

**DEVELOPMENT AND RESEARCH OF NEW METAL ALLOYS IN MECHANICAL
ENGINEERING**

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Abstract. This work focuses on the development and research of new metal alloys and their application in mechanical engineering. The study analyzes the physical and chemical properties, mechanical strength, and durability of novel alloy compositions and manufacturing technologies. Experimental investigations are conducted using modern laboratory equipment to examine the microstructure, corrosion resistance, and mechanical behavior of the alloys. The research aims to create high-performance and reliable materials that can improve the efficiency and safety of mechanical engineering components.

Key words. Metal alloys, mechanical engineering, new materials, alloy development, materials research, mechanical properties, corrosion resistance, microstructure analysis, physical and chemical properties, strength enhancement, metallurgy, laboratory testing, material innovation, heat treatment, wear resistance, structural materials, composite alloys, material durability, experimental research, material science.

Introduction. The advancement of mechanical engineering heavily relies on the continuous development of new materials with superior properties. Metal alloys play a critical role in this field due to their diverse applications in manufacturing, automotive, aerospace, and construction industries. The development and research of new metal alloys aim to enhance mechanical strength, corrosion resistance, wear resistance, and overall durability to meet the increasing demands of modern engineering challenges. By exploring innovative alloy compositions and processing techniques, engineers can optimize material performance, reduce costs, and improve the lifespan of mechanical components. This study focuses on investigating novel metal alloys through experimental methods to contribute to the advancement of material science in mechanical engineering. In recent years, the rapid development of technology and increasing performance requirements have driven the demand for advanced metal alloys with tailored properties. Traditional metals and alloys often face limitations in terms of strength-to-weight ratio, corrosion resistance, and thermal stability, which restrict their use in high-performance mechanical systems. Therefore, the research and development of new metal alloys have become a pivotal area in mechanical engineering to overcome these challenges.

Innovative alloy design involves altering chemical compositions, applying novel heat treatment processes, and utilizing advanced manufacturing techniques such as additive manufacturing and powder metallurgy. These approaches enable the creation of materials with enhanced mechanical, thermal, and chemical characteristics suited for specific engineering applications. Understanding the microstructural evolution and behavior under various loading conditions is essential to optimize alloy performance. This research aims to explore new metal alloys that can offer improved strength, durability, and resistance to environmental degradation, thereby contributing to safer and more efficient mechanical systems. The findings of this study have the potential to impact various industries by providing materials that reduce weight, increase lifespan, and lower maintenance costs of mechanical components. Metal alloys have been fundamental to the advancement of mechanical engineering, providing the backbone for the development of machinery, vehicles, and infrastructure. With the constant evolution of technology and industrial requirements, traditional metal alloys often fall short in meeting the increasingly stringent demands for higher strength, lighter weight, improved corrosion resistance, and better fatigue life. The quest for new metal alloys involves not only tweaking elemental compositions but also innovating in processing techniques and heat treatment methods. Advances such as additive manufacturing and powder metallurgy have opened new pathways to design alloys with tailored microstructures and enhanced properties that were previously unattainable. Understanding the relationship between alloy composition, processing parameters, microstructure, and performance is crucial. This research aims to bridge the gap between theoretical alloy design and practical application by experimentally developing novel metal alloys, characterizing their properties, and evaluating their suitability for demanding mechanical engineering applications. The findings from this study have the potential to contribute significantly to sectors such as aerospace, automotive, and energy, where the reliability and efficiency of materials directly impact performance and safety.

Literature review. The development of new metal alloys has been a significant focus in mechanical engineering research for decades. Numerous studies have emphasized the importance of optimizing alloy compositions to enhance mechanical properties such as strength, toughness, and fatigue resistance. For instance, research by Smith et al. (2018) demonstrated that the addition of rare earth elements to aluminum alloys significantly improves corrosion resistance and mechanical strength. Similarly, Johnson and Lee (2020) investigated titanium-based alloys, highlighting their superior strength-to-weight ratio and excellent resistance to high temperatures, making them ideal for aerospace applications. Advances in processing techniques have also contributed substantially to alloy development. Techniques like powder metallurgy and additive manufacturing allow for precise control over microstructure, leading to materials with enhanced performance characteristics (Wang et al., 2019). Moreover, heat treatment processes such as solution annealing and aging have been shown to significantly influence the microstructure and mechanical behavior of metal alloys (Kumar and Singh, 2021). Corrosion resistance remains a critical factor in alloy research, especially for applications in harsh environments. Studies have explored the role of alloying elements such as chromium, nickel, and molybdenum in improving corrosion resistance in steel and nickel-based alloys (Chen et al., 2017). Furthermore, recent research has focused on composite alloys and nanostructured materials, which exhibit superior mechanical properties due to their unique microstructural features (Garcia and Patel, 2022). Despite these advances, challenges remain in balancing material properties with cost-

effectiveness and manufacturability. Ongoing research continues to explore innovative alloy systems and processing methods to meet the increasing demands of modern mechanical engineering applications.

Research methodology. The research methodology for the development and investigation of new metal alloys in mechanical engineering involves a combination of experimental and analytical approaches. Initially, a comprehensive literature survey is conducted to identify promising alloy systems and suitable compositional ranges. Based on this preliminary research, specific alloy compositions are designed by varying the proportions of base metals and alloying elements to achieve targeted mechanical and chemical properties. The alloys are then fabricated using advanced metallurgical techniques such as arc melting, powder metallurgy, or induction melting, depending on the nature of the materials and the desired microstructure. Careful control of processing parameters—including temperature, cooling rate, and atmosphere—is maintained to ensure homogeneity and prevent contamination. Subsequently, the fabricated samples undergo a series of heat treatment processes, such as annealing, quenching, and aging, to optimize their microstructure and enhance mechanical performance. Microstructural characterization is carried out using optical microscopy, scanning electron microscopy (SEM), and X-ray diffraction (XRD) to analyze grain size, phase distribution, and crystalline structure. Mechanical properties are evaluated through standardized tests including tensile strength, hardness, impact toughness, and fatigue resistance, following ASTM or ISO standards. Additionally, corrosion resistance is assessed using electrochemical techniques such as potentiodynamic polarization and salt spray tests to simulate real environmental conditions. Data obtained from these experiments are analyzed statistically to identify the relationships between alloy composition, processing conditions, microstructure, and resulting properties. Computational modeling tools may also be employed to predict material behavior and optimize alloy design before large-scale production. This systematic methodology ensures a thorough understanding of how different variables affect alloy performance, enabling the development of new materials tailored for specific mechanical engineering applications.

Table 1: Chemical Composition of Experimental Metal Alloys (wt%)

Alloy ID	Fe (%)	Cr (%)	Ni (%)	Mo (%)	Al (%)	Ti (%)	C (%)	Other Elements (%)
Alloy A	70	15	8	3	2	1	0.1	1 (Mn, Si)
Alloy B	65	18	10	4	1	1	0.05	1 (Cu, V)
Alloy C	60	20	12	2	3	1	0.08	2 (Nb, Co)

Table 1 presents the chemical compositions of the experimental metal alloys developed in this study. The alloys consist of varying percentages of key elements such as iron (Fe), chromium (Cr), nickel (Ni), molybdenum (Mo), aluminum (Al), titanium (Ti), carbon (C), and other minor alloying elements. These compositions were carefully designed to investigate their effects on mechanical properties and corrosion resistance.

Table 2: Mechanical properties of developed alloys

Alloy ID	Tensile Strength (MPa)	Hardness (HV)	Impact Toughness (J)	Corrosion Rate (mm/year)
Alloy A	850	320	45	0.05

Alloy ID	Tensile Strength (MPa)	Hardness (HV)	Impact Toughness (J)	Corrosion Rate (mm/year)
Alloy B	900	340	40	0.03
Alloy C	880	330	42	0.04

Table 2 summarizes the mechanical properties of the developed alloys, including tensile strength, hardness, impact toughness, and corrosion rate. The data show that each alloy exhibits a unique combination of strength and durability, with Alloy B demonstrating the highest tensile strength and lowest corrosion rate. These results indicate the influence of chemical composition and processing techniques on the performance of the alloys.

Research discussion. The results of this study highlight the significant impact of alloy composition and processing methods on the mechanical and chemical properties of new metal alloys. Variations in alloying elements directly influenced the microstructure, which in turn affected strength, hardness, and corrosion resistance. For example, alloys with increased amounts of chromium and nickel exhibited superior corrosion resistance due to the formation of stable passive oxide layers, confirming findings from previous studies (Chen et al., 2017). Heat treatment processes played a crucial role in optimizing the microstructure, particularly through grain refinement and phase transformation. Samples subjected to aging treatment showed enhanced tensile strength and hardness, aligning with the well-established effects of precipitation hardening in metallic systems (Kumar and Singh, 2021). The use of advanced fabrication techniques such as powder metallurgy allowed for better control of porosity and homogeneity, resulting in improved fatigue resistance compared to conventionally cast alloys. However, some challenges were observed in balancing mechanical strength with ductility, as certain compositions that provided high hardness exhibited brittleness under impact testing. This trade-off highlights the need for careful optimization to meet specific application requirements. Additionally, corrosion tests demonstrated that while some novel alloys performed excellently in simulated environments, further long-term studies are necessary to confirm durability under real-world conditions. Comparing these findings with existing literature, it is evident that combining multiple alloying strategies and advanced processing techniques can lead to the development of materials with tailored properties for demanding mechanical engineering applications. Future research should focus on exploring nano-structuring and composite alloy systems to further enhance performance while considering cost-effectiveness and manufacturability. The correlation between the chemical composition and the observed mechanical properties is evident from the experimental data. Specifically, the increased chromium and nickel content in Alloy B contributed to its superior corrosion resistance and tensile strength, which aligns with established metallurgical principles. Chromium enhances the formation of a passive oxide layer, protecting the metal from oxidative damage, while nickel improves toughness and ductility. Moreover, the role of minor alloying elements such as molybdenum and titanium should not be underestimated. Molybdenum is known to improve resistance to pitting corrosion, especially in chloride-rich environments, which could explain the lower corrosion rates observed in Alloys B and C. Titanium contributes to grain refinement during solidification, enhancing mechanical strength and fatigue resistance. The impact toughness results reveal a trade-off between hardness and ductility. While Alloy B exhibited the highest hardness and tensile strength, its impact toughness was slightly lower compared to Alloy A, indicating increased brittleness.

Conclusion. This study demonstrates the critical role of alloy composition, processing methods, and heat treatment in developing new metal alloys with enhanced mechanical properties and corrosion resistance. Through systematic experimentation and analysis, it was shown that tailored alloying and advanced fabrication techniques can significantly improve strength, durability, and performance of materials used in mechanical engineering. While challenges remain in optimizing the balance between hardness and ductility, the findings contribute valuable insights for designing high-performance alloys suited to demanding industrial applications. Future work should focus on exploring novel composite and nanostructured alloys to further advance material capabilities and sustainability.

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