**AVAS VIBRATION MONITORING SYSTEM**
**TRACKING AND TRENDING MODULE**

UNIVIB
Universal Vibration Solutions

## 1. Overview of the AVAS Tracking and Trending Module

The AVAS Tracking and Trending Module performs a data-acquisition and analysis activity, collecting and analysing data during the rolling of each coil, then reducing it to a set of important numerical indicators of the energy levels associated with a variety of pre-defined forced vibration sources, or “exciters”. The magnitudes of these can then be trended on a coil-to-coil basis.

The primary function of this module is to assist the user to trace any potential strip-marking vibrations to their source. It also highlights any gradual, or sudden, increases in the vibrations generated by the bearings, gears, drives, etc, providing useful data concerning the condition of the key mechanical components of a mill.

The module can be configured to monitor upto 15 vibration signals and 1 speed signal per stand. Transducers are typically mounted on, or close to, each of the chocks and on the gearbox and motor, in each case.

The Tracking and Trending Module collects the reduced data for trending in a single data-file (around 10,000 coils typical working maximum).

## 2. Description of the Operation of Tracking and Trending Module

### 2.1 Location of sensors

Transducers should be located close to all potential sources of forced vibration. Key locations are, of course the work roll chocks.  If the mill uses rolling element bearings to support the back-up rolls, transducers should ideally be located on each of the back-up chocks, too. However, because of the need to remove and replace sensors during roll changes, these “ideal” locations are likely to lead to the system becoming unreliable, as operators will inevitably forget to remove or replace the sensors at some stage.

In its previous installations, UNIVIB  has found that good, practical alternatives are the load blocks (Mae West blocks), where the mill incorporates these, or on fixtures mounted to the roll-balance hydraulic pipe connectors. Both these locations have been found to be good for the detection of chock bearing defects.

Sensors should also be located on the gearbox at the input and output ends, adjacent to the bearing housings, and on the main drive motor of each stand to be monitored.

## 2.2 Configuration of the software

The initial configuration of the system is normally carried out during commissioning, but the user can modify the configuration at a later date, as needed.

Three types of parameters to be measured can be specified, derived, displayed and saved. These are:

- simple process parameter levels such as mill speed, load, tension, temperature, etc. (required as 0-10V dc inputs).
- the magnitudes of the vibration in any frequency band ($3^{rd}$- Octave, $5^{th}$ – Octave, etc.) computed from the vibration spectra.
- the " harmonic signatures" associated with the vibration from known vibration sources (see below).

During configuration of the software, a list of potential vibration sources of interest are specified. A typical list of exciters and parameters might include, but not be limited to, the following potential vibration sources:

1. Outer race defect frequency of **work roll bearing**
2. Inner race defect frequency of **work roll bearing**
3. Ball-pass frequency of **work roll bearing**
4. Cage precession (roller orbit) frequency of **work roll bearing**
5. Outer race defect frequency of gearbox **input shaft** bearing
6. Inner race defect frequency of gearbox **input shaft** bearing
7. Ball-pass frequency of gearbox **input shaft** bearing
8. Cage precession (roller orbit) frequency of gearbox **input shaft** bearing
9. Outer race defect frequency of gearbox **output shaft** bearing
10. Inner race defect frequency of gearbox **output shaft** bearing
11. Ball-pass frequency of gearbox **output shaft** bearing
12. Cage precession (roller orbit) frequency of gearbox **output shaft** bearing
13. Once-per-rev of **spindles** (gearbox output shafts)
14. Once-per-rev of main **drive motor** (gearbox input shaft)
15. **Gear-mesh** frequency of drive gears
16. Mill speed

Other exciters can be identified, defined and added to the list as experience with the system is gathered. For example, the bearing frequencies associated with all of the bearings in the motors would probably be of interest too. There is no limit to the number of exciters that can be specified, though the harmonic signatures of only three are displayed at any one time to avoid cluttering the display.

During configuration, the coefficients, or multipliers, required for the determination of the fundamental frequency of each exciter are entered. For the gear-mesh signature, the multiplier is simply the number of teeth on the gear of the shaft concerned. For the bearings, the multipliers are the bearing defect coefficients supplied by the bearing manufacturer.

It follows that a key requirement is a measure of work roll speed. The speeds of all the other rotating elements is then calculated from this measured speed. The fundamental frequencies associated with each of the bearing and gear-related parameters are then determined by applying the multipliers entered during configuration of the software to the measured and calculated shaft/roll speeds.

The harmonic signatures of each defined exciter are calculated from spectra taken for each transducer during rolling. The harmonic signature of an exciter is derived from the sum of the magnitudes of the fundamental and all of the harmonics within a certain frequency range, and is a single numeric value obtained for each spectrum. The signature analysis screen is shown in Figure 1.

Ideally, an accurate measure of roll speed is required for this activity. One way of achieving this is to mount an encoder at a convenient location in the drive-train. However, to avoid the need for this additional hardware, an algorithm has been developed that "hunts" down the signature. In the case of each exciter (bearing defect, etc.) that has been defined, the frequency of the fundamental and harmonics is firstly estimated, using the roll diameters passed from the mill controller and the "approximate" roll speed as indicated by the analogue signal provided by the mill controller. Tolerance bands are applied to each harmonic in the set (these shown in blue in the screen shown in Figure 1). A "test" harmonic set is then increased from the lower to the higher limit within these bands, and the **sum** of the harmonic magnitudes is calculated for each discrete test-frequency. In most circumstances this value will be maximum when the fundamental is set accurately on the ***true*** defect frequency (shown in purple in the slide). The maximum value is retained as the "true" value for that exciter.

This algorithm operates continuously and is displayed on the signature analysis screen which shows the "hunting" process being executed in real time. This screen provides a visual means by which the user can reassure himself that the correct defect frequencies, gear mesh frequencies have been entered during configuration, and that genuine and realistic data is being obtained, in each case.

## 2.3 Operating in "Track-Mode"

In "Track-Mode", the variation in the magnitude of the harmonic signature of the selected exciters is plotted on the display in real time as each coil is rolled. An example of the information displayed in real-time during rolling is shown in Figure 2. The upper and middle traces show the vibration levels associated with two different bearing frequencies, while the lower trace displays the speed. The user can select which harmonic signatures are displayed using the button under each trace.

Alarm thresholds are indicated by the amber and red lines on the graphs. The instantaneous alarm status (green, amber, and red) is indicated in the larger of the two boxes at the bottom right of each of the traces. The worst the alarm has been for the current coil is indicated in the smaller of the boxes. If one of the harmonic signatures that is not being displayed is in alarm, then this is indicated in the box at the top right of the display.

Coil identification is displayed at the top of the screen.

After the rolling of each coil has been completed, the data associated with each of the tracked signatures is reduced to a number of summary values. These summarised values are specified during configuration, and will typically be:

- mean value over run-speed section of coil
- maximum magnitude occurring over run-speed section of coil

Other methods of summarising the signature values for each exciter can be specified by the user. The magnitudes of the simple level measurements, such as speed, and the bandpass-filtered vibration levels are similarly summarised and included in the list. The resulting list of values constitutes a **vibration history** for that particular coil. Each vibration history will be labelled with the time, date and coil number, and can be exported to a database, if required. The list of values also automatically becomes the most-recent entry in a large data-file used for the Trend display.

## 2.4 Operating in "Trend-Mode"

This is the mode used to plot the vibration histories on a coil-by-coil basis in order to look for "events" that have occurred or trends that are beginning to occur. The magnitudes of any of the levels, filtered signals, or harmonic signatures can be displayed on a coil-by-coil basis, thus allowing the user to see any gradual changes which might indicate an incipient problem beginning to occur (slow deterioration of gear teeth condition, for example), or sudden changes associated with an event (servo-valve instability, for example).

An example of the display of the trended information is shown in Figure 3. In the example shown, each vertical line represent a coil rolled. The number of coils over which the trended information is displayed is selected by the user at the bottom of the screen. Clicking on one of the lines, or coils, causes the coil number to be highlighted.

In Figure 3 the upper and middle traces show the mean magnitudes associated with each of two different bearing defect frequencies trended over the last 500 coils rolled, while the lower trace shows the trend of the mean mill speed used to roll them.

As with the tracking display, alarm thresholds are also displayed.

Since the magnitudes of many of the vibration sources will be affected by resonances, amplified at some mill speeds and not at others, the software includes a facility that enables the user to "filter" the data displayed, as a function of mill speed. For example, the user can specify that the data for only those coils rolled between 550 m/min and 600 m/min be displayed. This helps eliminate potential false conclusions which might arise because of the effects of resonant amplification.

## 2.5 Summary screen

As experience with the system grows, other parameters and exciters to be measured can be specified, and can then be included in the tracking and trending process. Over time, it is possible that the total number of parameters might reach as many as several dozen. For obvious reasons of clarity, it is only possible to display a limited number of these at any one time. Indeed, a maximum of four exciters for display has been chosen as a reasonable compromise for display in the tracking and the trending screens.

However, to assist the user to decide which might be the most important parameters to include in the displayed trends, a summary screen can be called up, an example of which is shown in Figure 4. This screen shows a summary of the status of all the defined exciters, including current magnitude and alarm status, worst-case alarm status during current coil, and the worst-case alarm condition over a previous (user-selectable) number of coils

In the example shown, two of the parameters have clearly been “in the red” for a majority of the coils rolled, and this should indicate to the user that these are clearly worthy of further scrutiny in the trend display.

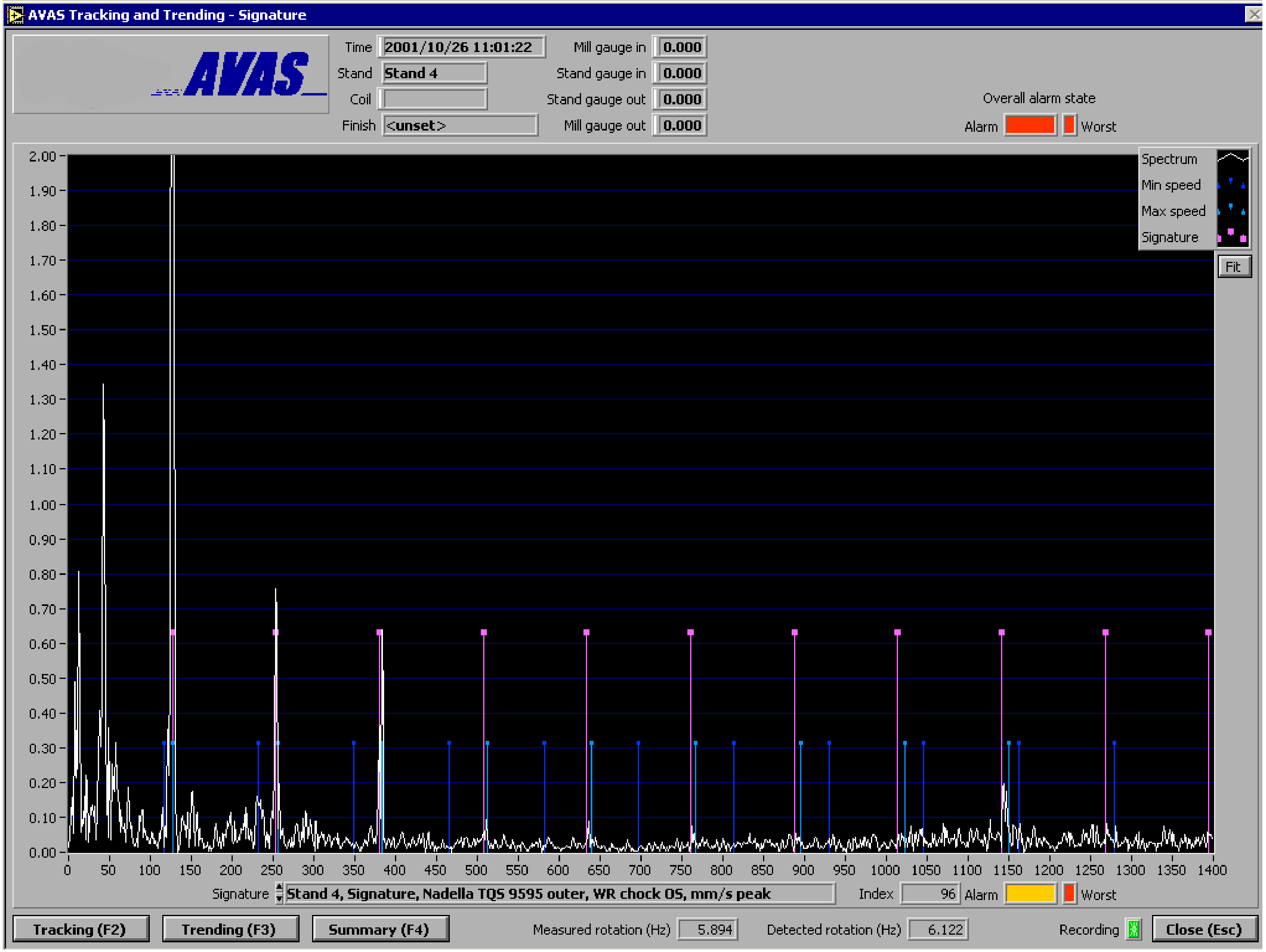


**FIGURE 1 EXAMPLE OF TRACKING AND TRENDING MODULE SIGNATURE ANALYSIS SCREEN**

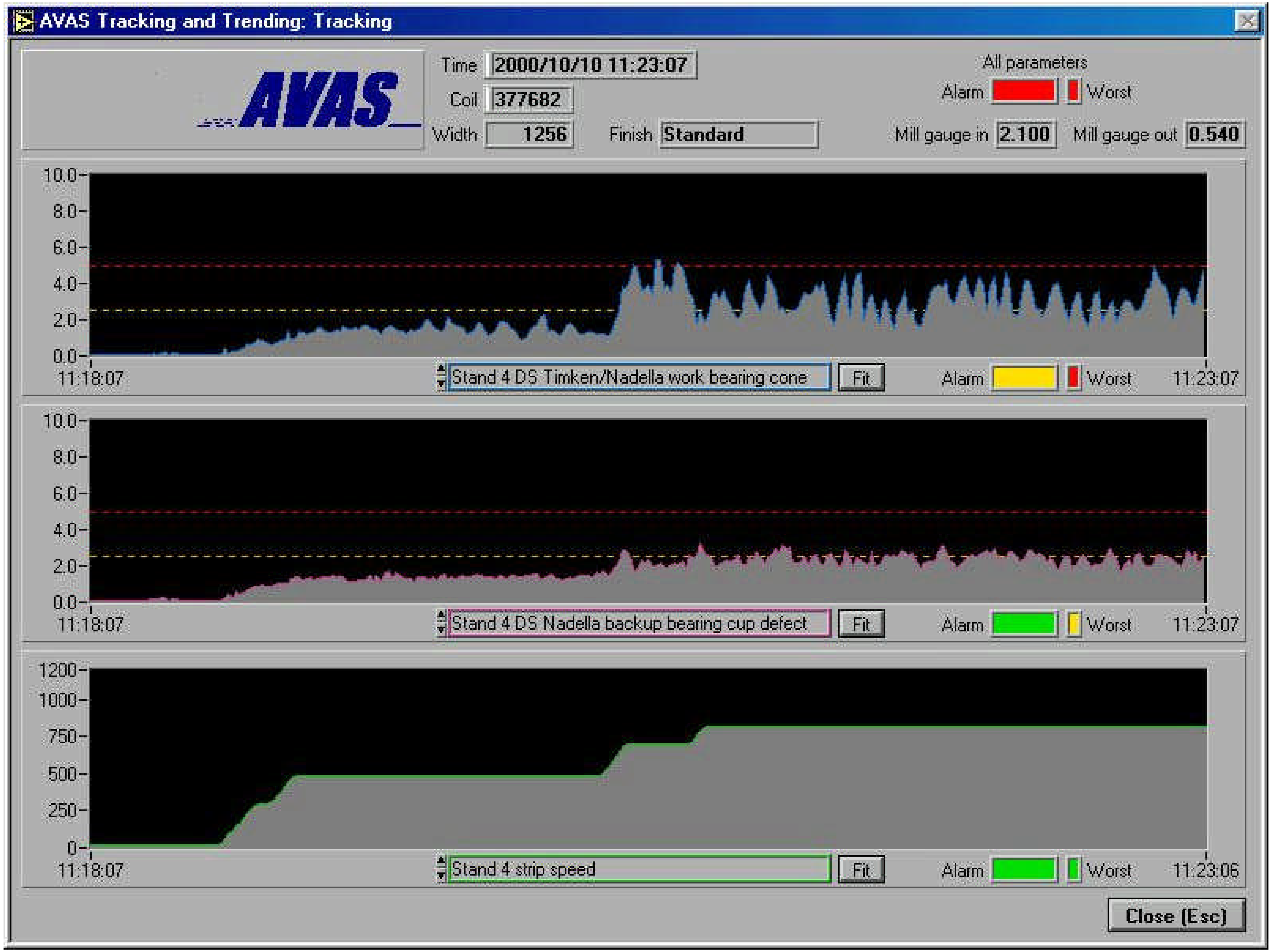


**FIGURE 2 EXAMPLE OF TRACKING AND TRENDING SYSTEM DISPLAY OPERATING IN "TRACK MODE"**

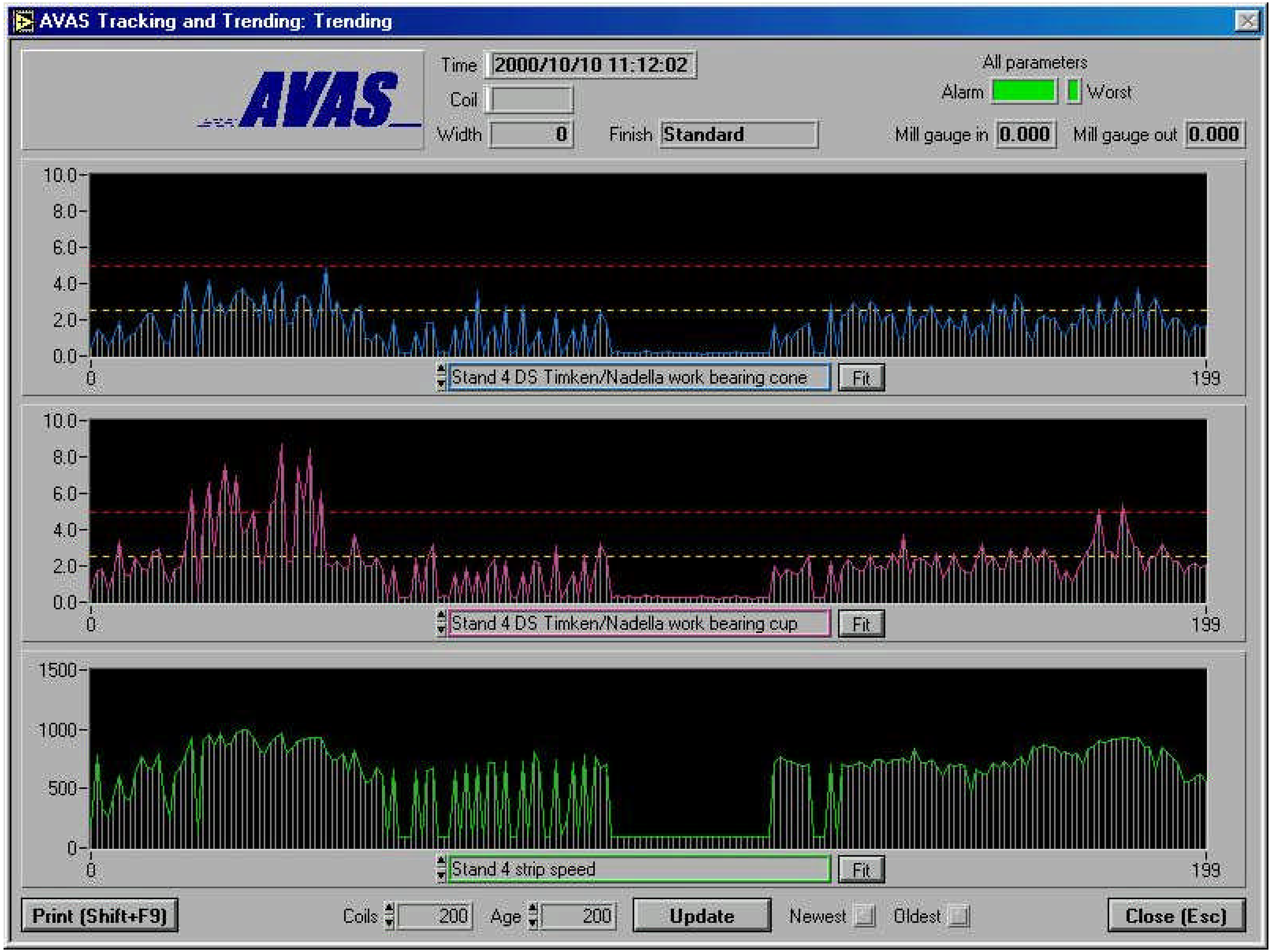


**FIGURE 3 EXAMPLE OF TRACKING AND TRENDING SYSTEM DISPLAY OPERATING IN "TREND MODE"**

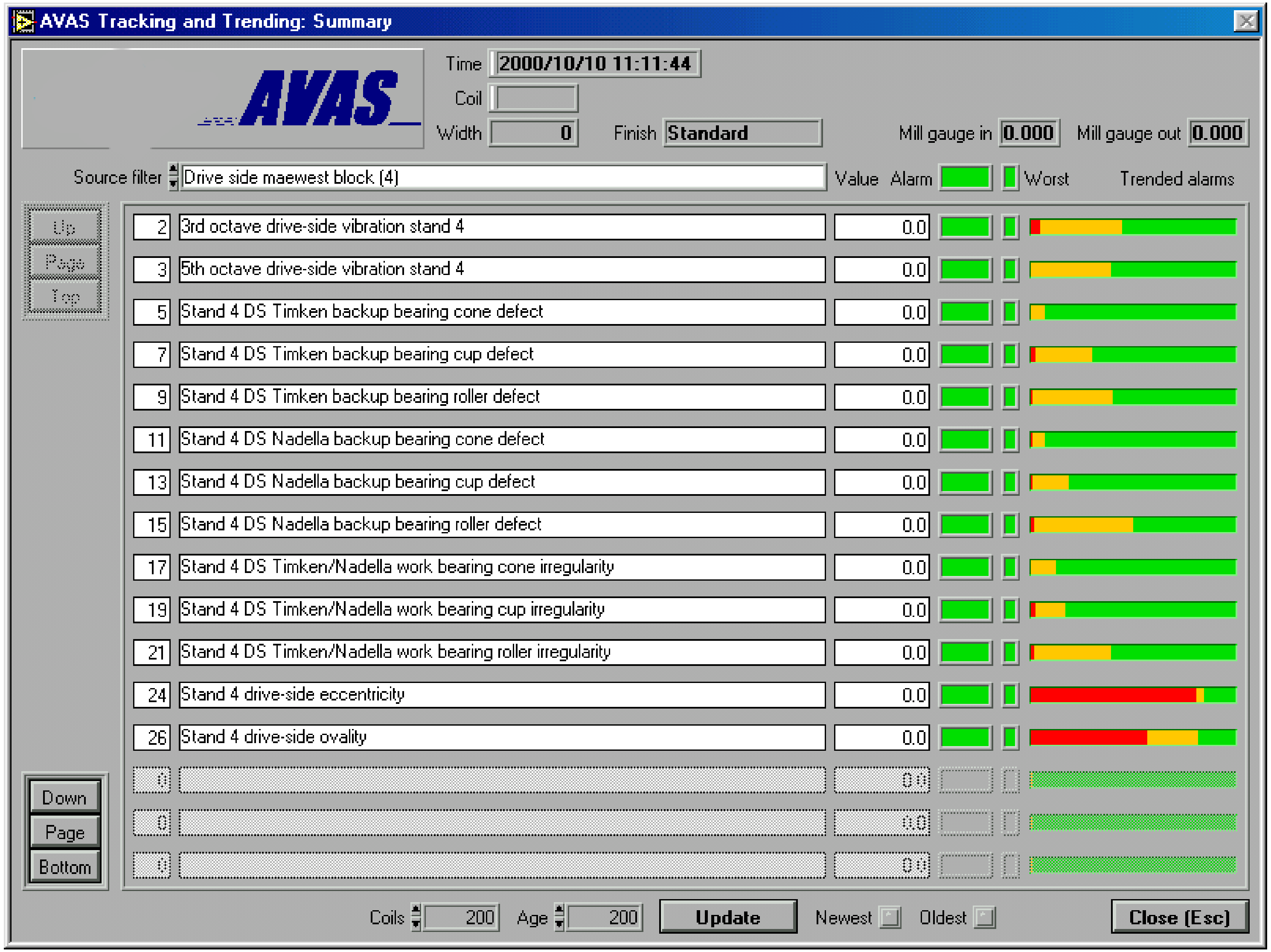


**FIGURE 4 EXAMPLE OF SUMMARY SCREEN SHOWING ALARM STATUS, CURRENT AND PAST, FOR ALL EXCITERS**