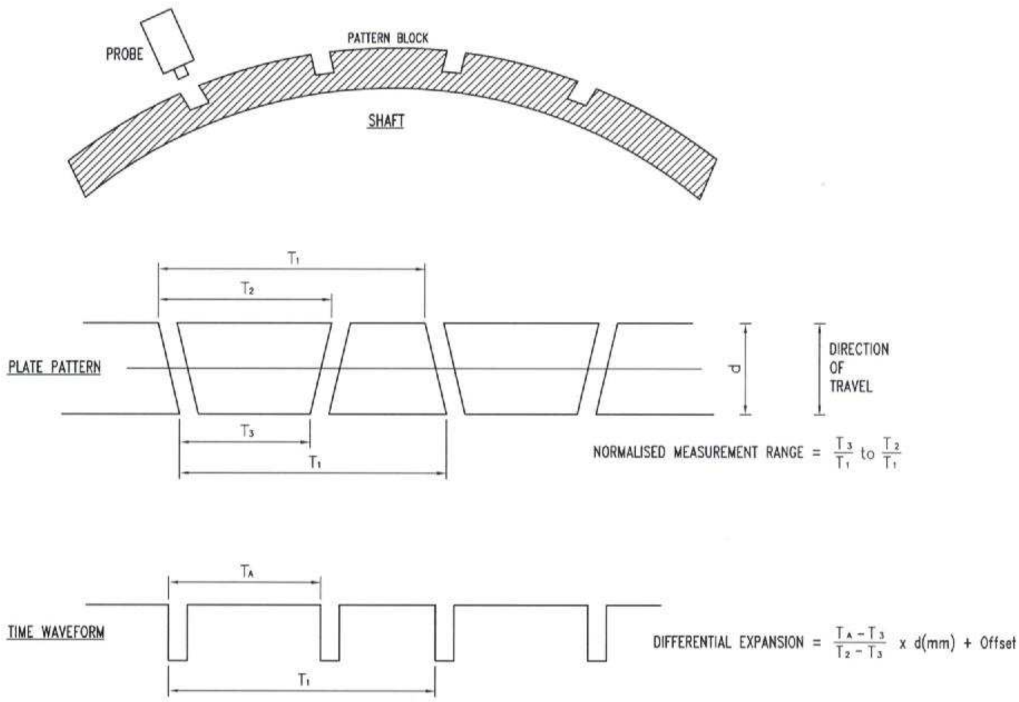
Sensonics Technical Note – DS1220

Differential Expansion Measurements on Large Steam Turbines

One of the challenges facing instrumentation engineers in the power generation sector is the accurate measurement of shaft growth relative to casing on large steam turbines. The measurement is commonly referred to as differential expansion and applies to various stages of the turbine – the critical areas being the turbine low and intermediate pressure rotor stages (due their large shaft lengths). From barring the turbine through to run up, the shaft can experience axial expansion of up to 50mm due to the operational temperature rise, depending on configuration and power rating. With today's steam turbine arrangements exceeding the 900MW barrier this measurement is as relevant as ever and a continuing challenge.

Common techniques for measuring large differential expansion ranges include extended range proximity probes against standard flat collars; tapered collars, which offer an effective extended range to a standard probe and magnetic follower arrangements. Large range probes require a sufficient target area to be linear (greater than 2x probe diameter) which is not always available, standard collar arrangements also, do not allow for other shaft movement (not in the axial direction) which can result in significant errors in measurement. The tapered collar arrangements overcome the proximity probe target issue by utilising a smaller probe and through the use of a four probe arrangement can effectively eliminate other movements in the turbine structure that can effect the true differential expansion measurement. However, these solutions are mechanically complex, problematic during commissioning and difficult to maintain calibration.

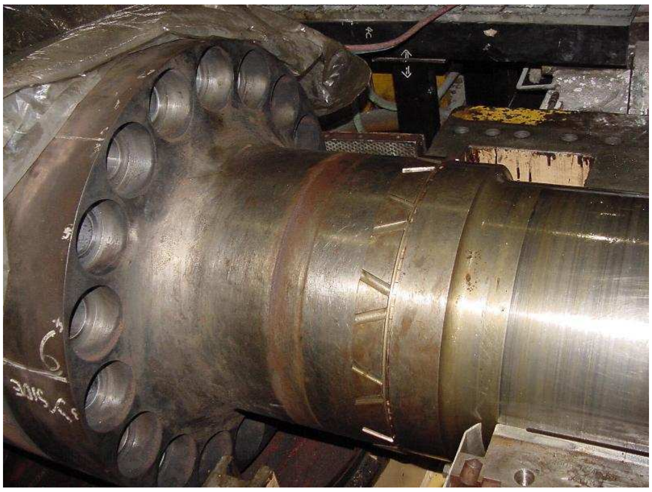
For a number of years Sensonics have been providing a differential expansion measurement solution based on a mark – space technique, which overcomes all of the shortcomings of the above methods. The principle operates on detecting movement on a series of plates attached to the turbine shaft. The shaft target pattern consists of a number of pairs of 'teeth' and 'slots' surrounding and rotating with the shaft. Each pair of teeth are tapered axially such that alternate teeth taper in opposite directions, the narrow parallel slot between the teeth being at an angle to the shaft axis. A wider parallel slot between each pair of teeth is used to allow the measurement system to identify each pair. The figure below illustrates the technique.



The technique operates on measuring pulse widths and detecting changes in the patterns to determine the differential expansion of the shaft. A standard speed probe can be utilised for the pulse measurement and with appropriate signal processing, changes in the probe gap across the measuring range have no effect on accuracy, since it is the shaft transitions that are measured. Therefore the measurement provides a true differential expansion reading and requires no further allowances for movement in the non-axial direction.

The technique has no real limit on the measurement range, being restricted only by the plate dimensions. During commissioning a normalised range is calculated by moving the probe across the required measurement window - determining the pulse width ratio at each extreme (T_2 and T_3 with respect to d). The true differential expansion reading can then be determined from the given formula.

A turbine shaft with mark-space plates is illustrated below.



Sensonics produce a specific measurement module as part of the 'Sentry' Turbine Supervisory Equipment Series to carry out the necessary signal processing and to assist with the commissioning activity. The MO8612 utilises a self-tracking threshold technique to ensure signal pulses are measured at the optimum position within the pulse height independent of the proximity probe gap. Specific plate patterns can be selected depending on application through the software interface and custom patterns created if required. It is usual to implement a number a plates around the shaft, the module makes multiple measurements per revolution and minimises 'plate wobble' through the implementation of averaging algorithms.

'Sentry' API670 Turbine Supervisory Equipment Series

While it is usual to implement a number of chevron patterns around the shaft, reality is quite different. From experience the quantity can vary from one set of plates to many - depending on the turbine engineer's preference. If an uneven distribution is selected it is important the overall balance of the rotating shaft is maintained, with the addition of opposing weights if necessary.

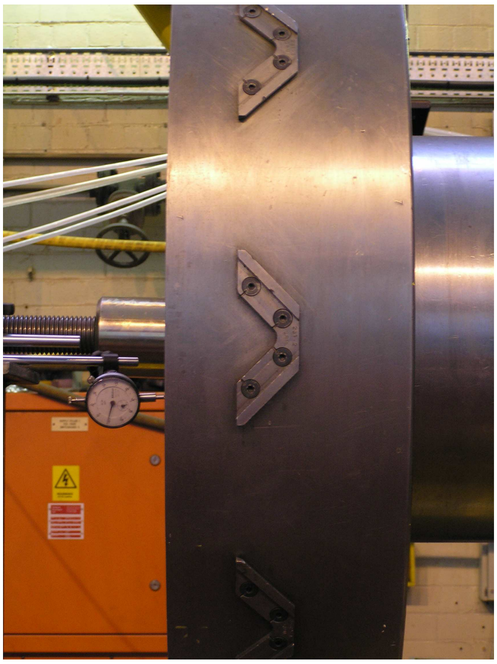
Didcot A Power Station in the UK has been successfully utilising this differential expansion technique since the mid - 1980's when the original GEC Elliot supervisory equipment dating from the mid 1960s was replaced with NEI Electronics: this included displacement channels using the mark/space technique~~.~~ However, in recent years, maintainability of the original signal processing equipment has become more difficult. Reluctant to move away from this measurement technique, Sensonics were contacted to supply and commission the MO8612 Mark-Space modules on the HP, IP and LP3 rotor sections of the four turbines, starting with Unit 2 in 2005.

Didcot A first started operation in the early 1970's and has a generating capacity of 2000MW across four steam turbine generator sets. During the 2006 Unit 1 outage, while the rotors were undergoing routine maintenance, the second differential expansion retrofit was carried out.

Didcot A 2000MW Power Station

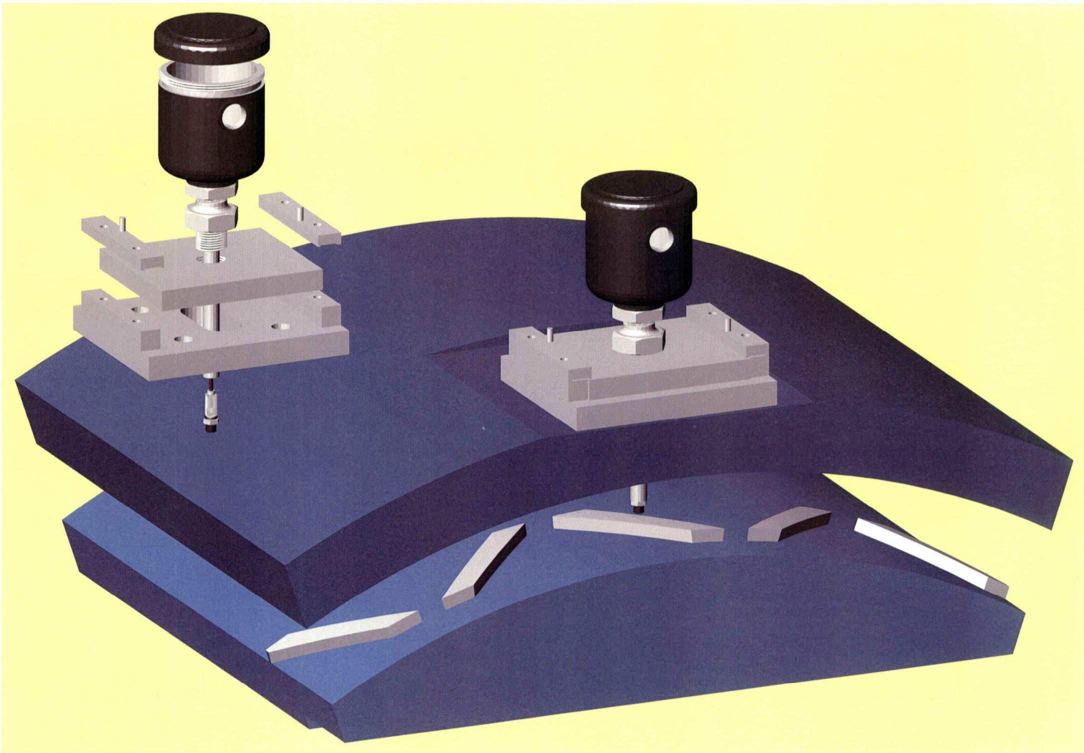
The plate pattern is fitted at a position on the rotor section close to where the shaft fits in to the bearing pedestal - this location allows straightforward access to the plate pattern through the bearing cover. The turbine casing and pedestal are mechanically joined in most circumstances, where the pedestal and casing movement is catered for with a sliding base arrangement. At the HP, IP and LP3 locations a bracket assembly fitted to the pedestal cover accepts a standard inductive proximity probe to generate the timing waveforms.

During commissioning the face of the probe was set to approximately 1.5mm distance from the maximum surface height of the plate on the shaft; this is achieved by monitoring the probe driver linearised voltage output and setting to -8.0V.



Didcot A
Plate Pattern

Provided the plate height produces a transition of greater than 2.5 mm on rotation of the shaft, the proximity probe will provide a clean square wave signal between -8.0V and -20.0V, time modulated to the plate pattern. A typical sliding bracket arrangement is illustrated below.



Typical probe sliding bracket and clamp arrangement

Commissioning of the differential expansion measurement system is completed during barring prior to turbine run-up, at Didcot A this was carried out at a speed of 2rpm or 0.033Hz. The station provided the following measurement ranges for the HP, IP and LP3 rotor sections based on past measurement experience and calculations.

HP Differential expansion range	-2.5mm (Governor end) to 10.2mm (Alternator end)
IP Differential expansion range	-7.6mm (Generator end) to 7.6mm (Governor end)
LP3 Differential expansion range	0.0mm (Generator end) to 25.4mm (Governor end)

The total measurement range was first established at each location by moving the probe in the bracket to each extremity of the plate pattern, the probe was then set to the centre of this range. To calibrate, the probe was first moved in the sliding bracket arrangement 50% of the required measurement range to the low end and the MO8612 commissioning software used to capture the timing waveform for this measurement point, -2.5mm for the HP rotor. A dial test indicator was then used to move the probe to the high end of the range (to an accuracy of 100um), +12.7mm travel for the HP; again the MO8612 mark-space unit captured the timing waveform for this measurement point. The module then calculated the required offset and slope to perform the measurement at any point in the set range.

This process was repeated at all measurement points on the set and further readings were taken to ensure correct linearity across the desired expansion range before the probe was returned to the centre point and the casing drilled and dowels fitted in the plate to ensure no further movement of the probe assembly. With steam applied to the set and the shafts positioned firmly against the thrust pads a further commissioning offset was applied in the 8612 of a few tenths of a millimetre to finalise the set up.

Following successful completion of the outage on Unit 1, Sensonics provided a training course for the station engineers on a simulation rig, as part of the system handover. During 2007, the differential expansion retrofit will be repeated on a further unit by the station staff.

Sensonics are a leading supplier of turbine supervisory and high integrity protection equipment to the power industry. With nearly 30 years experience in providing turbine instrumentation solutions in demanding environments, not only do they supply a full range of probes and API 670 compliant measuring and protection equipment, but also offer design through to installation & commissioning services.