**Finer ultrasonic evaluation of carbon – carbon vanes for Launch vehicle gas motors**

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**Abstract**

Carbon-Carbon vanes are used in liquid rockets of space launch vehicles. These vanes are individually processed through a long procedure. As the use is very critical and the quality of each piece is to be ensured. As practiced in conventional industry, samples are tested from a batch and assured quality is uniform and within acceptable range. This method of acceptance of products is not fully suitable for carbon- carbon vanes as the vanes are processed individually. As part of additional confidence building ultrasonic material characterization based on velocity mapping and sonic spectroscopic analysis was adopted for this item. Ultrasonic velocity mapping is done in three directions of the vanes to map quality variation if any. The data has been analyzed for variation of velocity in particular piece and also compared with previous batches. This paper gives details of work carried out by authors.

**1.0 Introduction**

Carbon-carbon composites are special materials which combines carbon fibre re-inforcement in an all carbon matrix. Carbon-carbon has wide applications in aerospace industry due to its high thermal stability, low coefficient of thermal expansion and light weight. In satellite launch vehicles, carbon-carbon vanes are used in hot gas motor of engine gimbal control system of liquid engines. These vanes are individually processed through a long procedure. Sample vanes are tested for mechanical properties like flexural strength and interlaminar shear strength. However there is no method for characterizing individual vanes without destructive test. Non-destructive material characterization and velocity mapping were attempted and successfully implemented for evaluation of individual vanes. The vanes are screened based on ultrasonic velocity in the material in three directions and uniformity of material is assessed. Acceptance standard was finalized based on velocity mapping after inspection of large number of vanes. These vanes after ultrasonic evaluation were used successfully in flight. Details of the work carried out is highlighted in this paper.
2.0 Brief studies on specimen level

To understand the ultrasonic characteristics of the material, sounds of various frequencies were sent to the material and responses studied. Digital ultrasonic system with sharp echo pulse was selected since high level of accuracy is required in velocity measurement. Due to the inherent characteristics of the material, pulse echo could not be used. Through transmission method with higher frequency of 2 MHz was adopted to attain maximum sensitivity.

Fig 2: Ultrasonic evaluation of vanes in progress

Fig 3: Signal recorded from thickness direction

Vanes from various batches were used for study purpose along with accepted batch. Velocity was measured in three different directions and results were analyzed. Thickness direction velocity was plotted and compared as histogram. As observed in Fig 4, low performance batch is having higher spread & lower peak value in histogram. Flight lot is having lesser standard deviation & high peak value in histogram which shows more uniform properties. This study gave the confidence that ultrasonic velocity can be used as a tool for non-destructive characterization of the material.

Fig 4: Histogram of thickness direction ultrasonic velocity for different batches
3.0 Ultrasonic characterization of vanes

Time of reception of signal was recorded in three different directions and velocity was calculated from corresponding thickness of vane. Histogram of ultrasound velocities was plotted and compared for different batches. Few batches showed higher dispersion in velocity in thickness direction, compared to the whole batch. These batches were studied for differences.

Histogram of velocities in thickness direction were compared for different batches of vanes. Acceptance standard was finalized based on standard deviation in velocity in thickness direction. Based on statistical analysis data of many batches, sigma limits for acceptance were arrived. 3 sigma value of standard deviation in velocity was about 35 m/s. Signal loss at any location and shape of signal are other factors monitored during inspection. Hence, vanes with standard deviation of more than 35m/s were set aside.

Table of typical velocity in three direction:

<table>
<thead>
<tr>
<th>Normal vane</th>
<th>Rejected vane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasonic velocity in each direction (m/s)</td>
<td>Ultrasonic velocity in each direction (m/s)</td>
</tr>
<tr>
<td>Idn</td>
<td>Thickness</td>
</tr>
<tr>
<td>AB 1606</td>
<td>1852</td>
</tr>
<tr>
<td></td>
<td>1863</td>
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<td>1852</td>
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<td>1863</td>
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<tr>
<td>Min</td>
<td>1818</td>
</tr>
<tr>
<td>Max</td>
<td>1875</td>
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<tr>
<td>Avg</td>
<td>1854</td>
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<tr>
<td>SD</td>
<td>17</td>
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<tr>
<td>Idn</td>
<td>Thickness</td>
</tr>
<tr>
<td>AB1634</td>
<td>1863</td>
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<tr>
<td></td>
<td>1840</td>
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<td>1796</td>
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<tr>
<td>Max</td>
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<tr>
<td>Avg</td>
<td>1791</td>
</tr>
<tr>
<td>SD</td>
<td>62</td>
</tr>
</tbody>
</table>

The vane with identification no: AB1634 showed higher standard deviation of 62 m/s in thickness direction. These vanes were standing out from the whole batch of vanes as observed in Fig 5 and were set aside.
4.0 Conclusion

Ultrasonic evaluation and characterization of carbon-carbon vanes has been made possible by ultrasonic testing. Methodology was developed, standardized and has been successfully implemented on vanes for flight use. The method has been proved to be an excellent way of characterizing individual vanes and assess the uniformity of material non-destructively.