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The function and the principle about how self-healing materials are used in metal wear condition

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Abstract. Due to the wide range of metals used in different industries, the increase in the service life of metals and metal materials has always been a more important research direction. Relevant research has proved that self-repairing materials in lubricants can help machines to repair themselves by utilizing self-modifying properties, thus restoring them to a better working condition. This paper mainly summarizes and analyzes the experimental materials by means of literature review, and discusses the working principle of such materials and the application of self-repairing materials in industrial production. The article also confirms through its analysis that during the operation of the machine, the composite lubricant reacts with the metal surface and forms a thin film, which results in a substitution reaction. In this way, the damaged metal is replenished by the composite material and the machine can return to normal operation. However, this method can only be applied to machines that work for a short period of time, and is not able to solve the problem of large areas of severely damaged machines, so the relevant materials to assist in the modification of the metal still need to be continuously developed and researched.

Keywords: Metallic self-repair, ITCS, Machine, Lubricate with catalyze. Chemical reaction.

1. Introduction

There are many forms of self-healing material, such as bio-mimetic, self-healing polymers and elastomers. Most of these materials were used as to self-repair plastic because the chemical bond that breaks between polymers and elements are much easier to repair. As for metal, due to the special bond-metallic bond-between atoms. It is hard for them to bond together without any other chemical reagents or catalyzer [1]. Also, damage for metal is really urgent, a small damage or crack might cause the machine and whole system to break down. For instance, a small crack from engine might cause the car to stop and stop functioning. It is extremely for driver especially when they are driving on the high way. However, there is a kind of materials, hydroxyl-silicate, that can help metal to self-repair without human constantly additions due to its similar function of self-healing [2]. There are two physical and chemical procedure in this process when hydroxyl-silicate is helping the metal to recover. Each step during the procedure does not only heal the metal, but also create a better condition for metal to exists. The physical procedure creates a condition for chemical reaction to exchange the metal from lubricate. This achieves the goal of effectively extend the machines' service life, and protecting it from further injuries that might occurred from severe conditions such as, collision between heavy objects. This paper mainly focus on the development for self material. The purpose is to use the self material in metal to improve the life of machine by using the physical and chemical reaction between the compound in lubricate and the metal.

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This research can be cited in the manufacture and maintenance of machines, thus helping companies to improve the efficiency and life of their machines.

2. The mechanism of action about self-healing metallic material.

According to the substitution reaction that can happen between metals, the scientists designed a system for hydroxyl-silicate to exchange the metal from the broken machine.

There are three basic procedures that hydroxyl-silicate work. The first step is the hydroxyl-silicate will be mixed in lubricant and added between the metallic machine. The hydroxyl-silicate will not react with lubricant. Due to the comparative large size with the protrusions on the metal. Hydroxyl-silicate can effectively furnish the surface of the damaged metal. The second procedure is that hydroxyl-silicate can help to clean the surface, so there is a more smooth surface for hydroxyl-silicate to prepare for the next step [3].

Both the first and second step can be considered as a physical change.

The third procedure can be counted as a chemical reaction between hydroxyl-silicate and the damaged metal. When the hydroxyl-silicate reaches the surface of the damage metal and the first two steps occur, the large particle of hydroxyl-silicate will collide and rub with the protrusions. During this process, large amount of heat will be released in a small period of time and create a perfect condition for hydroxyl-silicate to form a replace reaction with the protrusion or the cracks. Therefore, the cracks will be fixed up, the protrusion will be cleaned, and the metal or the machine recover.

This kind of self-healing metallic material can be considered as chemical reaction.-

2.1. The classification of the film which created by the self-healing material

When the material in lubricate substitute with the metal, there will be films formed by the self-healing product and it is the basic condition for substitution. There are four types of them.

First kind of film is formed directly between the metal from the surface of the machine and the additive in the lubricant. This can form a chemical film which contains polar molecule. Since it is polar, it will be physically absorbed by the pair surface of the metal so it can achieve the purpose for protecting the metallic surfaces from damage. This kind of film can normally be formed by the active additive in the lubricant such as s, p, cl, b. It can form chemical compound like ferrous sulfide, ferric chloride . Second kind of film are formed by lots of small crystal balls [4]. As mentioned above, during procedure one and two, the protrusion and the additive will rub and collide to release large amount of heat. In the high temperature condition, the additive and the metal from metallic surface will form eutectic balls. The film which is formed by these eutectics can not only repair the metal but also fill the gaps between pits and eventually let the pair surface to be much smoother. The third kind of film is formed by the additive in the lubricant. The lubricant just deposits on the pair surface and form the film. For instance, by adding MoS2 or graphite which both of them have flat structure will deposits on the pair surface of the metal. Since the Van der waals's force is extremely low between different layers. It can also make the surface smoother [5]. The last film can help the metal to adapt the friction between other objects. This film is normally metallic. It will not tire but has a higher special density.

The first and second film are totally formed by chemical reaction. However, the third kind of film was actually quite different, it does not involve in any chemical procedure and the fourth film was formed by chemical and physical reaction.

2.2. The reason people choose to use film to help metal to repair

The metal that rubs against each other does not looks like what it is. Most people believe that the surfaces just rub without any other materials. However, even for the material that has not been deal with anything will have films to let them rub against each other. For instance, like oxidation film will exists if this machine has not been preserved well. Normally, this film can protect the metal from damage. However, the film will still be destroyed if the condition is too harsh and there is not enough time for the metal to form a new film. This is why the additive must not only help the metal to repair itself, but also create films.

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3. In-situ tribochemical self-repair (ITCS) Working Principle

When people first discovered about that B, N, C, S can actually filtrate into some surface during friction [6]. People realized that metal can achieve similar effect, which is really similar to MRRs. In this way, the additive can filtrate into the metal through friction. After filtration, the additive can evoke response to form new structure or form new particle. For instance, Cu, Sn, Bi, Cr, W can all be used in this procedure as long as they are organic metal.

The possible material for the additive to achieve self-healing.

Nano-materials are be considered as the most important material. Nanoparticles OD-n is considered to be a type of ideal material for self-healing. During the first two steps of self-healing process, OD-n is able to produce Nanometals and metallic oxide can be used in the next to chemical process for self-repair.

There are two ways to achieve self repair and ITCS. The first way is to use soft repair. Soft repair can also be achieved in two ways. First, OD-n is a ball-like particle, so it can be used as a pom ball to fill between the pits. Just like the Second film and create a smooth surface for metal. Second, After the OD-n formed a film and is absorbed on the surface metal, it can achieve self-healing by adding the actual contact surface area of fictional duality and decreasing the imprinting force on the repairing surface. The second way is to use hard repair. OD-n can show its chemical activity, and let it self to form a reduction reaction by letting out the electron. Therefore, OD-n will turn into microcrystal. Due to the high temperature condition which was created when the additive rub against the pair surface, It can form a molten alloy film. This process required nanometal to react with OD-n, so it is important to choose nano CuO, PbO etc. These materials can effectively help OD-n to form a reduction reaction since they are easy to lose electron. As for the OD-n, people tend to choose Cu, silver, Pb, etc. Consider that they are wear resistant, these metals are good replacement for the damaged part. Therefore, the best additive should be n-CuS-MoS_2, n-Pb-MoS_2, etc.

4. The application for metallic self-healing material

4.1. Condition

The metallic self-healing material cannot use with new equipment or machines that require little time to maintain. It also needs the machine that is over run-in period. The reason that these three types of machines (the new machine, the machine that is not over run-in period and the machine that need little time to repair) cannot use is because these machines' surface does not need to be polish or grind. As for the machine or equipment that reach the condition for using the material, the lubricant can be added after the maintenance.

4.2. The perfect application for self-healing material

Cylinder in the engine can be considered as one of the machines that reaches the requirement for using the self-healing material. When the cylinder has not been hurt too much, the machine can be injected by the self-healing material directly into cylinder and turn off the engine. After the metal was injected by it, people need to open the engine per 10 second. In this way, it can make sure that self-healing materials are spread all over the engine. The surface of the cylinder can be identified as the Figure 1 [7]. Different density of the additive can cause different surface. When the temperature is around 200 degrees to 400 degrees, the additive can achieve its best effect. In the reality, when the first injection is finished, the second injection needs to be finished after the car has run over 400-600 kilometer. It can not only decrease the loss during working, but also help to replenish the material needed for self-healing.

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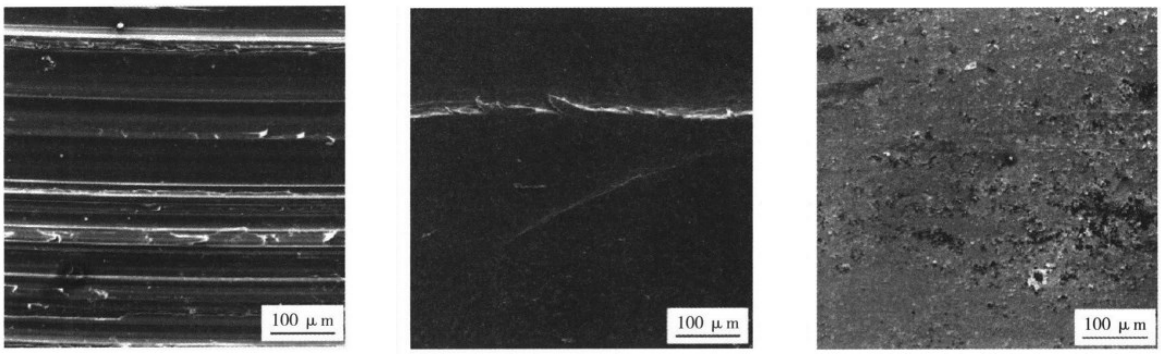

(a) concentration 0% (b) concentration 10% (c) concentration 20%

Figure 1. The effect of different concentration of magnesium hydroxysilicate on damaged surface [7]

4.3. Improvement for self-healing material

At the cylinder where 15-20cm to the top, the loss during working is quite obvious. Also, when the engine starts, the loss also reaches the maximum. When the temperature reaches 93.3 degrees, the loss decreases as temperature increases. Therefore, it is still important to track for the cylinder that has used this technology to find out what is the best condition to reach the best effect.

5. Conclusion

The paper focuses on the use of composites in lubricate to help the machine to self-repair. While the machine is in operation, the compound lubricate reacts with the metal surface and forms films, resulting in a substitution reaction. In this way, the damaged metal is replenished by the compound. However, there are still some pending issues with this approach. In some condition, if the surface of the machine is extensively and severely damaged, the compound can only help to repair part of the machine and cannot restore the machine to normal operation. In addition, this can only be applied to machines that work for short periods of time. Due to the heat generated and the conditions, the time required for composites to complete the process is not sufficient and hence not suitable for self-healing materials.

Due to time and resource reasons, this paper mainly discusses the topic in the form of theoretical analysis and review during the analysis, without involving specific experimental tests and within a certain range of literature references.

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