EFFECT OF CARBONIZING TEMPERATURES ON CHARCOAL PROPERTIES AS ADVANCED MATERIALS

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INTRODUCTION

During the last 30 years, there has been a rapid growth in the use of carbon fibres and their related composites, and in particular, these materials have found an ever-widening use in structural applications. Carbon-fibres and their composites are particularly noteworthy and are currently playing a leading role in the creation of a whole range of new materials for construction. Carbon materials, in general, are highly resistive to heat and fire, and are neither melted nor softened under a red heat. These materials glow slowly with mild oxidation at high temperature but their thermal deformation is rather small due to thermal conductivity.

In order to develop advanced materials utilizing residues and wastes from wood industries, forestry wastes, and unused wood species, a research and development on carbon composites from charcoal of wood materials was conducted. Effects of the carbonizing temperatures on the electrical and thermal conductivities of the carbon composites with their applications were discussed.

EXPERIMENTAL

The raw material of the carbon composites (abbreviated to CPS) was made from charcoal powder coated with 5 - 40 % B -stage phenol-formaldehyde condensate. The charcoal powder with an average particle size of 2 m was prepared by carbonization of the wood materials in an inert atmosphere under normal pressure, employing a heating rate of 4 °C/hr up to a temperature of 3000 °C followed by 3 - hour heating at constant temperature up to 3000 °C at 200 °C intervals.The raw materials for charcoal production were the powder of Sugi (Cryptomeria japonica D. Don), Ubamegashi (Quercus phyllinaeoides A. Gray), Mousou-chiku (Phyllostachys pubescens Mazel ex Houzeau de Lehaile) and their barks. The powder of cellulose, graphites, and a charcoal of phenol-formaldehyde resin were also used as raw materials in manufacture of other composites.

The CPS with particle size from 5 μm to 1200 μm, of course, have the advantages of carbon-composite materials, and have also good moudability and glueability due to the phenol-formaldehyde resin. Various kinds of the CPS were used as surface materials in the manufacture of a non-electrification board, and of electromagnetic shield and fire resistive boards. The electric resistivity of the carbon composites was tested by JIS K 6911 and electromagnetic shielding property was measured by a DUAL chamber method in accordance with a ASTM ES-7-83. The fire resistivity of the carbon composites was tested by a burn-through method (exposure in high velocity flame stream at 1130 to 1300 °C with 2.0 kg/cm^2 of steam pressure) and by a method in which the cutting rate by oxygen-acetylene torch at a temperature of 2750 - 3200 °C was measured and by the oxygen index method in accordance with JIS K 7201. Full scale tests of the electromagnetic shielding efficiency and fire durability of a CPS overlaid wood particle boards were done in accordance with U. S. MIL STD 285 and ISO 834 (JIS A 1304), respectively.

RESULTS AND DISCUSSION

The electric resistivity of the CPS boards was found to decrease with a rise in carbonization temperature of the raw wooden materials. It was particularly found to decrease severely in a temperature range of 600 - 800 ^{o}C. The electric surface resistivity of the CPS boards prepared from the charcoal powder of Sugi carbonized at a temperature less than approximately 600 ^{o}C, a temperature range of 600 - 800 ^{o}C, and higher than 800 ^{o}C were 10^{12} - $10^{8}\Omega$, 10^{8} - $10^{-1}\Omega$, and lower than $10^{-2}\Omega$, respectively.

The electromagnetic shielding efficiency of the CPS boards was found to increase with an increase in thickness and density of the boards. The shielding efficiency of the composite boards prepared with charcoal carbonized at 1200 ^{o}C was found to increase in the declining order : bamboo charcoal (Mousou-chiesu), wood charcoals (Sugi and Ubamegashi), cellulose charcoal, natural crystalline graphite, and the charcoal of phenol-formaldehyde resin. The electromagnetic shielding efficiency of a 3.5 mm thick CPS board prepared from charcoal powder of Sugi carbonized at 1200 - 1400 ^{o}C was the same as or superior to that of a control metal (3.0 mm thick aluminum) plate. The high electromagnetic shielding efficiency of the boards prepared from charcoal carbonized at 800 ^{o}C or above was due to the high electric conductivity of their charcoal.

The ignitability and flammability of the CPS boards measured by oxygen index decreased with a rise in carbonization temperature of wooden raw materials. The low combustibility of the CPS boards from charcoal carbonized at 800 ^{o}C or above was due to high carbonization of the wooden raw materials. The non combustibility of the CPS boards carbonized at 2000 ^{o}C or above was due to the graphitization of the charcoal. Fire endurances of the composite boards were improved by the time delay in the burning through of the board which is due to the fire resistivity, high thermal conductivity and slow oxidation of the charcoal carbonized by high temperature.

The resistance of the graphitized carbon composite boards to cutting by oxygen-acetylene torch were better than that of a stainless steel plate. The electric resistivity and electromagnetic shielding efficiency of 30 mm thick and 0.60 kg/m^{3} dense wood particleboard overlaid 10% CPS was less than 10Ω and was over 40 dB against electric fields, which satisfied a standard for shielding materials for partitions and enclosures of office buildings and computer aids.

CONCLUSIONS

The electric conductivity and thermal properties of the carbon composites made from charcoal in relation to the carbonization temperature were measured and discussed. Results show that the electric conductivity and thermal properties of the carbon composites were controlled by the carbonization temperature. The carbon composites from charcoal carbonized at 800 ^{o}C or above should be available for a wide range of new materials in the fields of building, automative, electrical and electronic, aerospace, engineering applications and others.