

Example Project Plan, Engineering Recommendations supplied with each SENTRY™ System.

Document purpose: This information is for **REFERENCE ONLY** to illustrate the diagnostic detail and capability of the Sentry solution when combined with Horsburgh and Scott Engineering Support Services.

Each Sentry solution, which includes a detailed Engineering Report, is configured to the specific application requirements unique to each customer.

Details of ‘Deliverables’ are in the reference Proposal which does take precedence (wherever differences exist).

The following is a Project effort summary combined with various Conclusions/Corrective actions/recommendations which are included in all Engineering Reports:

Note to the Reader: The effort summary was generated during the Project “kickoff” meeting to ensure Project Management initiatives and efforts were managed and shared. The Project Management Plan was co-developed with the customer and documented as part of the Project Performance objectives. As the project was performed, the document was updated as appropriate to ensure the best solution was reached at the lowest true cost. As the below is an **example only**, the interim, final Engineering reports are not included in this document.

Project Example: Autogenous Mill motor/gearbox drive vibration resolution.

Purpose of the project and project efforts/deliverables:

1. Condition Assessment: Collect (during peak loading) simultaneously sampled real time vibration, data on the drive train for real time on-line condition assessment. The Sentry and associated sensors will have a 5 day data collection cycle before conclusions and action plans can be determined. This integrated system will quantify the condition of the mill, gear box, drive & two drive motors, foundation, sole plate, and provide root cause analysis for the frequent gear/bearing failures. The analysis will utilize the existing permanent mounted accelerometers on the Mill accessible via an existing Junction box.

2. Dynamic Modeling: This same vibration data will be used to build an ODS model (Operational Deflection Shapes: a 3-D “Movie” Animation Illustrating Motion and Deflection) to better understand the mechanical stress on the drive train gear box. Sentry will sample the sensors in real-time (i.e. simultaneously), collect discrete data files and “baseline” trending /alarming for the most severe operating conditions.

This process will provide a true “real world movie model” of all existing forces (maximums, etc.) which will then enable a Predictive Action Plan to optimize Gearbox life.

The creation of the model will illustrate the mill rigidity/flexibility, motor/drive characteristics, vibration signatures of bearings/gears as a function of time AND frequency. This is a very powerful Sentry solution benefit.

It also includes data collection parameters, an interim, final report on the drive train loading and condition assessment. Also included is an ODS model and final analysis report with specific Corrective Action Plans and recommendations.

Each processing Cycle will be sampled and stored to allow remote trending / alarming via the Sentry System. Collection of the signals simultaneously (i.e in real-time) will determine misalignment, mechanical ‘looseness’, metallurgical deformation and out-of-balance conditions of the mill drive train. We estimate an installation time of 4 hours using two personnel. Signals will be monitored, collected, analyzed, alarmed, and stored by the Sentry System.

1. Material/labor/deliverable overview:

1.1 Material Includes: Qty 1 - Sentry 16/8 Channel in NEMA 12 enclosure, up to 8 additional vibration sensors and cables (as required), an Ethernet link is included (assuming customer provides the ‘link’ to their network). The network can provide Speed, Motor Volts and Amps.

1.2 Installation Labor Includes: Connecting existing sensors using temporary wiring and magnets fixed to the equipment machinery for the eight additional sensors. Sensor cables are low voltage and will be routed using existing structure (e.g. cable trays) from the sensors to Sentry located near the controller. No conduit or penetrations are included as they will be customer provided. Two men on-site for four days is provided. This Installation effort includes initial set-up of Sentry software.

1.3 Monitored Signals: The following signals will be collected in real time simultaneously allowing for the capture of the inter-action (in both the time & frequency domain) between the various operating parameters i.e. motor voltage & current, vibration (axial thrusting & radial loading), etc. See sketch No. 1 for sensor location.

1.3.1 Vibration: Vibration data will be collected on 6 Accelerometers positioned on the foundation and motors and 10 additional existing accelerometers mounted to the gear box bearings. The accelerometers will be used to check the condition of the drive components including gear mesh backlash, and phase lag. In addition they will be mounted to each of the bearings to assess their condition.

1.3.2 Motor Current: The drive motor will require a single current output to the Sentry system. We assume that the current output will be supplied by or with customer assistance.

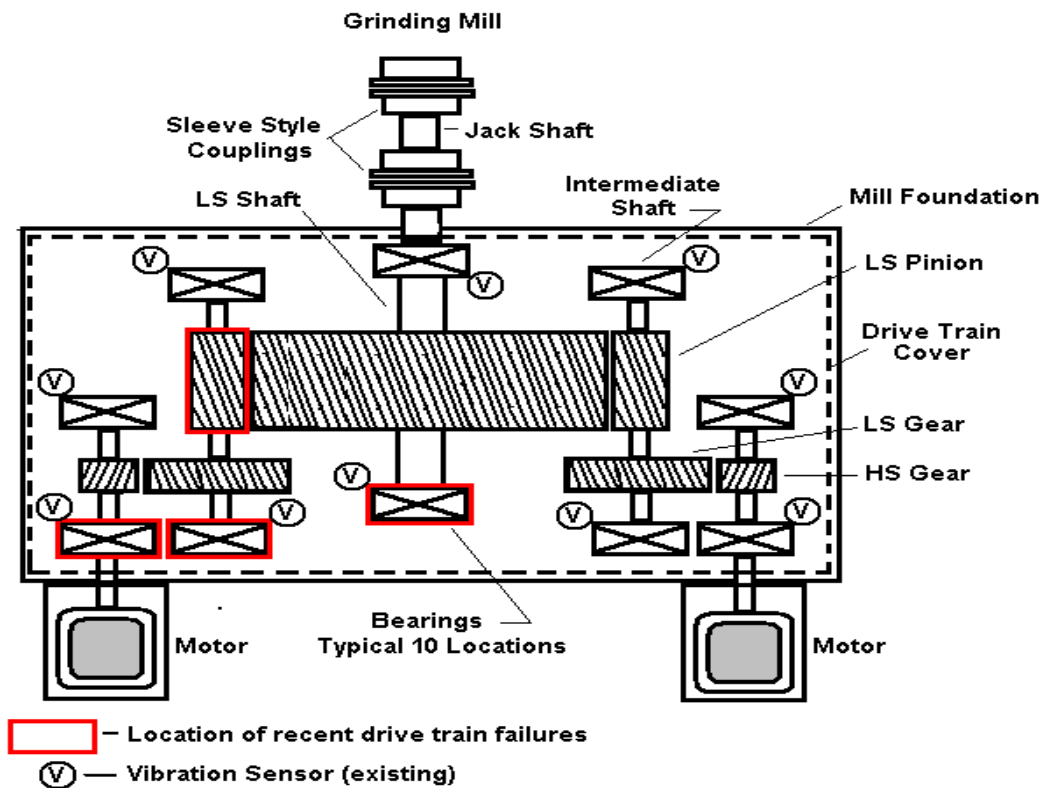
1.3.3 Speed Motor Shaft: Will be provided by H&S via an optical or proximity sensor. The output will be to the Sentry VSA. This speed sensor will require a short shut down (less than 10 minutes) to mount reflective tape to the motor output shafts.

1.3.4 Vibration Sensor Mounting: to be mounted using mounting magnets or mounting pads using adhesive.

1.4 Drive Train Analysis Includes: Multi-Variable display with data files of peak load during monitoring period, recorded variables include: vibration, torque, motor current & voltage, and speed. Condition based portion of analysis will include assessment of all gears, bearings, drive shafts, spindles, and motors using both time domain (waveform) and frequency domain (spectrum) analysis.

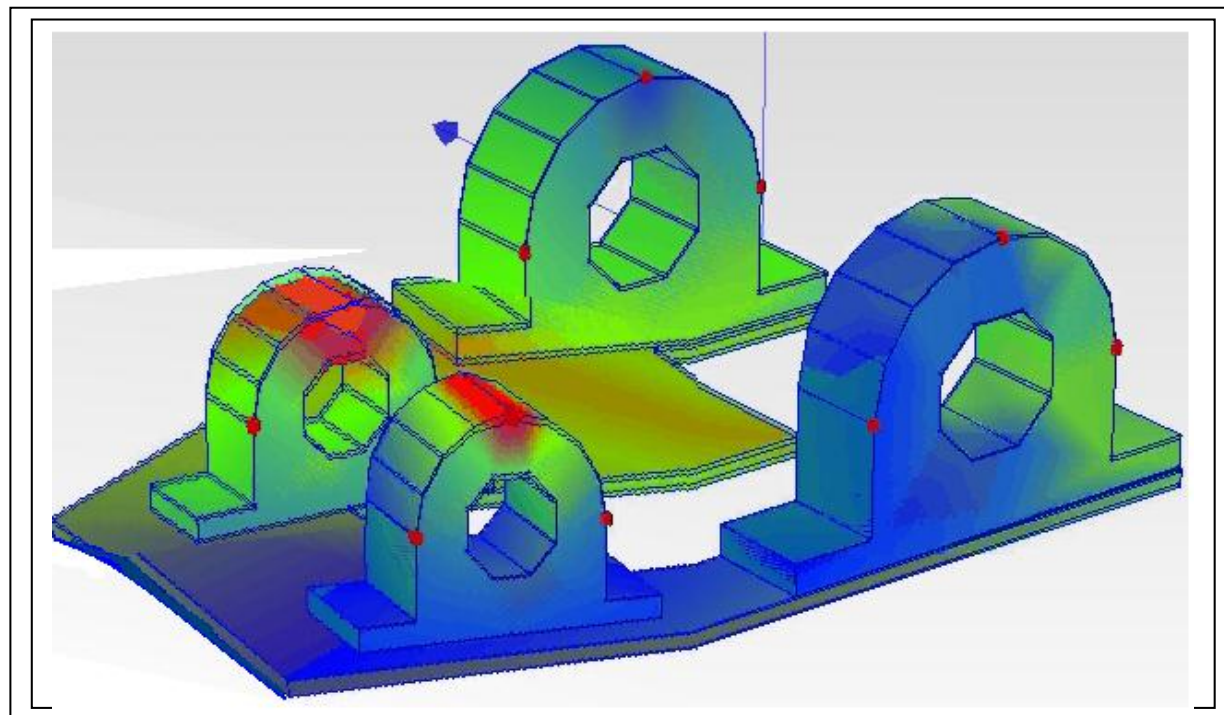
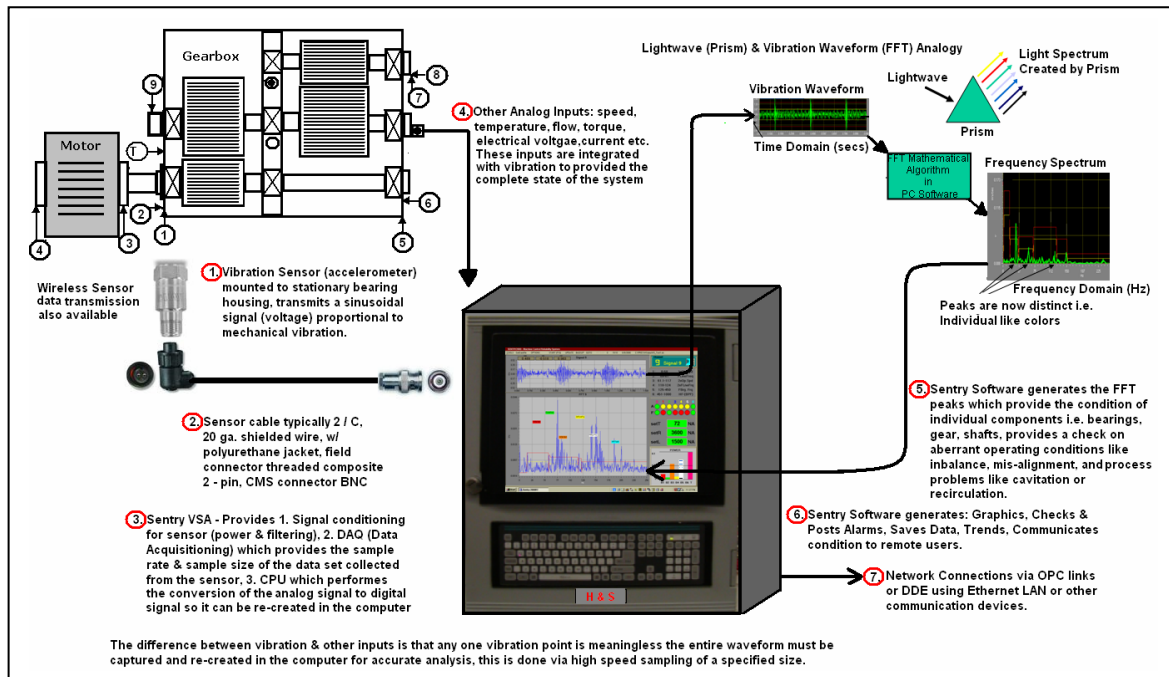
1.5 ODS Analysis Includes: Deflection shape analysis using vibration data. The 3-D Animation model will illustrate magnitude and direction of mechanical forces on the mill, gear box, shafts, housing bearings and gears.

Sketch No.1 shares scope of work which provides typical information on sensor quantity and location. All work and material will be provided based on Horsburgh & Scott standard terms and conditions.



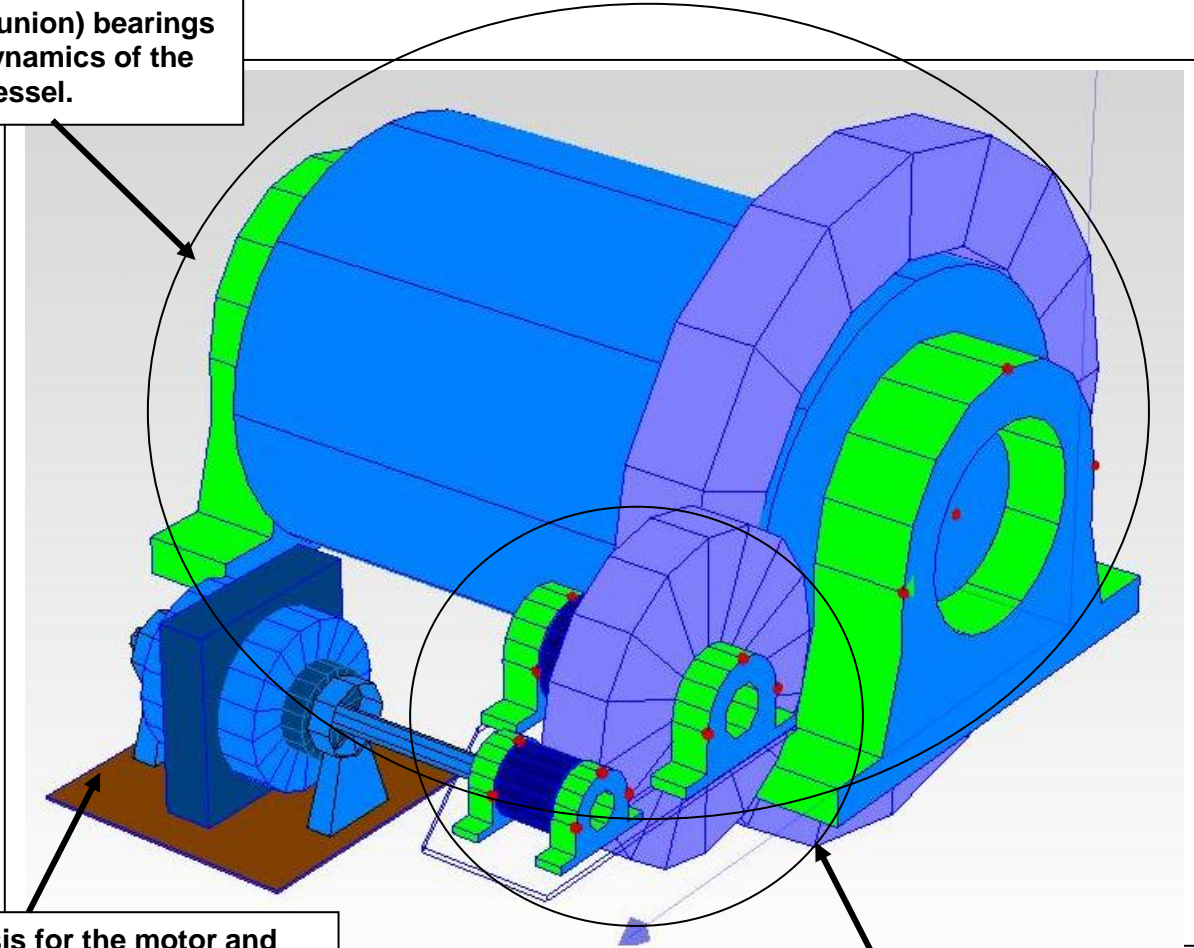
Sketch No.1: Drive Train at Autogenous Mill. Note: Depending on availability, both motor current and motor speed could be added to the vibration data collection.

Sentry Monitoring System common configuration:



Following Sentry start-up, this 'snapshot' was created from the 3-D "movie" that was generated by the Sentry data analysis. It shows the pillow block bearing foundation instability (the TRUE "root cause") which caused bearing defects (the "Effect"), excessive bearing temperatures and premature failure. **This deflection was captured during a peak loading period.** The solution was to correct the foundation instability. Bearings were now reliable and the Uptime, Throughput were maximized.

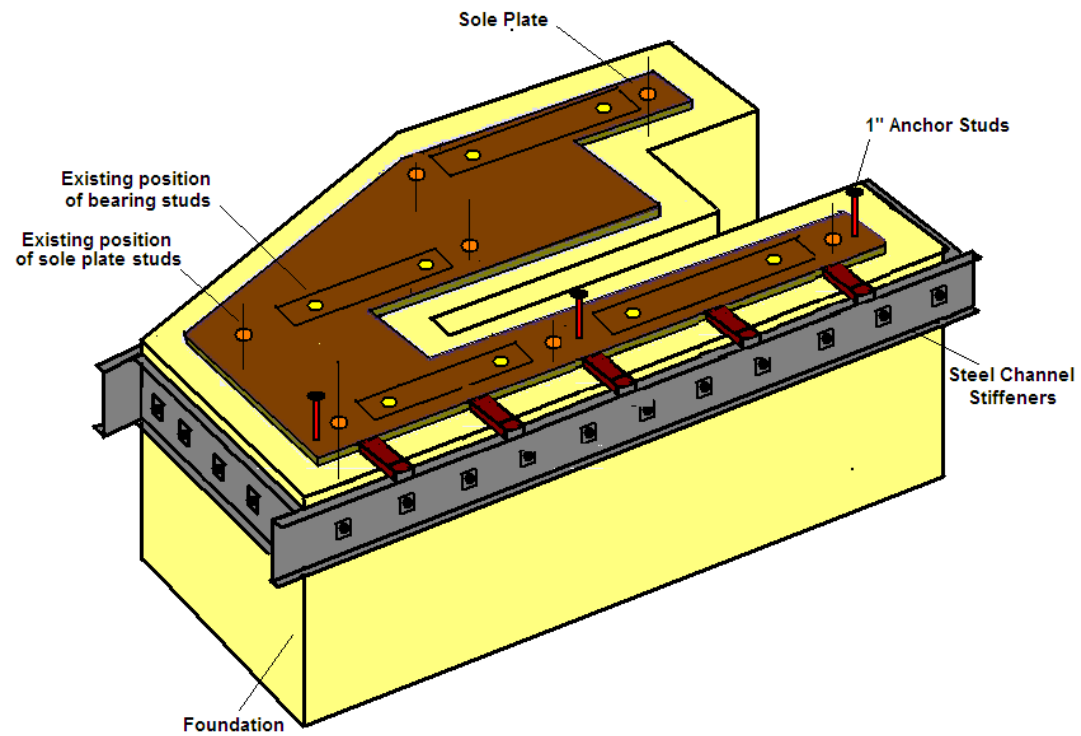
Analysis for the two journal (trunion) bearings and the dynamics of the rotating vessel.



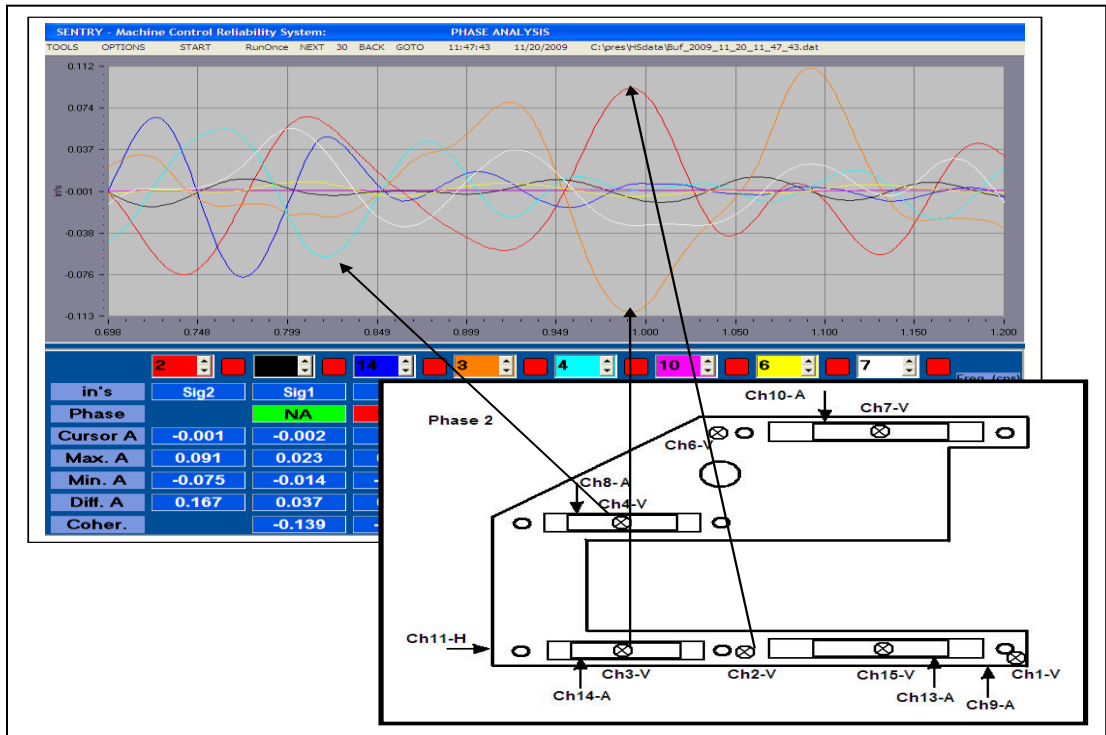
Analysis for the motor and structural support assembly.

Analysis for sole plate, four roll style bearing (mounted to the plate).

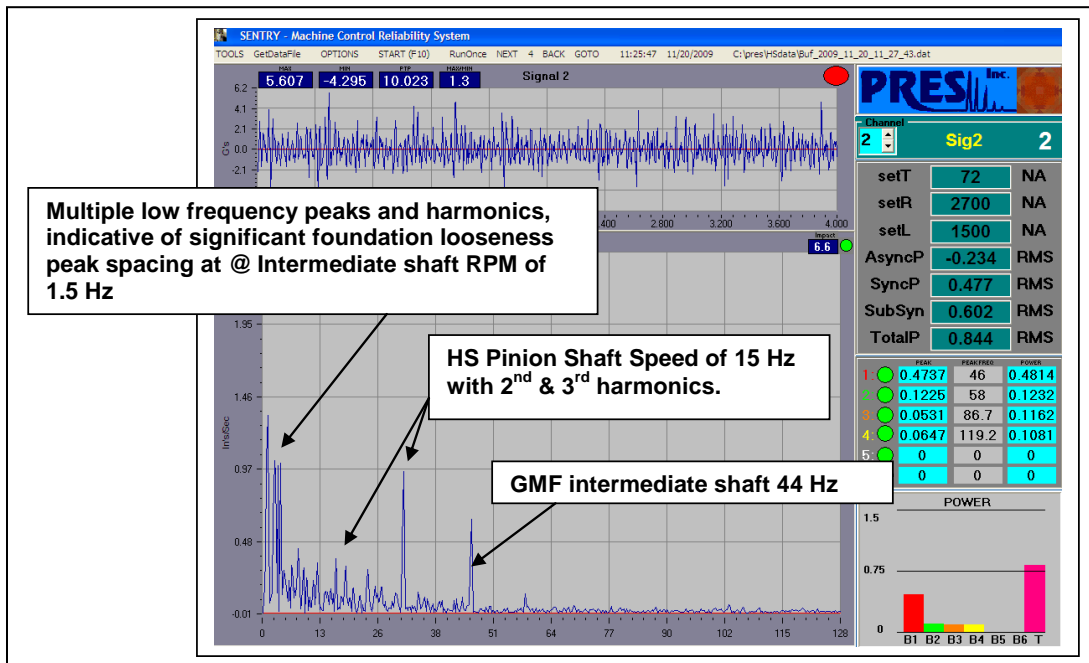
Typical Mill Monitoring & Analysis approach, areas of stress/failures.



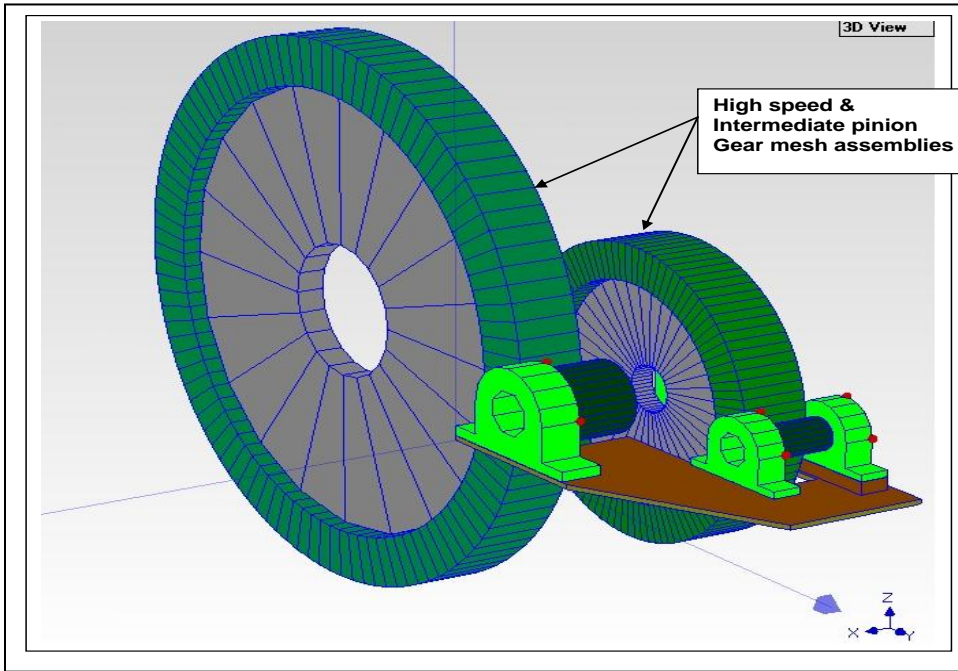
Recommended modifications to Autogenous Mill sole plate and foundation to eliminate “soft-foot” which was the “root cause” of excessive gear wear and bearing failure.



Phase analysis of vibration which determined the separating forces present. This caused excessive bearing temperatures and premature failure.

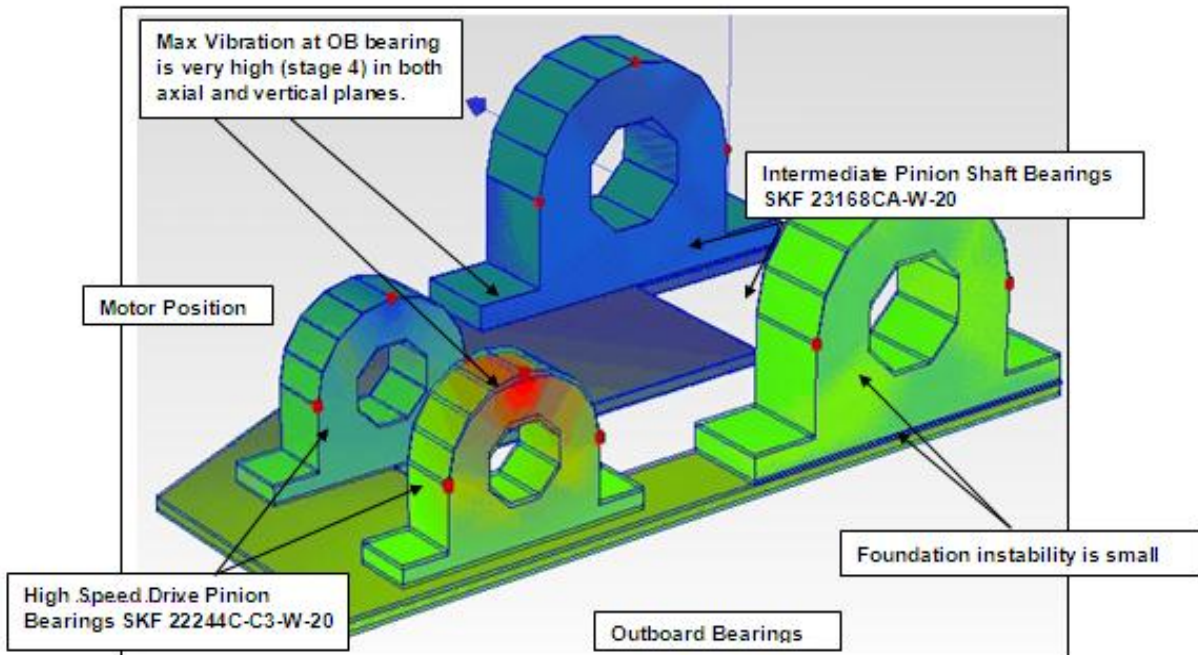


This screen shows magnitude of gear mesh frequencies for both high speed and low speed shafts. Peaks were the result of excessive "looseness".

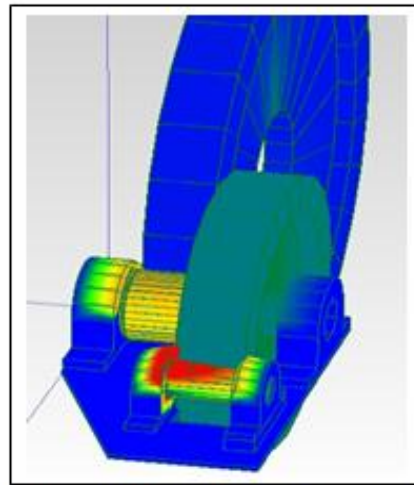
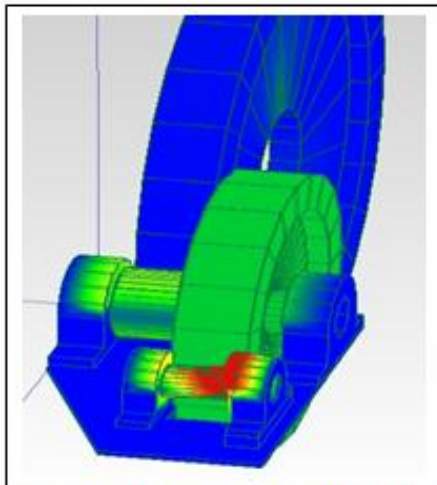


3-D model “snapshot” of an Autogenous mill gear set showing extreme mechanical stressing.

Section No. 3 - Phase No.1 & 2 Analysis Sole Plate & Roller Style Bearings:

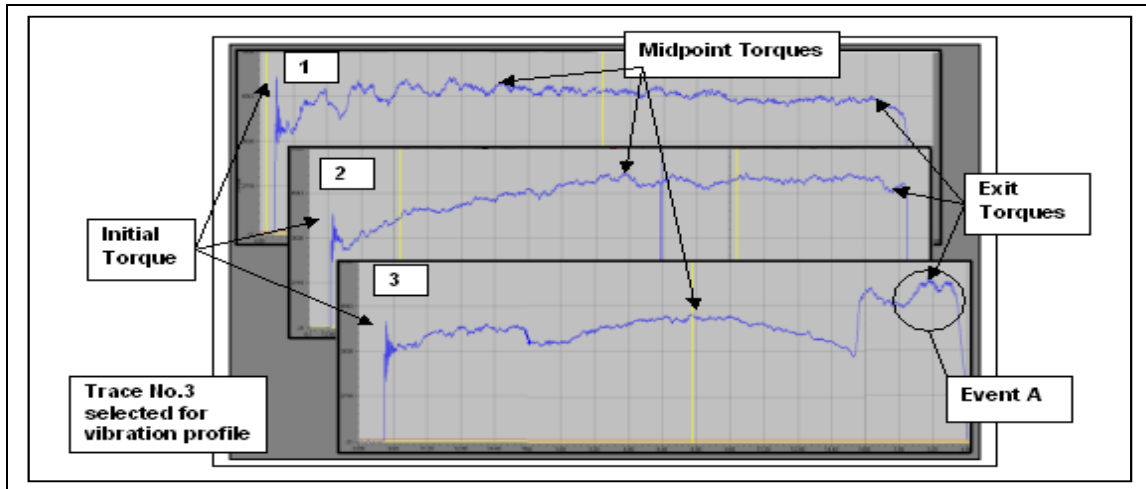


ODS Diagram No.4 Autogenous Mill No. 6 Sole Plate with high speed pinion & intermediate gear roller bearings. As the colors move from blue to red they represent increased motion (vibration).

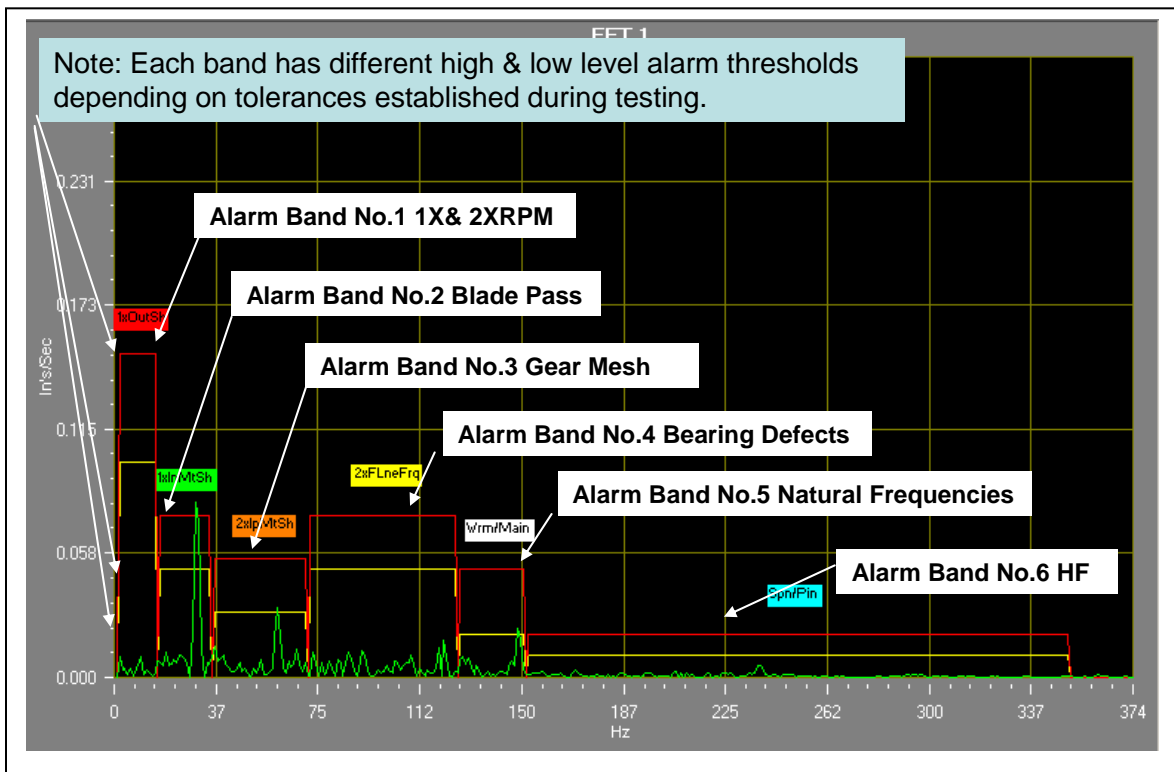


ODS Diagram No.5a & 5b Consecutive Data sets illustrating thrusting on HS bearings.

“Snap shots” from ODS 3-D animation which illustrate how heavy loading results in tooth slippage and thrusting.



Example review of torque profile for maximum load determination. This enables recommendations for higher Mill Throughput.



This data illustrates the Sentry ability to 'Narrow Band' data which enables specific isolation of the true root cause/effect dynamic situation. Specific recommendations and Corrective actions can now be performed.