# Rolling Element Bearing Acceptance and Life Testing (BAT)

(UK Patent # GB 0219584.0)

Prof. Dr. Ahmed Elkhatib

Prof. of Machine Dynamics and Diagnostics
Faculty of Engineering, Alexandria University, EGYPT

**Abstract.** The Rolling Element Bearing Acceptance Test (BAT) includes, the testing Methodology, the Testing Apparatus and the Software that are used to predict the Relative Bearing Life (RBL) from the results of a non-destructive, impact hammer test of the bearings. These results are to be taken from a well known procedure of modal parameter identification and extraction using Vibration Analyzers, hammer, and response transducer. The Important feature of (BAT) is its capability of obtaining Relative Bearing Life of bearings (new or used) which are to be tested together with a known life bearing called (Reference bearing). The results of tests can compare the life of any tested bearing to the life of the Reference Bearing. The software, hardware(s) and Methodology are explained in figs 1,2 and 3 together with the description and procedure.

## Introduction

The invention relates to Rolling bearing acceptance testing using Model parameters Resulting from Impact hammer Testing (Dynamic Non-destructive Testing) of the freely supporting bearing under Test.

The purpose of the invention is to correlate the dynamic properties of the tested bearing to any faults in the new or used bearing (Due to Material, Manufacturing or super Finishing Processes) that will affect the Life of the bearing when in use.

## The invention is composed of three parts

1. Methodology of the Test.
2. The Testing Apparatus.
3. The software that correlates the Modal parameter of the bearing to its Relative fatigue life.

Bearing life has been the Main concern of all manufactures and users of Rolling Bearing from the beginning of their invention till now.

Many Methods are proposed to calculate the bearing life of these bearings, non of which proved to be accurate. Due to the so many parameters that affect the bearing life (especially Fatigue life) Premature (sudden) bearing failures always occur, that seriously affect the use of these bearings both economically and safety wise. On the other hand Premature change of the bearings before the end of their claimed life also represent a big economic Loss.

## Bearing Life Testing

Due to the nature and complexity of this type of bearings no one bearing of a certain type can be expected to have the same life as other bearings produced by the same manufactures on the same machines at the same time on the same batch. Add to this dilemma, the errors expected in the mounting of the bearings, and their care during use. Hence at last when the bearing prematurely fails, their will be no one to be certain to blame.

To overcome this difficulty, which may lead to misconduct in the trade of bearings (which is a very wide market internationally), an accurate acceptance test is a must. This test must, in addition to investigating the different parameters of the bearing must produce a quantitative value of the bearing life for each bearing under test either absolute or relative to a known life bearing.

A test of this kind must be simple, accurate and cheap. This invention introduces a brand new acceptance testing Methodology based on the bearing fatigue life and presents two types of apparatus for testing and at last a software for transforming the results of the dynamic tests into bearing life indices.

The basics of the invention are depending on Modal testing that will need the presence of vibration analyzer (2-channels FFT at least), any analyzer in the market can fulfill this requirement.

The bearing under test is to be freely supported either using Method (A) represented in fig. A or Method (B) represented in fig.(B) and in either support the bearing will receive several blows (at least 4 blows) from an instrumented impact hammer (used in conjunction with vibration analyzer) and the results of the bearing response to these blows are taken via a vibration sensor (Accelerometer) attached (by wax) to the outer ring of the bearing. Each of the value of the strength of the hammer blows and the responses are fed to a separate channel of the vibration analyzer. The vibration analyzer (equipped with analysis software) will produce the Transfer Function of the bearing under test this transfer function represents the DNA of each bearing. To get accurate results the transfer function is monitored by a corresponding value called the coherence function (both functions are produced by the vibration analyzer). Values of transfer function at Resonance that corresponds to a coherence value of about (0.990) or more up to (1.000) is considered accurate. Values at coherence less than (0.99) should be discarded and the test repeated. This is taken care off in our invented software (BAT). This software taken automatically, the values of the modal parameters for accurate tests (Modal frequency) modal transfer function at resonance, and Modal damping) and correlates then to a value of bearing life that can be compared to the corresponding value for a given reference bearing (known to be of accepted life). The software (BAT) will produce a report for the modal parameters of all tested bearings (of same type) together with the reference bearing and will also produce the Relative Bearing life index, considering the bearing life of the reference bearing as unity and compares the values calculated for the bearing life of each tested bearing with that of the reference bearing to categorize each bearing according to the ratio of its bearing life value to the reference bearing.

If this technique is used as a quality control test at the end of batch production line of bearing of a certain type and dimension at a bearing manufacture facility, absolute bearing life values can be obtained by applying the test for each produced bearing at the end of the bearing assembly line and obtaining the bearing fatigue life value using (BAT) then one bearing of the batch is taken for an actual running test (under given conditions) until it fails.

The actual life of this bearing is thus correctly known. This bearing can be considered as the reference bearing and absolute lives of All other bearings in the batch can thus be easily determined. Hence each bearing can be marked with its actual absolute life under the tested conditions.

The bearing consumer can thus have an awareness technique that given then accurate values of bearing life for each bearing they are going to purchase.

Thus this invention can be used either as an acceptance test or a quality control test.

## Procedure of Work

## A. Manual Testing (Fig1):

1. The Reference Bearing (Bearing recommended to be acceptable or of known life value) is to be hanged vertically, using an elastic rubber band, to the rigid support.
2. An Instrumented impact hammer (fitted with line drive amplifier and a force transducer) is to be used to strike the outer race of the bearing with ***four*** (4) repeated light impacts in a any chosen direction at any chosen point. The value of the impact signal is to be taken from the hammer to channel (1) of (at least) ***Two*** channel Vibration Analyzer.
3. The response signal of the bearing to each hammer blow is taken through the ***accelerometer*** attached (by bees wax) to a point on the bearing at opposite side of the outer race (opposite to striking point). This accelerometer is connected to channel (2) of the Vibration Analyzer.

4. After ***averaging*** of the results of the 4 strikes, the analyzer will show the ***Transfer Function*** of the bearing represented as represented in a fig.4.This ***Transfer Function*** will contain the ***modal parameters*** (Modal frequency, Modal mobility, and Modal damping) for the first mode of vibration that will be ***extracted*** by (BAT) software.
5. Steps 1-4 above are to be repeated for ***All*** bearings to be tested.
6. BAT software will make the necessary calculations and will produce a report containing the modal parameters of all tested bearings together with their expected lives relative to the Reference Bearing.

## B. Automatic Testing (Fig2):

1. Each bearing is to be clamped on the PVC collect rested on the bearing carriage which is moving (without friction) on the air pad.
2. The motor is to be switch on, this will cause the bearing carriage to move a way from the hammer carriage.
3. In its way, the bearing carriage will press the limit switch 1 which will release the motor power and will send the bearing carriage for- word to impact with the hammer tip situated on the other end of the air pad
4. While the bearing is striking the hammer, the bearing carriage will press limit switch 2 which will energize the motor again to pull the bearing carriage away from the striking position.
5. Steps 3,4 are repeated many times (4 or more) governed by the counter circuitry given in fig.3 to average the results.
6. The switches and the motor drive circuitry are given also in fig.3.
7. Same procedure of signal detection, acquisition, Modal Parameter calculation and relative bearing life calculation as in (A) above, is used (step 4 to step 6).

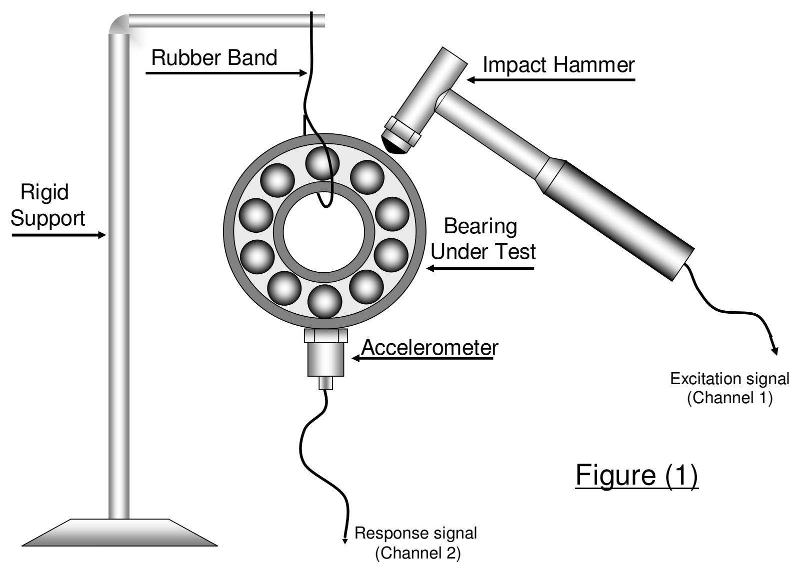



Figure (1)

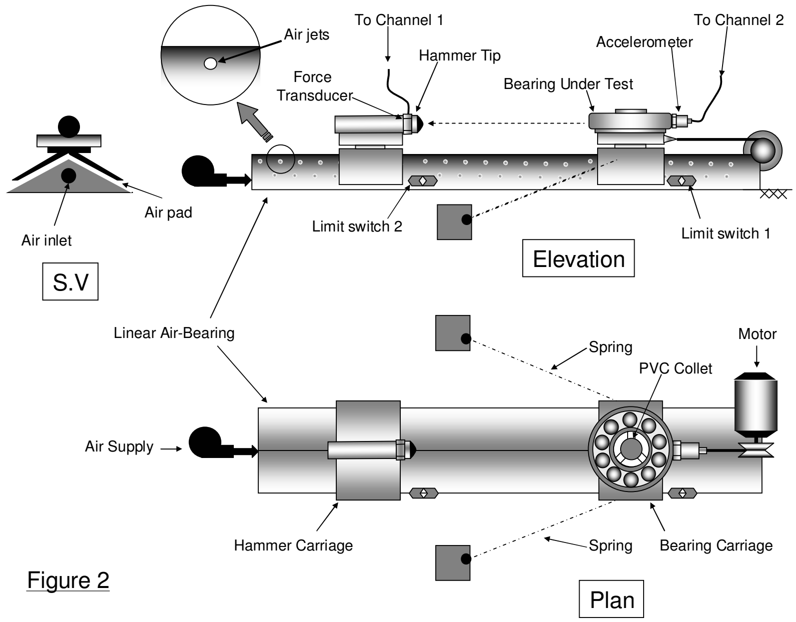



Figure 2

## Control of Bearing Carriage Motion

### 1. Devices used for motion control

#### a. DC Motor

The DC Motor is connected to the bearing carriage mechanically by a string and pulley system at the end of the air pad

#### b. Limit switches

Limit switches are used to determine the bearing carriage position. The first limit switch (1) is positioned at the beginning of the carriage stroke. When the carriage is released the switch will generate a stop signal to stop the motor. The second limit switch (2) is positioned at the end of the bearing carriage stroke .At this point the bearing will strike the hammer and the switch will generate a start signal to start the motor and pull the bearing carriage back to the initial position.

#### c. R-S Latches

R-S Latches are used to reshape the pulse and eliminate any disturbing noise that may affect the control pulse.

#### d. Toggle J-K flip-flop

Toggle J-K flip-flop used to toggle the pulse that controls the operation of the motor (ON-OFF).

#### e. Transistor:

Transistor is used to amplify the J-K flip-flop output current.

#### f. Normally Open Relay

Normally open relay is used to operate the motor.

### 2. Devices used for repeating the motion

a. Divided /5 counter
b. Seven segments display
c. Reset circuit

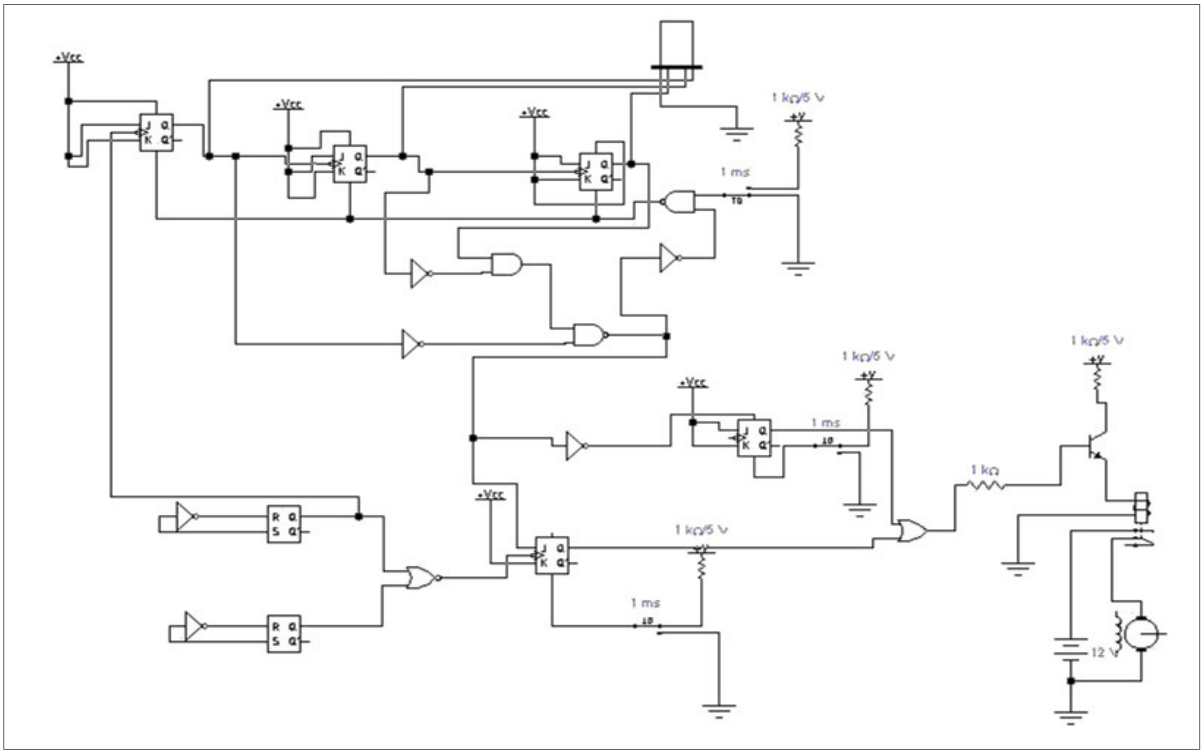

+Vcc
+Vcc
+Vcc
1 kΩ/5 V
+V
1 ms
1 kΩ/5 V
+V
+Vcc
1 ms
1 kΩ/5 V
+V
1 kΩ
+Vcc
1 kΩ/5 V
1 ms
12 V

Figure (3)

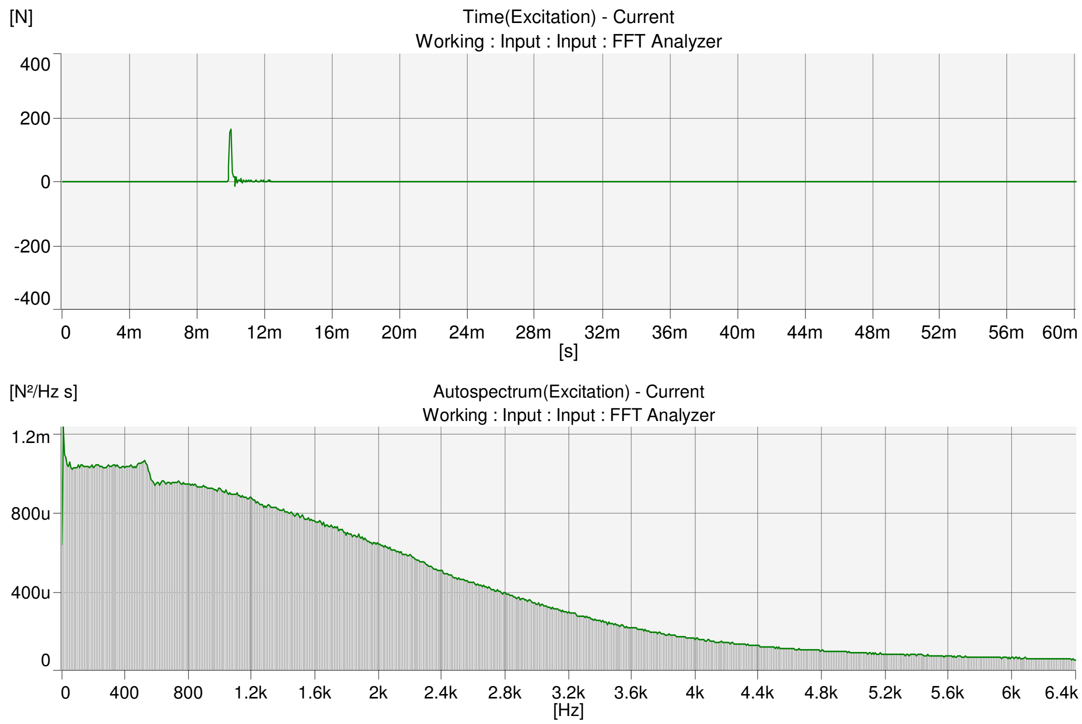



Figure (4) time wave form and frequency spectrum for the applied impulse.

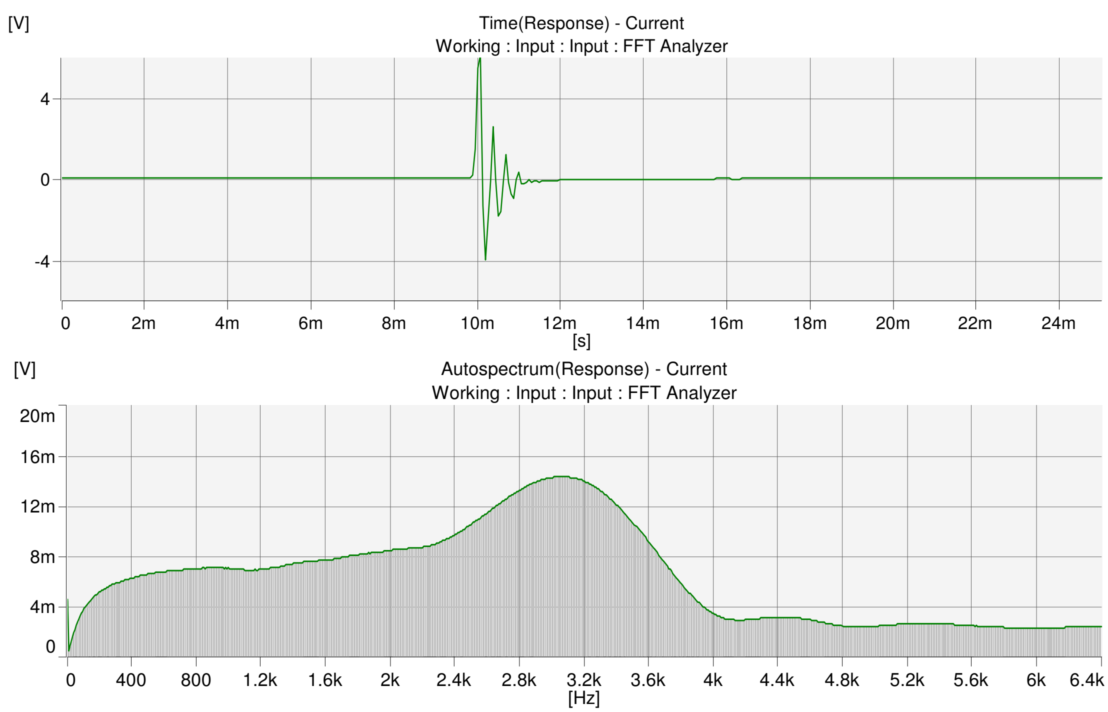
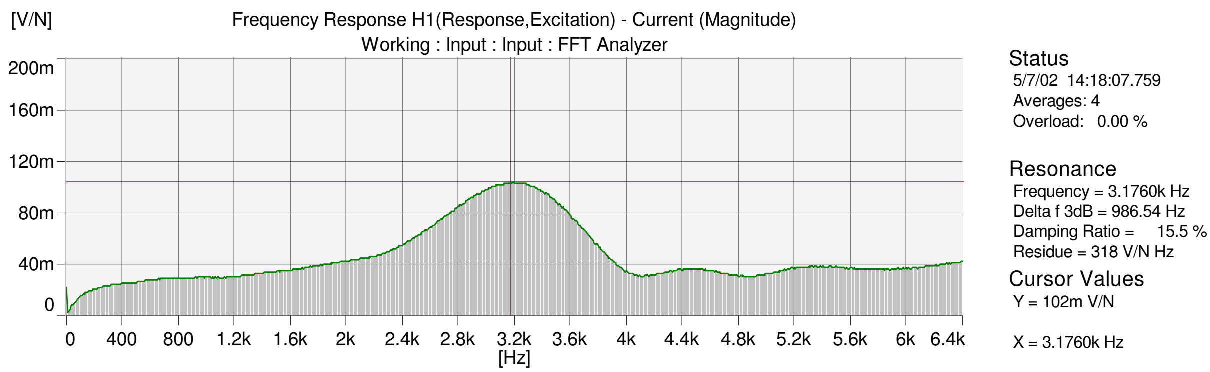
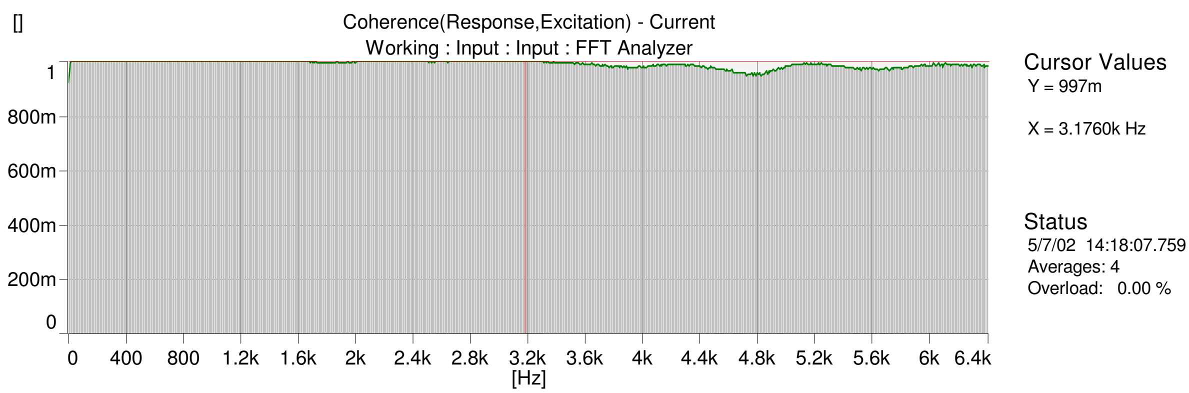



Figure (5) time wave form and frequency spectrum for the bearing response.




Fig(6) frequency response function and coherence function.