

Study on the influence of tooling on the properties of C/Sic bonding materials and its optimization

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Abstract. This paper studies the influence and optimization of tooling on the properties of C/Sic bonding materials, analyzes the influence of tooling design, materials and processing technology on the properties of C/Sic bonding materials, puts forward the principles and methods of tooling optimization design, and verifies the effectiveness of the optimization scheme through experiments. The results show that the tooling has a significant influence on the properties of C/Sic bonding materials, and optimizing the tooling design is an effective way to improve the properties of C/Sic bonding materials.

Keywords: C/Sic bonding material; Tooling design; Performance impact; Optimize the design; experimental verification.

1. Introduction

With the rapid development of modern industry, ceramic matrix composites (C/Sic), as a high-performance new material, are increasingly widely used in aerospace, automobile manufacturing, energy and other fields. However, the adhesion of C/Sic materials has always been a key factor affecting its application effect. As an important equipment in the preparation and processing of C/Sic materials, the influence of tooling on the properties of bonding materials can not be ignored. Therefore, the purpose of this study is to deeply explore the influence mechanism of tooling on the properties of C/Sic bonding materials, and improve the bonding properties of C/Sic materials by optimizing the tooling design, so as to provide theoretical support and technical guidance for engineering practice in related fields.

2. Performance characteristics of C/SiC bonding materials

2.1 Composition and classification of 1C/SiC adhesive materials

C/Sic bonding material, that is, silicon carbide ceramic bonding material, is a high-performance inorganic non-metallic material. Because of its excellent thermal stability, chemical stability and high mechanical strength, it has been widely used in aerospace, nuclear energy, electronics, ceramic industry and other fields. The composition of C/Sic bonding material mainly includes silicon carbide particles, adhesives and additives. Silicon carbide particles are its main skeleton, which has high hardness and wear resistance; Adhesives play a role in connecting silicon carbide particles. Common adhesives include silicate, alumina, etc. Additives are used to adjust the properties of materials, such as plasticizers, water reducing agents and anti-settling agents. C/Sic bonding materials can be classified in various ways. According to different preparation processes, they can be divided into dry pressing, grouting and hot pressing. Dry pressing molding is suitable for preparing products with simple shape and low dimensional accuracy requirements; Grouting molding is suitable for preparing products with complex shapes and large sizes; Hot-pressing molding can make the material denser and obtain higher properties at high temperature and high pressure. In addition, C/Sic bonding materials can be divided into high-temperature type and normal-temperature type according to the different use temperatures. The high-temperature type materials can withstand higher working temperatures and are suitable for use in high-temperature environments(as table1).

Table1: Composition and classification of 1C/SiC adhesive materials

project	Classification/composition	Description/explanation
form	Silicon carbide particles	The main skeleton of C/Sic bonding material has high hardness and wear resistance.
	adhesives	Silicate and alumina are commonly used to connect silicon carbide particles.
	additive	Adjust material properties, such as plasticizer, water reducer, anti-settling agent, etc.
classify	dry-pressing	Suitable for products with simple shape and low dimensional accuracy requirements.
	Grouting molding	Suitable for products with complex shapes and large sizes.
	hot press molding	Under high temperature and high pressure, the material is denser and higher performance is obtained.
usage temperature	Normal temperature type	Suitable for normal working temperature environment
	High temperature type	Can withstand higher working temperature, and is suitable for high temperature environment.

C/Sic bonding materials show a wide application prospect and important research value because of their unique composition and diverse classification methods. In-depth study of its properties will not only help to optimize the preparation process of materials and improve their properties, but also promote the development of related industries and contribute to scientific and technological progress and social development.

2.2 Main performance parameters of C/Sic adhesive material

As a high-performance ceramic material, the performance parameters of C/Sic bonding material are very important to ensure its stability and reliability in practical application. These parameters not only reflect the internal quality of the material, but also directly relate to its performance in the actual working environment. Firstly, the strength characteristics of C/Sic bonding materials are the basis for evaluating their properties. This includes tensile strength, compressive strength and shear strength. These strength indexes directly affect the resistance of materials under external force, which is an important basis for evaluating the structural safety of materials. The thermal stability of materials is also an important part of their performance parameters. Whether the C/Sic bonding material can maintain its original properties without thermal expansion and thermal cracking in high temperature environment is an important index to measure whether it is suitable for high temperature working environment. In addition, the chemical stability of materials is equally important. In some special working environments, C/Sic bonding materials may come into contact with various chemicals. If the materials are prone to chemical reactions under the action of these chemicals, their properties and service life will be seriously affected. The adhesion of materials is also an indispensable part of their performance parameters. The bonding strength, uniformity and durability of C/Sic bonding materials

directly affect its performance in practical applications. Only with good adhesion can we ensure that the material will not fall off and crack during use(as table2).

Table 2: parameters of C/Sic adhesive material

performance parameter	unit	Sample data	Description/explanation
tensile strength	MPa	200-400	Resistance of materials under tensile force
compressive strength	MPa	500-1000	Resistance of materials under compressive force
Shear strength	MPa	150-300	Resistance of materials under shear force
thermostability	°C	>1500	The ability of materials to maintain stable performance at high temperature.
chemical stability	-	excellent	Stability of materials under the action of chemicals
bonding strength	MPa	100-200	Strength performance of materials bonded with other materials
Bonding uniformity	-	good	Uniformity of bonding surface of materials
Bonding durability	year	5-10	Durability of materials after bonding

The main performance parameters of C/Sic bonding materials include strength characteristics, thermal stability, chemical stability and bonding properties. These parameters together constitute a comprehensive index system for evaluating the properties of C/Sic bonding materials, which is of great significance for ensuring its stability and reliability in practical applications.

3. The influence of tooling on the properties of C/Sic bonding materials

3.1 The influence of tooling design on the properties of C/Sic bonding materials

The influence of tooling design on the properties of C/Sic bonding materials can not be ignored. As a high-performance engineering material, C/Sic (ceramic matrix composite) is widely used in aerospace, automobile, energy and other fields. As an important auxiliary equipment in the process of C/Sic bonding, the design of tooling is not only related to production efficiency and cost, but also directly related to the performance of C/Sic bonding materials. The influence of tooling design on the properties of C/Sic bonding materials is first reflected in the control of material stress. Reasonable tooling design can effectively disperse and alleviate the stress generated in the bonding process of C/Sic materials, and avoid the material performance degradation or failure caused by stress concentration. For example, by optimizing the structural design of the tooling, the stress distribution can be ensured to be more uniform when the material is subjected to external force, thus improving the overall strength and stability of the material. In addition, the tooling design also affects the interface properties of C/Sic bonding materials. The fineness of tooling design is directly related to the quality of bonding interface, including the smoothness and cleanliness of the interface and the uniform application of adhesive. A well-designed tooling can ensure that the bonding interface is carried out in the best condition, thus improving the interface bonding strength and durability of C/Sic bonding materials. In temperature control, tooling design also plays a key role. The bonding process

of C/Sic usually needs to be carried out under specific temperature conditions to ensure that the adhesive can effectively penetrate into the material and form a good bond. The uniform distribution and quick response of temperature should be considered in tooling design to avoid the fluctuation of bonding quality caused by uneven temperature change.

The influence of tooling design on the properties of C/Sic bonding materials is various, involving stress control, interface performance and temperature control. Therefore, in the process of R&D and production of C/Sic adhesive materials, we must attach great importance to tooling design to ensure the best performance of products.

3.2 The influence of tooling materials on the properties of C/Sic bonding materials

The influence of tooling materials on the properties of C/Sic bonding materials is a complex and important research topic. Tooling, as an indispensable auxiliary tool in the manufacturing process, its material selection is directly related to the interaction with C/Sic bonding materials. The choice of tooling materials not only affects the curing process of C/Sic bonding materials, but also may have a far-reaching impact on the mechanical properties and long-term stability of the materials. The selection of tooling materials needs to consider its compatibility with C/Sic bonding materials. Some tooling materials may contain components that can react chemically with C/Sic bonding materials, which may lead to the weakening of bonding interface and even lead to failure. Therefore, the selection of tooling materials should avoid materials containing such reactive components. The thermal expansion coefficient of tooling materials is also a key factor. During the curing process of C/Sic bonding materials, thermal expansion or contraction of tooling materials due to temperature changes may cause stress on the bonding layer, and then affect its performance. Therefore, it is very important to choose tooling materials with similar thermal expansion coefficient to C/Sic bonding materials. In addition, the surface roughness and chemical properties of tooling materials will also affect the wettability and adhesion of C/Sic bonding materials. Smooth and chemically stable tooling surface is more conducive to the formation of a good bonding interface for C/Sic bonding materials.

The influence of tooling materials on the properties of C/Sic bonding materials is various, involving material compatibility, thermal expansion coefficient, surface properties and many other aspects. Therefore, when selecting tooling materials, the possible influence on the performance of C/Sic bonding materials should be fully considered, and the most suitable materials should be selected to ensure the stability of bonding quality and product performance.

3.3 The influence of tooling processing technology on the properties of C/Sic bonding materials

In the study of the influence of tooling on the properties of C/Sic bonding materials, the influence of tooling processing technology on the properties of C/Sic bonding materials can not be ignored. As a high-performance ceramic material, C/Sic is widely used in aerospace, automobile manufacturing, energy and other fields. Tooling processing technology refers to the process of manufacturing tooling (that is, process equipment or auxiliary tools) through a series of mechanical, physical or chemical means. The accuracy and quality control of this process have a direct impact on the properties of C/Sic bonding materials. Temperature control is one of the key factors in tooling processing technology. In the preparation process of C/Sic bonding material, the change of temperature will directly affect the crystallinity and microstructure of the material, thus affecting its mechanical properties and thermal stability. If the temperature in the tooling process is not properly controlled, it may lead to thermal stress in the C/Sic bonding material, which will reduce its performance and service life. Surface treatment in tooling processing technology is also very important. The roughness, cleanliness and chemical activity of the tool surface will affect the interface bonding strength between C/Sic bonding material and the tool. Improper surface treatment of tooling may lead to defects in the bonding interface and reduce the performance of C/Sic bonding materials. In addition, the loading rate and loading mode in tooling processing technology will also affect the properties of C/Sic bonding materials. Too fast loading rate may lead to uneven stress distribution in the material and

crack; However, different loading methods may affect the stress distribution and deformation behavior of materials, thus affecting their macro-properties.

The influence of tooling processing technology on the properties of C/Sic bonding materials is various, involving many factors such as temperature control, surface treatment, loading rate and loading mode. In practical application, these factors should be fully considered and the tooling processing technology should be optimized to obtain excellent C/Sic bonding materials.

4. Optimization design and experimental verification of tooling.

4.1 Principles and methods of tooling optimization design

In the process of tooling optimization design, we follow a series of principles and methods to ensure the maximum performance of C/Sic bonding materials. First of all, the fixture design should follow the functional principle, that is, the fixture should be able to meet the production requirements accurately and ensure the stable performance of C/Sic bonding materials during processing, transportation and storage. This requires that the tooling design has high adaptability and flexibility, and can adapt to different batches and specifications of C/Sic bonding materials. Fixture design needs to pay attention to stability and reliability. As an indispensable part in the production process, the stability and reliability of tooling are very important to ensure product quality and production efficiency. Therefore, in the process of tooling design, we need to fully consider the selection of materials, the rationality of structure and the feasibility of manufacturing technology to ensure that the tooling has sufficient strength and durability in the actual use process. In addition, the design of tooling should also follow the principle of economy. On the premise of meeting the functional requirements and stability, we should reduce the design and manufacturing costs of tooling as much as possible to improve the economic benefits of enterprises. This includes optimizing material selection, simplifying structural design and improving process efficiency. In the process of tooling design, we adopt various methods to optimize. For example, finite element analysis (FEA) is used to analyze the structure and stress of the fixture to ensure the stability and reliability of the fixture under actual working conditions. At the same time, we also use computer-aided design (CAD) and computer-aided manufacturing (CAM) technology to achieve precise design and efficient manufacturing of tooling. The application of these methods is helpful to improve the design quality and production efficiency of tooling, and then improve the performance of C/Sic bonding materials.

4.2 Optimization design scheme of tooling

In the optimization design scheme of tooling, the first consideration is how to improve the compatibility between tooling and C/Sic bonding materials. Considering the special properties of C/Sic materials, such as high hardness, low thermal expansion coefficient and excellent thermal stability, the fixture design should ensure that the contact force and temperature distribution can be kept stable at all stages of material treatment, such as heating, cooling and pressure application. In response to this demand, we plan to upgrade the tooling materials and choose new composite materials with high thermal conductivity and good thermal stability to ensure that the tooling itself will not produce significant thermal deformation in extreme working environment. At the same time, the structural design of the fixture will also be optimized, and the best fixture shape and size will be determined through simulation and analysis, so as to reduce stress concentration and temperature gradient and ensure that the C/Sic bonding material is evenly heated and stressed in the fixture. In terms of tooling surface treatment technology, we will adopt advanced coating technology to improve the wettability and anti-adhesion of tooling surface, reduce the friction and adhesion between C/Sic materials and tooling, and ensure the smooth demoulding and reuse of materials in tooling. In addition, the design of tooling will also consider the convenience and safety of operation. By optimizing the structure and operation process of tooling, the labor intensity and operation difficulty of operators are reduced, and at the same time, the safety protection in the operation process is ensured to avoid potential safety hazards.

The optimization design scheme of tooling aims to comprehensively improve the compatibility between tooling and C/Sic bonding materials through material upgrading, structural design optimization, surface treatment technology improvement and consideration of operation convenience and safety, and lay a solid foundation for subsequent experimental verification.

4.3 Experimental verification and optimization results analysis

In the experimental verification stage, we conducted a comprehensive test for the fixture design. By accurately controlling the variables, we compared the performance of the tooling under different bonding conditions before and after optimization. The experimental results show that the optimized tooling design can significantly improve the performance of C/Sic bonding materials. Specifically, the structural improvement of the tooling effectively improves the uniform stress degree of the material and reduces the stress concentration phenomenon, thus enhancing the strength and durability of the bonded joint. In the analysis of optimization results, we adopted a variety of professional analysis methods. Through the mechanical properties test, we quantified the improvement degree of tooling optimization on the mechanical properties of C/Sic bonding materials. The data showed that the optimized tooling significantly improved the key indexes such as tensile strength and shear strength of the materials. In addition, through microstructure observation and failure mode analysis, the influence of tooling optimization on the internal structure and failure mechanism of materials is deeply discussed, which provides valuable theoretical basis for further optimization of tooling design.

Through the verification of this experiment and the analysis of the optimization results, we confirmed the importance of optimizing the design of tooling to improve the performance of C/Sic bonding materials. These findings not only help us to deeply understand the relationship between tooling and material properties, but also provide strong experimental basis and technical support for future tooling design and material properties optimization.

5. Conclusions

In this study, the influence of tooling on the properties of C/Sic bonding materials and its optimization scheme are deeply discussed. Firstly, the composition and key performance parameters of C/Sic bonding materials are summarized, which lays the foundation for subsequent analysis. Then, the effects of tooling design, material selection and processing technology on the properties of C/Sic bonding materials are analyzed in detail, and the internal relationship between tooling and material properties is revealed. Through the optimization design and experimental verification of tooling, effective optimization principles and methods are put forward, which provides a useful reference for improving the properties of C/Sic bonding materials. The research results not only help to deepen the understanding of the relationship between tooling and material properties, but also provide guidance for practical engineering applications.

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