ULTRASONIC IMAGING OF CARBON AND GRAPHITE ARTIFACTS

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Introduction

GrafTech has developed a testing and analysis program to non-destructively determine the uniformity and macro-structure of carbon and graphite artifacts. Large-scale graphite artifacts are manufactured in a multiple stage batch process involving repeated thermal and mechanical cycling, which can result in non-homogeneity and structural defects in the product. Historically this could only be detected with destructive testing techniques that render the product useless after analysis. To further improve our ability to evaluate production samples prior to real-world application, GrafTech has developed an ultrasonic test capability to measure and image product uniformity and macrostructure. We have recently demonstrated the ability to completely evaluate carbon and graphite artifacts weighing up to 3 metric tons. Analysis output can be displayed in complete two- or three-dimensional topographical images. By combining thousands of cross-sectional images, a “virtual” artifact is reconstructed, which directly reveals the exact location and size of defects, inhomogeneities, and various morphological variations. Rapid scanning allows for quick evaluation of complete products that can be used for R&D purposes, or high volume Quality Control applications.

Experimental

Graftech has typically used destructive testing techniques to understand and improve internal artifact structure. These typically are restricted to one plane visual analysis by slicing the artifact in half. Graftech developed an ultrasonic testing device to allow diametrical scanning of large size industrial graphite artifacts. By developing a transducer wheel with the correct sonic capabilities, we were able to transmit a signal for each degree of rotation and for small increments of movement along the artifact length. This allows us to completely characterize the artifact internally.
Work continued in Graftech to understand the sonic signal and relate it to known internal structure and defects. Multiple artifacts were scanned in each processing stage (green carbon, baked carbon, and both un-machined and finished machined graphite) and scanning results were analyzed statistically. Artifacts of interest were cut open to relate observed areas of interest to actual defects. The ultrasonic technique proved very effective in finding areas of porosity, tiny to large cracks and splits, and in quantifying the uniformity of the artifact.
These results have been related to the known processing history of the artifact to understand and improve the process. Further development work allowed Graftech to

complete a series of chordal scans of an artifact and using finite elemental analysis, develop a 3-dimensional view of the artifact sonically.

Results and Discussion

Multiple cylindrical artifacts have been analyzed from all Graftech locations. We have analyzed a range of products from coarse grain to specialty grade and very fine grade carbon materials. A typical scan output is a topographical map of the artifact, with the X-direction axis being the angle of artifact rotation (0-180o); and the Y-direction axis is the length of the piece. This is shown in Fig. 1

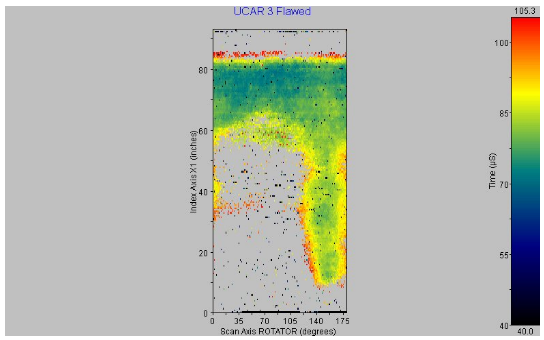

Figure 1. Typical Ultrasonic Scan Result

The sonic signals are set with a gate to capture the leading wave. The range is set depending on the material characteristics. Defects such as an internal unobserved crack could be detected either by signal attenuation or time of flight. To date we have concentrated on time of flight exclusively. For a major defect like the one shown below in Fig. 2; the signal will be outside of our signal gate; and we see it as the gray area of no transmission (see Fig. 1 above).

Figure 2. Typical Ultrasonic Discovered Artifact

The testing unit has been in place at a production facility since 1999; and continues to measure a large number of artifacts per year. Unit has rotary encoder, drive system to rotate from 17” to 32” diameter and from 30 to 120” long cylinders, two transducer wheels, and a fully computerized sonic control and measurement system. Typically it takes 30 minutes to load and complete one artifact.

Using a series of radial chord scans and finite elemental math modeling, we can take a series of scans and develop a three dimensional view of the sonic velocity variation in our product. This can be directly related to any artifact forming and processing variation. A typical plot constructed this way through the major axis of the artifact is shown below in Fig. 3.

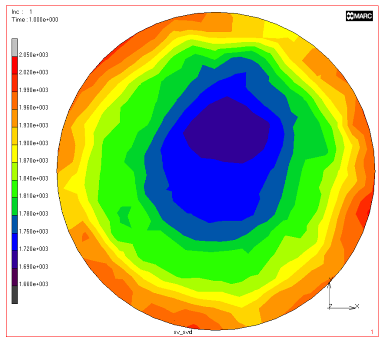

Figure 3. Artifact Ultrasonic Testing Machine

Conclusions

Implementation of this technology represents the industry's first example of a rapid scanning technique that can acquire information sufficient to enable definitive conclusions regarding material improvements, and uniformity. At the same time, this analysis technology will help to ensure the delivery of defect-free industrial scale products such as arc furnace electrodes and nuclear grade graphite materials.