Ramp differential expansion measurements with the SKF Multilog On-line System DMx

By Marcel de Boer • SKF

As described in the differential expansion application note, publication number CM3073 EN, the SKF Multilog On-line System DMx is specifically designed to perform critical measurements which are used in the control of large steam turbine generator trains. One of the most important measurements is that of differential expansion.

Differential expansion monitoring measures the change in axial clearances between the machine rotor and stationary casing 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 the common sensor configuration of ramp differential expansion (abbreviated to "RDE"). The sensor orientation is considered, together with the appropriate SKF Multilog DMx configuration example.

There could be a number of reasons for using ramp differential expansion instead of straight differential expansion (SDE):

- The desired working range of the non-contact Eddy Current Probe is not enough. A ramp provides "mechanical" advantage.
- Due to machine design, there is not enough space available to mount a probe of sufficient diameter versus required range for a straight measurement.

The SKF Multilog On-line System DMx.

- To keep the diversity of used probes to a minimum, 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 enough in most cases.

How does ramp differential expansion work?

In **Figure 1** *and* **Figure 2**, the ramp differential expansion measurement uses two sensors viewing a concave or convex ramp integral to the rotor assembly. The amount of differential expansion capable of being measured is based upon the angle of the target ramp and the linear range of the sensor making the measurement.

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.

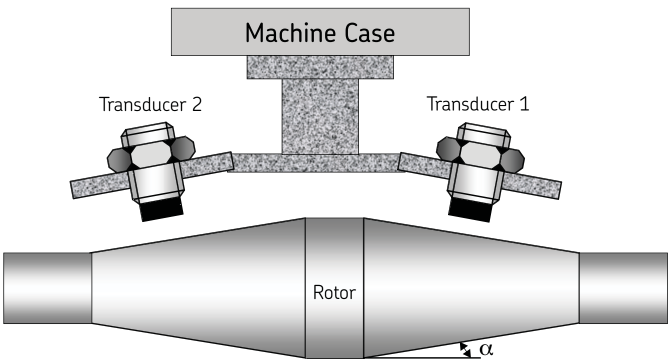


Figure 1

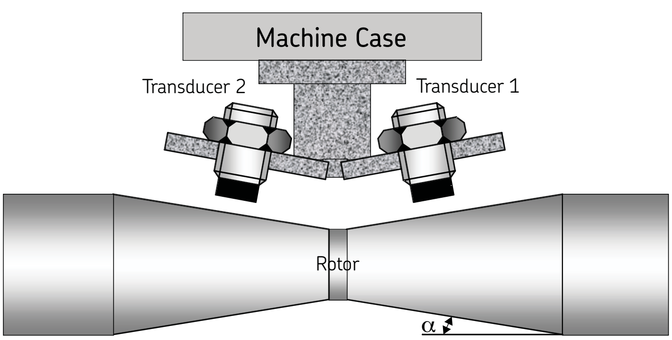


Figure 2

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

Dual ramp differential expansion

Figure 1 *and* **Figure 2** represent what is called dual ramp differential expansion, which uses two transducers, both which measure radial and axial movement of the shaft.

Single ramp differential expansion

Figure 3 illustrates single ramp differential expansion, which uses two transducers. Transducer 1 measures the axial and radial movement of the rotor. Transducer 2 measures only the radial motion.

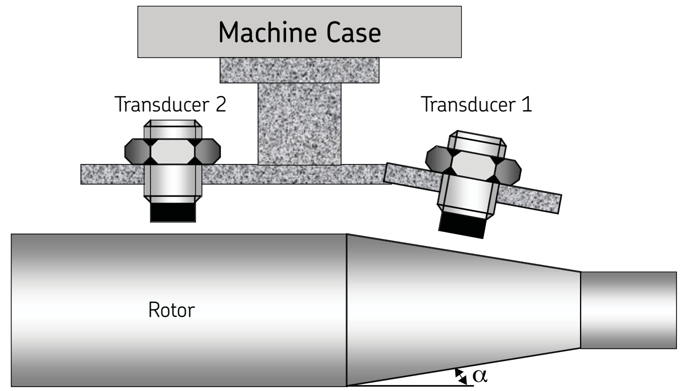


Figure 3

- Single ramp expansion performed by the SKF Multilog DMx needs transducer 1 facing the ramp.
- Transducer 1 is facing the ramp and the angle of the transducer has to be defined as **α**.
- Transducer 2 is facing the shaft and the angle of the transducer has to be defined as 0° (if the angle ≠ 0 dual ramp differential expansion is assumed!)
- To achieve standard active /inactive definitions, the programmed angles should be both positive with concave configurations, or both negative with convex configurations (Active is presented as a shaft movement to the right in **Figures 1-3**).

Note:

- As ramp expansion measurements are based on a dual channel input, the SKF Multilog DMx only accepts this kind of configuration if a channel pair is used. RDE should be set up for channel 1 and 2 or channel 3 and 4. Strictly speaking, we are only interested in the axial displacement of the rotor, but as an additional benefit, the radial displacement from the dual channel will also be calculated. This result is available for display, but should be used as information only. Normally there won't be any alarming for the radial displacement.

If all of the above rules have been applied, the axial displacement will be presented by the first measurement and the radial displacement is available from the second measurement (depending on the set up this could also be presented by channels 3 and 4 respectively).

How to set up the SKF Multilog DMx for RDE

The following example is how to set up the SKF Multilog DMx (model CMMA 9910) for dual ramp differential expansion. A real-world example is used, as shown in **Figure 4**. In this example, externally powered "probe sets" are used (comprised of a probe, extension cable and driver) as more care should be taken with this kind of setup. Where possible, direct ECP probes using the SKF Multilog DMx internal digital drivers are recommended, as they have a much higher accuracy and range, and so are more tolerant of user error.

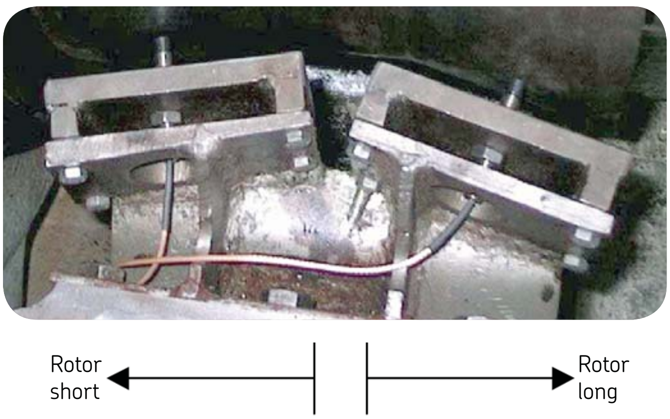


Figure 4

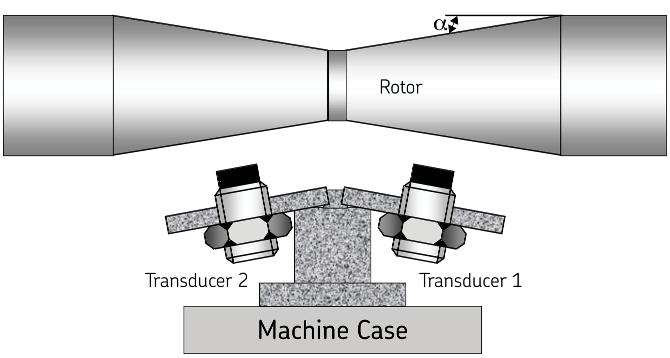


Figure 5

Probe: CMSS 68
Driver: CMSS 668-5
Usable range: 145 mils = 3.7 mm
Sensitivity: 100 mV/mil ≈ 3937 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

SKF Multilog DMx configuration setup

Two "Config" channels will be configured like this:

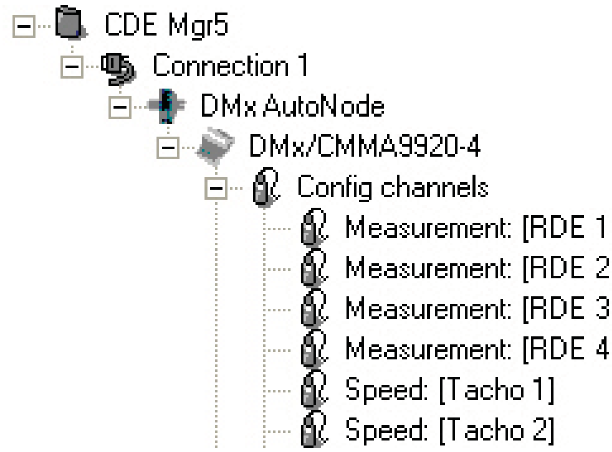


Figure 6

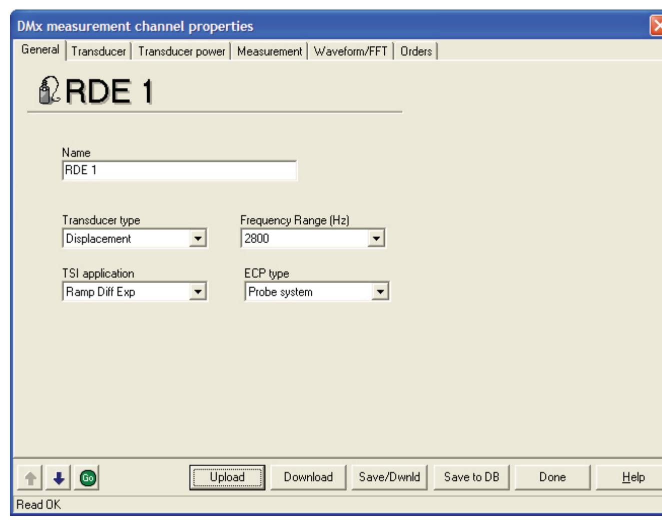


Figure 7

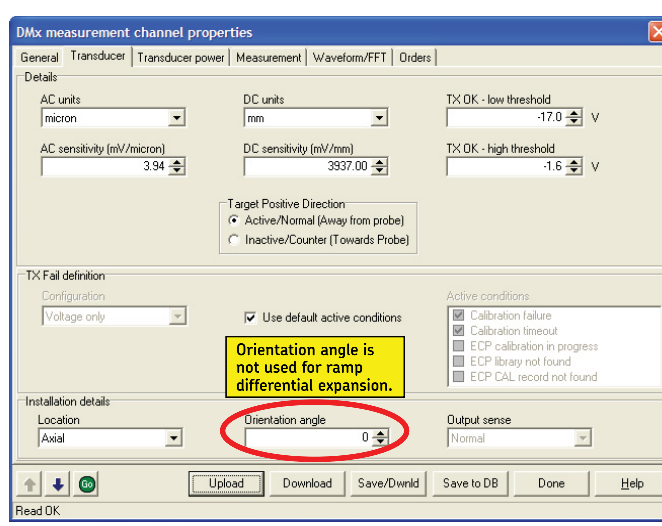


Figure 8

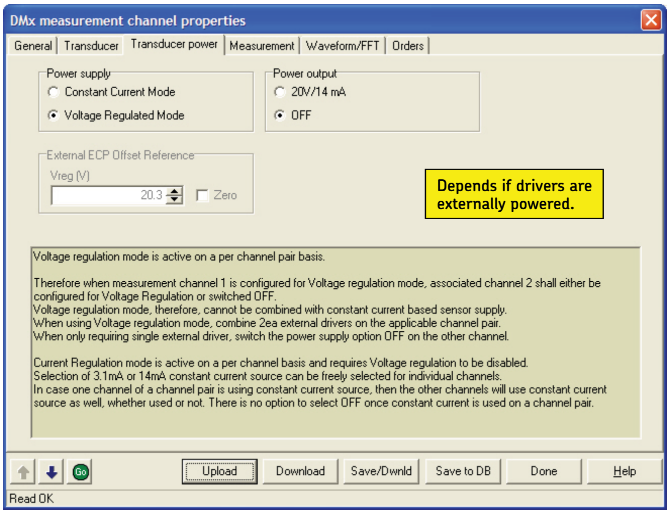


Figure 9

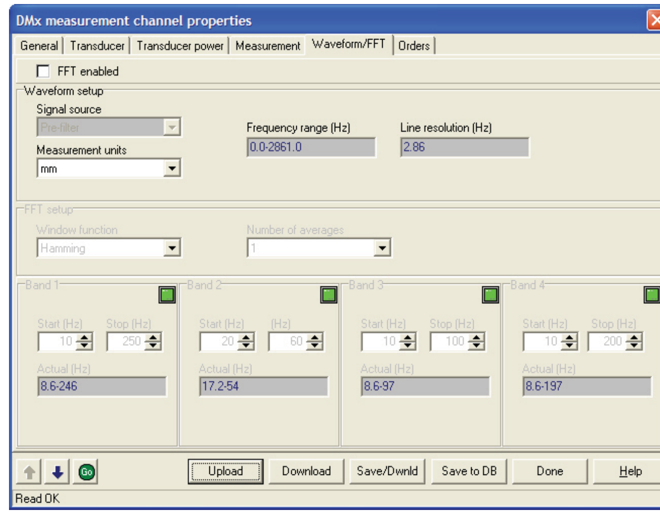


Figure 11

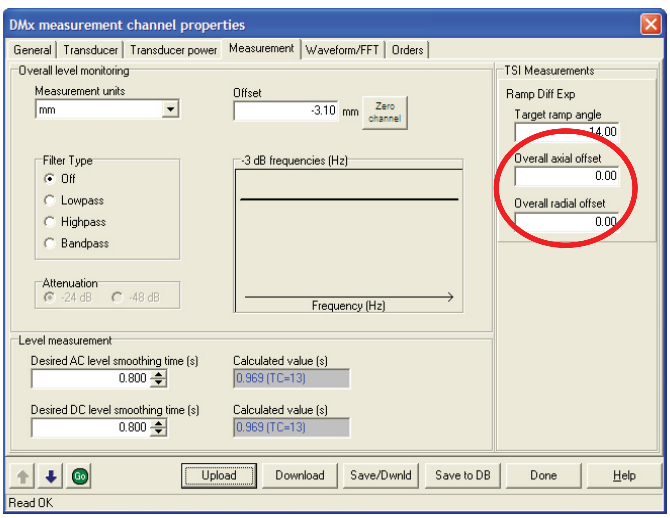


Figure 10

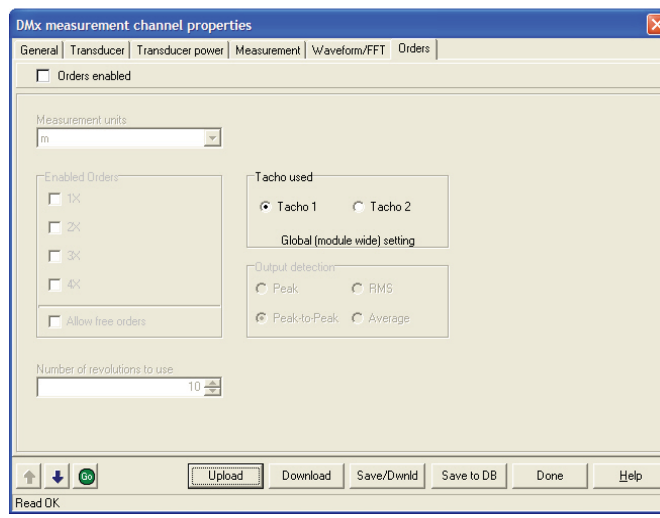


Figure 12

In the measurement tab, an optional flied called “Overall axial and radial offset” provides extra flexibility for commissioning purposes. The programmed values will be added to the end result of the axial processed output and the radial processed output. This can be used after the mechanical zeroing of the rotor to set the final results to the desired value. The last two tabs in the measurement properties, the Waveform and the Order tabs should be disabled for optimized processing optimizing.

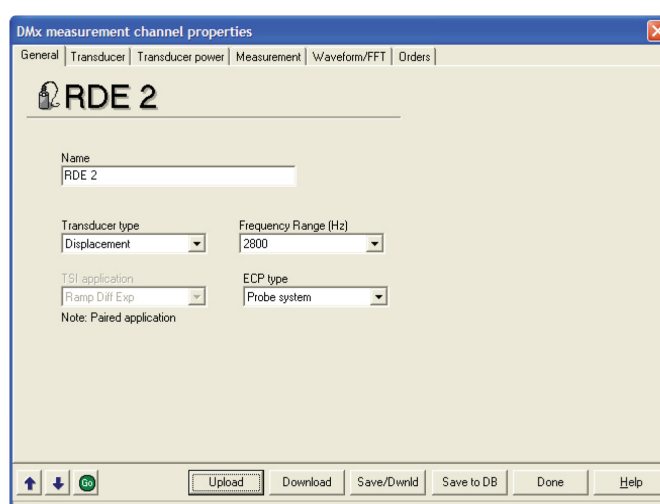


Figure 13

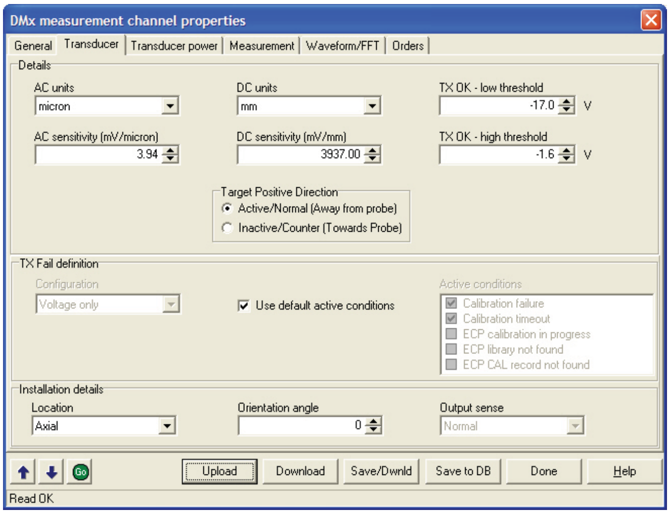


Figure 14

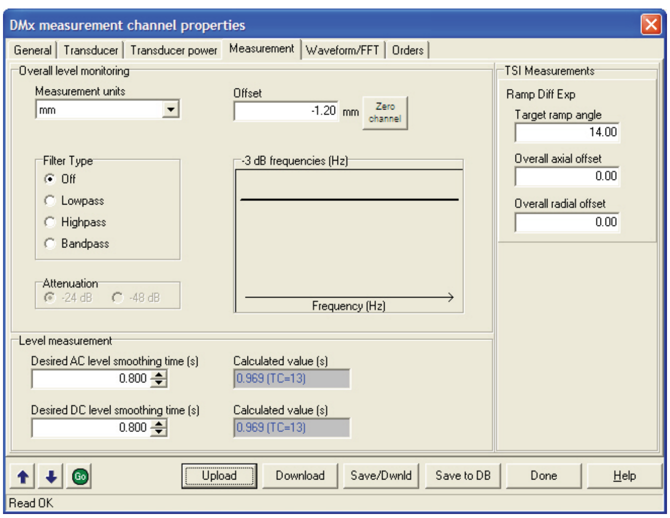


Figure 15

Two “Process” channels will be configured like this:

Where RDE 1 will process the axial displacement of the rotor and RDE 2 processes the radial position of the rotor. The latter is not necessary for the RDE measurement but can be used for informational purposes.

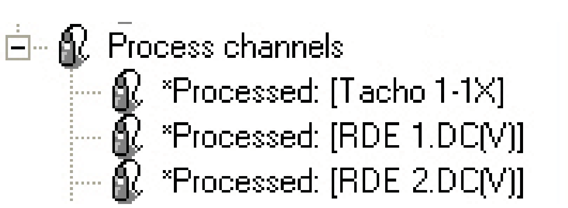


Figure 16

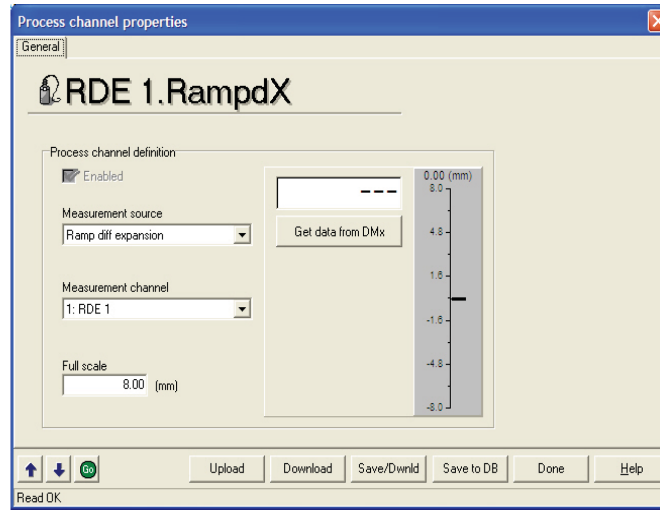


Figure 17

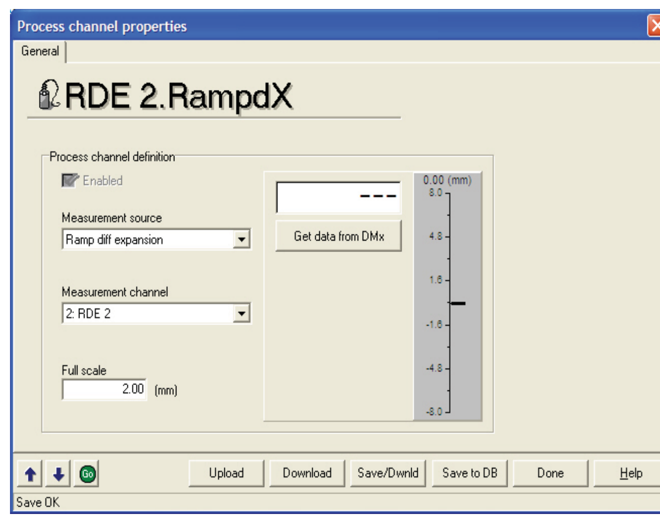


Figure 18

Alarms on this processed output are set accordingly as shown in **Figure 19** *and* **Figure 20**.

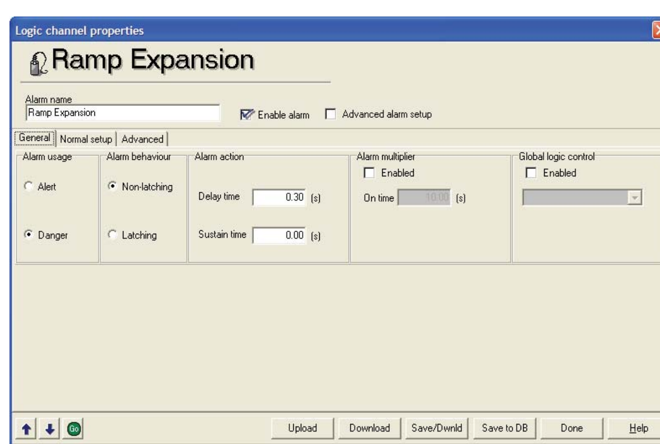


Figure 19

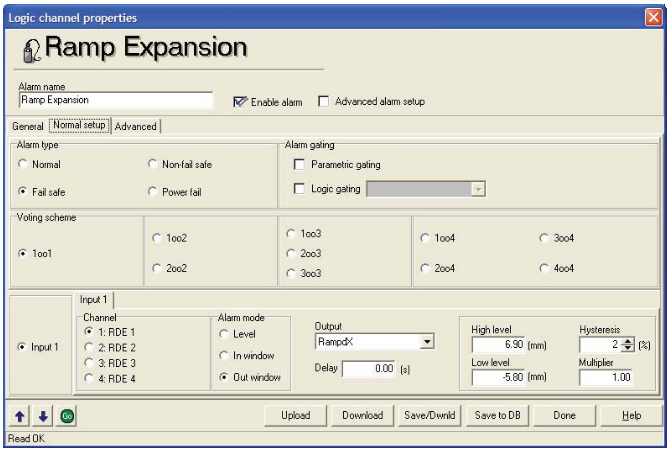


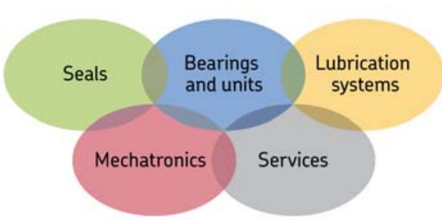
Figure 20

Ramp differential expansion: advantages and disadvantages

The significant advantage of using a ramp is that it increases the working range of the installed Eddy Probe.

However, there are some disadvantages with RDE when compared to SDE which one should be aware of:

- **Installation costs:** the installation of two transducers instead of one transducer for SDE will increase costs.
- **Machine design:** it will be very difficult, and maybe impossible, to rework an existing shaft to provide a ramp that can be used for measurements. Even if this can be done, problems often arise with mounting the brackets for the two transducers. Therefore, ramp expansion is almost always a feature in the original machine design.
- **Accuracy of the measurement:**
  - Due to the increase of the working range, the sensitivity decreases.
  - Because there are two transducers necessary for one axial measurement, problems will arise 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 sensor is installed. This will lead to errors in the axial displacement. This problem also occurs if the transducers are mounted too far from each other. This possible error should also be considered during periods of high eccentricity measurements (e.g. at startup).
  - Due to the fact that the ramp has an angle, the mounting of the transducer facing this ramp should be perpendicular. If the transducer is not mounted accurately, this will result in misleading results.
- **Calibration of the measurement:** the only reliable way to check a RDE measurement is to do this on the machine itself. This is not possible for ramp expansion because:
  - 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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