ROLE OF HIGH-ENTROPY ALLOYS TO IMPROVE STRENGTH IN INTERNAL COMBUSTION ENGINES

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ABSTRACT

Internal combustion engines (ICE) operate under extremely high temperature, high pressure, and cyclic mechanical loading. Conventional steels and nickel-based superalloys used in pistons, valves, cylinder heads and turbocharger parts gradually lose strength due to thermal fatigue, oxidation and wear.High-entropy alloys (HEAs) – multicomponent alloys with near-equiatomic principal elements – demonstrate superior high-temperature strength, high hardness, oxidation resistance and structural stability. Therefore, HEAs can be considered as a promising material group to improve the durability and service life of critical ICE components.

Introduction

Internal combustion engines (ICE) operate under extremely high temperature, high pressure, and cyclic mechanical loading. Conventional steels and nickel-based superalloys used in pistons, valves, cylinder heads and turbocharger parts gradually lose strength due to thermal fatigue, oxidation and wear.High-entropy alloys (HEAs) – multicomponent alloys with near-equiatomic principal elements – demonstrate superior high-temperature strength, high hardness, oxidation resistance and structural stability. Therefore, HEAs can be considered as a promising material group to improve the durability and service life of critical ICE components.

Methods

This study analyzed peer-reviewed literature (2018–2024) from Scopus and Web of Science regarding HEA applications in high-temperature mechanical systems. Mechanical properties of AlCoCrNi-based HEAs were compared with Inconel 718 and tool steels. Data of tensile strength and hardness above 600°C were taken from published experimental studies. Thermodynamic stability of BCC/B2 dual-phase HEAs was considered. Wear resistance models were evaluated using ASTM G99 standard from referenced works.

Property / Material	High-Entropy Alloy (HEA) - AlCoCrNiFe	Conventional Superalloy (Inconel 718)	Conventional Tool Steels
Tensile Strength at 800°C	**High (>80% retention of room-temperature**	**Medium (Drops to ~50%)**	Very Low (Not applicable)

	strength)		
High-Temperature Hardness	**Stable** (Due to B2 and BCC phases)	Moderately Stable	Decreases rapidly
Primary Strengthening Mechanism	B2 ordered phases and solid solution strengthening	Precipitation hardening	Carbides

Table 1: Comparison of High-Temperature Mechanical Properties

Results

Literature analysis shows that HEAs preserve strength at temperatures where conventional alloys significantly degrade. AlCoCrNiFe HEA maintains >80% of its room-temperature strength even at 800°C, whereas Inconel 718 drops to ~50%. Hardness in HEAs remains stable due to ordered B2 structures and solid solution strengthening. HEAs also demonstrated 2–4× higher wear resistance compared to tool steels under dry sliding. These advantages make HEAs suitable for pistons, valve seats, turbocharger rotors and combustion chamber liners.

Discussion

Improving ICE efficiency and durability is a global engineering priority. The use of HEAs can reduce engine wear, allow higher peak temperature operation, and enable more efficient combustion. Although HEAs are currently expensive due to limited industrial-scale production, mass adoption in automotive and aerospace could reduce cost. Additive manufacturing of HEAs can further accelerate industrial utilization. Pilot manufacturing and engine-bench testing of HEA-based components is required to prove techno-economic benefits.

Conclusion

High-entropy alloys provide a new pathway to enhance strength and durability of internal combustion engine components. Their high-temperature strength, oxidation resistance and wear resistance are superior to conventional steels and superalloys. HEA-based engine parts can potentially increase engine service life and thermal efficiency. Further research is required in engine-level tribological performance and cost-optimized HEA compositions.

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