Temperature Monitoring Of Nozzle Guide Vanes (NGVs) Using Ultrasonic Guided Waves

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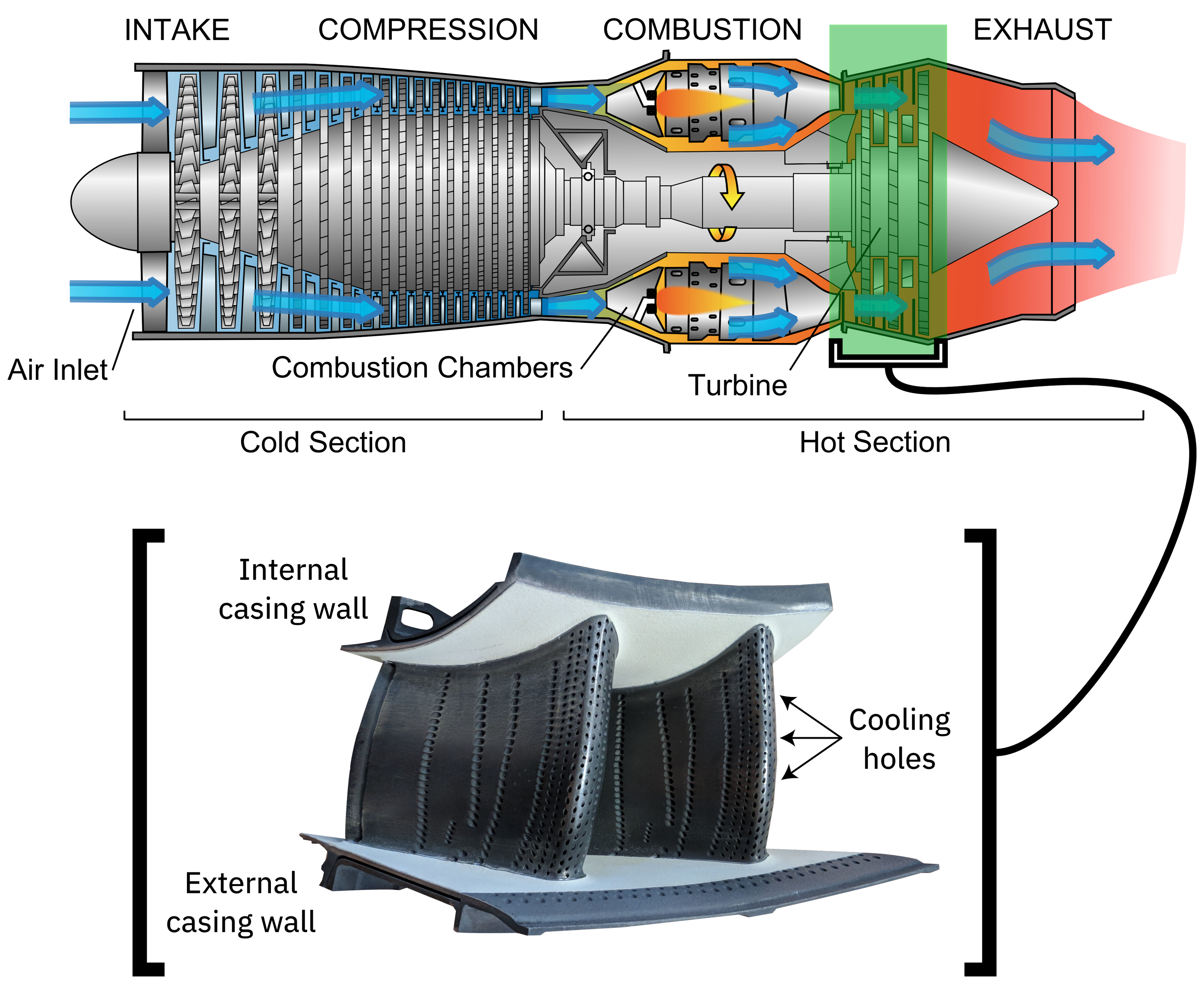
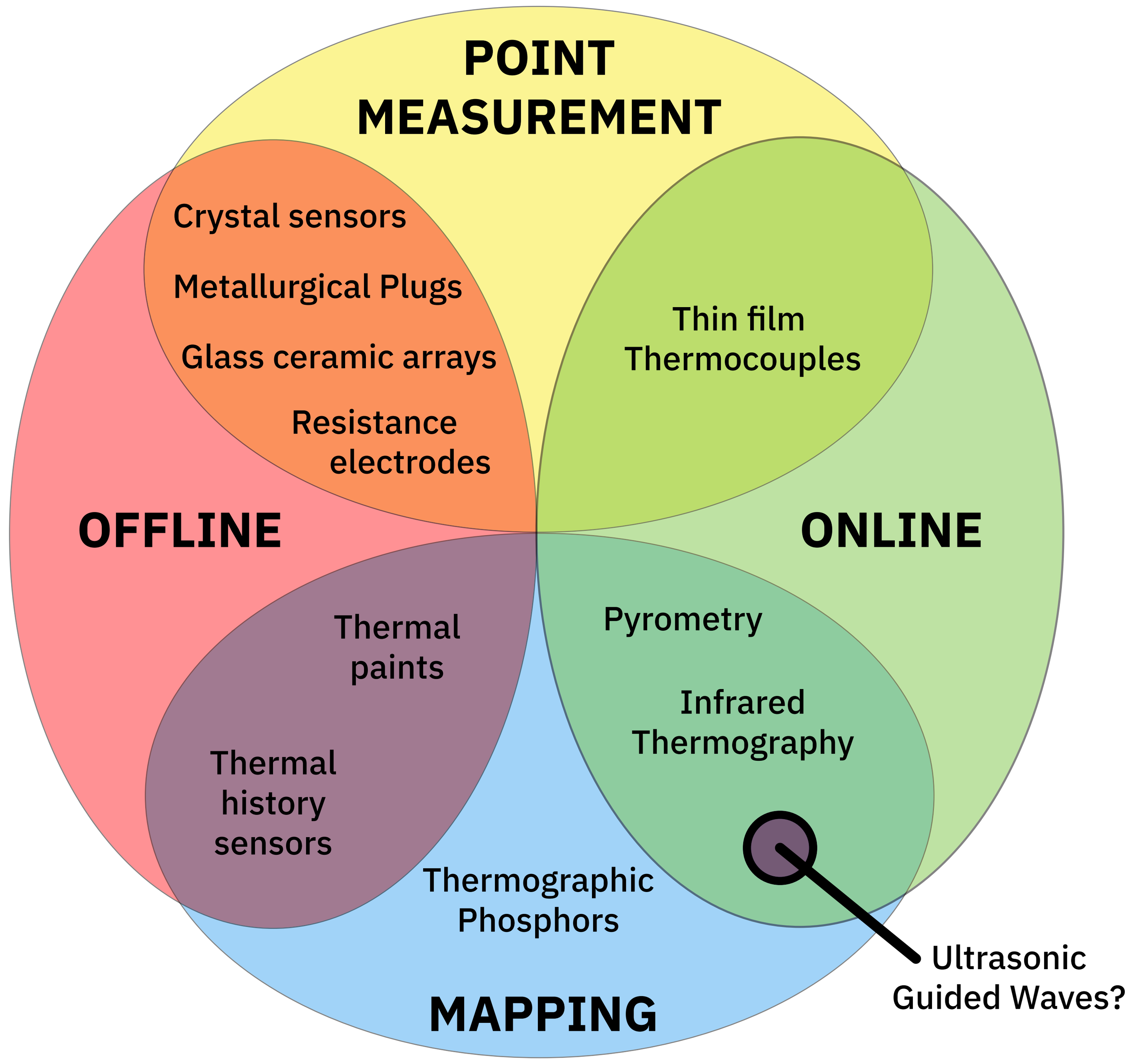
Why Monitor Nozzle Guide Vanes?

Real time condition monitoring of jet engines can lead to considerable improvements in efficiency, reducing pollution and fuel costs. Nozzle Guide Vanes (NGVs) found in the turbine section of the engine undergo extreme thermal stress during operation, reaching temperatures up to 1500°C.



What Are The Benefits Of Ultrasonic Guided Waves?

- Transducers can be placed away from the extreme conditions of the turbine, not impacting operation of the blade or engine.
- Measurements can be carried out over the entire temperature range of interest with a high level of precision.
- Accuracy will not be affected by conditions inside the turbine, as with pyrometry methods.
- Map resolution can be comparable to thermal paints and phosphors by utilising reflections from the numerous cooling holes on the surface of the vane.
- No optical access is required, unlike online thermographic phosphor sensing or pyrometry.

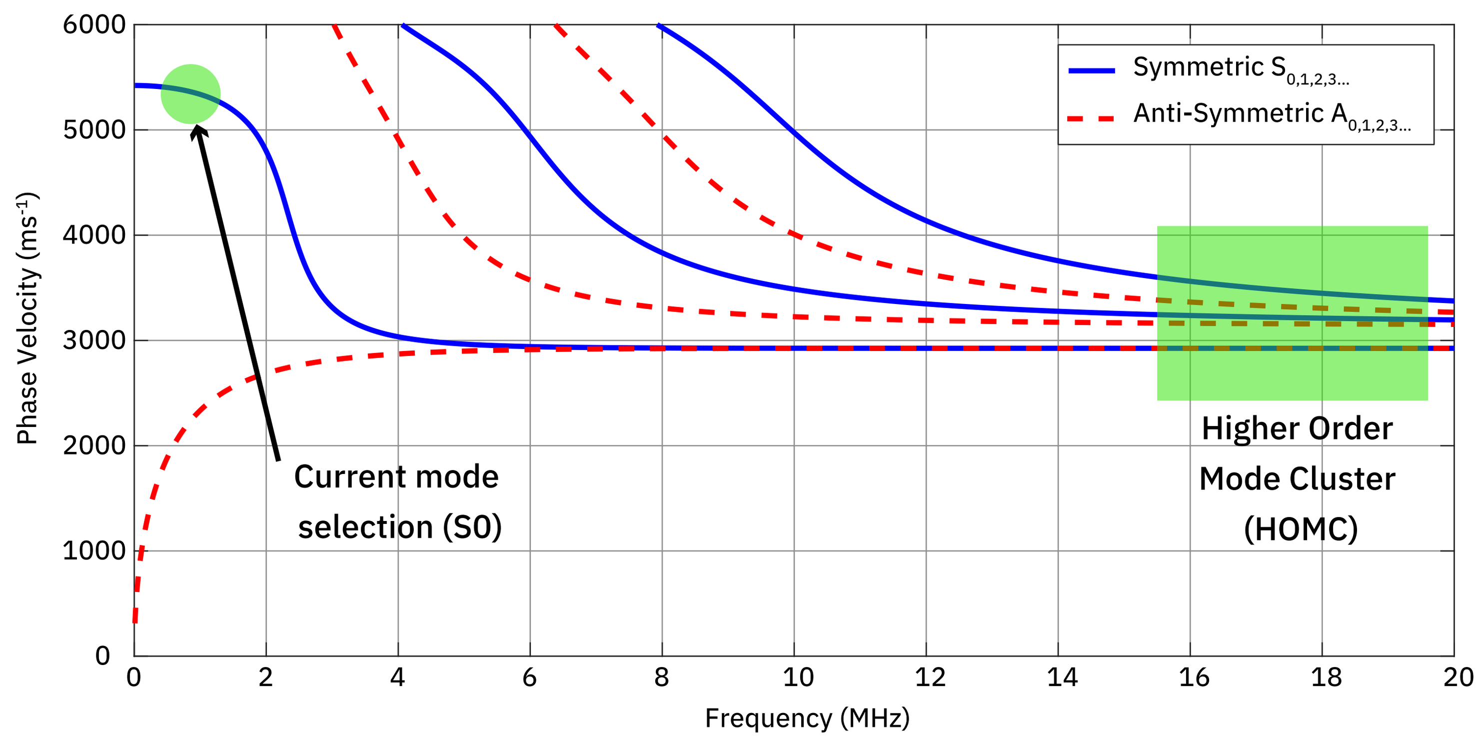


How Will The System Work?

Ultrasonic waves will be generated, transmitted, and received through the structure of the NGV using a pair of ultrasound transducers. Working at high frequency (MHz range) will allow precise measurement of wave velocity, from which a change in temperature can be infered.

Due to the thickness of the NGV and the frequency range of interest, **Lamb waves** will propagate. These types of wave are dispersive, meaning that their wave velocity changes with frequency. This presents a challenge in analysing the transmitted signal.

The plot below shows phase velocity dispersion curves for Aluminium (the chosen test material for this study).

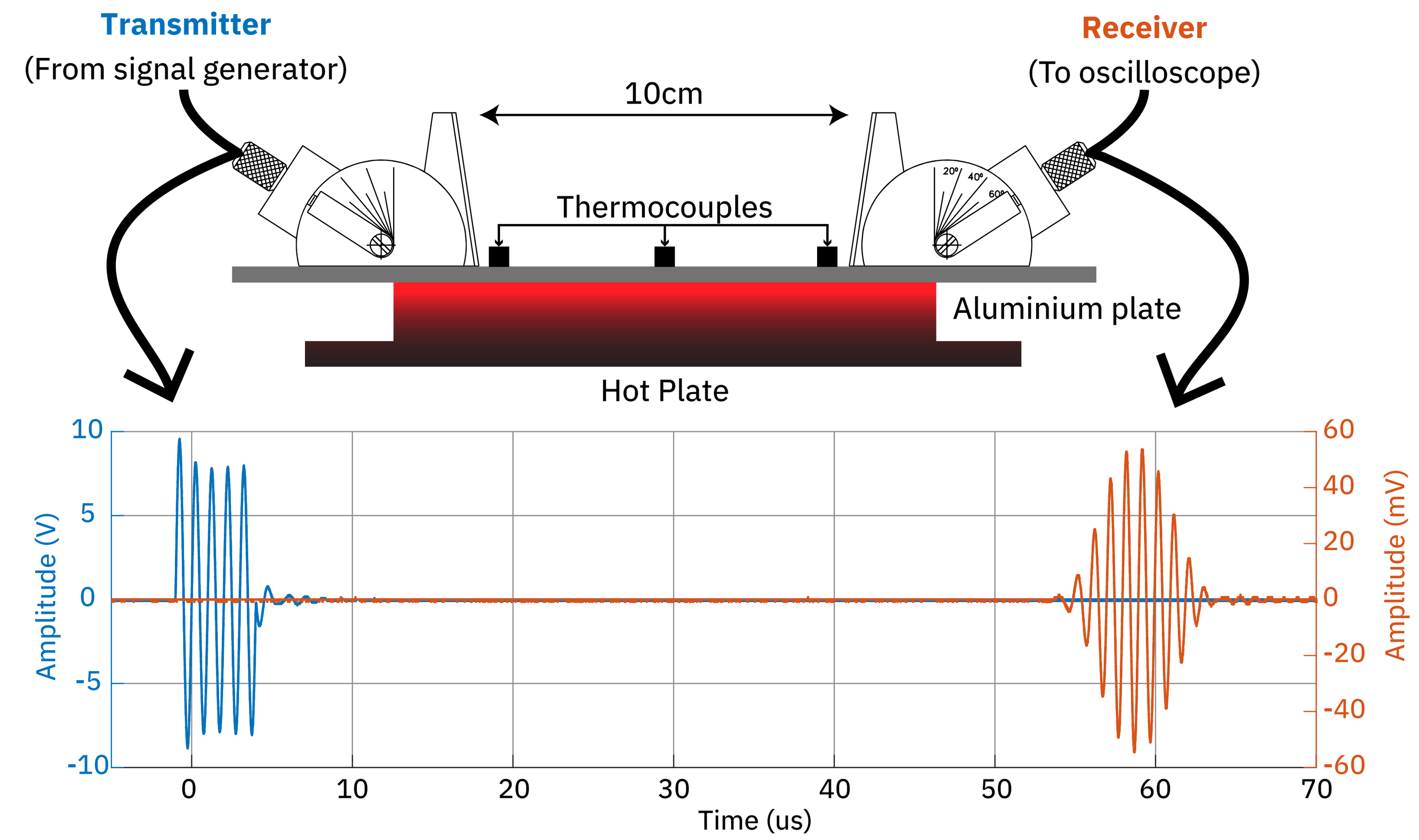


Experimental Setup

A preliminary investigation has been carried out to understand the effect of temperature on the propagation of Lamb waves, which will propagate through the structure of an NGV.

A signal generator is used to produce a 5 cycle 1MHz toneburst transmitted through a perspex wedge at a specific angle to selectively excite the S0 Lamb wave mode of a 1mm thick aluminium plate. At this frequency-thickness product the mode is relatively non-dispersive, making it easier to process than the higher order mode groups. The wave is recieved using a second wedge and transducer connected to a USB oscilloscope, sampling at 500MS/s. Cross correlation is used to measure the time difference between them, and wave velocity is calculated in combination with the distance between wedges (10cm).

Temperature of the plate is controlled using a hot plate, with a number of thermocouples placed along the transmission path to use for validation.



Further Development

- Experimentally investigate the effect of the cooling holes on wave propagation and develop a system of mapping temperature across the blade.
- Adapt the system for operation at considerably higher temperatures.
- Improve resolution by increasing frequency of excitation and sampling rate.

Operating at higher frequency-thickness products will excite more modes simultaneously which are difficult to analyse, but targeting areas where the phase velocities are similar to each other will create clusters of modes that act like a single mode. This is called a **Higher Order Mode Cluster (HOMC)**.

Wedge transducers could be replaced by Hertzian contact points, which are more applicable for installation on an NGV.