Cinar et al. (2022) implemented predictive maintenance for intelligent manufacturing systems, while Chakroun et al. (2024) proposed a health assessment model for assembly robots using machine learning. Such approaches minimize unplanned downtime, yet they primarily target system reliability rather than reducing cycle time in assembly tasks.

Švaco et al. (2012) introduced adaptive robotic control strategies for uncertain assembly conditions, and Rozo et al. (2013) presented a learning-from-demonstration framework for force-based manipulation. While adaptive control enhances flexibility, its application to screw tightening cycle efficiency has not been demonstrated. Jia et al. (2018) surveyed automated threaded fastening technologies, identifying key industrial trends such as error detection and feed-while-drive systems. Sága et al. (2020) analysed a robotized screwing application with vision sensing integration, focusing on accuracy and automation. These works point toward advanced fastening technologies but again do not quantify cycle time bottlenecks in existing machines.

Since the modern standards of quality involve higher scrutiny, a more efficient robot is likely to sustain its place in the long term in delivering quality products) and for safety reasons (Some of the operations in the industry are hazardous to be carried out by humans. Operations such as welding, working near toxic fumes, waste management etc can be automated to reduce the risk and accidents in the industry). Hence, we can see a rise in the number of automated systems being installed in factories (Chakroun et al. 2024).

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