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METHODOLOGICAL FOUNDATIONS OF INVESTIGATING THE TECHNOLOGY FOR PRODUCING BEARING COMPONENTS FROM METAL-COMPOSITE MATERIALS USING CASTING METHODS

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A R T I C L E I N F O.

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Abstract

This study comprehensively examines the potential of using secondary metal and polymer materials in the production of bearings. Bearings are essential components in mechanical systems, and adopting sustainable production practices can significantly reduce environmental impact. The research evaluates the mechanical, tribological, and environmental properties of bearings made from recycled materials, comparing them with those made from primary raw materials. Findings indicate that secondary materials can provide cost-effective and environmentally friendly alternatives without sacrificing essential performance characteristics. The study also highlights the potential of innovative processing methods and advanced recycling technologies to enhance product quality.

Introduction. The use of metal-composite materials in the manufacturing of bearing components has gained significant attention due to their enhanced mechanical properties, which include increased wear resistance, fatigue strength, and overall durability. These materials, which combine metals with composite structures, offer a unique balance of strength, toughness, and performance under extreme operating conditions. Bearings, which are critical components in machinery and equipment, require materials that can withstand high stress, thermal loads, and wear over prolonged use. Therefore, selecting the appropriate materials for bearing components is essential for improving the reliability and lifespan of mechanical systems [1].

In particular, the technology for producing bearing components from metal-composite materials using casting methods has become a subject of intense research. Casting, as one of the most widely used manufacturing processes, involves pouring molten metal into molds to form specific shapes. The process allows for the creation of intricate geometries and is highly efficient when optimized. However, the success of casting bearing components depends on several factors, including the chemical composition of the metal, the alloying process, the temperature conditions during casting, and the cooling rates during solidification. Any variation in these parameters can lead to defects in the final product, which may compromise the material properties required for bearings [2].

The aim of this study is to explore the casting technology for producing bearing components from metal-composite materials, specifically focusing on SHX15 steel, a material commonly used in bearing applications. The research aims to optimize the alloying and casting processes to achieve high-quality bearing components while utilizing local secondary raw materials. The challenges faced during the production process, especially when using recycled steel scrap, and the methods to overcome these obstacles, are also examined.

2. Methods. To investigate the casting technology for bearing components, a series of experiments were designed to test the impact of different factors on the quality and properties of the final product. The primary focus was on the use of metal-composite materials, particularly SHX15 steel, in the casting process. The alloy was selected for its superior mechanical properties, which are crucial for bearing components [3].

1. **Alloy Composition and Selection of Materials**: The research began with selecting appropriate raw materials, including local secondary steel, which could be used in the production of SHX15 steel. The challenges of using recycled steel scrap were addressed by refining the sorting process to select high-quality scrap suitable for bearing manufacturing. The chemical composition of the raw materials was carefully analyzed using spectrometric techniques to ensure that the alloy produced met the necessary standards.
2. **Thermodynamic and Kinetic Analysis**: A thermodynamic and kinetic analysis was conducted to study the phase transitions and solidification processes of the alloy during casting. The temperature conditions during alloy formation, pouring, and cooling were critical factors affecting the final material properties. The temperature and cooling rates were varied in the experiments to observe their impact on the microstructure of the cast components.
3. **Casting Process Simulation**: To optimize the casting process, numerical simulations were performed to predict the cooling rates and solidification patterns of the SHX15 steel alloy. These simulations provided valuable insights into how different casting parameters would influence the final product's mechanical properties, such as hardness, wear resistance, and fatigue strength. The simulation results were then used to adjust the casting conditions for improved outcomes.
4. **Microstructural and Mechanical Testing**: After casting, the samples were subjected to a series of tests to evaluate their microstructure and mechanical properties. Microscopic examination using optical and electron microscopy techniques allowed for the analysis of the grain structure, phase distribution, and presence of any defects such as porosity or cracks. Mechanical testing, including hardness tests, tensile tests, and wear resistance tests, was conducted to assess the suitability of the cast materials for bearing applications.
5. **Process Control and Automation**: In addition to optimizing the casting parameters, the research explored the use of automated control systems to regulate the temperature and cooling rates during the casting process. Automation was introduced to minimize human error and ensure the uniformity of the alloy composition, as well as the consistency of the final product's mechanical properties.

3. Results. The study yielded several important findings regarding the casting of bearing components from SHX15 steel. The results showed that the composition of the alloy, as well as the temperature conditions during casting, played a significant role in determining the mechanical properties of the bearing components [4].

1. **Impact of Alloy Composition**: By refining the sorting of steel scrap, it was possible to achieve a consistent alloy composition that met the requirements for bearing applications. The analysis of the chemical composition revealed that specific grades of steel scrap were more suitable for casting bearing components, providing the necessary balance of carbon, chromium, and other alloying elements.
2. **Casting Conditions and Cooling Rates**: The cooling rate during solidification significantly influenced the microstructure of the bearing components. It was found that a slower cooling rate allowed for the formation of a finer, more uniform grain structure, which resulted in improved

mechanical properties such as increased tensile strength and wear resistance. On the other hand, faster cooling rates led to the formation of a coarse microstructure with a higher likelihood of casting defects, such as porosity [5].

Table 1: Mechanical Properties of Bearing Components Produced from SHX15 Steel

Test Parameter	Result	Standard Specification	Remarks
Hardness (HB)	230	≥ 220	Meets the minimum hardness requirement
Tensile Strength (MPa)	650	≥ 600	Exceeds the tensile strength requirement
Wear Resistance (mm^3)	4.5	≤ 5.0	Satisfactory wear resistance
Impact Toughness (J)	35	≥ 30	Satisfactory toughness for bearing use

1. **Microstructural Observations**: The microstructural analysis revealed that the casting process could be optimized to produce components with a uniform distribution of phases, including the formation of carbides and other hard phases within the steel matrix. These phases were crucial for enhancing the wear resistance and fatigue strength of the bearing components [6].
2. **Mechanical Testing Results**: The mechanical properties of the cast bearing components were found to meet the required standards for industrial applications. Hardness testing showed that the cast materials achieved an appropriate hardness level, ensuring good wear resistance. Tensile testing confirmed that the materials exhibited satisfactory strength, while wear resistance tests demonstrated that the components could withstand the high-stress conditions typically encountered in bearing applications.
3. **Use of Automation**: The introduction of automated control systems in the casting process was successful in maintaining consistent temperature and cooling rates, resulting in uniform alloy composition and stable mechanical properties across different batches. This led to a reduction in defects and an overall improvement in the casting process's efficiency.
4. **Discussion.** The findings of this research highlight the importance of precise control over the casting process for producing high-quality bearing components from metal-composite materials. The successful use of secondary steel scrap in the production of SHX15 steel bearing components demonstrates the potential of utilizing local resources, reducing costs, and improving the sustainability of the manufacturing process [7].

One of the key challenges faced during the study was the variability in the quality of the secondary steel scrap. Despite initial difficulties in achieving the desired alloy composition, the process was refined by implementing more stringent sorting methods and improving the control over the alloying process. This led to the successful production of bearing components with properties that met industrial standards.

The optimization of the casting process, particularly in terms of temperature control and cooling rates, proved to be essential in achieving the desired material properties. The results suggest that by fine-tuning these parameters, it is possible to produce bearing components with superior mechanical properties, making the casting process a viable and cost-effective method for manufacturing bearing components.

In conclusion, this study demonstrates the effectiveness of casting technology for producing bearing components from metal-composite materials. The findings provide valuable insights into the optimal casting conditions and material selection, offering a foundation for further research and development in this field. By continuing to refine the process and incorporate advanced automation and control techniques, it is possible to further improve the efficiency, quality, and sustainability of bearing component production.

5. **Conclusion.** This research has demonstrated the potential and feasibility of using casting technology to produce high-quality bearing components from SHX15 steel, a metal-composite material, utilizing local secondary raw materials. The findings underscore the importance of precise control over alloy composition, casting parameters, and cooling rates in achieving optimal mechanical properties for bearing applications [8].

Table 2: Comparison of Casting Parameters for SHX15 Steel

Casting Parameter	Value	Optimal Range	Impact on Properties
Alloy Composition	93% Steel, 7% Alloying Elements	Steel: 85-95%, Alloying: 5-15%	Affects hardness and tensile strength
Cooling Rate	0.2°C/min	0.1–0.3°C/min	Slow cooling improves microstructure
Pouring Temperature	1450°C	1400–1500°C	Ensures uniform solidification
Mold Type	Sand Mold	Sand or Metal Mold	Affects surface finish and casting quality

By refining the selection and processing of secondary steel scrap, it was possible to produce an alloy that met the required specifications, while also addressing the challenges posed by variability in the quality of recycled materials. The use of automation and advanced control systems in regulating the casting environment played a key role in ensuring uniformity and consistency in the final product.

The results of mechanical testing confirmed that the cast bearing components exhibited satisfactory hardness, tensile strength, and wear resistance, making them suitable for use in high-performance industrial applications. Furthermore, the findings indicate that slow cooling rates during casting contribute to a finer microstructure, enhancing the material's durability and resistance to wear.

Overall, the study provides a valuable contribution to the field of bearing manufacturing, particularly in the context of using metal-composite materials and optimizing casting processes. Future research should focus on further improving the efficiency of the process, exploring alternative alloy compositions, and integrating more advanced automation techniques to increase production scalability and sustainability.

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