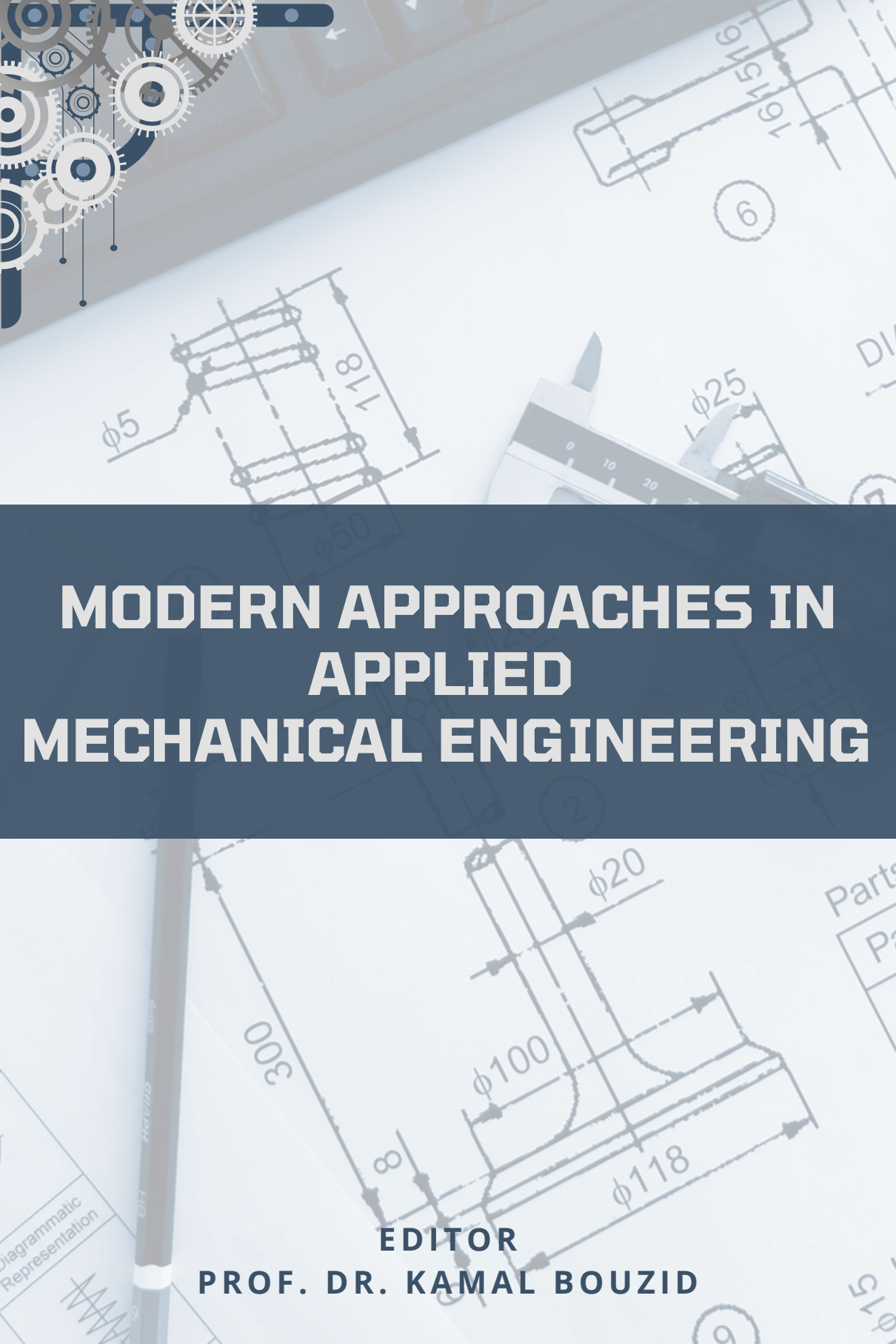

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CHAPTER 2
ADVANCEMENTS IN POWERTRAIN ARCHITECTURES AND ENERGY MANAGEMENT STRATEGIES FOR ELECTRIC AND HYBRID VEHICLES: A MECHANICAL ENGINEERING PERSPECTIVE

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INTRODUCTION

This chapter provides a comprehensive examination of the revolutionary developments in electric and hybrid vehicle powertrain technologies from 2020 to 2025. The analysis reveals that series-parallel hybrid systems have achieved market dominance with 89% growth in 2024, while advanced energy management strategies demonstrate potential for 20-35% overall system efficiency improvements. The integration of emerging technologies such as solid-state batteries with 750-mile range potential and multi-phase motor architectures achieving 10% efficiency gains represents a paradigm shift toward sustainable transportation solutions. From a mechanical engineering perspective, the field faces critical challenges in thermal management system design, vibration control for in-wheel motor applications, and the integration of advanced power electronics with traditional mechanical systems.

1. EVOLUTION OF POWERTRAIN ARCHITECTURES

The contemporary automotive landscape has witnessed the unprecedented dominance of series-parallel hybrid powertrain architectures, which have become the cornerstone of modern plug-in hybrid electric vehicle (PHEV) development. In 2024, China's PHEV market approached 4.5 million units, representing an extraordinary 89% year-on-year increase, with growth rates surpassing battery electric vehicles (BEVs) for three consecutive years. This remarkable expansion stems from the dual-mode powertrain capability that allows vehicles to operate in both electric-only and hybrid modes, providing precise adaptation to diversified travel needs.[1]

From a mechanical engineering perspective, series-parallel hybrid systems represent a complex integration of mechanical and electrical components that requires sophisticated control strategies to optimize performance across multiple operating modes. The system architecture combines the benefits of both series and parallel hybrid configurations, enabling efficient power flow management through multiple pathways. During low-speed urban driving, the vehicle can operate in pure electric mode, utilizing the electric motor's high torque characteristics at low speeds. At highway speeds, the internal combustion engine can directly drive the wheels while simultaneously charging the battery, maximizing overall system efficiency.[1]