Double open resonator for localized non-contact acoustic testing

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Abstract

There exist two concepts of open resonators that can be combined into a device for acoustic non-destructive testing. The device is non-contact and based on the fact that an airgap between a transducer surface and the test object can be set into resonance. This occurs for the conditions that makes this an open resonator (open because the air volume is not closed), and the wave field is amplified so that a larger amplitude is reached at the object surface. Let us assume that the object is a plate. When the acoustic wave enters the plate, one can let the frequency be the resonant frequency for one of the modes for the plate thickness. A limited part of the plate may be seen as a resonator, open to the sides. When the conditions for an open resonator is fulfilled for the plate thickness, the wave field will be greatly amplified within a region close to the insonified plate surface, and thus the linear or nonlinear response from this excitation is local. The device may then be used to scan the plate for material parameter changes.

1. Introduction

The concept of open resonator has earlier been introduced for two separate utilizations [1].

First as a method to increase the transferring of energy from a non-contact transducer in air to an object. This is accomplished by fulfilling the criteria for acoustic resonance of the air-gap between transducer and object [2]. This technique partly overcomes the bad conditions for energy transfer from a transducer to air, and from air to object, both due to the impedance mismatch.

Secondly, the resonant acoustic field inside an object may be largely localized within a certain region close to the transducer [3]. This helps bringing localization of damaged regions possible for different acoustic and ultrasonic nondestructive testing methods, in particular for the nonlinear acoustic methods like Slow Dynamics [4].

These two techniques might be combined into a non-contact double resonant nondestructive testing system, which in this paper will be conceptually introduced.

2. Airgap and plate resonant wave fields

The wave field in the air between the transducer and the object can look different in its amplitude distribution depending on the properties of the resonator, that is on the acoustic impedance, size, shape and dynamics of transducer and of object, of the frequency, of the power and of the distance and medium properties in between. The field might be strongly nonlinear [5] and it is this field that excites the object.

A qualitative example is shown in Figure 1. The wave field inside the plate excited by the airgap field on the object surface also depends on the many factors mentioned above. The field can be fairly concentrated with a peak in the middle while diminishing fast outside the limits of the exciting surface field.

This is the main goal of this device. It is useful because any damage indication must then come from the wave field region, so by moving the device over a surface, or moving an object past the device, the positions of damaged regions may be obtained.

One consequence of the double resonance is that it must be the object’s thickness resonance which determines the frequency. This frequency depends on the thickness d and sound speed c in the object. This means that, in order to also have a resonance for the same frequency in the airgap, the airgap distance h must be varied in order to conform to the resonance criterium \( h = n \lambda / 2 \).
Figure 2: **Double open acoustic resonator**
(where \( n \) is an integer and \( \lambda \) is the wavelength).

A schematic picture of the double open resonator is in Figure 2.

The airgap and the plate resonators are both open as they carry losses at the sides. The plate is seen as extended and there will be no major reflections from the ends.

In order for the double resonator to be a completely non-contact device one may monitor the airgap wave field with a normal pressure sensor and the object surface by a laser vibrometer.

### 3. Discussion

The double resonator concept described above was based on measurements of the open resonator concepts individually. A device, as such described above, is at the moment of writing being assembled and measurements from this will be available later on.

### 4. Conclusions

The double open resonator for non-contact acoustic non-destructive testing was introduced and conceptually shown. It will yield a higher energy transfer to the object than normal non-contact transducers. In addition, it will yield a localized wave field that can be used in mapping damage regions, while avoiding unwanted disturbances and reflections. The criteria for open resonance taking place in both the airgap and inside the object must be taken into account.

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### 6. References


