Measuring Ramp Differential Expansion with the VM600

By Marcel de Boer • SKF

As described in application note CM3074, SKF / Vibrometer's VM600 Machinery Protection System is specifically designed to perform critical measurements that help control large steam turbine generator trains. One of the more important types of these measurements is differential expansion.

Differential expansion monitoring measures change in axial clearances between the machine rotor and the stationary casing. These changes are caused by thermal changes inherent in most machines. The primary purpose of a differential expansion monitor is to guard against axial rub between rotating and stationary parts, the consequences of which can be catastrophic.

There are many configurations for measuring differential expansion. This Application Note discusses common transducer configurations for ramp differential expansion (RDE). Transducer orientation is considered, along with the appropriate MPC-4 Machinery Protection Card configuration.

There are a number of reasons for monitoring ramp differential expansion instead of straight differential expansion:

- If the desired working range of the non-contact eddy current probe is insufficient, a ramp provides a "mechanical" advantage.
- To minimize the diversity of probes used. Often, a standard eddy current probe with a range of only 2 mm can be used with a ramp differential expansion measurement (by using the ramp, the amplification of the measuring range is sufficient in most cases).

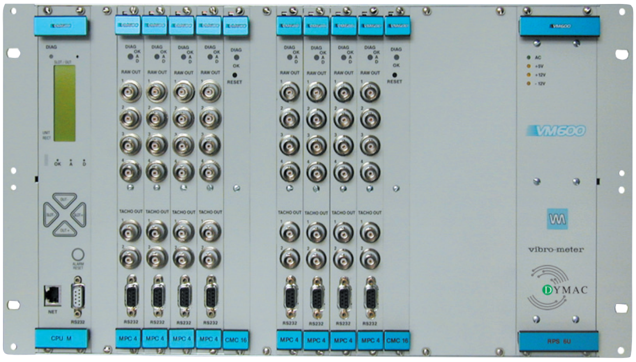


Figure 1. VM600 machine monitoring and protection system.

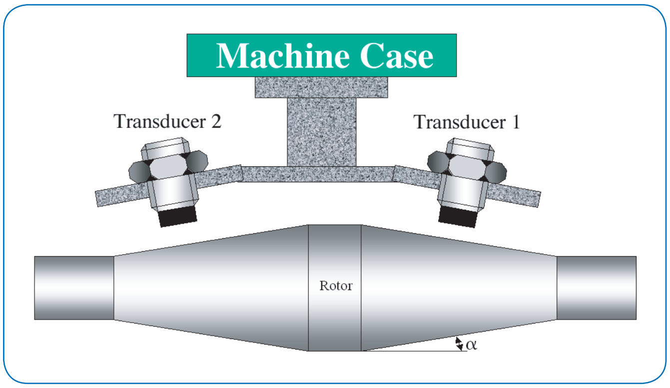


Figure 2.

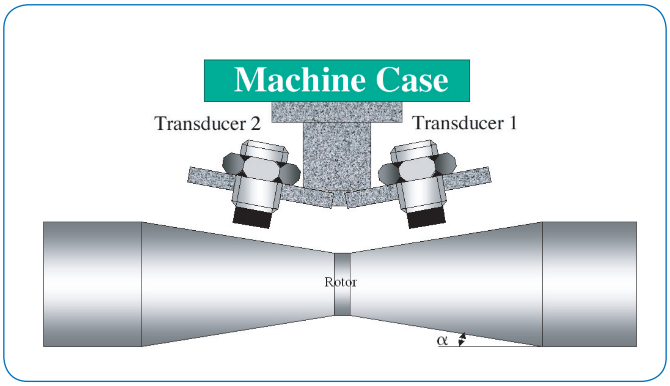


Figure 3.

How does it work?

In **figs. 2** and **3**, the ramp differential expansion measurement uses two transducers viewing a concave or convex ramp that is integral to the rotor assembly. Typical ramp angles found in today's machines range from 9,5° to 14,5°, although, in rare cases, 30° to 45° angles are found. The potential for measuring differential expansion is based upon the angle of the target ramp and the linear range of the transducer making the measurement.

As the rotor thermally expands or contracts, the rotor target area moves at the sine of the ramp angle. This effect increases the transducer's maximum range, as a large axial change in rotor position results in a much smaller relative perpendicular gap change. This increase in the transducer's maximum range effectively decreases the transducer's sensitivity in a manner proportional to axial movement.

Figs.2 and **3** illustrate dual ramp differential expansion. **Fig. 4** illustrates single ramp differential expansion. For both types, the second transducer is only used to measure the rotor's radial movement. For example, if the shaft moves upwards, both transducers measure the motion. With this information from both channels, the measuring device has the possibility to subtract the radial movement of Transducer 2 from the measured value of the first transducer. This results in the desired axial movement of the rotor.

As mentioned above, Transducer 1 faces the ramp, the angle of the transducer is defined as α. Transducer 2 faces the shaft, the angle of the transducer is defined as 0°. If Transducer 2's angle is greater than 0°, then dual ramp differential expansion is assumed.

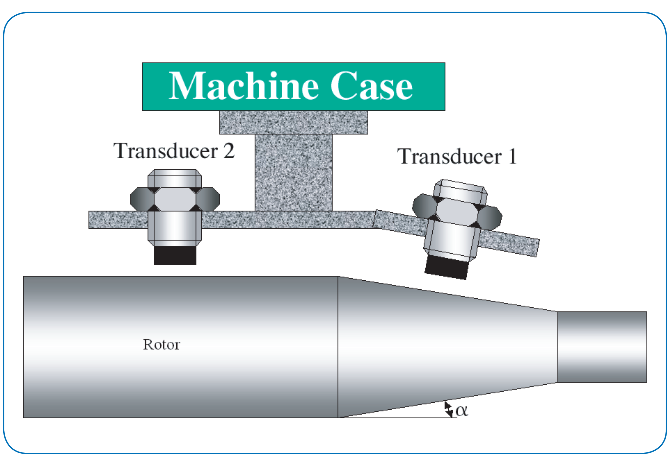


Figure 4.

Single ramp expansion uses two transducers:

- Transducer 1 measures the axial and radial movement of the rotor.
- Transducer 2 measures only the radial motion.

Note: Single ramp expansion performed by the VM600 (MPC-4) requires Transducer 1 to face the ramp.

How to set up the VM600 equipped with an MPC-4

Example 1 – dual ramp differential expansion

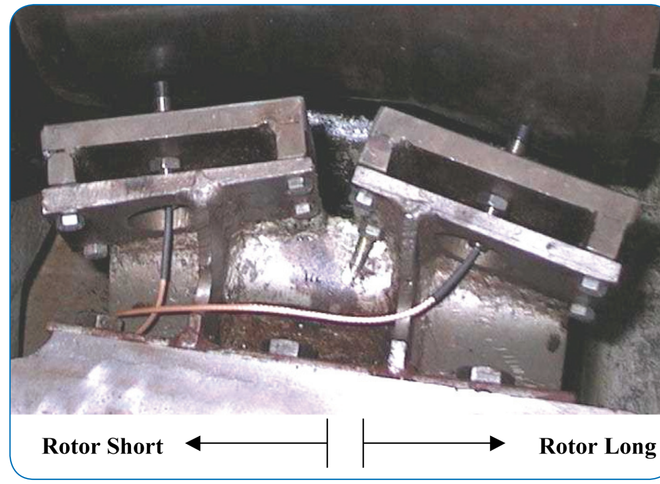


Figure 5.

- Probe: CMSS 68
- Driver: CMSS 668-5
- Usable range: 145 mils = 3,7 mm
- Sensitivity: 100 mV/mil = 4 000 mV/mm

	Transducer 1	Transducer 2
• Sensor sensitivity:	3 937 mV/mm	3 937 mV/mm
• Measurement range:	15,2 mm	15,2 mm
• Ramp angle:	14°	14°
• "Zero" voltage:	–12,20 V	–4,71 V

- Danger rotor short: –5,8 mm
- Danger rotor long: +6,9 mm

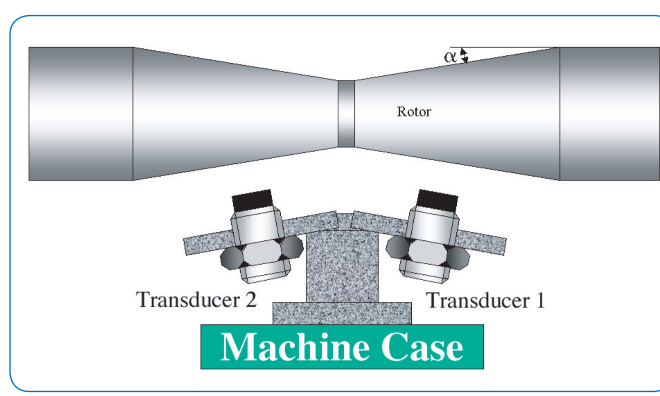
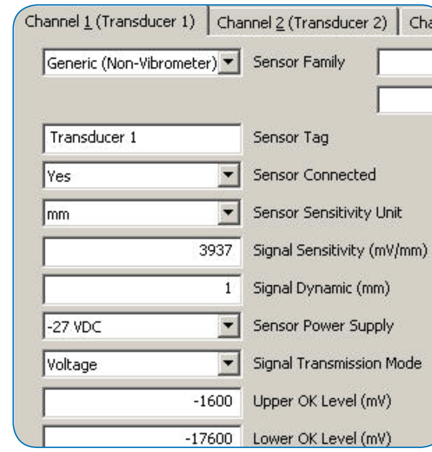


Figure 6.

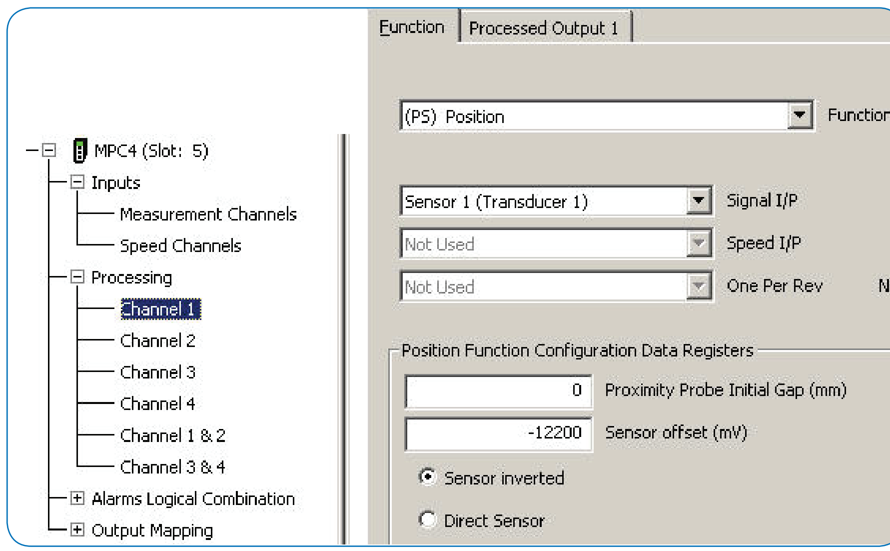
MPC-4 input

Two input channels are configured with the following settings:



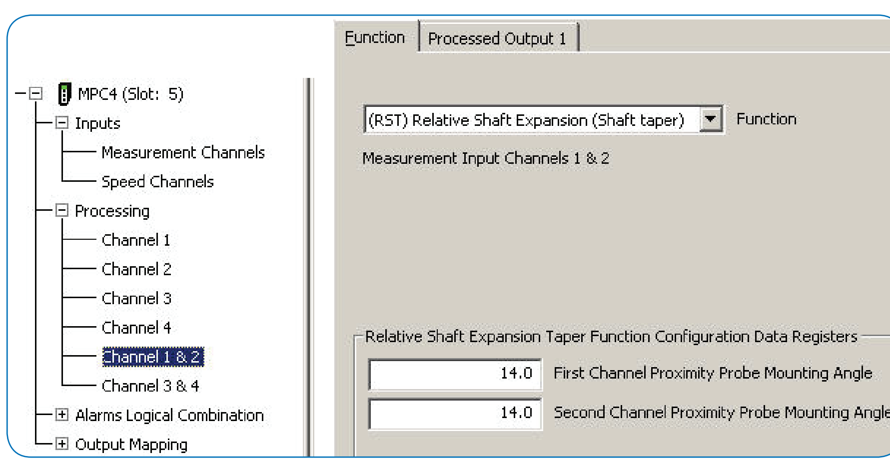
MPC-4 processing

In the processing part of the MPS software, both channels are configured with the following settings:

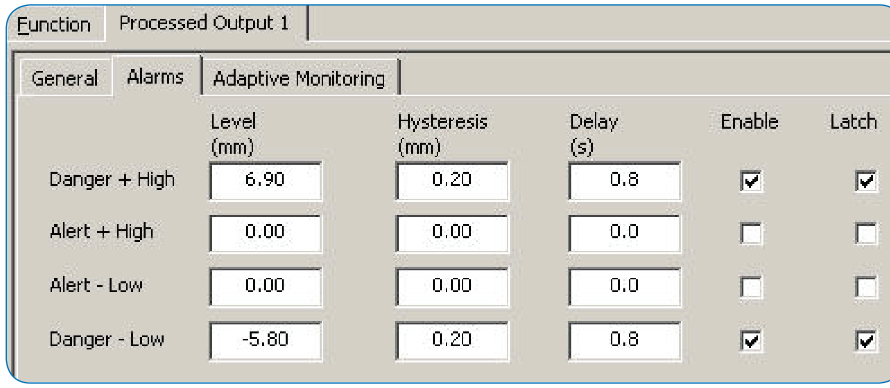


Channel 1 and Channel 2 processing

In the processing part of the software, both channels are combined to one processed output:



Alarms on this processed output are set accordingly:



Example 2 – single ramp differential expansion

- Probe: CMSS 68
- Driver: CMSS 668-5
- Usable range: 145 mils = 3,7 mm
- Sensitivity: 100 mV/mil = 4 000 mV/mm

	Transducer 1	Transducer 2
• Sensor sensitivity:	3 937 mV/mm	3 937 mV/mm
• Measurement range:	10,8 mm	3,7 mm
• Ramp angle:	20°	0°
• “Zero” voltage:	–12,20 V	–9,00 V

- Danger rotor short: –5,8 mm
- Danger rotor long: +6,9 mm

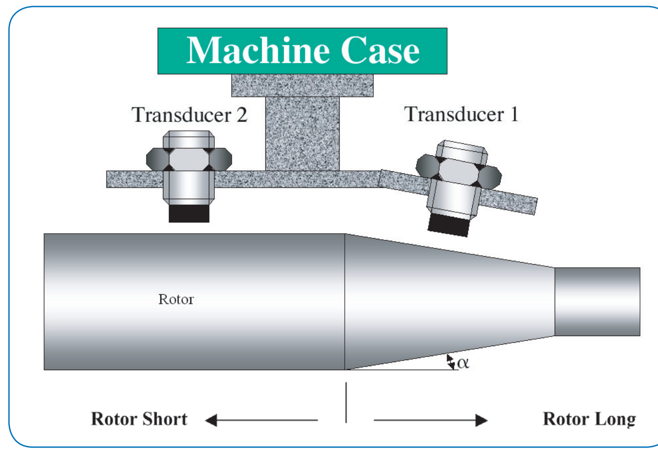
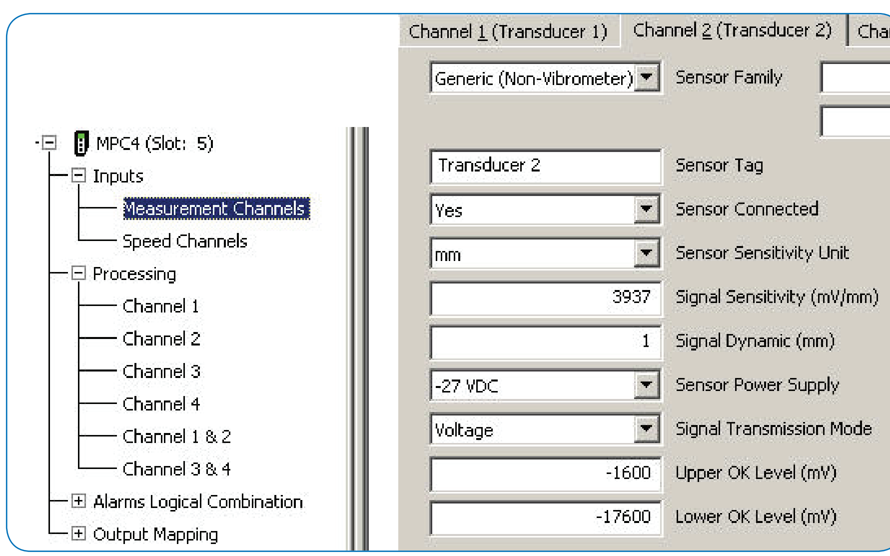


Figure 7.

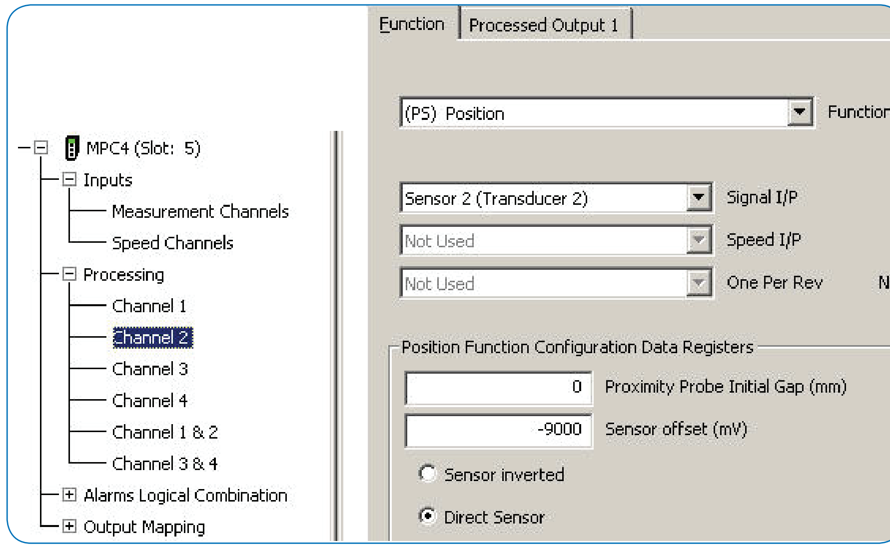
MPC-4 input

Two input channels are configured with the following settings:



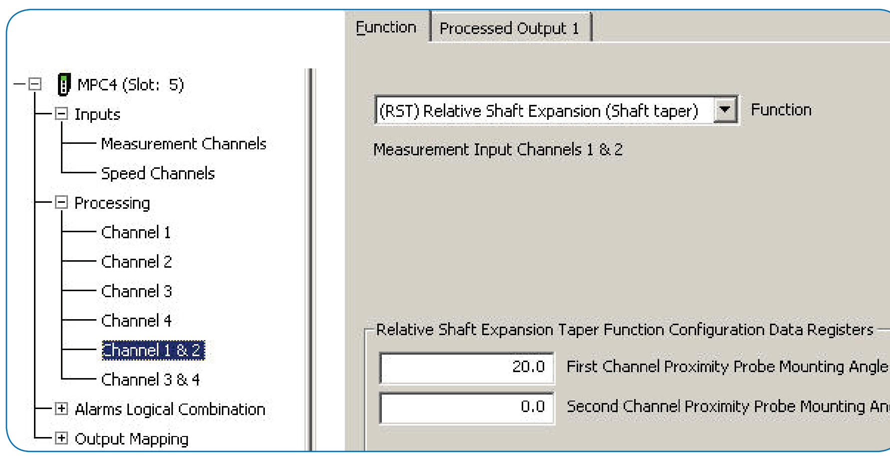
MPC-4 processing

In the processing part of the MPS software, both channels are configured with the following settings:

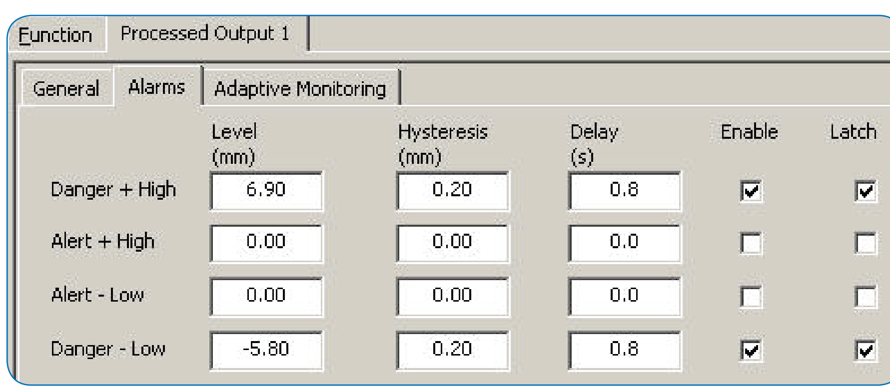


Channel 1 and Channel 2 processing

In the processing part of the software, both channels are combined to one processed output:



Alarms on this processed output are set accordingly:



Considerations

Although a ramp increases the working range of the installed eddy probe, there are some disadvantages to measuring ramp differential expansion (RDE) compared to straight differential expansion (SDE).

Installation costs

The installation of two transducers for ramp differential expansion versus one transducer for straight differential expansion increases cost.

Machine design

It is difficult, or even impossible, to rework an existing shaft to provide a ramp that can be used for measurements. Even if possible, problems often occur when mounting the brackets for the two transducers. Therefore, ramp differential expansion is usually dictated by the original machine design.

Measurement accuracy

- Due to the increased working range, sensor sensitivity decreases.
- Because there are two transducers necessary for one axial measurement, problems occur if the shaft bends. The radial motion measured by the second transducer may not be the same as the radial motion at the position where the first transducer is installed. This leads to errors in calculating the axial displacement. This problem also occurs if the transducers are mounted too far away from each other. This possible error should also be considered during periods of high eccentricity measurements (e.g., at startup).
- The ramp has an angle. The mounting of the transducer facing the ramp should be perpendicular to the angle. If the transducer is not mounted accurately, misleading results occur.

Measurement calibration

- The only reliable way to calibrate a ramp differential expansion measurement is on the machine itself. This is not possible for ramp expansion.
- It is not possible to move the shaft in both directions to get close to, or even beyond, the danger values.
- It is not possible to move the shaft accurately in an axial and a radial direction simultaneously.

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