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Publication

Quality Control Measures for Auto- mated Acoustic Resonance Testing Systems

Overview

Acoustic Resonance Testing is suitable to identify defective items in the automated production environment. Testing criteria are caused by physical properties of the items, the natural frequencies and natural vibrations. This contribution considers the innovative approach of setting-up the testing system by means of statistics on items produced. That approach abdicates on the traditional teaching concept which is characterised by the use of (unreliably) pre-sorted good and bad items, but takes advantage from the (mostly) correct assumption, that majority of the items manufactured are good ones; some accompanying quality assurance measures are recommended.

Introduction

The acoustic resonance testing (ART) is a technology that has gained importance for fully automatic, line integrated quality testing. The acoustic resonance testing, frequently also called as sound testing, uses the clear physically caused vibration behaviour of elastic components, in order to identify a performance relevant conspicuousness through a comparative measurement. The technology is therefore so interesting, since on one side the complete component is checked objectively and on the other side the automated execution is comparatively easy, quick and takes place without ecological damage. This volume oriented test technology is advantageous above all for complex component geometries.

MEDAV developed Chameleon technique for CrackMaster system. Chameleon technique is an innovative concept for:

- setting-up an inspection system by use of un-labelled items from the production line in a stabile process (this means that the majority of the parts manufactured are “good” parts)
- automated definition of tolerances to the quality features,
- identification of untypical items within a series of items,
- automated optimisation of system parameters by application of quality control loop,
- automated adaptation of tolerances to the production scatter,
- and recommendation of accompanying quality assurance measures.

For both concepts, the traditional (see below) and the innovative one, we assume that the testing technique of ART provides suitable features to detect reliably defective items.

Problems of the traditional approach of teaching an inspection system

The traditional approach to set-up a testing systems is to collect items which are assessed as “good” and as “defective” (= “bad”) parts, together the “**reference parts**”. In a second step, these parts are used for the teaching process of the system. Differences in quality related features will be used to set tolerances to the features for the “good” parts in that way, that the defective items fail that tolerances. This concept seems to be reasonable and effective. But in practise, this concept often fails through its in-effectiveness and unreliability. Here we distinguish the main categories of problems related to “reference parts”:

a) Collection of parts

The training process requires references for “good” and “bad”. As a consequence of this demand, the references have to cover the complete spectrum of good and bad items - related to the production process scatter. This is an impossible requirement concerning the scatter effect to good parts, and to get available all type of defects, located everywhere on the parts. A compromise is necessary; but is that compromise a realistic one?

In some production processes defective parts are very seldom, maybe 1 per million of parts. How to teach a testing system in such a process?

Our innovative approach is that we abdicate on a teaching process with pre-labelled parts. We take a (big) stack of items from the production line, and apply statistics; postulate is that the majority of these parts are “good” parts – a reasonable and realistic assumption which is usually confirmed by accompanying quality measures.

b) Reliable assessment of parts

The reference parts, which should be used, have to be allocated to their corresponding quality class. In some cases, defects are clearly visible, in many cases not or not reliably visible; the assessment problem of “good” parts is similar. The user can apply offline testing methods like magna flux, ultrasonic, X-ray, but usually will not conduct such inspections for as many parts which are needed for system teaching.

Summarising that problem, teaching of the system is performed by parts which are uncertainly assessed. The consequence of that uncertainty is that the system taught with “wrongly labelled” parts will repeat that wrong decision on new parts. Defective parts may pass and good parts may be rejected by the testing system.

Our innovative approach is to collect the items which are used for the system set-up. By means of statistic, the typical range of the quality features for the majority of the items is evaluated. Since the majority of the items are “good” quality related items within a reliable process, the items related to untypical feature values are the most conspicuous ones which should be assessed by using non-destructive or destructive testing methods. Only a few parts has to be tested accordingly.

c) Process dynamics

Production processes are not static. There are some influences to the process caused by material lots, tolerances and wear of tools, parameter settings of machines, kiln temperature, environmental conditions et al. These effects may not be stringent critically to the quality of the product, but they cause some scatter of the product characteristics.

The traditional approach considers this kind of process influences usually through two strategies: Describing wide tolerances for the features of good parts or repeating the teaching process with new parts. Typically the difference of features between “good” and “bad” parts is big, if the defect is a voluminous one – this kind of problem is usually not a challenge; if the defect is a “small” one, then often the differences of the features for good and “small defect parts” are also small.

Our innovative approach is that ART system adapts the tolerances of the features automatically to the production scatter. This helps to avoid a new and time-consuming teaching process.

In the following we describe the steps necessary to setup our innovative inspection system Crack-Master using ART technique.

The ten steps to a reliable production system

The first two steps are more lab oriented tasks; the other steps will be performed in or close to the production line:

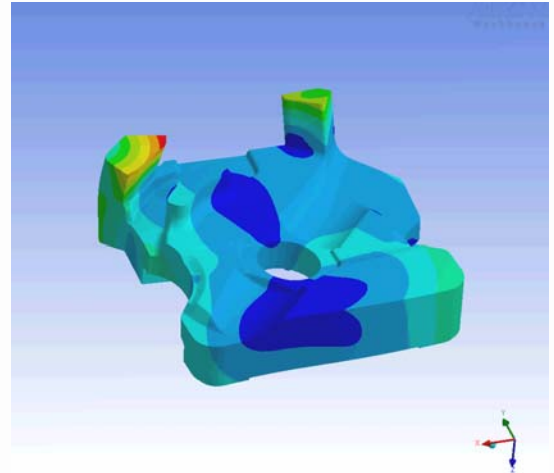
1) To get acquainted with the vibration behaviour of the items

Objective of step 1 is to learn more about the vibration behaviour. [1] is a contribution related to the advantage of Finite Element Models (FEM) to understand the vibration behaviour.

If the vibration behaviour of the items is known, the user benefits through the following reasons:

- (i) Knowledge of the important vibration modes to identify (local) defects
- (ii) Knowledge of any limitation of defect identification if applicable

It is important to understand that FEM is helpful for challenging problems, i.e. small defects (cracks). "Big defects" are usually easy to detect and does not require any sophisticated FEM simulation



2) Development of a measuring set-up

The measuring set-up considers aspects for

- Alignment of items. An exact positioning and a decoupling of the item from test bed are necessary to measure the normal frequencies.
- Stimulation of vibration modes. Impact or drop techniques are popular. Locations of impacts are important for excitation of vibration modes. Depending on the physics, for some geometries more than one impact are necessary for a reliable stimulation and evaluation of vibration modes.
- Measurement of vibrations. Typically microphones, laser vibrometers or accelerometer based tips are useful for signal acquisition
- Test and optimise repeatability



The assessment of the measuring set-up considers knowledge of the FEM results, or as a suitable heuristic objective, to use that set-up that provides as many natural frequencies as possible (for motivation: see 5)).

3) Recording reference data in the production line

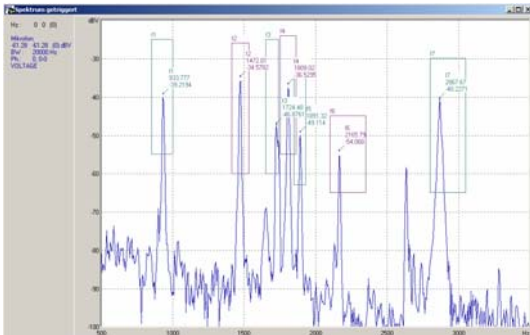
With the outcome of 2), reference data for items can be recorded in or close to the production line. Typically 100 to 200 items will be used for the basic parameter setting.

Since the production process is stable, we know that most of the items of the reference parts are “good”, but some can be defective – which ones, if applicable, is unknown.

We prefer to record the reference data in the series of production (FIFO principle).

We record for each item it's serial number, or if serial numbers are not available, we identify each item with a unique number. This is necessary to have a reliable relationship of the data recorded and the corresponding item.

4) Selection of normal frequencies to be used for quality testing



Now frequency spectra are calculated for all data recorded, and “frequency windows” are defined off-line.

The definition of the windows follows the objective that all “good” parts have at least one frequency in the corresponding window. Items with a strong defect may have no frequency in all windows.

Typically some ten windows are defined.

5) Definition of a basic set of quality related features

The normal frequencies which are selected by step 4) are the basic features for the ART system. But modern ART systems use additional features deducted from the normal frequencies, amplitude, damping, frequency splitting if applicable, et al. - for each normal frequency).

We define many physically motivated quality features, e.g. 10.000 features if 20 to 30 normal frequencies are selected. The big number of “sensitive” features is the reason that we are in the position to have a very accurate look onto and into the item, and through this accuracy CrackMaster can identify relevant abnormalities which can not be identified by other ART systems.

Each additional normal frequency recorded increase the capability of the system to identify additional relevant defects.

6) Statistics applies for identification of typical items

Now all features of the basic set due to 5) are calculated for all items of the reference group.

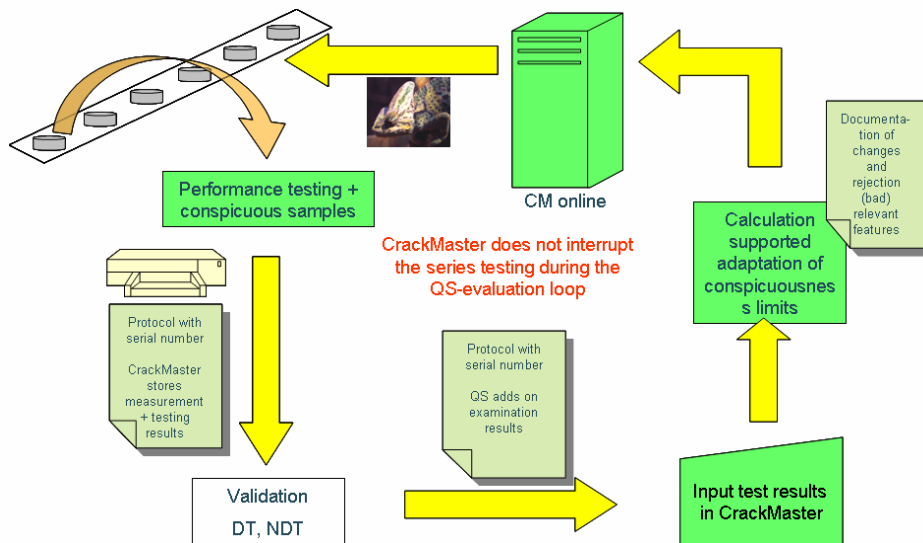
To consider the situation that there can be some defective items (let's say less than 5% of the references may be defective) within the references, we apply an “outlier removal”: 5% of those feature values which have the largest distance to the most homogeneous feature value range will be ignored before mean values and standard deviations are calculated – independently for all features.

8) Optimising the system and automated tolerance adaptation

During the start-up phase a continued optimization of feature tolerances is required during the series production. The following figure highlights the process. Settings in the system are restricted essentially to input of results from the QS testing (QS = Quality Assurance) of conspicuous components. Additionally the conspicuousness limits of the current process development adapt themselves in case of Chameleon-process, e.g. as fixed tolerance band to a gliding mean value of each feature.

The claim in this QS-closed loop is, that in case of possibly less interaction with the system the quality assessments of the responsible department is represented on the system. Thereby it is assumed, that defective components are always noticeable in the current subsequence and the majority of components are “good” – which must be ensured through QS- measures.

Through the **automatic adaptation of abnormality limits** with the process trend a comparatively more accurate process control than the static tolerance band is initiated and with that there is a possibility to recognize less relevant conspicuousness. If the subsequence is not observed from the production, then the control of characteristics is compulsorily bigger and the recognition of less relevant conspicuousness will be less. This means, that through the automated adaptation, the latest item will be compared to the feature range of a history of the last (maybe) 200 items: if it is a “typical” item related on the last 200, then it is “good”; if it is untypical (out of feature range), then it will be rejected. After the assessment of the last item, the “history” will be adapted by adding the last item to it and to forget the oldest one. It is evident, that if testing in the manufacturing subsequence, the feature range of the last 200 items should be smaller than it is over the last 50.000 items, which may apply for a static tolerance band.



QS evaluation loop for assessment of performance test samples and conspicuous items in series process by incorporating the QS (Quality Assurance) assessment results in the system with the help of forms.

The CrackMaster online system locks out performance testing samples and conspicuous samples and document components and relevant measurement data records. The abnormal components can be examined for performance effect by QS with available methods (destructive and non-destructive tests). This process is documented and the “correct assessment” is given into the CrackMaster system. CrackMaster automatically changes the existing conspicuous limits in such a way that the abnormal components at the point of its online – assessment would be assessed as “correct”, i.e. according to the QS assessment. In addition statistics is added to features so that “premium features” remain unchanged (very important features for the recognition of performance-relevant conspicuousness).

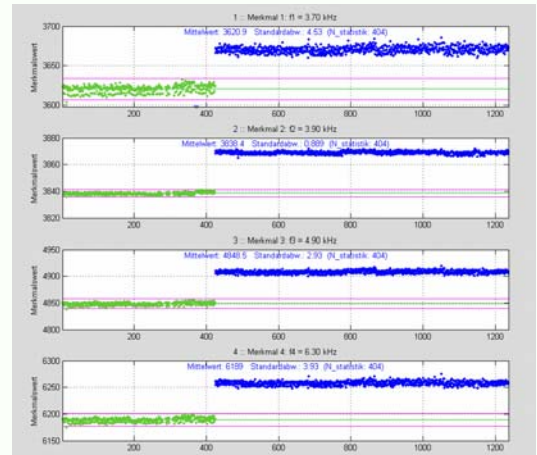
9) Adaptation to process relevant interferences, e.g. a new lot

In case of lot changes a volatile change of absolute values of features can occur, e.g. conditional through a new material charge or process parameter. These interferences can be more significant than the difference between good and bad components within a lot. CrackMaster supports the adjustment of the conspicuousness limit to the new lot parameters through an automatic lot adaptation strategy. Thereby it is required that CrackMaster gets a corresponding control signal, e.g. from PLC or manually actuated keys and of a manually accompanying component examination of performance testing samples.

10) Maintenance and reference parts

ART systems are suitable for production testing. Calibration of transducers, impact devices and requirements to repeatability are some issues which have to be considered if systems should be introduced into the production line. The availability of a master part is recommended to test the system regularly for working in a suitable tolerance.

Master references for “good” and “defective” parts are not applicable in the same way as used for other testing techniques, but it is not really reasonable. Our innovative approach supports that in a particular “master good / bad part assessment” set-up only and not online, because, and this is the big opportunity of our approach – Chameleon has automated adaptation capabilities to identify small defects – smaller ones as the differences between good ones over a longer period can be.



Summary

MEDAV provides with the CrackMaster system a configurable system solution, where the operation of the system takes place possibly automated and simply. It is essential that the arrangement is on the basis of unvalued serial samples with the help of statistical process. With the Chameleon technique there is a chance, to recognize less relevant variations in non-static processes. Accompanying quality assurance measures are required, in order to practice a process safe solution.

CrackMaster with Chameleon technique is introduced in the production as automatic solutions and represent an economical technology for the mass product testing. Besides the applications in the sinter industry experiences consists of e.g. foundries, forging, sheet metal forming, and in the ceramic industry.

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[1] H. Jonuscheit, E. Ernst: Crack Detection Using Acoustic Testing
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