MECHANICAL TECHNOLOGY

MAY 2000

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Advertising:
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Cover design:
Lesley Marshall
Production and layout:
Gail Smith
Subscriptions:
Wendy Charles
Circulation & reader enquiries:
Radha Naidoo

Published monthly by:
Crown Publications cc
Cnr Theunis and Sovereign Streets
Bedford Gardens
PO Box 140, Bedfordview, 2008
Tel: (011) 622-4770
Fax: (011) 615-6108
E-mail: crownmag@infodoor.co.za

Website: www.crown.co.za

Printed by:
Ince Cape
Reproduction by:
Bowens

Pica Award 1999

Mechanical Technology is endorsed by The Southern African Institute of Welding

Average circulation (Jan - Dec 1999) 3935

AUTOMATIC IDENTIFICATION OF POLYMERS

by JB Hull and A Lotfi, Department of Mechanical and Manufacturing Engineering, The Nottingham Trent University, Nottingham, United Kingdom

[presented at SACAM 2000]

In order to reuse polymeric materials, polymer identification and analysis of additives are required. Economic aspects demand fast response times, easy handling and integration in automated or at least semi-automated systems. As macroscopic physical methods, for example, those based on density measurements, are not sufficient to separate polymers, identification has to use methods monitoring structural or molecular properties of the polymer under investigation[1]. A number of techniques have been developed to assist in identification of polymers. They are: Near Infrared Spectroscopy[7,12,13]; Direct Pyrolysis Mass-Spectrometry[11]; Electrostatic method: Triboelectric[4]; X-ray Spectroscopy[2]; and Chemical Recycling[9]. However, none of these methods has proved to be either completely satisfactory or acceptable in dealing with a wide proportion of the polymer waste. The most recently developed technique, Broadband Ultrasound Attenuation analysis, is a versatile technique that can be applied to a wide variety of material analysis applications.

For recycling purposes, it is necessary to identify which particular polymeric material has been used for a given product. Most consumers recognise the types of polymers by the numerical coding system which was introduced by the Society of the Plastics Industry in the late 1980s. There are six different types of polymer resins that are commonly used to package household products. They are:

- Polyethylene Terephthalate (PET)
- High-Density Polyethylene (HDPE)
- Polyvinylchloride (PVC)
- Low-Density Polyethylene (LDPE)
- Polypropylene (PP)
- Polystyrene (PS)

Polymer consumer goods not identified by code numbers are not usually recycled. There are thousands of different varieties of polymer resins or mixtures of resins. For example, PVC bottles are hard to tell apart from PET bottles, but one stray PVC bottle in a melt of 10 000 PET bottles can ruin the entire batch. Therefore, identifying the type of recycled polymers is very important. Equipment to sort polymers is being developed, but currently most recyclers are still sorting polymers manually.

The most recently developed technique, Broadband Ultrasound Attenuation (BUA) analysis[5, 6], is a versatile technique that can be applied to a wide variety of material analysis applications. It is based on a simple principle of physics. The motion of any wave will be affected by the medium through which it travels. Thus, changes in one or more of any measurable parameters associated with the passage of a high frequency sound wave through a material, such as transit time and attenuation, can be correlated with the physical properties of polymers.

Ultrasonic technique

Ultrasound waves are mechanical vibration, involving movement within the medium in which they are travelling[10]. The particles in the medium vibrate, thus transferring energy from particle to particle, along the wave path. Ultrasound pulses are normally generated and received by piezoelectric transducers that have been acoustically coupled to the test material. An ultrasound wave is launched by exciting the transducer using an electric signal. The sound wave travels through the test material, being received by another transducer at the far side. The received signal is then amplified and analysed.

The relevant measurement parameters will typically be sound velocity, attenuation and spectrum content in the received signal. The speed of sound is directly related to both elastic modules and density. Sound energy is absorbed or attenuated at different rates in different kind of polymers, governed in a complex fashion by interactive effects of density, hardness, viscosity, and molecular structure. Attenuation normally increases with frequency in a given polymer. All kinds of polymeric materials tend to act to some degree as a low pass filter, attenuating the higher frequency components of a broadband sound wave more than the lower frequency components. Thus, analysis of changes in the remaining frequency content of a selected broadband pulse that has passed through the test material can track the effect of attenuation.

The time-domain representation of the signal in an ultrasonic spectroscope

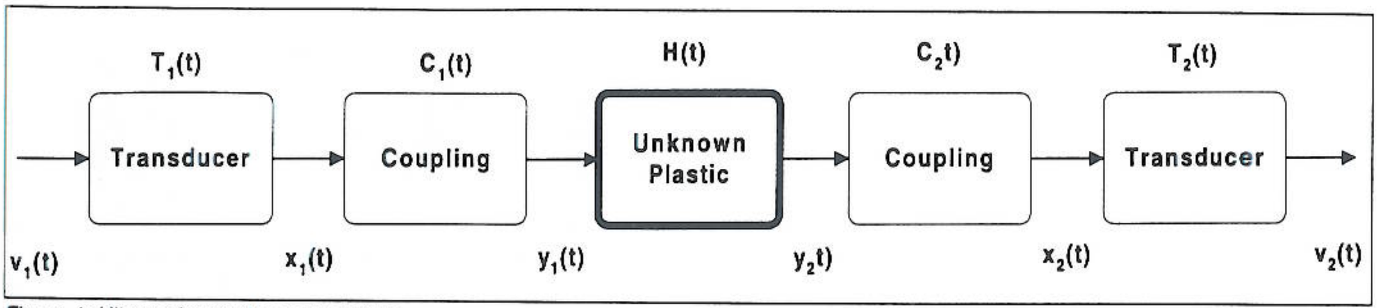

Figure 1: Ultrasonic spectroscopy system

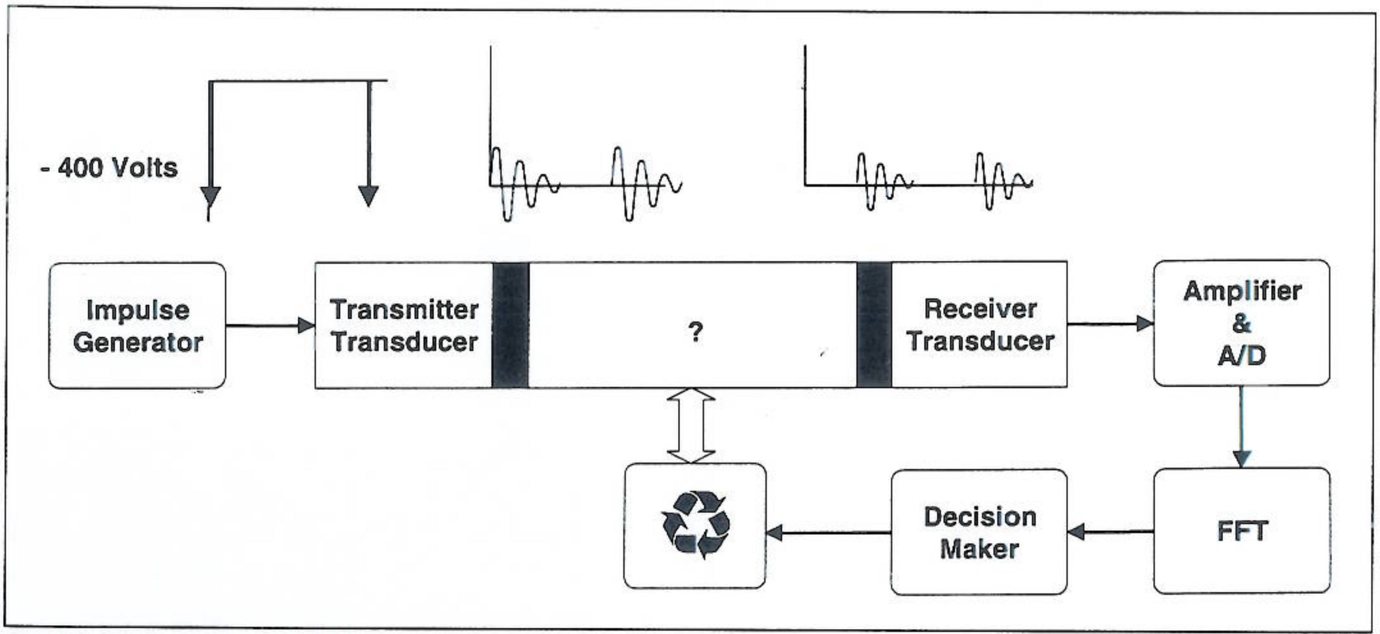

Figure 2: Schematic block diagram illustrating the waveforms in different stages

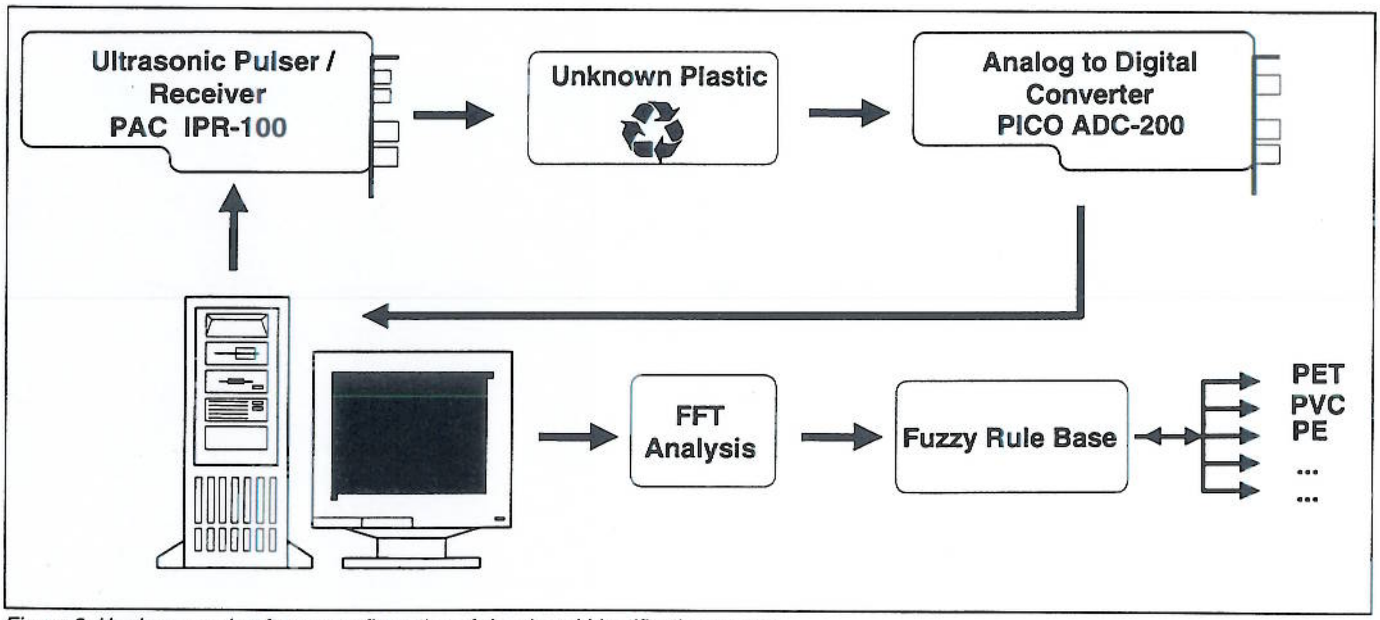

Figure 3: Hardware and software configuration of developed identification system

model is shown in *Figure 1*. The analysis of subsystems provides the transformation to the frequency domain. In research work[3] the analysis was performed assuming that all subsystems are Linear Time-Invariant (LTI). To identify the impulse response of the unknown polymer H(t) from input and output signals $v_1(t)$ and $v_2(t)$, the impulse response of other subsystems must be known.

The pulser generates a series of sharp spike pulses $v_1(t)$, which is applied to the first transducer. The piezoelectric crystal is therefore suddenly strained and deformed and then released. However, the displacement of the crystal does not exactly follow the applied pulse. This is due to the mechanical resonance of the crystal. The vibration from the transducer is coupled into the polymer test piece by the liquid couplant. The sound travels through the test piece and the second transducer in the opposite side vibrates, which in turn produces an electrical signal $v_2(t)$. *Figure 2* illustrates the waveforms in different stages of the process.

Equipment

A schematic of the hardware setup for the developed system is shown in *Figure 3*.

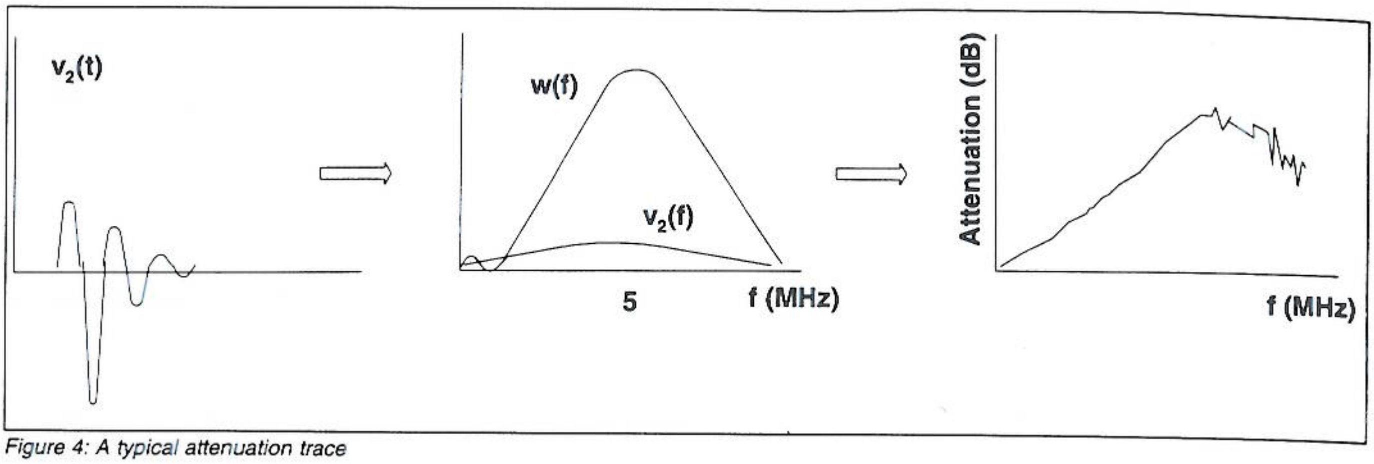

Figure 4: A typical attenuation trace

The IPR-100 pulser/receiver unit from Physical Acoustics Corporation is a PC based expansion card with a high energy spike pulser, and a wideband (100MHz) amplifier receiver. The pulser produces an impulse (spike) electrical signal. It is a negative pulse programmable from 50V to 400V. The rise time is less than 5 nanoseconds with a repetition rate from 0,5Hz to 10 000Hz. There are four programmable energy levels, and variable damping control from 34ohms to 2 000 ohms.

The ADC-200 data acquisition unit from Pico Technology Limited is a two channel analog to digital converter. The minimum sampling time is 10 nanoseconds (100MHz). This card features a signal generator from 2Hz to 25kHz, which is used as an external trigger for the pulser/receiver unit. The transducers are piezoelectric, having resonant frequencies of 5MHz from Panametrics.

Identification technique

The Fast Fourier Transform (FFT) algorithm calculates the amplitude spectrum, $v_2(f)$, of the received signal $v_2(t)$. The resulting amplitude spectrum for unknown polymers is subtracted from the amplitude spectrum for a reference material, w(f), chosen to be de-gassed water. Water is used due to its minimal attenuation properties. A typical attenuation trace for polymers is shown in *Figure 4*.

Attenuation of a certain type of polymer is a function of thickness. To eliminate the effect of thickness, researchers[6] presented a technique to use the velocity of sound to get a signature, independent of the thickness of test materials.

To identify a certain type of polymer, it is necessary to create a set of rules for attenuation information for different kinds of materials. Therefore, a knowledge-base containing the attenuation and velocity information for different polymer types must be established.

When an unknown polymer is presented, the attenuation and velocity information is compared with the information in the knowledge-base. A new technique has been developed[8] using a fuzzy rule-based system to retrieve a right kind of polymer. A new rule is generated when a certain kind of polymer is presented. When there is an unknown polymer, the closest rule from the rule-base is returned indicating the kind of polymer presented.

Conclusions

An intelligent technique, using a fuzzy rule-based system and ultrasound attenuation analysis has been introduced to produce a signature, independent of component dimensions for a range of different polymers such as PET, PE, PS, etc. The early study indicates that the method is a powerful tool for the identification of components of complex shape.

In this investigation separate transmitting and receiving transducers on opposite sides of the test component are used (through transmission mode). It is more practical for industry to use a single transducer coupled to one side of the test piece serving both as transmitter and receiver (pulse/echo mode).

References

There are 13 references to this article. Please contact Karen Smith on (011) 622-4770 for the full list. ❑

POLYURETHANE ROTORS AND STATORS

Previously imported polyurethane rotors and stators are now available to the minerals processing and mining industries. These are part of a local manufacturing programme embarked on by Profpro on behalf of Finnish mining company, Outokumpu.

The moulds have been designed to Outokumpu's stringent specifications. The stators and rotors are used in flotation processes to beneficate the valuables from ores.

Designer, Marius Kotze of Profpro, says the company has invested a substantial amount of money, a great deal of time and has been working on the project since October last year. He maintains it will be a worthwhile exercise, not only from a rapid turnaround point of view, but the cost savings will benefit the mining industry. Savings are twofold in that superior polyurethane is used in the local manufacture. It has been proven that between 40% and 80% better wear life is achieved and tests have confirmed this will reduce R/ton costs significantly.

The units are being manufactured in conjunction with polyurethane specialist, Allthane Technologies International, in Carltonville.

The intricate and highly specialised moulds were manufactured by Reppod Engineering and the larger units were machined by Anicic Heavy Engineering, one of the few machine shops with the capability of machining components of this size to the extremely tight tolerances necessary for this operation.

The first size produced at the end of last year was a 750mm rotor stator combination. There are now five sizes available which are the 500mm, 650mm, 750mm, 825mm and 1 050mm and, within the next quarter, Profpro will endeavour to get 900mm and 1 200mm sizes into production.

According to Alan Tuck of Allthane Technologies, the company has, under instruction from Outokumpu, investigated the abrasion properties of numerous types of polyurethane, some well known and some specialised systems. These findings showed that one of the new systems, with minor modifications to the formulations, gave the outstanding results required for these arduous and abrasive applications.

Tests under the auspices of Outokumpu are ongoing and when these new generation formulas are developed to offer improved results for other applications, they will become available.

Alan Tuck maintains that the spin-off from the research and development is that Outokumpu will remain in a position to offer leading technology in this field, including the development of other products.

Future plans on line are moulds for new product lines.

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