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Application and Prospects of High-strength Lightweight Materials used in Coal mine

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Abstract. This paper describes some high-strength lightweight materials used in coal mine, and if their performance can meet the requirements of underground safety for explosion-proof, anti-static, friction sparks mine; and reviewed the species, characteristic, preparation process of high-strength lightweight materials for having inspired lightweight high-strength performance by modifying or changing the synthesis mode used in coal mine equipment.

1. Introduction

The mechanical strength of the material is an important indicator on the project, it is an important measure of material carrying capacity. The traditional structural materials mainly iron and steel, which can be improved metallurgy, heat, cold, etc in strength and hardness. However, with the development of technology, portable energy device is widely used, such as automotive, aircraft, its shell required light weight, low energy consumption and a certain intensity. As a result of its low energy consumption and green modern philosophy, lightweight, high strength material has been widely used and developed. Down hole coal industry has high risk, in order to ensure coal mining enterprises develop sustainable, safety and inhibition of major accidents[1].So the use of automated equipment to replace the manual operation to go down is an inevitable trend of development, while to extend underground work time lightweight device is one of the important factors, portable energy device and mine rescue robot used underground are all urgent need for the development and application of high-strength lightweight materials. The complexity of the underground environment asked higher demands on equipment and materials, miners working underground space which is small, complex geology, easy fire, gas explosion, flood and other extremely hazardous accidents[2] while mine rescue robots are applied mine disaster scene catastrophic, sudden, secondary and destructive characteristics[3], and under such an environment vulnerable to encounter a variety of secondary explosions and other dangerous conditions[4], in order to protect mine safety, equipment and materials selection strict control standards.

2. Requirements for coal-mine materials

2.1 Explosion-proof, flame retardant

For housing material used underground, nation has clear limits, GB38361-2000 provide the metal shell material containing light metal, the total content of aluminum, titanium and magnesium are not allowed more than 15% (mass percentage) for class I electrical equipment manufacturing, moreover titanium and magnesium total contenting are not allowed more than 6%. Steel, tensile strength of not less than 120 MPa can be used for class Ⅰ drill hand-held or bracket (supplied with the unit and plug), portable instrumentation, the lamp housing. Manufacture Class II-electrical-equipment housing Material, amount of magnesium must less than 6%. However the flameproof enclosure material of underground Robot was not stipulated clearly[5]. Actually, exposed on the robot must be flame retardant material, such as a housing material and rail.

2.2 Antistatic, non-sparking requirements

Equipment for coal mine, the housing material must be prevented explosion, also should meet the requirements of anti-static and low friction generating sparks. GB 38361-2000 provides class I electrical equipment should be designed to prevent ignition of dangerous electrostatic charge structure when the shell surface is plastic which surface area more than 100cm^2 and surface insulation resistance measured less than 1GΩ at a temperature of (23 ± 2) ° C, relative humidity of (50 ± 5)% than perform plastic flame test, aging test light plastic, light-alloy friction sparks safety test, after these can be used.Friction sparks safety testing methods and determination of metal for coal mine is stipulated by GB/T13813, light metal material which should through free drop hammer impact test, after 32 times test gas do not be ignited, considered acceptable conversely ineligible. In 1985 the State promulgated the standard MT113-85 "Coal mine safety inspection of non-metallic polymer products specifications", which specifies two standards for the use of the polymer down hole, namely ① antistatic properties, surface resistance of less than 1×108Ω, ② flame retardant properties, oxygen index greater than 27.

2.3 Strength requirements

Mechanical tests should be applied in the case include impact and drop tests, impact test testing standards are hemispherical impact head, 25mm diameter made by hardened steel and hammer weight 1kg drop vertically from h on housing surface (derived from the impact energy E, h = E / 10; h, m; E, J). The level of mechanical risk is judged by the impact energy E. Drop test is samples are dropped from the height of 1m in using state to flat concrete surface 4 times (Drop position of the sample is determined by the test unit). Non-plastic housing device at temperature of (20 ± 5) ° C, when the material data shows impact resistance reducing at low temperature the test shall be performed at the lowest temperature specified in temperature range. Housing should not cause damage to the equipment, not affect the proof requirements, minor damage and small recessed surface which can not be considered after mechanical tests. In addition, Class I electrical equipment should meet the plastic shell heat and cold tests. According to the standard GB3836.1-2000 Explosion specified in 8.3, Class Ⅰ drill hand-held or bracket (supplied with the unit and plug), portable instrumentation, the lamp housing, the ensile strength must less than 120 MPa. Light alloy housing should pass the examination of friction spark test can be used according to the provisions of GB13813.

3. Current study on lightweight materials used in coal mine

3.1 Metal materials

3.1.1 Aluminum

Explosion and friction sparks security concerns must be considered for light metals used in coal mine. Currently aluminum alloy is main mining material, as ZL401, ZL104, ZL102 cast aluminum alloy, etc. Flameproof housing of coal drill motor minted only by cast aluminum alloy grades for ZL401[6]. Zhou Dan[7]etc. manufactured flameproof compartment body of small flameproof mobile robot platform by ZL401, the compartment body has a cylindrical and rectangular housing with the volume of 8L, its internal explosion pressure were 0.55MPa and 0.51MPa, a full set of equipment has external dimensions of 560 mm × 590 mm × 250 mm, the quality is 21kg. If the equipment made by steel, the weight is more than 40kg. However the sparks and static friction problems were not mentioned in this paper. For friction sparks safety problems of high-strength aluminum, Su changxue[8] thought, could be solved by two technical solutions regulating the content of the recipe by chemical elements and preparing protective coatings. However this method exists durability, then the security concerns of friction sparks for light alloy lift vessel was raised friction sparks safety indicators depending on heat treatment after aluminum alloy composition determined, the key is prescription system, high-strength aluminum alloy LC15 not only can be enhanced the mechanical strength to meet the requirements of hoisting container but also used in down hole with reliable safety friction sparks after the bipolar overage (CGSI) Processing.

3.1.2 Steel

Needless to say steel material has high strength but its quality is great, it is difficult to carry, install and separate, besides poor mobility. All of these are determined by the properties of the material itself, if we want to reduce the quality restructuring is the key way. Minimize the usage amount of steel with meeting the strength requirements. Steel material is often used as proof system of coal mine rescue robots because lightweight aluminum is prohibited due to containing combustible magnesium. Above a certain grade of steel is used for explosion-proof robot system in order to ensure a sufficient proof strength, its thickness is 4-6mm[9] has larger mass. Explosion-proof system is a generally closed metal housing, charged elements are all inner, if explosion occur flame is prevented out by high strength sealed housing thus protecting combustion of coal mine gas explosion. While housing steel is too heavy has high energy consumption and poor mobility as consumption of mobile systems. Therefore, to optimize the weight and strength of the explosion-proof enclosure effective, stiffness become a huge challenge[10]. Wang changlong[9] proposed a static positive pressure explosion-proof technology as protection measures for mine rescue robots, the whole sealed enclosure using a thin steel plate Q235A chassis and cover using angle iron welded frame only. Hermetic housing was filled with protective gas to reduce the oxygen content below 1% (Volume ratio). This way can prevent the generation of internal explosion fundamentally, thus greatly reduced the demand for flameproof enclosure and only meet the mechanical strength requirements of robot enclosure. The weight of robot was reduced greatly and the mobile performance of it was promoted extremely with the structure.

3.2 Organic composite materials

With the research and development of high-strength material, polymer materials gradually entered the era of the stage it is not limited to metallic material able to meet the strength requirements. In order to sophisticate material lightweight, Wang tongyuan[11] proposed a "plastic steel" concept used in the coal industry, because of polymers having a light weight, corrosion resistance, high strength, easy processing, excellent performance. Li Heng[12] made climbing robot using polyoxymethylene (POM) as the body shell in line with principles of lightweight and compact.

Plastic products used for coal mine equipment should be the flame retardant and antistatic properties. The methods for polymer materials antistatic contain external coating and internal mixing. The internal mixing method is much wide, it is assimilated with antistatic agents. Its mechanism is mainly manifested in two aspects, the one is continuous film which has a certain moisture absorption and ionic formed on the surface of the polymer material could reduce surface resistivity and leaked generated electrostatic charge. The other is suppressing and reducing the generate electrostatic charge by enhancing the lubricating property of the surface and reducing coefficient friction. Sheng shouzhai[13] add carbon black as a conductive filler in PVC to reduce the surface resistivity, improve flame retardancy, mechanical properties threw adding flame retardants and modifiers, while experiments show that flame retardant anti-static PVC sheet can replace wooden plates used for coal mine.

4. Prospect of lightweight, high strength material

Currently investigate Lightweight, high strength materials can be divided into two categories: one is light metal material, one is fiber-reinforced polymer composite materials. High-strength aluminum alloy is widely used in coal mine but its strength is little poor as robot flameproof enclosure material. Titanium alloy are widely used in industry with its low mass, high strength, high toughness, high corrosion resistance, and other excellent performance, but the price is too expensive and used in coal mine need to modified some defect.

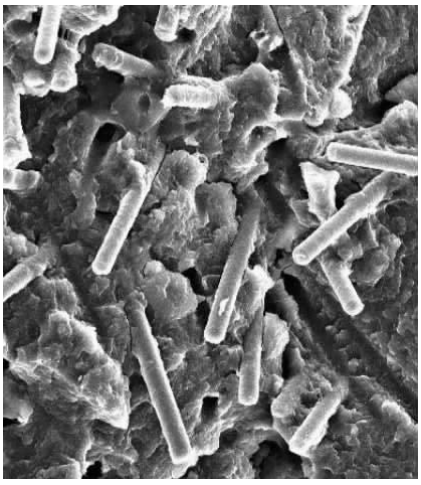

Figure 1. SEM for carbon fiber

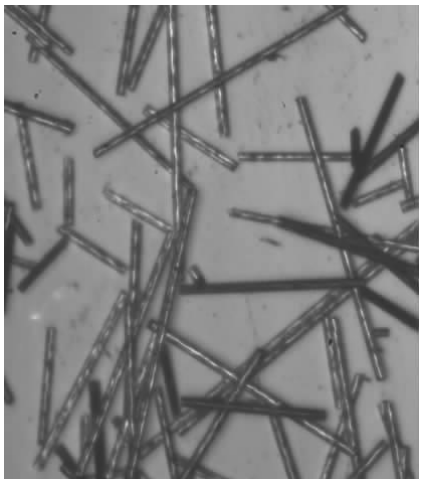

Figure 2. Micro-examination for carbon fiber

Table 1. Performance index of carbon-fiber cloth.

	High strength grade I	High strength grade II
Weight(g/m^2)	300	200
Tensile strength (MPa)	⩾4900	⩾4100
Elastic modulus (GPa)	⩾240	⩾210
Elongation(%)	⩾2.0	⩾1.8

Fiber-reinforced polymer composite materials (figure 1and figure 2) is another focus. Carbon fiber as a high-performance fiber, which has a high specific strength, high modulus ratio, creep fatigue, expansion coefficient and the friction coefficient of performance, has been one of the most important composites reinforced material (table1). In addition Kevlar as reinforcing fibers also have very strong mechanical properties, it is used for military protection, under the same conditions its weight is half of the glass protective steel, made into laminated sheet its toughness is 3 times of steel and can withstand repeated impact. These are the directions for future development.

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