

# Digital Ship

## Hong Kong Conference

***Condition Based Maintenance***

***What it is, how to start it  
and how to benefit from it***



# Who am I

## ➤ Giampiero Soncini

- 1971-1986 Italian Navy Officer
- 1987-1998 NATO Ship Manager of 2 RVs.
  - ✓ One of them was, and still is, the quietest vessel ever built, with virtually zero noise radiated into the water at 1mt from the hull
- 1998 – 2003 SpecTec/Xantic VP South Europe
- 2004 Xantic AMOS VP sales worldwide
- 2005 to date shareholder and CEO of SpecTec

# Maintenance

- Maintenance is defined as:
  - *“the combination of all technical and administrative actions, including supervisory actions, intended to retain and item in, or restore it to, a state in which it can perform a required function”*

# Preventive Maintenance

- Preventive Maintenance is defined as:
  - “*maintenance carried out at **predetermined intervals** or **according to prescribed criteria**, and intended to reduce the probability of failure or the degradation of the functioning of an item”*”

# Maintenance modes

- So, the ISO/IEC definition of Maintenance points out that there are two main types of maintenance:
  - at predetermined intervals (Planned Maintenance)
  - according to prescribed criteria (on Condition Maintenance, or also Predictive Maintenance)

# Planned Maintenance

- The most common used form of maintenance
- It is based on periodic inspections at given periods:
  - time (Day, Weeks, Months, Years)
  - counters (hours, km, start-ups, shut-downs, lift-offs, landings)
  - periods defined by rules and conventions (Surveys)
- All the above periods have in common:
  - they are fixed,
  - they are unmovable if not by exception,
  - they are easy to measure or determine

# The – of PMS

- PMS provides for maintenance to be carried out, regardless on whether or not the item to be maintained has given any sign of malfunctioning
- On some items, this has a negative impact, and the maintenance procedure can lead to an increase of the failure probability, once the action has been taken

# Enter CBM

- As the term implies, CBM is based on Maintenance carried out on the basis of the physical condition of one or more parameters of the item under maintenance
- The parameters must be measured, regularly, according to specific methodologies

# Most common CBM techniques (ships)

- Vibration monitoring
- Infrared photography
- Oil analysis

**Of the above,  
Vibration monitoring is the  
King of CBM**

# ATTENTION!

- Vibration monitoring is valid for rotating machinery only
- You can't have a Preventative Maintenance Program without Planned Maintenance, while you can have it without CBM
- CBM is a technique which refines, and makes more cost effective, Preventative Maintenance

# Vibration Monitoring

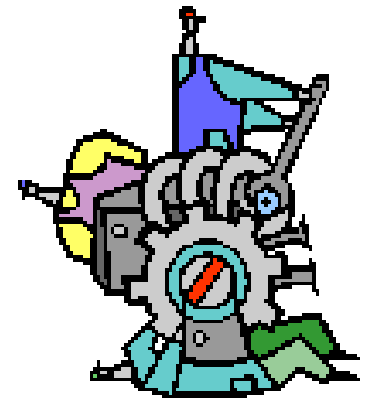
- VM is the technique to measure Vibration levels of a rotating equipment, and comparing the data measured to the status of the equipment
- It requires:
  - following simple but precise rules
  - training and understanding
  - hardware and software
  - money and time

# The rules

- Vibration Monitoring is defined by:
  - **ISO 1925** Mechanical vibration – Balancing - Vocabulary
  - **ISO 2041** Vibration and shock – Vocabulary
  - **ISO 7919-1** Mechanical vibration of non reciprocating machinery
  - **ISO 10816** Mechanical Vibration – Evaluation of machine vibration by measurements on non-rotating parts
  - **ISO13373-1 and 2** Condition Monitoring and diagnostics of machines – Vibration condition monitoring

# If you do not have time...

- Read only:
  - **ISO 10816** Mechanical Vibration – Evaluation of machine vibration by measurements on non-rotating parts
  - **ISO13373-1 and 2** Condition Monitoring and diagnostics of machines – Vibration condition monitoring
- If you really have no time, this one is enough:
  - **ISO 10816** Mechanical Vibration – Evaluation of machine vibration by measurements on non-rotating parts



# But, finally, what is VM

- It is a mechanical phenomena, always caused by an excitation force.
- This force may be externally applied to the object, or it may originate inside the object.
- The rate (frequency) and magnitude of the vibration of a given object is completely determined by the excitation force, direction, and frequency.
- Vibration monitoring and analysis can determine the excitation forces at work in a machine.
- These forces are dependent upon the machine condition, and knowledge of their characteristics and interactions allows one to diagnose a machine problem.

# In other words.....

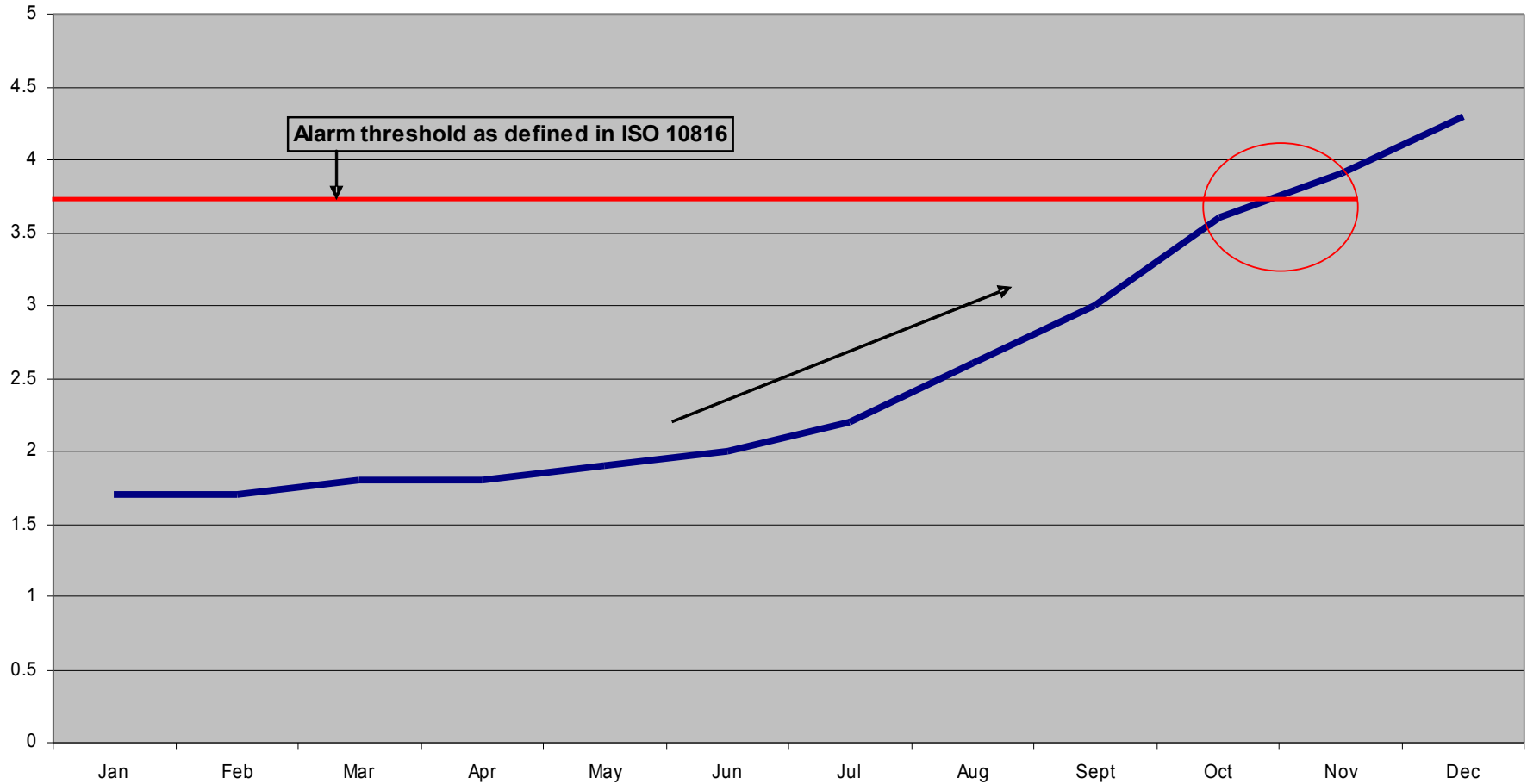
- When I measure vibration in a rotating machinery, I am able to determine, by looking at the measured data:
  - if the equipment has a problem and, if I used Vibration Analysis methodology
  - which type of problem it has (bearing fault, misalignment, unbalancing, cracks, impeller problems etc.)

# Two types of VM

## ➤ Trend monitoring:

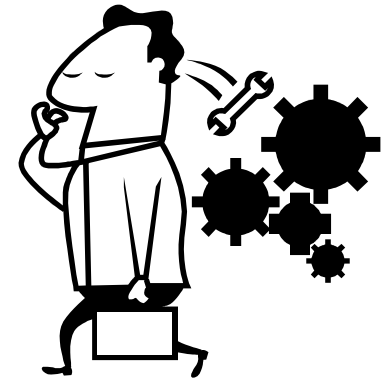
- it makes use of a simple vibration monitoring tool, which takes a simple reading (one number) of the vibration level (an average generally from 10 to 1kHz)
- I can compare this reading with the thresholds set in ISO 10816, and determine if the equipment is ok or not
- BUT: if there is a problem, I can't say what it its cause

# Trend monitoring



# How do I practically do it?

- I buy the equipment
- I identify the items to be measured
- I prepare a route (i.e. a sequel of items and points to me measured)
- I insert the route in the software (and I plan the measurements in a PMS such as Amos)
- I take the readings:
  - Green=good
  - Yellow=ahi
  - Red=Houston, we have a problem



# An example.....

**The ST-101 goes beyond the idiot light approach of traditional hand-held vibration overall RMS meters.**

Green and red bar graph segments show acceptable/unacceptable representations of machine vibration.

The bar graph displays indicate vibration levels based on Acceleration, Velocity and Displacement measurements.

Simple patterns on the bar graph displays aid in the identification of underlying machine problems such as unbalance, misalignment and bearing wear.

In addition, a numerical display allows the user to log these readings for the purpose of historical data and machine condition trending.



# But....

- If I do not know what is wrong, what do I do?
  - well, you perform the inspection as it would have done with a “normal” PMS
  - the difference is that I open the equipment **ONLY** because I know that there is something wrong, not because I have reached a given number of running hours.....
- This means less openings of equipment, lower costs, better efficiency

# Is it easy?

- Yes, yes, yes
- But, like anything related to proper equipment maintenance, it requires:
  - attention in how the measurement is taken (repeatability of measurement: same working conditions, same methodology, same direction, same tool, at same intervals)
  - to be constant in using the system

# What if I am so good that I want to do more?

Enter **Vibration Analysis!!!!**  
The Mother of all CBM!!!!



- It allows understanding on what is the cause for the high vibration level recorded, so you know exactly what needs to be done
- Easy? No! It requires understanding, training, precision but more than anything a comprehensive Database construction: each piece of equipment must have its Characteristic Frequencies calculated, which is easy but time consuming....

# Bearings frequencies

- **Outer race frequency**

$$(F) \times (n) \times (R1) / (R1 + R2)$$

- **Inner race frequency**

$$(F) \times (n) \times (R2) / (R1 + R2)$$

- **Train frequency**

$$(F) \times (R1) / (R1 + R2)$$

- **Ball frequency**

$$(F) \times (R1) \times (R2) / (R3) \times (R1 + R2)$$

- **Where :**

F is the basic frequency

n is the ball number

R1 is the inner radius

R2 is the outer radius

R3 is the radius of the ball

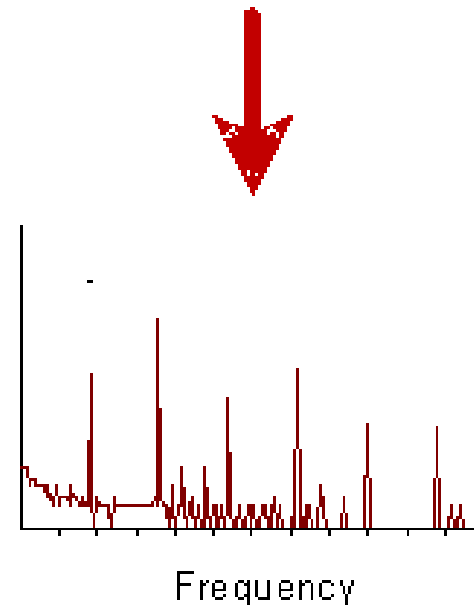
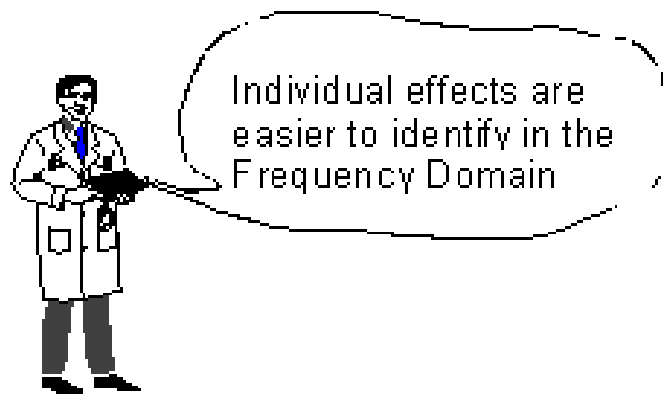
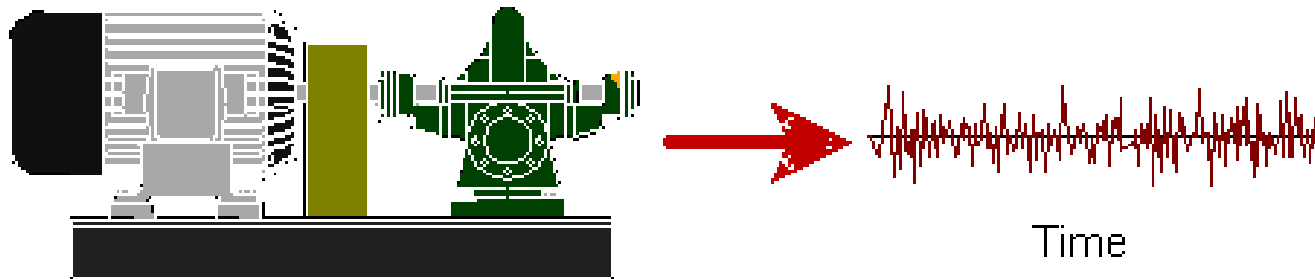
- **And the following conditions apply :**

fixed outer ring

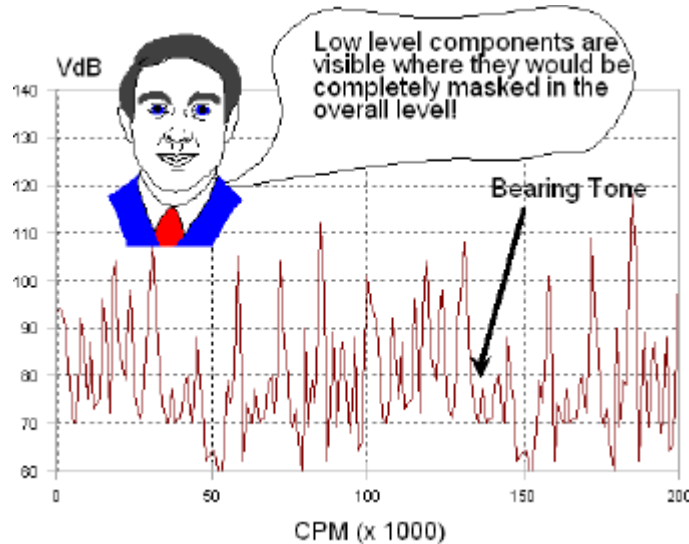
the angle of contact between the ball and the ring equals 0.



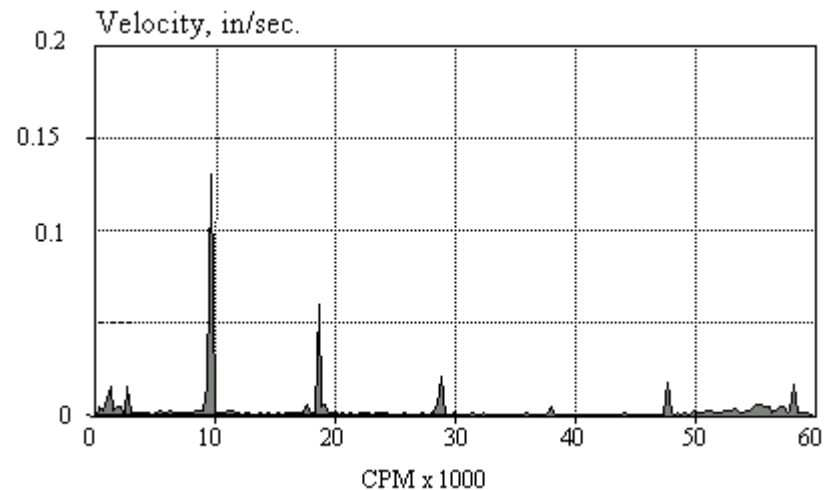
# The Analysis



# The Time domain vs. Frequency domain



Thanks to Mr. Fourier, 1768-1830



*Any physical function that varies periodically with time with a frequency  $f$  can be expressed as a superposition of sinusoidal components of frequencies*

# The peaks

- Each peak that I can read in the Frequency graphic, represents a characteristic part of the equipment
- If the peak tends to increase in time, it is a clear sign that the associated part is having a problem
- Normally, it is fairly easy to detect problems on:
  - bearings
  - impellers
  - rotors
  - unbalance and misalignment of couplings

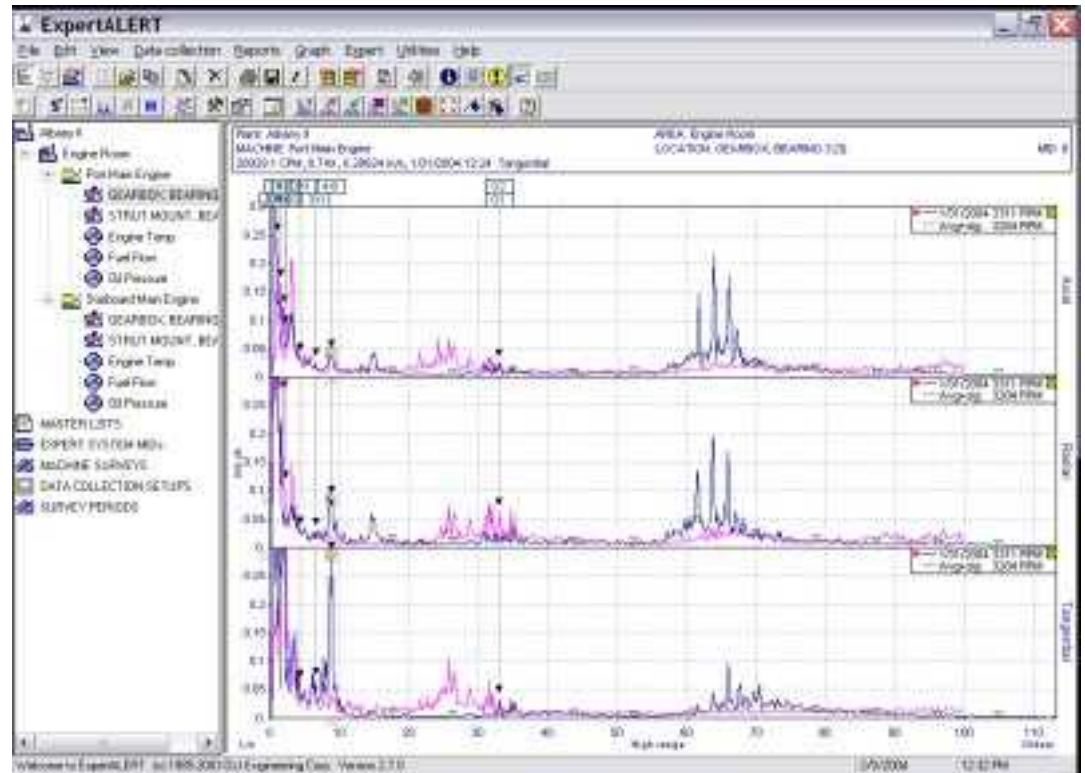
# Table of the Main Failures and their Connected Frequencies

PROBLEM	DOMINATING FREQUENCY	DIRECTION
• Unbalance	RPM x 1	Radial
• Misalignment	RPM x 1	Radial and axial
• Bent Axle	RPM x 2	
• Damage to Bearing	Typical bearing freq.	Radial and axial
• Damage to Bearing	High frequency 1 - 5 kHz up to 60	
• Damage to Gears	RPM x N°. teeth	Radial and axial
• Component Looseness	RPM x 2, at times 1/2 o 1/3 RPM	
• Belts not under Tension or Damaged	RPM x 1,2,3,4	Radial
• Turbulence and Cavitations	RPM x Nr. blade	Radial and pump or turbine axial
• Electromagnetic Effects	RPM x No. blades	Radial and axial

# How I take the readings

- As for Trend monitoring, but it would be better to have a magnetic stud, or a screwed one, than a pointer
- The equipment to be used is normally more bulky and the software more complex to use

# DLI equipment



# Final considerations

- VM can be done, but it requires that you fully understand what it implies, and that your staff is trained and instructed on what to do and on how to read/interpret the data
- If you want to do it, start with Trend Monitoring. If this works well, move to Vibration Analysis at a later stage, or subcontract it to an external company
- Trying to implement VM with Vibration Analysis at the very beginning, with changing crews, is a waste of time and money

# My experience

- Not a single bearing failure in 13 years
  - but I had a very steady crew
  - all vibration analysis done by myself
  - measuring belt driven compressors was a challenge
  - no influence from main machinery



# Remember

- If you use Vibration Monitoring, you'll have very good results in Maintenance
- But you must always start with Planned Maintenance, because this is where it all starts, and you still have to plan your routes and your measurements
- Amos links with CBM, in order to differentiate between PM and CB activities. It reads the alarm signal and activates the repair Work Order, with relevant instructions

**Thank you for  
your attention**

