Rapid Hot Pressing Technology for Composite Materials Manufacturing

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Introduction

Carbon/carbon composites have been recognized as high performance advanced materials, used mainly for defense and aerospace applications where economic factors are of secondary consideration. Due to its high cost of manufacturing and long production times, C/C composites have not been acceptable for general industrial applications. Over the past two decades, carbon fiber costs have declined reducing the major raw material cost significantly. GrafTech's novel rapid hot pressing process is designed to address the other main aspect of the high cost by using a low-cost novel process to produce C/C composites.

GrafTech has been producing refractory bricks for blast furnaces since about 1960, based on a licensed technology[1]. In this process, combinations of coal tar pitch binder with coke and ceramic fillers are placed in a mold and subjected to simultaneous application of mechanical pressure and electrical current to form the brick product. We are working to modify that technology in our pilot processing plant in Parma, Ohio to develop a rapid hot pressing process that can carbonize and densify composite materials, such as carbon/carbon composites or carbon/ceramic composites.

Experimental

In the experiments, binder pitches and mesophase pitch-derived carbon fiber were used. The mixture of two components was hot mixed in a high temperature mixer. The hot mixed materials were subsequently pressed into a block to form a preform for pressing. In the hot pressing process, the fiber/binder mix preform was charged into the mold box which has the dimension of 9 ¼" x 8 3/4", the mechanical pressure of at least 35kg/cm^2 was applied simultaneously along with AC current passing through the mix. The mixture provides sufficient electrical conductivity such that the mixture reaches a temperature of at least 500 °C to achieve a carbonized and compressed block. This total process time was several minutes. After the hot pressing, these blocks were taken through two pitch impregnation/rebake cycles for further densification. Finally, the material went through a graphitization process to obtain a graphitized block. The composite block had an average bulk density of about 1.6 gm/cc after hot pressing and could be increased to about 1.75g/cc after two pitch impregnation, rebake, and final graphitization. The described rapid hot pressing process is outlined in Figure 1. A U.S. patent has been issued for this rapid hot pressing technology[2].

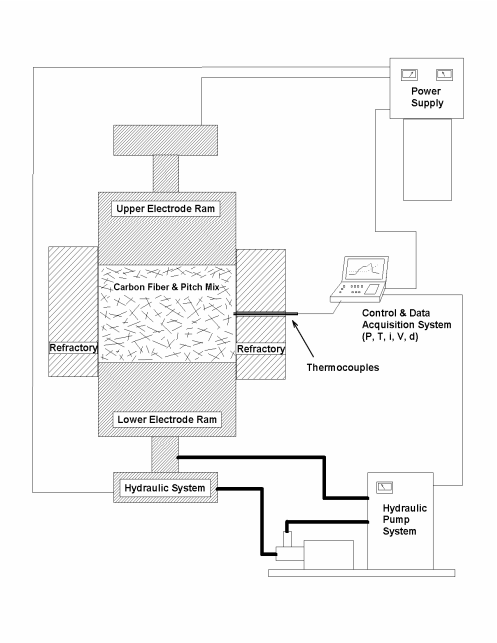

Figure 1: GTI's resistance heating rapid hot pressing process

The large block that was made from rapid hot pressing process (before pitch impregnation, rebake, and graphitization) is shown in the following Figure 2.

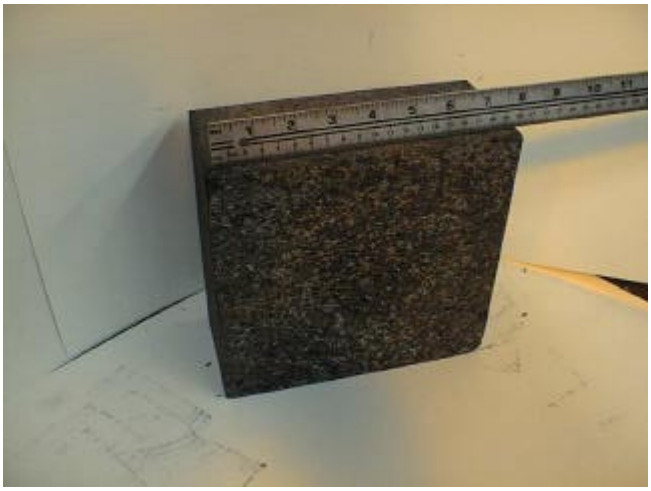

Figure 2. Carbon/Carbon composite brick after hot-pressing process and machining to remove surface skin (~1.6 g/cc density).

Additional experiment were sucessfully carried out to rapid hot press carbon composite with several ingredients such as chopped carbon fiber, graphite and coke powders, and ceramic fillers.

Results and Discussion

This process can produce carbonized carbon/carbon composites with a density of 1.4-1.6 g/cc in less than one hour compared with a few days that are necessary with other commercial processes[3]. As shown in Figure 3, the major advantage of this novel technology is that carbonized composite blocks can be produced in a very short time, thereby providing a low cost carbonized product for further process, such as densification to make carbon/carbon composite or metal infiltration to make ceramic matrix composite (CMC).

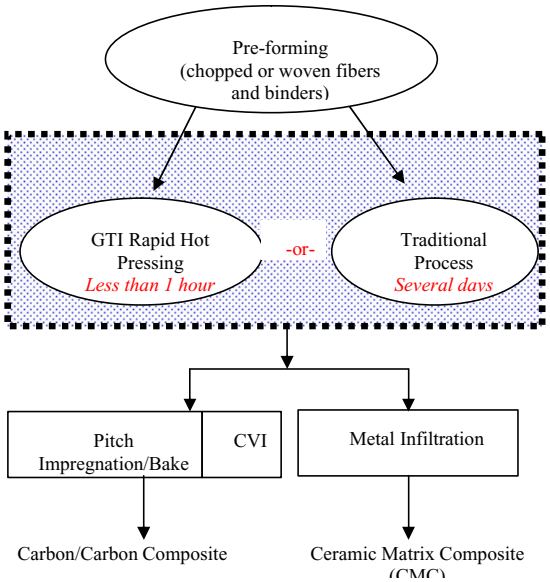

Figure 3. Composite process steps

The typical physical properties of graphitized carbon/carbon composite obtained through this process are shown in Table 2.

Density (g/cm^3)	1.75
Specific Resistance (μΩm)	12
Flexural Strength (kg/cm^2)	700
Compressive Strength (kg/cm^2)	900
Young's Modulus (x10^6, kg/cm^2)	0.36
Thermal Conductivity (W/mK)	75
Ash Content (wt%)	< 0.1

Table 2. Typical physical properties of graphitized carbon/carbon composite made from rapid hot press processing

The typical microstructure of graphitized densified carbon/carbon composite made from rapid hot press processing are shown in Figures 4 and 5. Under the controlled combination of pressure and current, gross macro cracks are absent from the microstructure of carbon/carbon composite even after the mixture went through a rapid carbonization process using this novel hot pressing technology.

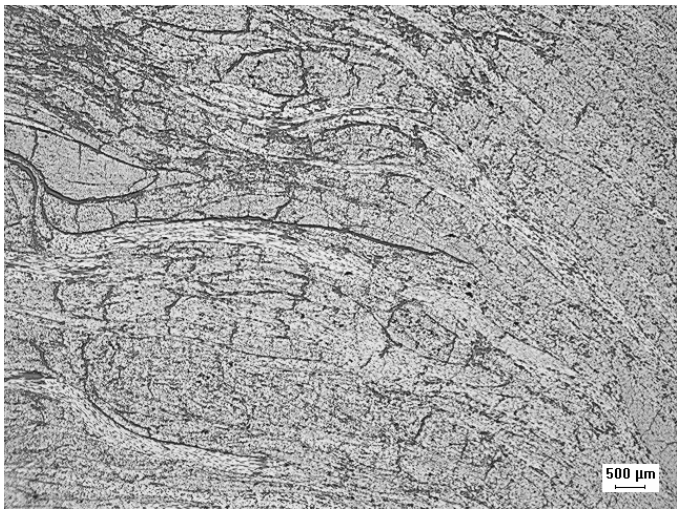

Figure 4. Typical carbon/carbon composite microstructure made from rapid hot pressing

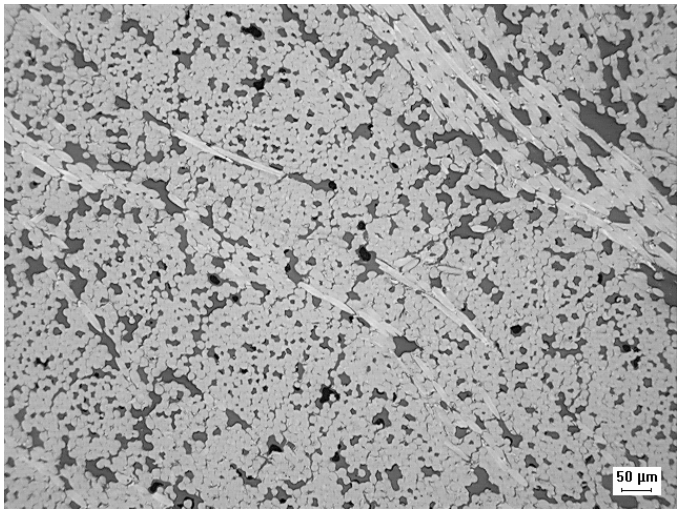

Figure 5. Typical carbon/carbon composite microstructure made from rapid hot pressing

Conclusions

GrafTech's rapid hot-pressing process can reduce the manufacturing cost of composite materials significantly with shorter production times. Near net shape capability will minimize the machining required. This rapid hot-pressing process is a platform technology, which lends itself to manufacturing different grades of materials for a given application.

References

[1]. Balaguer, R.R. "Method of Making Carbon Articles", US Patent 3,001,237, 1961.
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[3]. Savage, G. "Carbon-Carbon Composites", Chapman Hall Publishers, New York, NY, (1993).