Application note

Real3D blade tip clearance measurement

Summary

Evaluation of compressor blade tip clearance (BTC) is one parameter used to determine gas turbine engine efficiency. Too much clearance negatively impacts efficiency, while too little can result in unwanted rub against the abradable liner or shroud that can cause secondary problems such as excessive temperature build up that affect metallurgical properties leading to embrittlement and indeed cracking.

The two methods to evaluate in-situ BTC involve the use of borescopes equipped with digital measurement capability such as stereo or 3D phase measurement (3DPM). The former method provides limited field of view which severely restricts the area that can be captured and evaluated.

The most common method requires the borescope to be fixed into position and the rotor is indexed to enable repeated measurements from all blades in that given stage; the other requires the borescope operator to manipulate the probe around the annulus to collect the data from as many blades as possible without risking damage to the probe and entrapment that could result in severe disruption or cost implications. Full circumferential collection is sometimes not possible due to gravitational effects that result in the probe being too far away from the target to enable measurement acquisitions. Both methods provide valuable information to the owner, the operator and perhaps the OEM. The static probe method provides information about the blades within a given stage from a fixed reference point in the casing; the other provides information relating to casing ovality since the probe is navigated around the annulus itself.

Both methods are time consuming and the data produced is prone to include a large amount of variation due to incorporation of many variables that affect measurement calculations.

This application note discusses the most common BTC measurement method: the static method that requires rotor indexing.

Challenge

Time:

To measure each clearance, the inspector must of course perform the same measurement on each blade. Regardless of the borescope measurement type i.e. Stereo or 3DPM, the “depth” measurement is employed. It requires the assignment of a reference plane on to the abradable liner using three cursors then the fourth cursor is placed on to the adjacent blade tip. The length between blade and perpendicular liner plane is then calculated, see Image 1. Dependent on the inspection procedure, the operator performs this numerous times to produce typical measurement values before indexing the rotor to repeat once more until the entire set has been evaluated on the borescope from one given stage in the compressor. It is now easy to understand how this task can consume a significant period of time that requires full concentration of the borescope operator. So, as for all time consuming manual tasks, human factors can affect the outcome of the dataset collected.

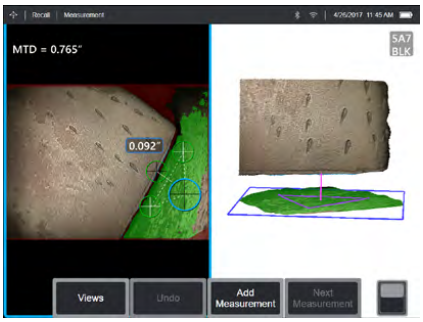

Image 1: Single depth measurement

Measurement quality:

Manual assignment of cursors on to the captured image is likely to produce the greatest source of measurement variation. This can be offset by increasing the number of measurements taken but at the expense of overall task time so a trade-off will always be necessary. Although the borescope is static or fixed into position, the assignment of the reference plane (on to the liner) along with the positioning of cursor(s) on the blade tip will never always be precisely repeated along with the actual presentation of the blade themselves as they are incrementally indexed.

Blade Counting

It is often the simplest high frequency tasks that can become the most challenging. This can be said for simply counting aerofoils!! Unless the operator(s) has a system in place that is strictly followed, the chance of miscounting blades is a realistic outcome. Distractions and all sorts of human factors can result in errors being made.

Subsequent labelling or annotation of the screen to facilitate post processing of images and data is also time consuming and prone to error.

In summary, the task of collecting BTC data from a fixed position presents the following challenges and uncertainties

- Measurement quality: manual assignment of cursors
- Task time: the greater the number of measurements performed on a given blade should improve measurement quality but at the expense of overall task time
- Blades may be mis-counted resulting in inaccurate results or repeated work

Solution

Through a combination of software features, powered by artificial intelligence, the Mentor Visual iQ is now capable to significantly reduce the time it takes to perform tip clearance measurements, while also providing more accurate and reliable results.

Blade tip clearance is a measurement type provided by Real3D™ measurement which automatically identifies the blade and liner, maps the edge of the blade, and determines the minimum, maximum and average clearance values within the measurement scene, see Image 2. Used with Auto-repeat function, this can all be done with a single button click with a full 105 degree FoV capturing a large scene and the entire blade chord.

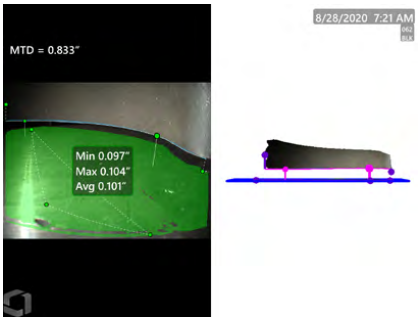

Image 2: Automated blade tip measurement

In Blade Counter, Waygate Technologies offers Feature Detection analytic technology providing the solution for counting blades passing through the live scene during in-situ gas turbine remote visual inspections. The ability to count blades during live video inspections enables the user and subsequent reviewers to identify individual blades without subjectivity or influence by human error. Simultaneous image captures can be done without interrupting video capture so the entire task can be seamlessly captured in video whilst capturing all discrete measurement images containing all annotation and measurement information required as shown in Image 3.

Image 3: Blade tip clearance measurement used with Blade Counter.

3D phase measurement

XL4TM61105FG (forward version)	Black	105	8-250	(.31-9.84)
XL4TM61105SG (side version)	Blue	105	7-250	(.27-9.84)
XL4TM61105FN-8651	Orange	105	3-120	(.12-4.72)
XL4TM61105SF (side version)	Green	105	15-inf	(0.59-inf)

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