# AIR-COUPLED ULTRASONIC DETECTION OF ERRORS IN TEXTILE PRODUCTS

**E. Blomme, D. Bulcaen, F. Declercq and P. Lust**
KATHO dept. VHTI, Kortrijk, BELGIUM
erik.blomme@katho.be

**Abstract**

By means of an overview of selected experiments, the feasibility is demonstrated to test ultrasonically without contact and with respect to various quality aspects a large scale of textile products, both wovens and non-wovens. All measurements have been performed in through-transmission mode at normal sound incidence and at sound frequencies between 400 kHz and 2 MHz.

## Introduction

Ultrasound as a tool for testing textiles is rather unknown. The reason is that conventional ultrasonic inspection methods are either immersion or contact techniques but the need for a liquid, a coupling gel or direct contact makes the ultrasonic approach non attractive or even useless for the on-line investigation of textile products. This is changing. Thanks to the availability of special air-coupled transducers and a careful design of the electronics, it is nowadays possible to develop non-contact ultrasonic (NCU) methods in order to detect various kinds of errors in many textile materials.

In the present contribution, the feasibility is demonstrated to detect fluctuations in the thickness and weight of coatings, the penetration of a coating into a textile substrate, common weaving errors, the presence of grease or oil spots, density variations of a non-woven and the quality of an impregnation on a fibre web product. Other examples can be found elsewhere [1-3].

Before discussing a selection of experimental results, an explanation of the applied air-coupled ultrasonic measurement system is presented.

## Measurement system

Fig. (1) shows a simplified scheme of the measurement system. The direct digital synthesizer (DDS) generates a continuous sinusoidal signal with a frequency between 250 kHz and 3 MHz depending on the material under investigation and the kind of error to be detected. Then the signal is amplified (PA) up to (max.) 18 Vpp. The distance between transmitter (T) and receiver (R) is 3 cm. In absence of a sample, losses due to acoustic impedance mismatches and absorption in air vary from 50 to 65 dB depending on the frequency and the type of transducer. Inserting the sample, additional losses may vary from 10 up to 100 dB, depending upon the nature of the textile product. Hence losses are phenomenal and, as in most textile products one cannot take advantage of resonant frequencies, the electronics at receiver side have to be designed very carefully in order to extract the useful information from the weak signal. A first step to achieve this is the insertion of a low noise amplifier (LNA) which can improve the signal level by 34 dB and, if necessary, a second identical LNA can be added. Secondly, the signal is passing through a superheterodyne receiver (SHR) where a frequency selective amplification of the signal is established, resulting into an improvement of the SNR up to 20 dB. Hence the system has a total dynamic range of about 150 dB. Finally it should be noted that the sample is attached to a computer controlled XY-stage while the ultrasonic transducers stay in fixed position. The step of the XY-stage is 1/mm in both the X- and Y-direction. At each point of a line or surface scan, the signal strength is imaged onto an arbitrary scale ranging from 1 to 4096, which is related to a dB-scale. For the examination of the textile samples, either piezo transducers with matching layers (type ULTRAN, Secondwave Systems, USA) or capacitive transducers (type BAT, MicroAcoustics Instruments., Canada) have been used.

## Experiments on woven materials

One important issue in textile testing is the control of a finishing process such like the thickness or weight of a coating or the penetration of a coating into the textile carrier. The first two examples are related to this topic. A third example shows the possibility of detecting oil spots or other kinds of soil. A fourth example demonstrates the feasibility of detecting typical weaving errors by air-coupled ultrasound.

### *Weight of a coating*

A protective coating was applied to 4 cotton samples of 117 g/m². The coating weight was 25, 39, 53 and 65 g/m² respectively. Ultrasound of 700 kHz was

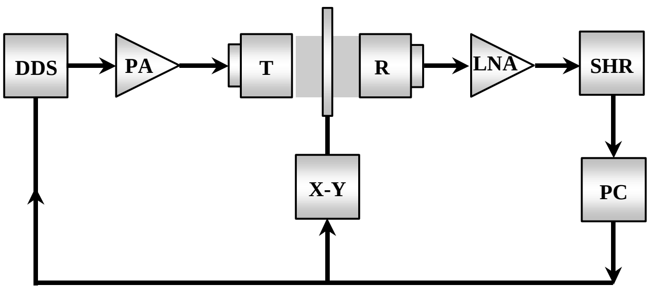


Figure 1 : Scheme of the non-contact ultrasonic measurement system.

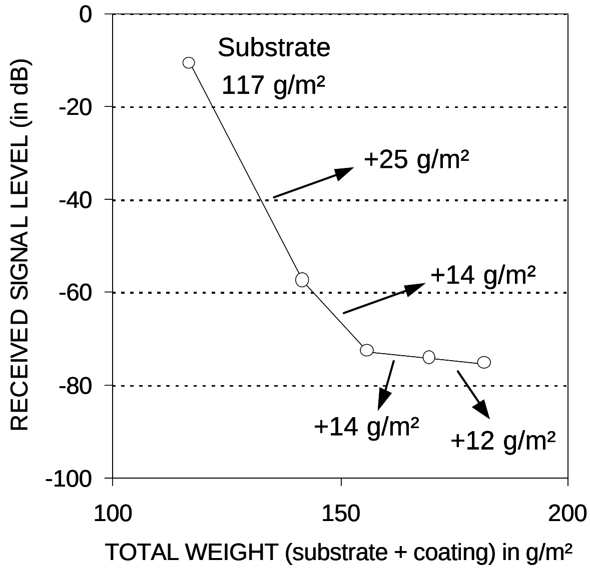


Figure 2 : Air-coupled through-transmission measurements of a series of cotton samples with an increasing coating weight. The successive additional coating weights are indicated.

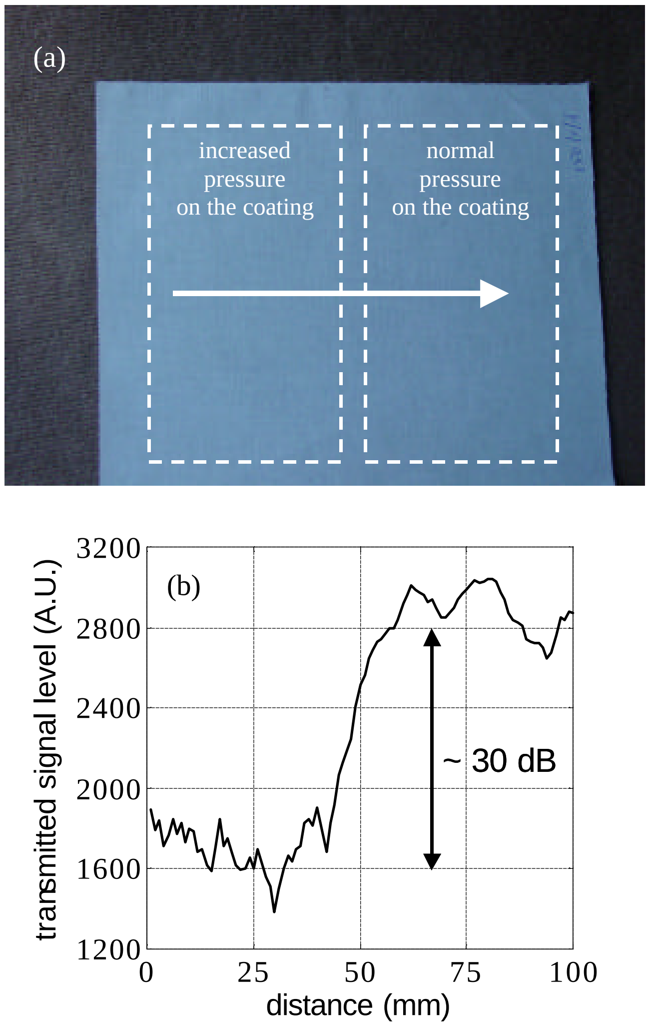


Figure 3 : (a) photo of a coated cotton sample with varying degree of penetration of the coating (deeper penetration left than right, invisible by eye); (b) air-coupled line scan at 0.7 MHz in the direction of the arrow.

transmitted through the textile and the average transmission values of a matrix of 25 × 25 measurements covering an area of 5 × 5 cm² was determined for each sample. The diagram in Fig. (2) shows the averaged signal levels against the total weight of the samples. The zero level on the dB-scale refers to the situation without sample. However, it should be noted that the level of the received signal in that case already was 65 dB lower with respect to the input signal level. One can see that the level of the received signal decreases with increasing coating weight. This can easily be understood from the increase of the cover degree - i.e. the percentage of the textile area covered by yarns and coating - as more coating is applied. Most significant changes occur up to 40 g/m², which demonstrates the possibility to monitor small variations of coating weight by NCU during the application process. Further increasing the coating weight, the substrate gets saturated with coating and some stabilization of the signal level occurs, also due to reaching the limits of the dynamic range of the measurement system. More details about these and other related experiments can be found elsewhere [2-3].

*Penetration of a coating*

Not only the uniformity of a coating is important, also the penetration of the coating into the textile is a quality parameter. When the pressure on the coating is changed during the application process, then also the penetration varies and hence also the local density of the textile material. As ultrasound is very sensitive to density variations, it is to be expected that areas of increased or decreased pressure can be detected, even if the difference between such areas cannot be detected by vision or gravimetric systems. Fig. (3a) shows a photo of a coated cotton sample (130 g/m² + 34 g/m² coating) comparable to the ones mentioned in the previous experiment. Fig. (3b) is the result of a line scan obtained at 0.7 MHz in a direction indicated by the arrow in Fig. (3a). The lower level of acoustic transmission at the left (ca. 30 dB) is due to the higher pressure exercised on the coating.

*Oil spots on a fabric structure*

A frequently encountered problem in the inspection of woven textiles is the detection (and removal) of oil spots. In a certain sense, an oil spot can be considered as a very local "coating" which may more or less penetrate into the substrate. Fig. (4) shows two air-coupled ultrasonic scans of a cotton/polyester fabric (102 g/m²) which was soiled by two oil spots: at the left side with a non-evaporating oil and at the right with evaporating oil. The oil was transparent and hence almost invisible. The scan on Fig. (4a) clearly reveals both spots. After two hours, the second spot had evaporated and disappeared from the new ultrasonic image, as can be seen from Fig. (4b).

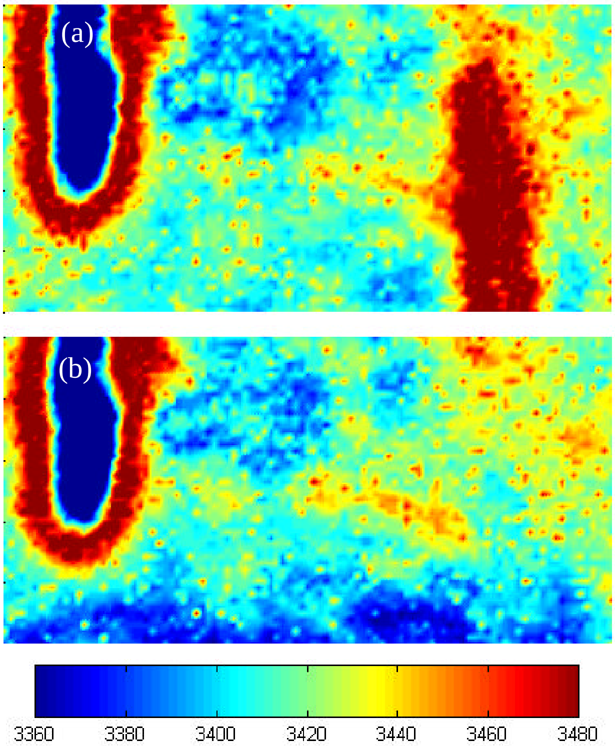


Figure 4 : (a) Air-coupled ultrasonic picture of two oil spots on a fabric structure (0.8 MHz); (b) 2 hours later after the right spot had evaporated.

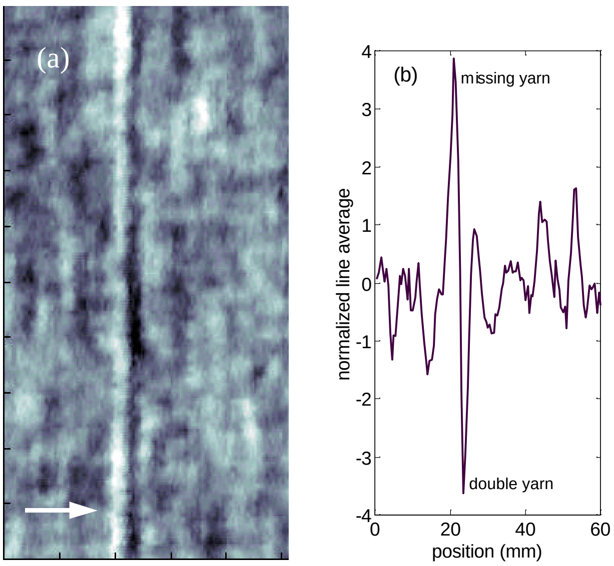


Figure 5 : (a) Air-coupled ultrasonic scan of a polyester sample with a shifted warp; (b) B-scan in the horizontal direction averaged over 13 lines.

*Typical weaving errors*

Air-coupled ultrasound also opens new perspectives with regard to the detection of weaving errors. In principle, errors in both the pick and warp direction can be detected. However, errors may be so small that 100% surface scanning is required. In that case, air-coupled transducer arrays can provide a solution [4]. Here we present an example where a typical weaving fault can be detected by a line scan (B-scan) using a single transmitter/receiver pair. Fig. (5a) shows a scan of a polyester sample with 36 warps/cm and 18 picks/cm. The picture was obtained at a sound frequency of 2 MHz by means of a transmitter of ∅ 25 mm and a receiver of ∅ 3 mm. Exceptionally, the step of the XY-stage was 2 steps/mm in the X-direction. The scan clearly reveals the position of a shifted warp, i.e. a missing warp (white strip, increased transmission) immediately followed by a double warp (dark strip, decreased transmission). The picture also reveals that it would not be appropriate to draw conclusions from single line scans in the X-direction, but an average of several lines can serve the purpose very well, as can be seen from Fig. (5b).

## Experiments on non-woven materials

The air-coupled ultrasonic technique also opens new perspectives for testing different kinds of non-woven materials with respect to various quality aspects. An important class of non-wovens are fibre webs. Below, two examples are presented. The first one deals with density fluctuations in a metal fibre web. The second example is about the quality of an impregnation process on a needle felt, i.e. a non-woven made of synthetic fibres.

*Local density changes in a fibre web*

Fig. (6a) shows an X-ray picture of a non-transparent 10 × 10 cm² web made of ∅ 2 µm metal fibres. The thickness of the web (non compressed) is circa 4 mm. Encircled are some areas with locally an increased density (dark areas). It depends on the application whether these fluctuations are allowed or not. Fig. (6b) shows an air-coupled scan of the area at 1.7 MHz obtained with ∅ 3 mm transducers. The ultrasonic picture clearly reveals the irregularities in the distribution of the fibres. On the other hand it should be mentioned that discontinuities with a thickness smaller than 0.1 mm are difficult to detect. An 80 µm thread inside the web and indicated by the arrow on Fig. (6a), is not revealed by the ultrasonic scan.

*Impregnation of a felt*

If a non-woven material is impregnated with some substance, both the homogeneity and the completeness of the impregnation are important quality factors. Fig. (7a) shows a photo of a needle felt, a web product

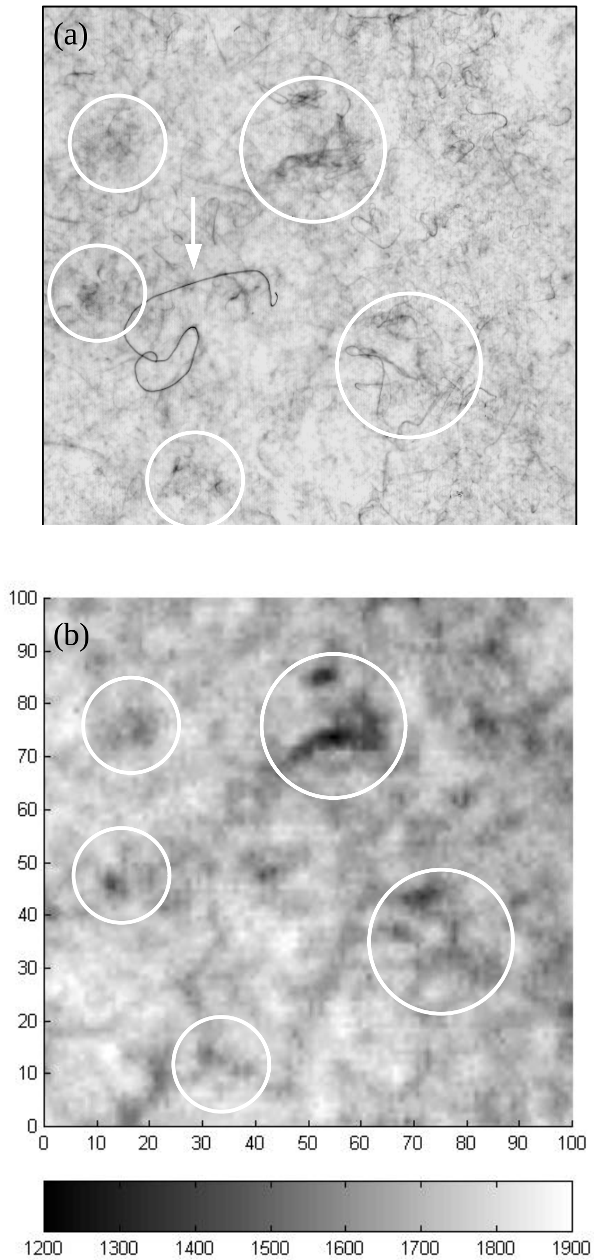


Figure 6 : Local density variations of a fibre web composed of 2 µm metal fibres (a) X-ray picture and (b) ultrasonic picture (1.7 MHz).

composed of visceous fibres and impregnated with synthetic resin. Fig. (7b) shows the result of an air-coupled scan taken at 400 kHz by means of ∅ 9 mm transducers and after completing 2/3 of the impregnation process. Fig. (7c) demonstrates the considerable change in acoustic transmission properties after finishing the process. Obviously this opens new perspectives for the monitoring of quality aspects of web products in general and an impregnation process in particular.

**Conclusion**

The availability of air-coupled ultrasonic equipment operating in the frequency range 0.4 – 2 MHz opens

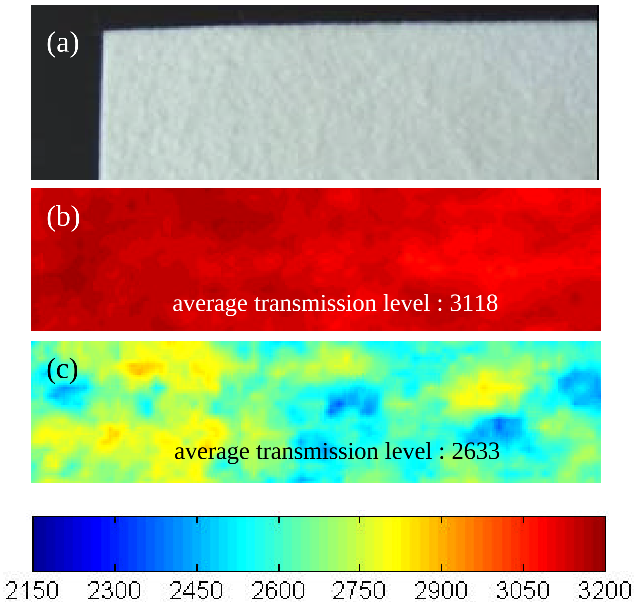


Figure 7 : (a) Photo of a needle felt impregnated with synthetic resin; (b) ultrasonic image at 0.4 MHz after 2/3 of the impregnation; (c) ultrasonic image after completion of the impregnation process.
Scan area: 10 × 3 cm²

new perspectives for monitoring many kinds of textile materials with respect to various quality parameters. The non-contact ultrasonic approach can be complementary to existing techniques such as gravitometric and vision systems.

**Acknowledgement**

The present work has been performed within the framework of the HOBU-Fund project 000197 supported by the Institute for the Promotion of Innovation by Science and Technology in Flanders (IWT) and several Flemish companies.

**References**

[1] E. Blomme, D. Bulcaen and F. Declercq, "Air-coupled ultrasonic NDE: experiments in the frequency range 750 kHz-2 MHz," NDT&E Int. vol. 35, pp. 417-426, 2002.
[2] E. Blomme, D. Bulcaen, F. Declercq and P. Lust, "Non-contact ultrasonic testing of textile products," Unitex N°2/2003, pp. 38-43, 2003.
[3] E. Blomme, D. Bulcaen, F. Declercq and P. Lust, "Air-coupled ultrasonic evaluation of coated textiles," in Proc. IEEE Int. Ultras. Symp. 2002 (Munchen), pp. 736-739.
[4] H.-T. Chien, S.-H. Sheen, W.P. Lawrence, K. Razazian and A.C. Raptis, "On-loom real-time non-contact detection of fabric defects by ultrasonic imaging," In Review of Progress in Quantitative Nondestructive Evaluation (18B), pp. 2217-2224, Plenum Press, New York, 1999.