International Measurement Solutions

# FiNE TUNE

**International Measurement Solutions**

Phase Analysis & Operating Deflective Shape (ODS) Module



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This manual was written by François (Frank) Gagnon in collaboration with René Archambault.

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# FINE TUNE Version 1.0

## 2.0 Introduction

Complex Functions

As a maintenance engineer or technician, you're already using complex numbers on a daily basis. You probably just did not remember it ! Look at any graph : it has TWO components, the X axis and the Y axis. In vibration, most of the time, this means X=amplitude and Y=frequency. Even entry level personnel goes beyond this : a waterfall display uses the same as above, plus a third component which is time related, whether expressed in minutes, days or date. X and Y remain the same, Z=time.

Any vector used in balancing is also composed of an X and a Y, but in this case, we use POLAR coordinates : X= amplitude and Y=angle to map out on a chart. Descartes would be all smiles to see just how much his mathematical musings influence our daily lives : TV, computers, spreadsheets, games, the Cartesian coordinates (X,Y) are everywhere !

2-channel functions imply complex functions. And the most obvious is the collection of a spectrum with simultaneous collection of PHASE components. This type of information may also be used to draw a Nyquist plot, where amplitude and phase VARY because the RPM is changing, and so, plotted on a polar graph and indicating the RPM at a given moment, we draw many conclusions to support our diagnostic work regarding machine behavior.

2-channel is important in bringing back structural information on the REACTIONS of a machine or a structure to the input of a KNOWN force : using a load cell hammer, we measure the force of the impact, the duration of the impact, the phase reaction and the waveform going through the structure, expressed in the frequency domain or FFT. In animating a structure, we may use roaming force, roaming sensor or a combination of both. In relying on rotational forces (and defects) to supply the energy, then we may animate a machine through its **Operating Deflection Shapes aka ODS**, but this is yet another application.

They are close, but ODS just requires FFT (or partial information thereof including but not necessarily limited to first order amplitude), 1X phase (and possibly other orders if more precision is desired and the capacitty to collect and process the information is present), and a network of points which yield a descriptive array of what the machine and its structure may be doing.

ODS, then, is the more complex goal of FINE TUNE !

As a musical instrument needs to be tuned appropriately before the musician may play it, a machine and its structure need to be adjusted to our needs before entering service or when it evolves beyond the best desirable parameters ; an instrument goes out of tune, and a machine accumulates fatigue, confronts varying process demands and generally ages WHEN it has been installed properly from the outset, a condition which is unfortunately not that common !

Failing this process of adjustment, a machine no longer is capable of delivering top notch performance. It degrades ! Energy gets wasted, often in the form of unproductive vibration instead of supplying necessary work !

The adjustment process calls for various techniques enabling the engineer to recalibrate both machine and structure in such a way as to optimize production performance. These techniques, a series of tools encompassing the varied ammunition of the vibration engineer's arsenal, go from the simplest, such as balancing or vibration spectral analysis, to progressively more complex forms of dealing with the problem : time domain analysis, synchronous time waveform averaging, phase analysis, **Operating Deflective Shape Analysis** and finally, all the 2-channel instrument's complex functions !

## FINE TUNE & Operating Deflective Shape Analysis

ODS, for short, is a VISUAL technique, marrying AMPLITUDE and PHASE data so as to show the observer HOW the machine and/or its structure are moving whilst in operation.

This typically involves the construction of a machine and structure SKETCH that we will animate according to the collected data.

Field observation is made difficult because machines operate at speeds that do not enable the engineer to capture the **relationships** involved in the various movements.

ODS grants the possibility of SLOWING DOWN the movement and the capacity to observe the RELATIVE movement of one component versus another.

In understanding the relation between these machine and structure components' movements, we may identify particular problems and arrive at a PROPER modification or solutions of the components.

ODS also EXAGERATES the displacement or amplitude of the movement : very small movements are difficult to perceive, whereas an exagerated movement is readily visible when slowed down to a proper pace !

ODS REDUCES the machine to a simple SKETCH which can easily be observed, as opposed to dealing with the physical dimensions of the machine and running back and forth to and from various reference points while the machine is in operation.

FINE TUNE enables the end user to quickly build ODS templates to animate them once the proper data has been collected in the field.

As any ODS study supposes STEADY STATE, process variations should be altogether eliminated. These would introduce (a) variable(s) which may be part of the vibration problem. Some experience is thus required on the part of the user to determine when process (temperature, load, water column, speed, etc) may or may not be a contributing factor to the perceived problem.

For machines that are called upon to work in wildly varying conditions, maintaining the process variables during a short time to finish the collection of a given data set (defined according to the process variations) will enable the user to compare different ODS !

As a change in process means a change in various loads applied to the machine, an extensive study MAY reveal the nature of an heretofore unseen problem !

## ODS vs. Modal Analysis

ODS is easier to perform and far more accessible than modal analysis. It is, however, not at the same level of sophistication : while ODS applies to observe a machine's workload induced movements,  modal analysis leads to a full structural analysis. As such, ODS is often a viable step enabling better understanding of the machine's performance and the evaluation of feasability or necessity of going onwards to modal techniques.

Modal techniques proceed from the modelization of the structural responses to the application of a calculated or measured force through the concept of mobility whereas ODS remains strictly in the operations generated dynamic loads domain.

## **PHASE** (Time Domain Context)

ODS is particularly useful since PHASE, the relative measurement of HOW (or when) various parts move in relation to one another, generally remains poorly understood. Reliance on this concept will enable an experienced user to determine the relationships involved in the measured vibration BUT a full comprehension and a sound and methodical approach are then necessary. FINE TUNE thus provides an extra tool to play with this concept.

In its simplest expression, the comparison of two parallel linear movements, we find that most people fully understand the concept. More so when the movement is perfectly opposed, meaning that the phase measurement shows a 180 degrees discrepancy.

Phase Fig. 1 / Two identical springs are dropped at the same instant. Their vertical oscillating movements are perfectly synchronized and therefore are said to be synchronous. There is no relative movement.

Phase Fig. 2 / The same springs are dropped at different moments in time. At this point, we need to define a REFERENCE SYSTEM. Since this is a very simple case, the ZERO moment in time can readily be defined as the moment when the first spring (on the left hand) reaches the top of its vertical course.

Phase Fig. 3 / The perfectly opposite movement of the previous example enabled the definition of an ultra SIMPLE system of reference. Here, things get a little more complicated...

## Rotational Movement & Phase

Within the context of a rotating machine analysis, the simplest reference system is the rotation of the machine itself : some EVENT becomes our point of departure, such as the MOMENT IN TIME when a given part of the machine (or something we've added to the machine) passes in a specific point of space...

The former can be the passage of the keyway at the top of the vertical axis ( zero degrees or 12:00 noon). The moment when a tape glued to the machine passes in front of photocell and thus triggers the signal is also acceptable.

NB : the choice of the point of reference is really more one of convenience than an absolute... The important factor is the CONSISTENCY of maintaining that point of reference for all phase readings collected throughout a series of measurements used as a foundation for an ODS analysis.

## Phase Analysis

Phase data remains a crucial turning point in the evaluation of data. As mobility or structural rigidity is not necessarily a constant on all axes considered (we wish !), a little wherewithal helps the expert in separating a mere misalignment problem from a bent shaft, a dynamic imbalance couple generated axial motion from a foundation problem, etc.

The various aspects or specialties of phase analysis, such as balancing, phase analysis, alignment precision fault detection, foundation analysis or bearing housing analysis, are all available under the Preferences button.

The various denominations refer to specific tasks, such as the proper ID of a cocked bearing, a phase analysis detection of a resonant condition, the multi-plane balancing procedure correction of an excessively vibrating rotor, looseness at or near the base, etc.

## AMPLITUDE

Amplitude is noted in displacement, mainly because this measurement is free of a time connotation (unless expressed as a displacement ocurring at a given discrete frequency). From an ODS analysis point of view, the choice of units has little or  no bearing on the end result, as opposed to adjusting one's own "heuristics" or rules of processing the data when considering severity from an RMS context to a PEAK context, or a linear to VdB context.

In the context of structural, base or foundation analysis, one of the most important roles of amplitude (and one of the most neglected) is not one of absolute severity evaluation but rather one of comparison of what is there, and what isn't ! The transmission of vibration or lack thereof is a powerful indicator of behavior as will confirm any pulp and paper engineer used to dealing with sole plates, or any centrifugal compressor  expert dealing with bases.

## ORDER

1 X RPM defines a frequency known as synchronous and also known as FIRST ORDER !

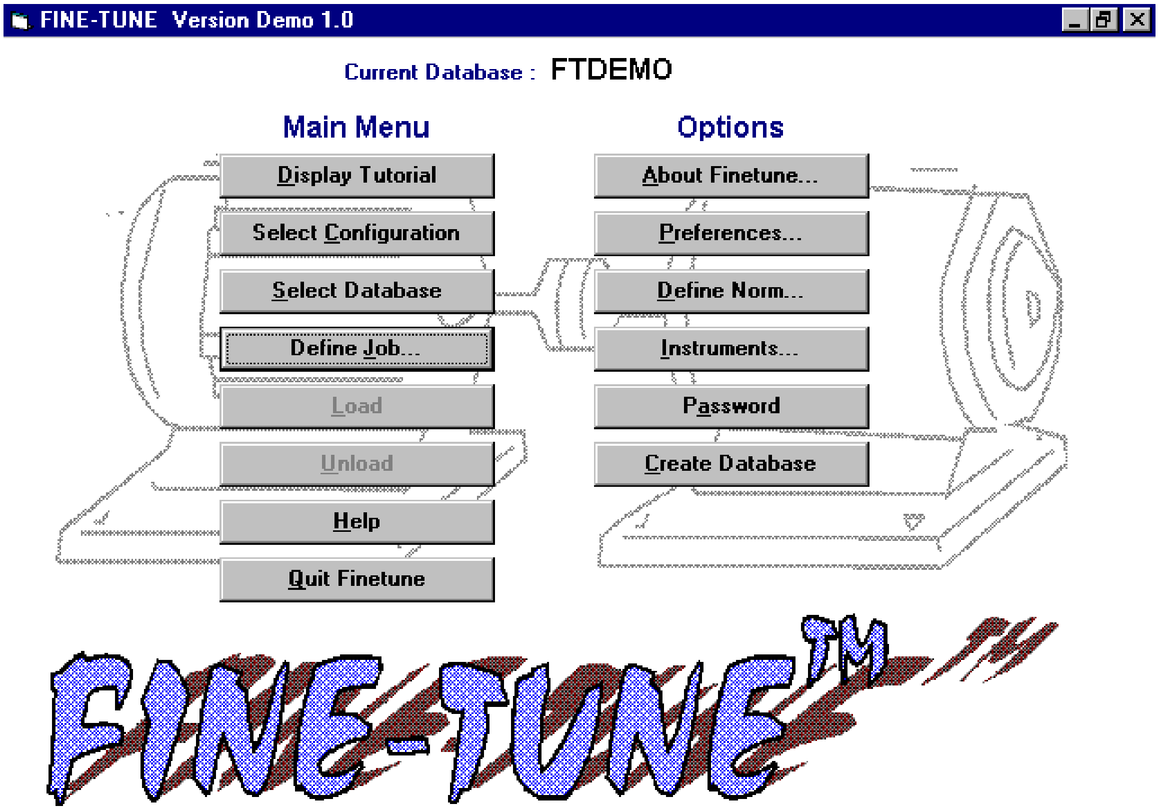
Even multiples of this frequency are known as second, third order, etc, meaning 2X RPM and 3X RPM. The notation is so widely accepted that the typical text will merely express 1X, 2X and 3X without further ado.

When there are various components operating at different speeds, it becomes an ABSOLUTE necessity to include which component is being refered to : MOTOR RPM and driven rotor RPM are rarely equal UNLESS the machine is direct drive.

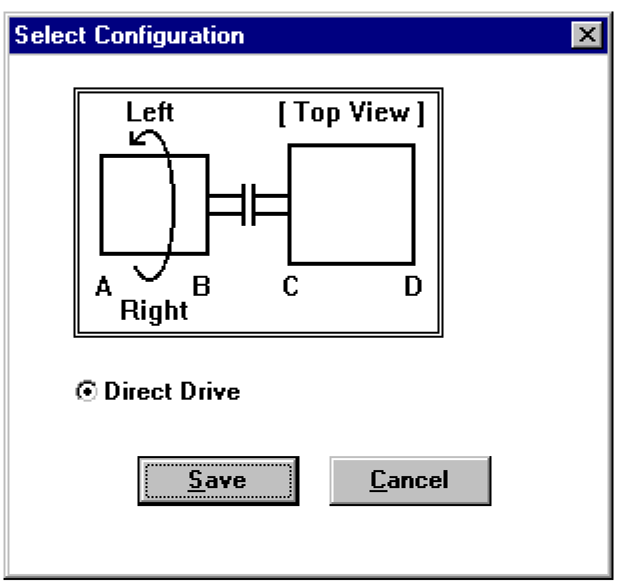
A gear reducer will exhibit several RPMs according to which  shaft is being looked at. Input is equal to motor speed, one  or two intermediary shafts may show significantly lower RPMs as one progresses along the train and finally, the output RPM defines the last components' first order.

These factors are not as yet important as FINE TUNE only offers the basic DIRECT DRIVE configuration, but the comment should serve in other areas of your PM program as well as in the near future (as other FINE TUNE configurations become available).

# OPENING MENU



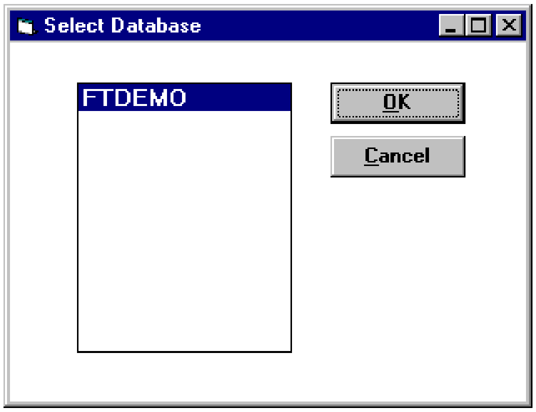

Display Tutorial : at present, a misnomer for a quick overview of the importance and the effects of vibration.




Select Configuration : at present, FINE TUNE only contains the two component machine Direct Drive Configuration.

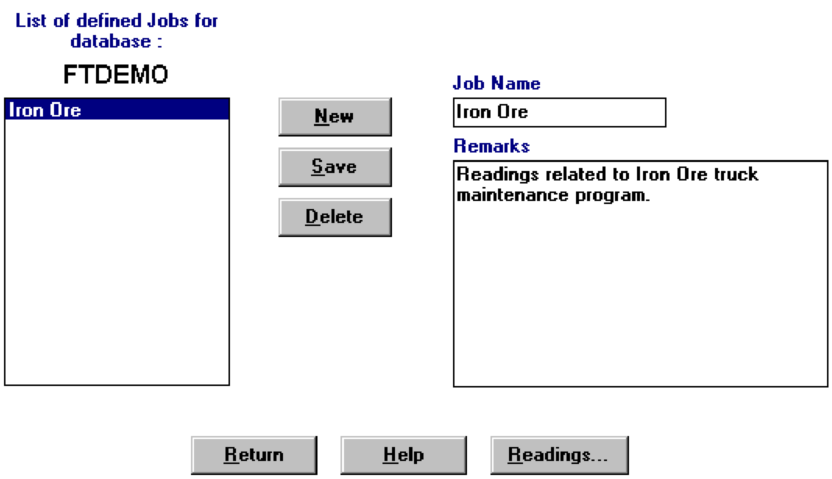
The Direct Drive machine does fulfill expectations for roughly 60+% of machines usually coming under scrutiny.

Other Configurations have been devised and are presently undergoing the final testing stages, the first of these being belt driven machines with two distinct RPM.

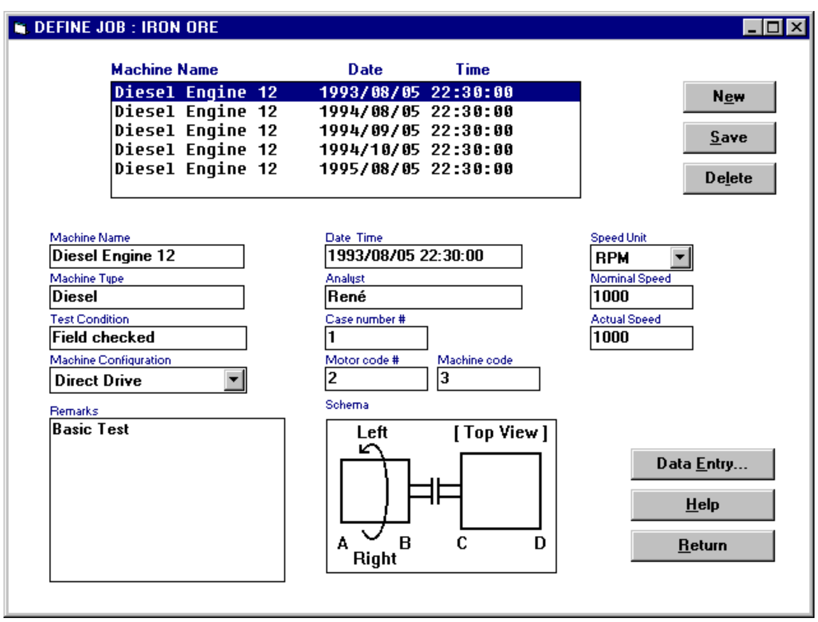



Select Database : straightforward. A reminder : your file or database names should be descriptive enough to facilitate recognition.

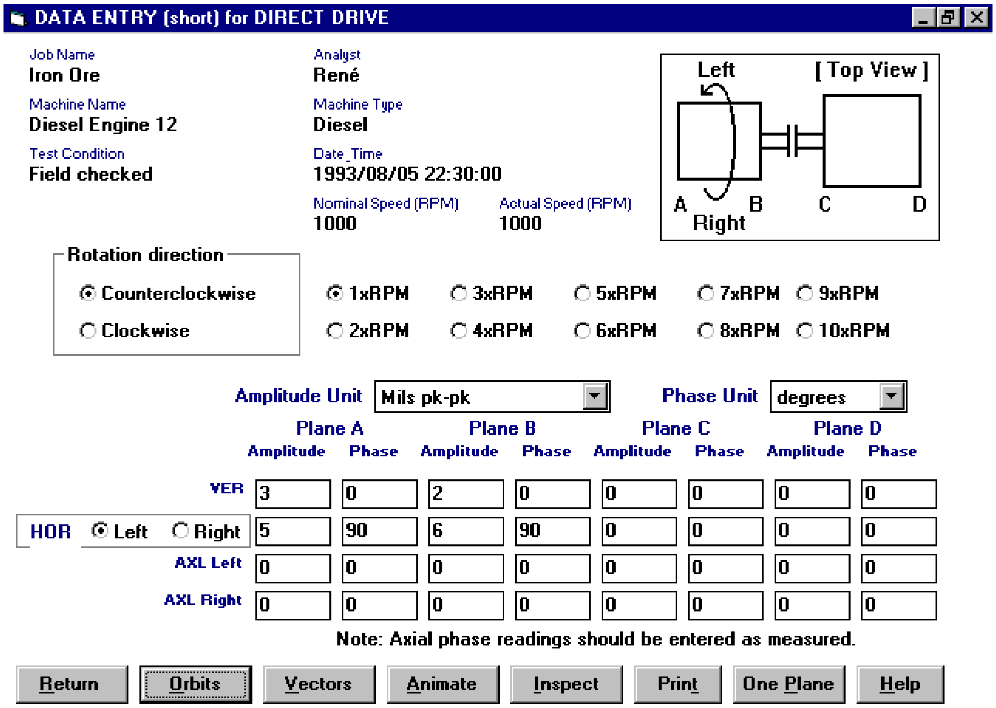
**Define Job** : This function is really the door opener to all of FINE TUNE's interesting function. Where the rest may be management and book-keeping, this is the trail leading to Pandora's box.



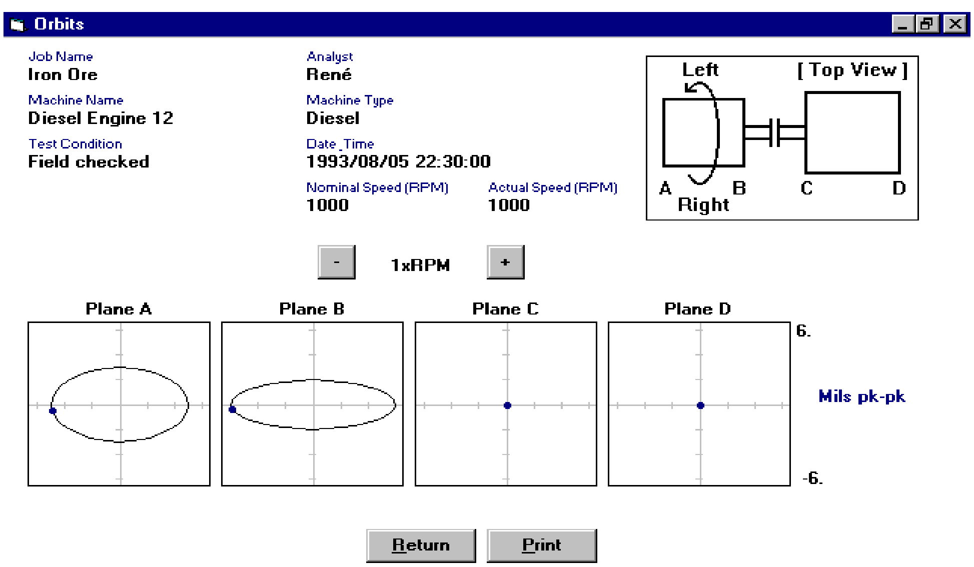

**The READINGS BUTTON leads to all other functions...**



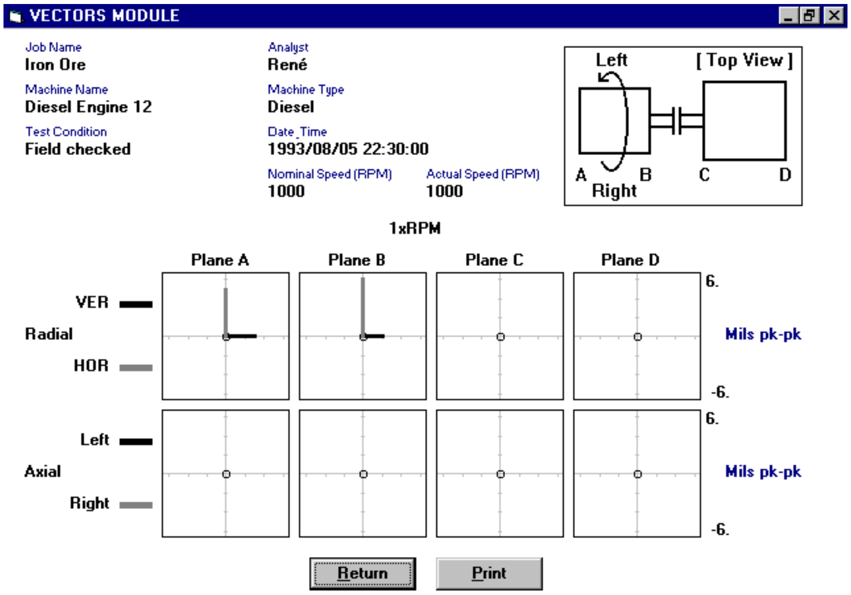
# DATA ENTRY BUTTON




Rotation Direction : any analytical process requires knowledge of the direction of rotation in relation to the “mesh” of measurement points which will be necessary for animation. The configuration merely enables the end user to define this simple aspect which will define many of the reactions when the structure is later animated.

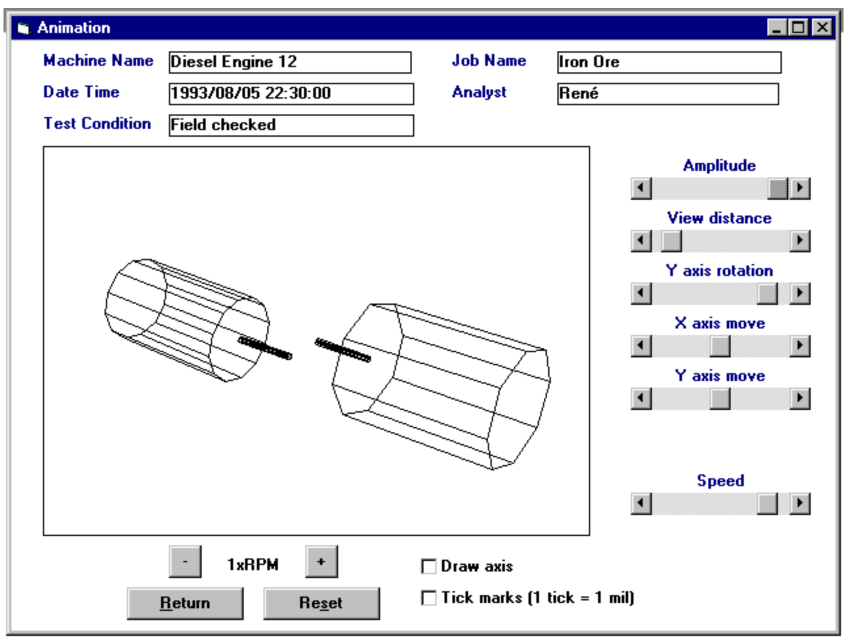



The actual orbits have “live” animated relationships animated before you.




The "Vectors" Module merely expresses the information is static table form.

The user will rarely refer to this section unless balancing, or transcribing data for analysis into a different type of software (supposing incompatibility with FINE TUNE).

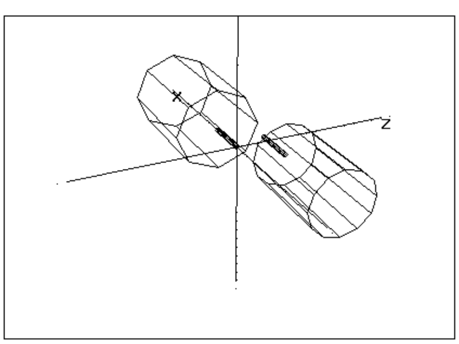



"Amplitude" determines the degree of movement exaggeration for purposes of illustration.

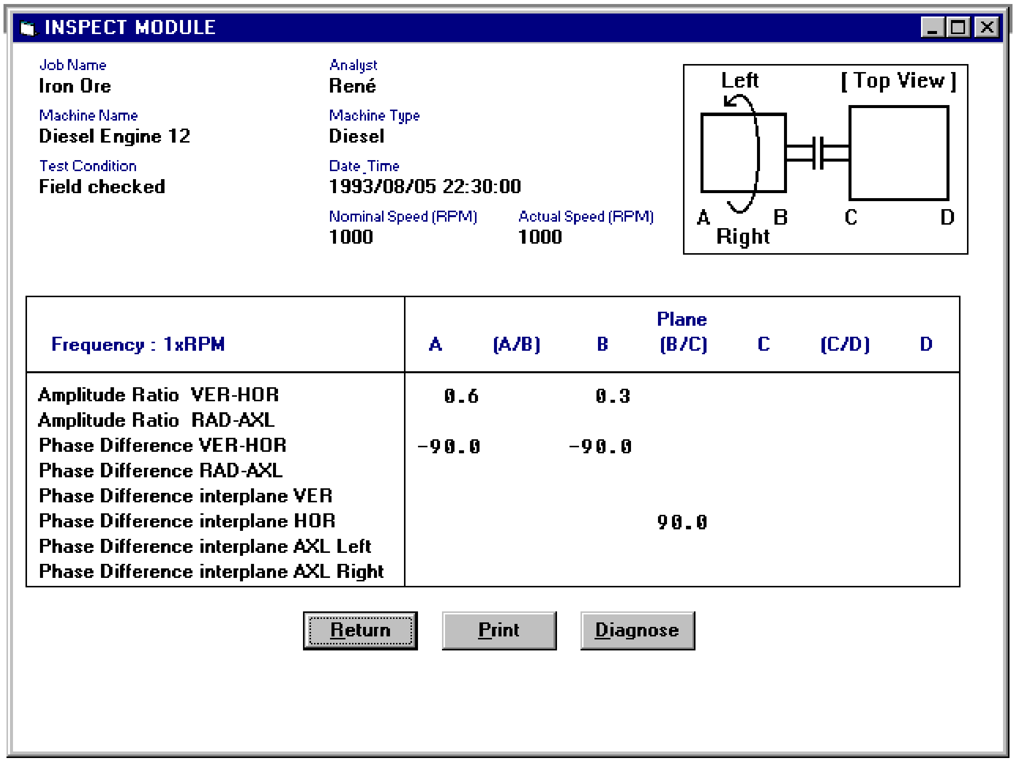
"View Distance" brings us closer or away from the animation.

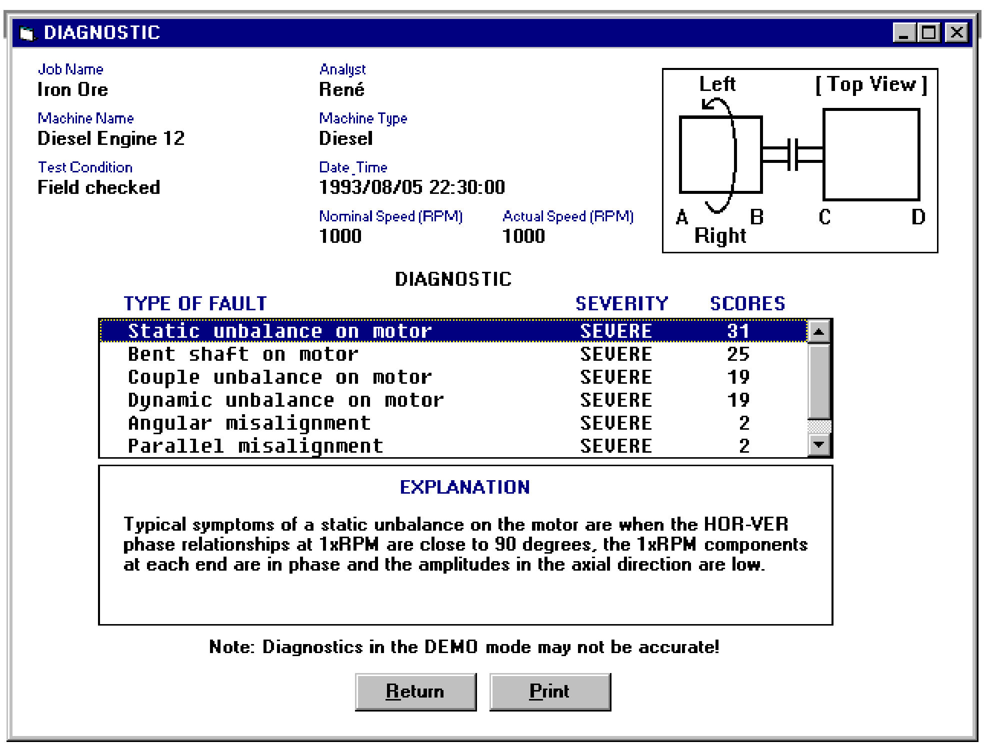
X and Y axis moves displace the animation within the viewer.

Finally, "Speed" controls the rate of movement in animating the rotor(s). NB : no "real time" is involved in this control function.




A mere illustration of a variation on a theme... The view has been rotated to some extent.



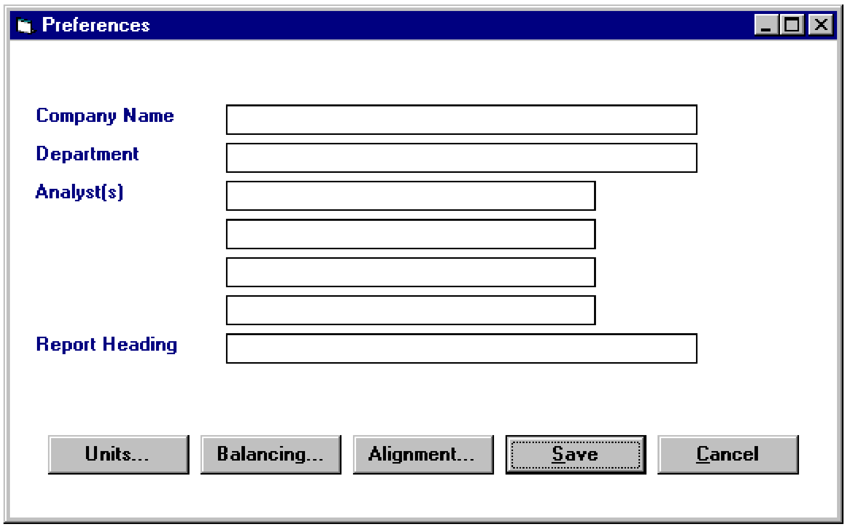

The Diagnostic Module reduces the data to give the user the most likely cause of trouble. The higher the numbers, the higher the probability of ocurrence of a particular fault, based on predefined rules of analysis or heuristics derived from experience. This automated Diagnostic function becomes even more sophisticated when the power of IMS' SEARCH & DIAGNOSE is added to FINE TUNE.

Load / Unload : data according to collector / analyzer in use.

Help : context sensitive Help is forever increasing in scope

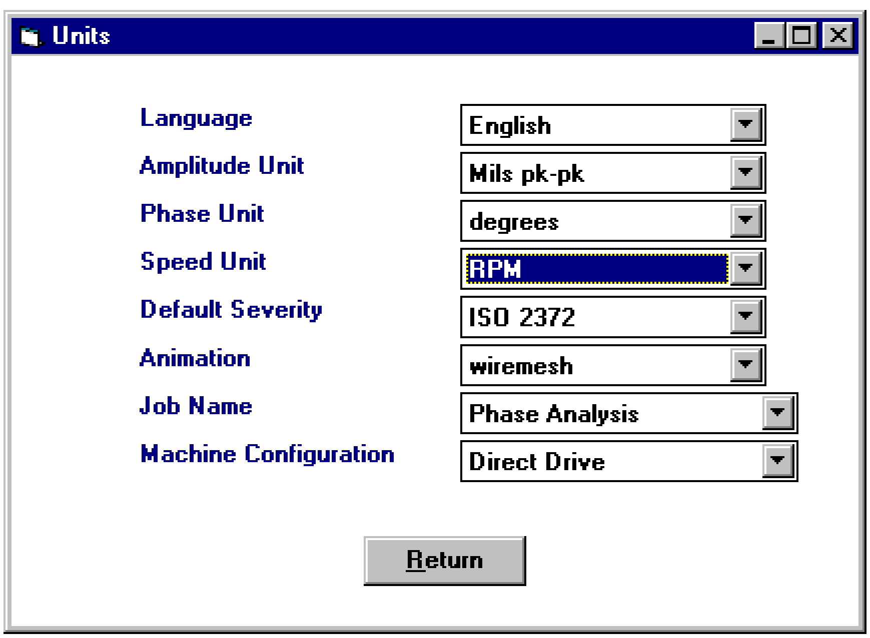
Quit FineTune : Exit ! **About Fine Tune** will give you quick access to IMS coordinates

**Preferences** :



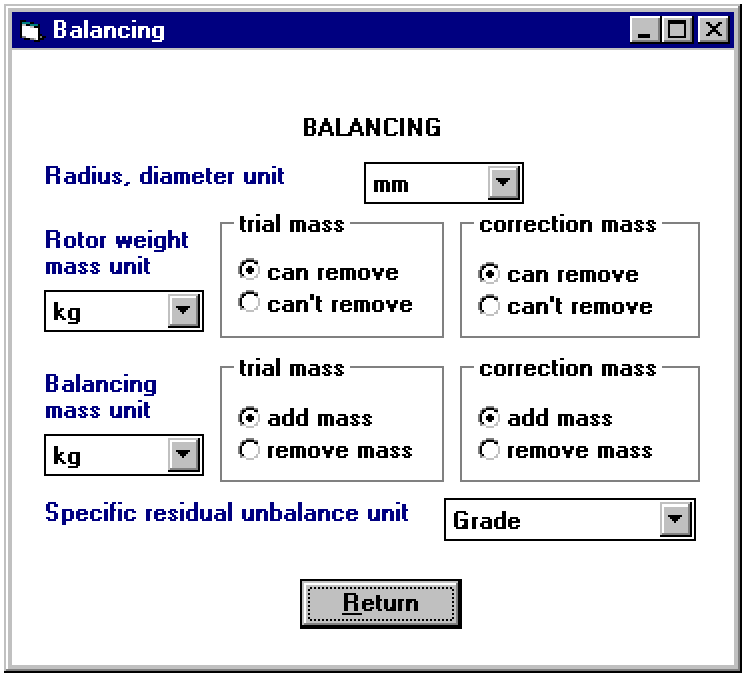

The first "Preferences" screen is dedicated to administrative details.

Comments regarding the use of the various buttons follow.




"Language" gives acces to French, English and Spanish versions.

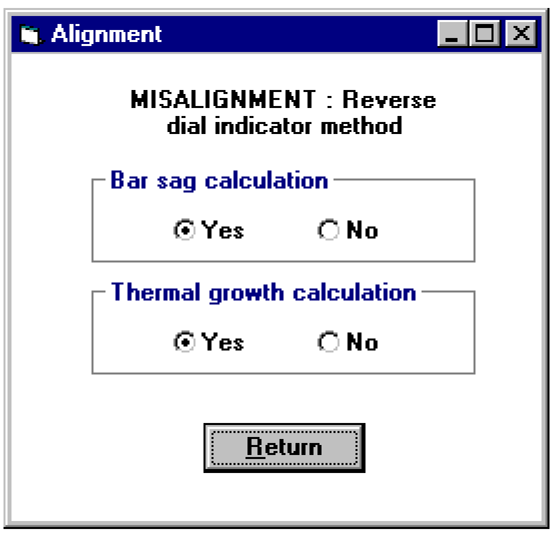
The rest is relatively self-explanatory.




Under Balancing, various preferences (or unfortunate obligations) are dealt with to better document and understand machine behavior during this corrective operation.

Metric or Imperial units are readily available for all functions.

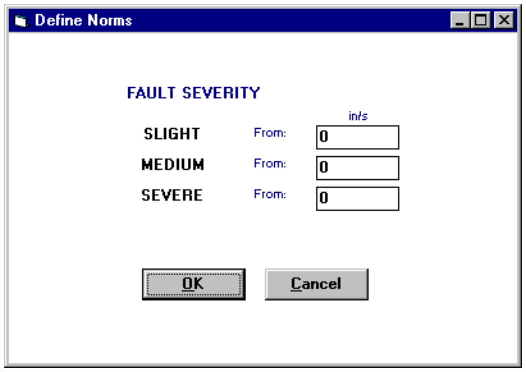
Grade refers to ISO 1940 and to permissible residual imbalance as defined by the user if so desired.




When performing alignment related work, the calculations relating to bar sag, an often neglected occurrence, and thermal growth, when “hot” alignment is impossible, should be documented properly.

Do remember that OPERATIONAL CONDITIONS may impose stresses that will displace certain machine components from their position at rest.

Also keep in mind that for machinery of significant size GROWS into alignment, hence, severe vibration observed at start-up while the machine remains cold should ease up as components reach proper positioning.




**Define Norm** : see also Default Severity under "Preferences"

This particular table enables definition of the specific levels deemed excessive by the END USER. Do remember that it has become standard practice to define CORPORATE and purchasing acceptance testing expectations that usually exceed and go far beyond the established standards.

Instruments : various choices according to the FINE TUNE compatible collector/analyzer in use at your facility.

Password : the end user may herein define a password to limit access to authorized personnel.

Create Database

APPLICATIONS

It is generally believed that in the course of analyzing an excessive vibration problem either detected through a regular PM program or simply perceived by plant personnel, several logical steps will be followed...

0) Establishing proper documentation from day one and properly defining monitoring parameters
Several authorities offer valuable opinions on these topics.

1) ID of trends (if available) and spectra comparison
Analog Overall trends (as opposed to Digital or spectrum energy contents calculated overalls) are of primary importance in predicting machine behavior. Properly defined spectra with significant resolution, as well as DEDICATION to deciphering the collected spectra, is the next crucial step.

2) Phase Analysis
If and when various anomalies are detected, this step may confirm suspected defects. It is otherwise not a scheduled periodic step unless the machine is crucial and unreplaceable.

3) Data Processing & Correlated Analysis
Number, picture and reference crunching.

4) If the diagnosed or suspected behavior falls under the documented list of 1x and/or 2x problems (such as balance, misalignment be it angular or parallel, bent shaft, etc) which appear infinitely more subtle to split into proper categories (as in "assign the resposibility to the proper culprit"), or if base, foundation or structural problems are suspected, you probably need to resort to ODS.

FINE TUNE is made to make your lives easier, particularly in cases where toying with phase relationships proves too tedious, or where no clear certainty is extant as to where or what to collect after the initial collection and analytical steps are concluded.