ANISOTROPIC PROPERTIES OF NEEDLE PUNCHED CARBON/CARBON COMPOSITES

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1 Introduction

Carbon/carbon composite made by needle punching is competitive because of its unique features such as high productivity, low cost, fine internal structure and good through-the-thickness homogeneity. Therefore it is suitable for producing high-temperature parts of complex shapes like screws or valves. It employs plenty of needles with protruded barbs on the lateral sides like Fig. 1. All these needles move up and down, repeatedly penetrating the layered materials. The barbs on the needles hook the fibers in the layered materials and insert them vertically in descending motion. These rearranged fibers provide a reinforcing effect between the layers, and the layered materials are compacted and combined with each other like Fig. 2.[1-3]

Fig.1. Needle with barbs.

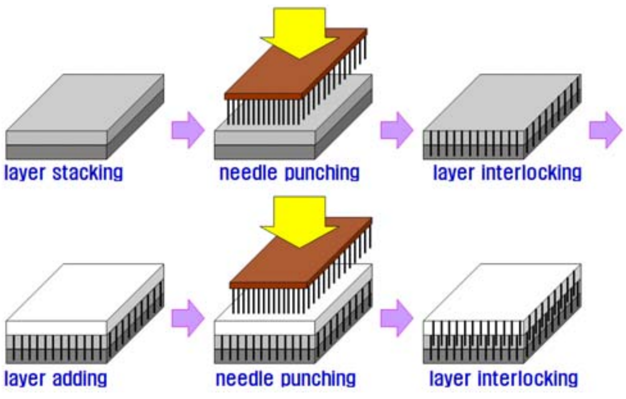


Fig.2. Needle punching process.

Inherently, needle punched carbon/carbon composite is expected to show different properties along the in-plane and through-the-thickness directions because it has layered structure. The purpose of this work is to evaluate the anisotropic properties of needle punched carbon/carbon composites with various textile structures.

2 Experiments

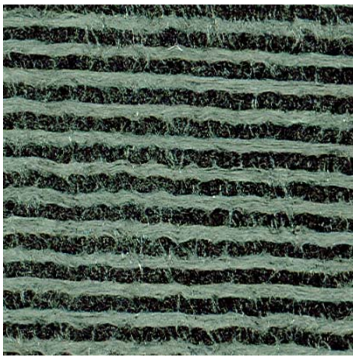
2.1 Materials

Four kinds of carbon/carbon composites were manufactured by needle punching. All of them were made from oxidized polyacrylonitrile(oxi-PAN) fibers, but their textile structures were different.

Type-1 specimen was fabricated with uni-directional fabric layers from 12K oxi-PAN fibers, Type-2 specimen was composed of uni-directional fabric layers from 12K oxi-PAN fibers and oxi-PAN web layers, Type-3 specimen was fabricated only with oxi-PAN web layers, and Type-4 specimen was made of uni-directional fabric layers from 320K oxi-PAN fibers. Fig. 3. shows the image of cross-section of each specimen.

2.2 Carbon/carbon composite Preparation

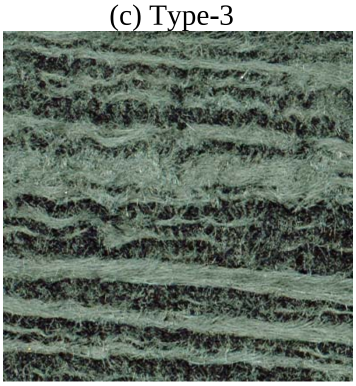
After needle punching of above four kinds of specimens, carbon/carbon composites were prepared using thermal gradient chemical vapor infiltration(TGCVI) and pitch impregnation(PI) process. Propane gas and coal-tar pitch were used as carbon source in the TGCVI and PI process respectively, and Fig. 4. shows TGCVI process schematically.



(a) Type-1

(b) Type-2

(c) Type-3



(d) Type-4

Fig.3. Image of cross-section of each specimen

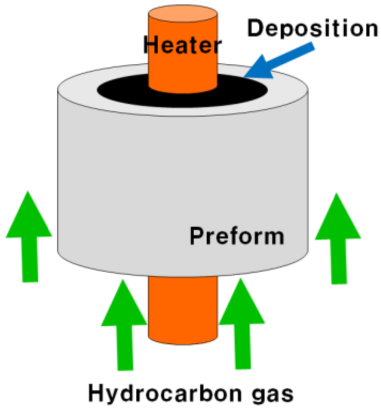


Fig.4. Thermal gradient chemical vapor infiltration.

3 Results

Mechanical and thermal properties were measured along the in-plane and through-the-thickness directions with four kinds of carbon/carbon composites.

3.1 Mechanical Properties

Fig. 5. shows that tensile strength along the in-plane direction is pretty higher than along the through-the-thickness direction with all specimens because the bound fibers along the through-the-thickness direction are weaker than the aligned fibers along the in-plane direction.

Type-2 with 12K oxi-PAN fibers shows outstanding tensile strength along the in-plane direction than Type-3 with oxi-PAN web layers or Type-4 with 320K oxi-PAN fibers for its better alignment of fibers. And oxi-PAN web layers in Type-2 seem to have the synergy effect with 12K oxi-PAN fibers with the help of fiber binding during the needle punching process.

Fig. 6. shows that compressive strength along the in-plane direction is lower than along the through-the-thickness direction with all specimens because the compressive load along the in-plane direction can make the delamination between the layers, which is the weak point of needle punched structure.

Type-2 shows better compressive strength along the through-the-thickness direction because of the effective fiber binding between 12K oxi-PAN fibers and oxi-PAN web layers as mentioned above.

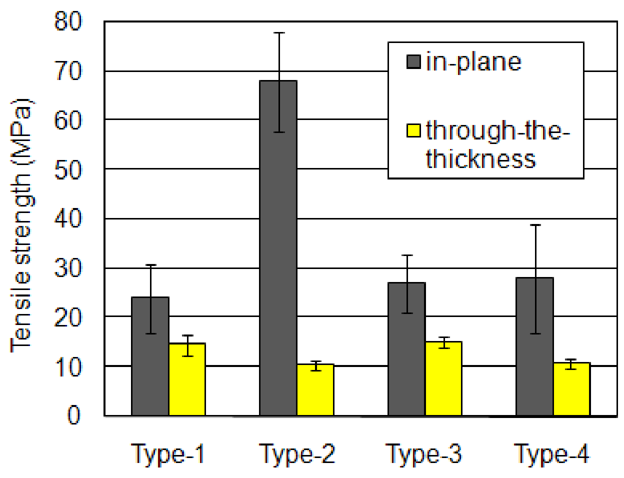


Fig.5. Tensile strength of needle punched carbon/carbon composites.

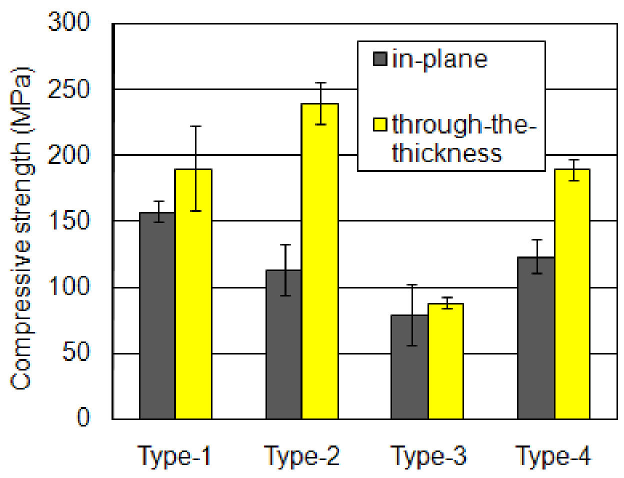


Fig.6. Compressive strength of needle punched carbon/carbon composites.

3.2 Thermal Properties

Fig. 7. shows that thermal conductivities in both directions are similar, which means that they are not the result of fiber alignment or binding but the result of fiber and carbon matrix continuity.

Type-3, which was made only with oxi-PAN web layers, has remarkably high thermal conductivities because oxi-PAN web layers have most entangled fiber-network-structure after needle punching process like monolithic solid as shown in Fig. 3(c).

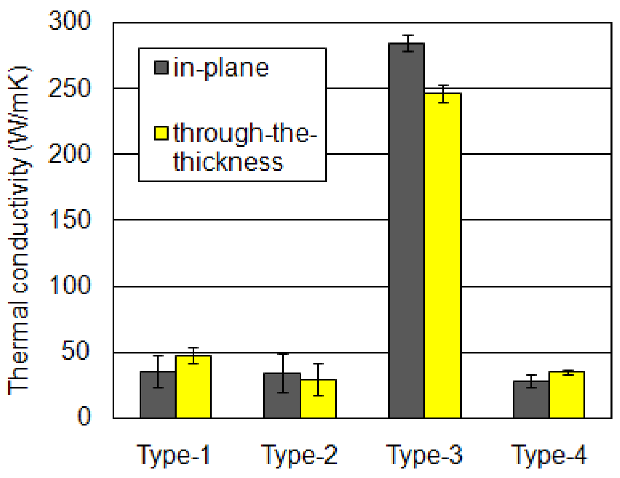


Fig.7. Thermal conductivity of needle punched carbon/carbon composites.

4 Conclusions

With the needle punched carbon/carbon composites, it is found that the mechanical properties such as tensile strength and compressive strength are anisotropic, in other words, there are big differences along the in-plane and through-the-thickness directions with four kinds of needle punched carbon/carbon composites. Among the four kinds of needle punched carbon/carbon composites, the hybrid of uni-directional fabric of 12K oxi-PAN fibers and oxi-PAN web layer shows most effective fiber binding.

The results of thermal conductivities are not so anisotropic because they are not the result of fiber alignment or binding but the result of fiber and carbon matrix continuity.

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