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Character of Self-healing – a Review

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Abstract

Nowadays foreign and domestic scientists present technologies for solving social problems. The development and characterization of self-healing structural ceramics have been inspired by researchers in which damage triggers an autonomic healing response. This is one of the emerging and fascinating areas of research that could significantly extend the working life and safety of the ceramic components at higher temperature. The structural ceramics are superior in strength to metal at high temperature, but they are brittle and sensitive to flaws. Due to this, the structural integrity of the ceramic components is seriously affected. There are few advantages in crack healing ability of materials (a) higher fabrication efficient at low cost, of the self-healing takes place after the machining is performed, (b) reliability of the material improves, when all the cracks are healed and (c) if the crack gets healed in service, the full strength of the material is recovered. In this paper, Overview of various self-healing concepts for structural ceramic materials.

Keywords: Self-healing, ceramics;

1. Introduction

Self-healing process has a long history. Relevant processes in concrete have been studied microscopically since the 19th century. Self-healing materials only considered as a widely recognized field of study in the 21st century. In 2007, there was the 1-st international conference about self-healing materials [12]. It's considered that the idea of self-healing materials is from biomimetic materials as well as to other novel materials and surfaces with the embedded capacity for self-organization [10].

Generally, ceramics are stronger than metals at high temperatures, although they are breakable and sensitive to flaws and it is not good as structural materials because of their integrity and reliability [11]. The MAX Phases, also known as $M_{n+1}AX_n$ phase, can heal crack damage caused by an intrinsic healing mechanism by itself. The oxides fill the small cracks by thermal stress thanks to the MAX phase constituents, when the ceramics exposure to air in high temperature [14]. The first observation of filling the crack gap was Ti_3AlC_2 by oxidation at 1200 C in air [13]. The self-healing process is processive to the end of the element depletion. We can enhance the local strength, which depends on the filling-oxide [2]. However, mullite, alumina and zirconia aren't belonging to the self-healing group. They could get the self-healing capabilities by embedding 2-nd phase components into the matrix. During cracking, these particles are exposed to oxygen, and during heating, they create new form of materials filling the gap while the volume of the material expends

[9]. This theory is testified by SiC healing cracks in a matrix made of alumina [7], and in future studies the high temperature strength [8], and the static and cyclic fatigue strength of the healed part were tested [1].

There are three specific problems that show the limitation of the self-healing ceramics:

- When grinding, polishing and some other machining, cracks would occur. It would decrease the reliability of the ceramics. To prevent this kind of cracks, more precise polishing is necessary in the end of the machining, which costs more time and less efficiency when raising the fabrication cost.
- The reliability is affected when the cracks are 10um. The NDE inspection isn't yet developed for measuring cracks of 100um in depth.
- Due to different causes during higher temperature, it's more likely to occur cracks in the components.

There are 3 technological approaches which would help to overcome these 3 problems:

- Using microstructure control and fiber reinforcement to improve the toughness of the material.
- Create a new NDE detector to inspect before service, and repair dangerous cracks.
- Introduce self-crack-healing ability into the ceramic, so that all dangerous cracks can be healed.

2. History of crack healing process

In 1966, Heuer and Roberts investigated a strengthening test of ceramics with heat treatment [3]. Lange and Gupta were the first people to use the term "crack-healing" [4] when the report called "the strengthening of Zinc Oxide and Magnesium Oxide by heat treatment" was reported. Many reports found in strengthening of cracked ceramics were made. The crack-healing is divided into (i) re-sintering, (ii) relaxation of tensile residual stress at the indentation site, (iii) cracks bonding by oxidation Re-sintering of the ceramic component commences with a degradation of the primary crack but generates the cylindrical voids in the immediate crack tip. In the 2-nd situation, relaxation enhance the recovery ability of the strength, but it can't heal the crack. Lange was the first to bond the crack using oxidation [5]. He tested the strength recovery of SiC using the high temperature at 1673K in open air. The bending strength of the specimen is 10% higher than the smooth specimens after the heat treatment for 110 hours.

3. Mechanism of Self-healing

At high temperature self-healing function in the structural ceramics raised in ceramic matrices which based on silicon carbide or silicon nitride particles. In ceramic components, the rapid catastrophic brittle fracture usually takes place because the stress concentrates at the crack tip. During various machining situation, the surface crack could be healed by silicon carbide or nitride components. The silicon carbide or silicon nitride particles can contact the oxygen in the surrounding atmosphere at the surface of the cracks. During high temperature, the oxidation could be caused by oxygen contact as per the following equation,

$$SiC + {}^{3}/_{2}\, O_2 \rightarrow SiO_2 + CO \tag{1}$$

It could give almost 2 times volume expansion by the oxidation, so the formed oxide can fill the gap between the crack walls fully. Because of the high temperature, it will establish a strong bonding between the formed oxide and the ceramic matrices. By this, the degraded strength

recovers completely and enhanced with high mechanical reliability. The schematic diagram of self-crack healing mechanism of SiC is shown in fig. 1 [6].

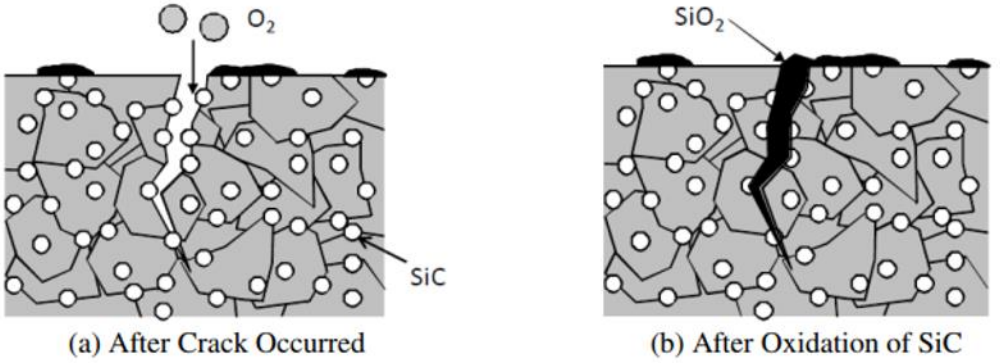

Fig. 1. Crack healing mechanism

4. Conclusion

In this paper, we talk about self-healing ceramics, showed about its history, characteristic and mechanism. This paper gives us a general picture of self-healing method and helps us for further research.

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