DETERMINATION OF QUALITY AND SAFETY INDICATORS OF POLYMER PRODUCTS BY NON-DESTRUCTIVE CONTROL

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ANNOTATION

According to the influence on the object of control, as a result of which the object (product) can retain its properties or irreversibly change them, it is divided into non-destructive and destructive. Non-destructive - this is a type of control, after which the product can be used for its intended purpose. Non-destructive methods allow continuous control. The need to move from selective control to continuous control increases with the complication of controlled products. Of all the known methods of quality control, physical methods of NDT have the greatest functionality, which are currently the most massive technological operation.

Keywords: Intrusive control, non-intrusive, automatic control, satellite methods, polymer materials

INTRODUCTION.

Today's steady growth of foreign trade turnover, on the one hand, the restrictive measures of the global pandemic COVID-19, on the other hand, force the search for optimal forms and mechanisms of quality control of imported products. is one of the most important stages in the process of customs clearance of foreign trade goods.[1]

In this regard, the study of ways to remotely control the quality of imported goods without breaking their packaging remains a topical issue.

Such methods are usually called non intrusive methods of control, one of its types is the control of the quality and safety of the product with the help of an image obtained using X-rays or gamma rays. allows you to control the load of the contender or vehicle

without opening or unloading. This method significantly reduces the number of unnecessary checks and reduces the time spent on it. The non intrusive method, unlike the intrusive test, provides for verification of the quality, reliability and safety of objects without destruction, that is, then it is possible to carry out the control without purposeful use of products and, in some cases, without interrupting the operation of the object.[2]

For example, if the control of imported goods transported by motor transport can last up to 8 hours with a simple intrusive method, then with the help of the control technique using the nnu, its verification takes an average of 10 minutes. Thus, the use of non-corrosive methods of inspection allows to significantly reduce the time of Customs Control and increase the permeability of car transfer punches.

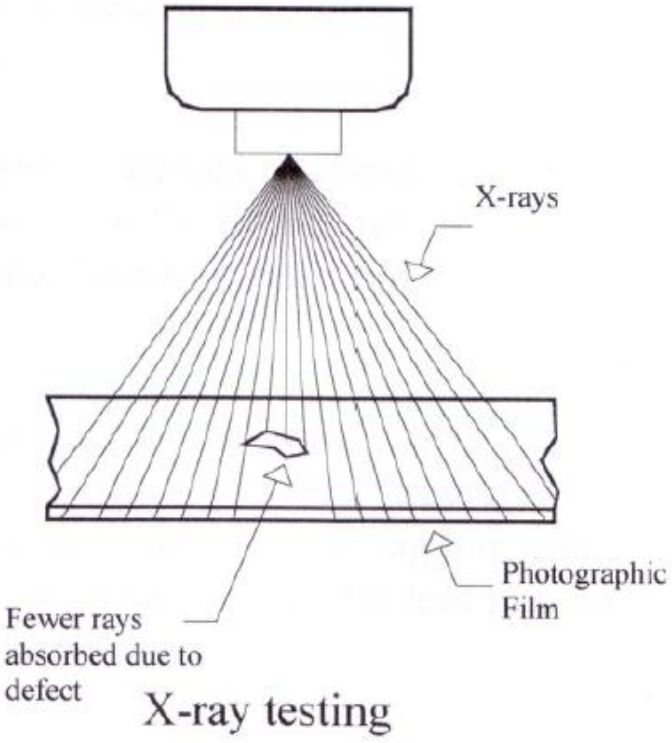
It can be safely and legally argued that the following basic definition of the concept under consideration can be used: non-destructive testing is a control that does not destroy the object being checked. The second official definition states that non-destructive testing is a field of science and technology that covers the study of the physical principles underlying the methods, technologies and means of control that do not impair the suitability of objects for operation and do not violate their integrity. Non-destructive testing methods provide a unique opportunity - to test the product, which will subsequently be used for its original purpose. [3]The product/object/detail can be checked both completely - to examine both the whole system and testing only "dangerous" areas, which, from the point of view of operational reliability, cause the greatest concern. A variety of non-destructive methods, each of which is sensitive to a certain property of the product, product or material being tested, makes it possible to obtain information about a variety of characteristics of non-destructive testing objects.

METHODS FOR NON-DESTRUCTIVE TESTING

1. X-Ray Diffraction for Polymers and Composites

X-ray testing is a suitable non-destructive test for assessing internal faults. Radiation from an x-ray tube is passed through the weld. If no defects are present, the amount of absorption is uniform across the area exposed to the x-ray beam. If a defect is present in the weld, a smaller amount of rays is absorbed giving a variation in the intensity of the emergent beam. This can be detected by placing a photographic film on the side of the material opposite the radiation source. On a negative film, the defect shows as a dark spot.[4]

Polymers and composites by X-ray diffraction analysis determines the degree of crystallinity for semi-crystalline, amorphous polymeric and composite materials Performing X-Ray Diffraction (XRD) analysis on samples of polymers or composites provides important solid-state structural information such as the degree of crystallinity.



X-ray testing

Polymers come in many forms, including highly crystalline, semi-crystalline, microcrystalline or amorphous, and it is possible that in a single polymer sample, all three may be observed. [5]The presence and relative quantity of these forms depend on how the polymer was formulated and processed and this in turn is known to affect mechanical properties such as compression, tensile strength, buckling, and creep. Consequently the degree of crystallinity is an important property to accurately determine.

2. Radiographic Testing

Industrial radiography uses electromagnetic radiation in the form of either X-rays or gamma rays to penetrate and travel through a material to then be recorded by a detector. This allows for a pictorial volumetric inspection, meaning the interior of a specimen can be visually inspected by the use of pictures generated from the methods. Radiographic methods are some of the most common methods for NDE. One of the reasons why radiography is so common is because it is one of the few groups of NDE methods which are capable of inspecting the interior of almost any materials. A commonly used industrial method is Computed Tomography (CT) which is able to produce 2D slices which can be stacked to create 3D images of the inspected specimen, allowing both interior and exterior NDE

3. Ultrasonic Testing, linear

Linear Ultrasonic Testing (UT), or ultrasound, uses high-frequency (20+ kHz) sound waves to measure certain quantities depending on which method is used. One of

the most common and according to [19] most important methods is the *pulse-echo method* which utilizes a transducer to send a sound pulse through a material and in the case of inhomogeneity, an echo is reflected which is picked up by a receiving probe, which is usually the same transducer which transmitted the wave. A similar method to pulse-echo is the *pitch-catch method* which utilizes one transducer to send the ultrasonic wave and another to receive the waves. These methods primarily measure the sound pressure amplitude of the echo and the transit time. Not only will an inhomogeneity induce an echo, so will the back wall of the subject being tested. Given that the size of the discontinuity allows waves to travel past it. Thus, the material thickness can be evaluated and the location of defects can often be quite accurately determined. Ultrasonics is widely used for NDE in many applications, medical and industrial alike. This is because UT is able to detect subsurface and surface discontinuities in any material allowing traveling mechanical waves without posing any health risks, unlike RT. The size of discontinuities that UT can detect relies on which frequency is used, i.e. the wavelength. This can be troubling when inspecting materials which exhibit high damping where high frequencies are effectively damped which might imply difficulties in finding very small defects.

4. Visual Testing

Visual Testing (VT) is, as the name suggests, the act of visually inspecting an object. The naked eye can spot certain exterior discontinuities on an object, however, sometimes this direct visual approach might need aids such as magnifiers or measurement devices. When the operator cannot access the area which is to be inspected, remote visual techniques can be used with the aid of equipment such as boroscopes or fiber cameras. Visual testing is likely the oldest method used for NDE as the method has always been available to man and most people use it on a daily basis when inspecting everyday life items. Visual testing is often used as a component in other methods of NDE, Liquid Penetrant Testing (PT) is one of these methods. PT uses a highly visible and viscous fluid that penetrates surface voids on an object which can then be inspected more easily by the use of VT. As with all testing methods, VT has its advantages and disadvantages, a brief summary of such is presented below.

RESULTS

1. **X-Ray Diffraction**

XRD analysis can assist in assessment and quantification of the crystalline phases (polymorphism), polytypes and all types of solid state molecular arrangements. If the polymer is crystalline, then the XRD diffraction pattern is a result of a crystal structure (as related by Bragg‘s law); the pattern can be indexed and represented by a stick pattern of positions and intensities. We use this to aid the identification of semi-

crystalline polymers in a polymers sample using the position and relative intensities of the X ray fingerprint of the crystalline phases of polymer.

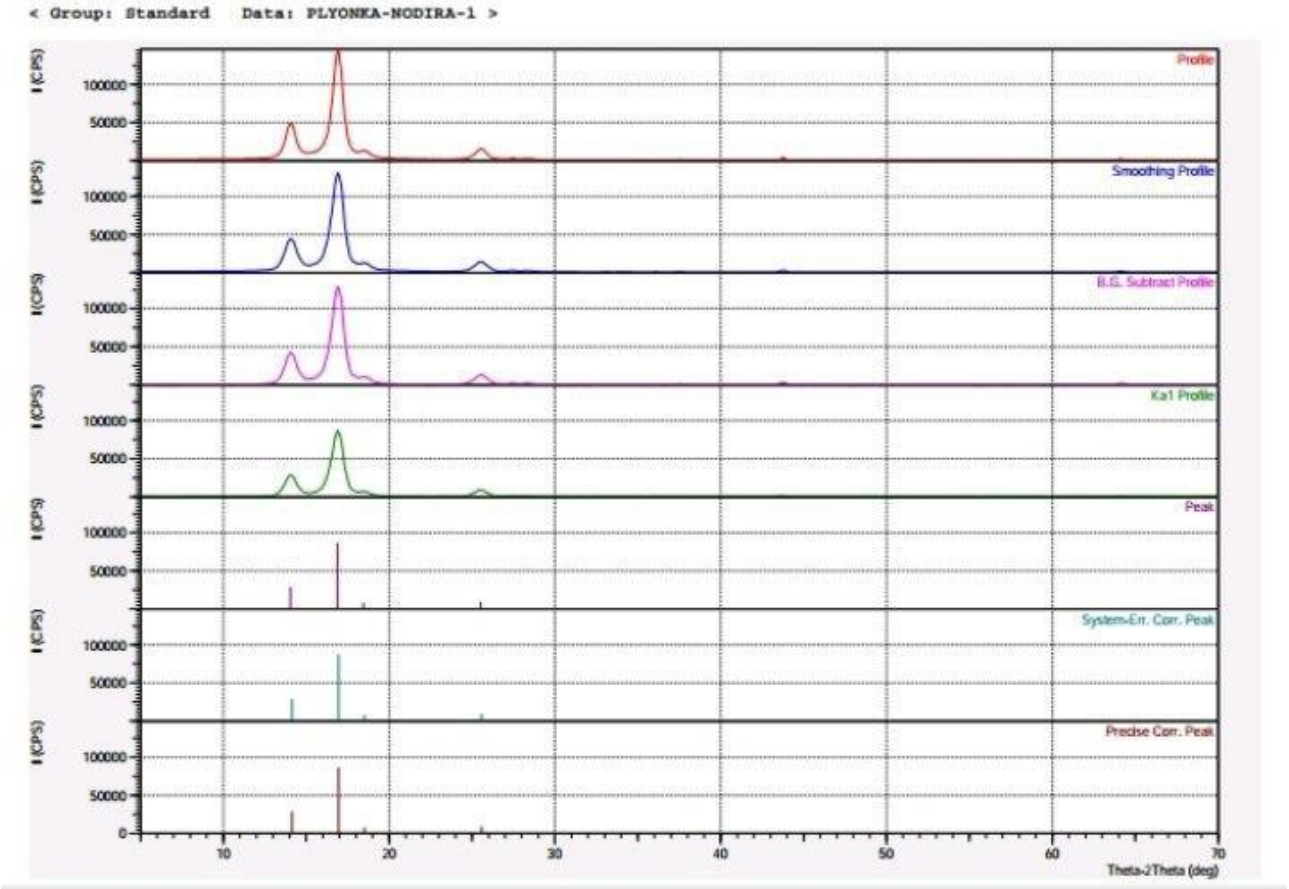
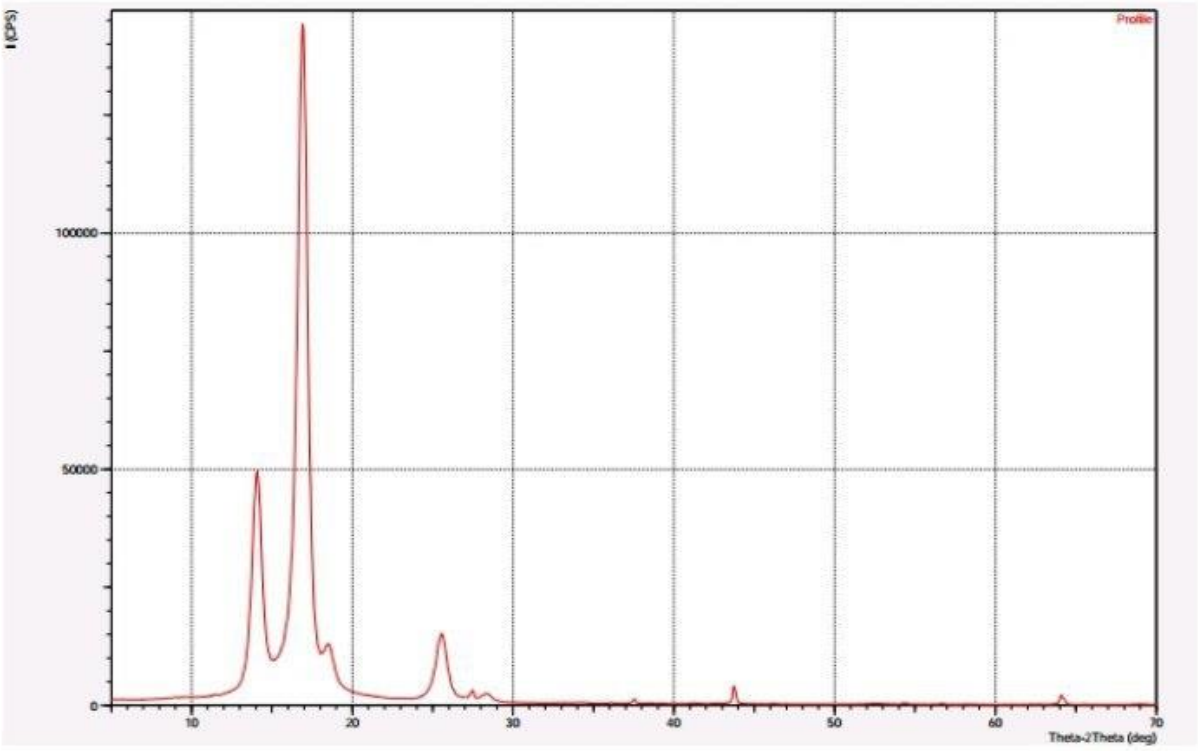


Figure 1.x-ray image of polyethylene film



Polymers can be processed into fibres and films and can be molded and extruded. Each of these processes can orient the molecules and the diffraction can be used to measure the orientation – in both crystalline and non-crystalline materials. We used XRD patterns as the primary tool for the determination of crystalline orientation through the Hermans orientation function.[6]

2. Nonlinear Resonant Ultrasound Spectroscopy

Nonlinear Resonant Ultrasound Spectroscopy (NRUS) is a method in which an excitation in the form of an acoustic wave with constant amplitude is sent through a test object with varying frequency within a certain interval around a resonance frequency of the test object. NRUS detects discontinuities by monitoring the change in resonant frequency. When a sample is damaged it exhibits stronger nonlinearity than an undamaged one which induces a shift in resonance frequency and amplitude [10]. An illustration of constant amplitude frequency sweeps for NRUS can be seen in Fig. 3.

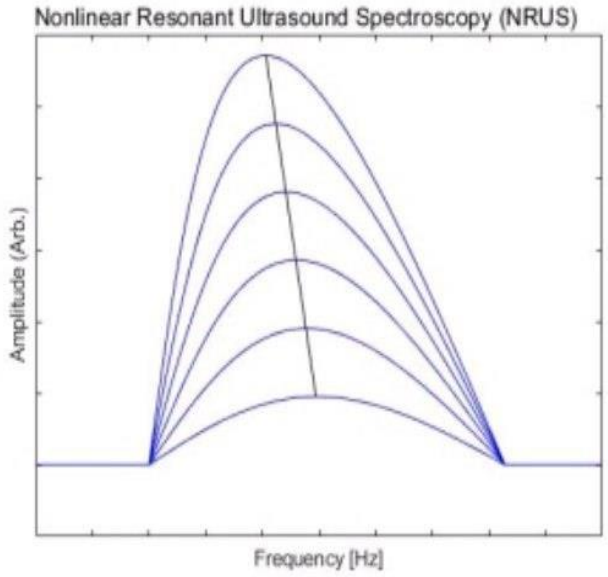


Figure 3 . Illustration of increasing nonlinearity with increasing amplitude. Thus, also a change in resonance frequency. The resolution and quality of the data obtained from the experiments depend on numerous variables, e.g. sweep time, and frequency interval. Damage can be detected by conducting several NRUSs with varying amplitudes and inspecting changes in frequency content. Damaged samples will exhibit changes in resonance frequencies and amplitudes. Frequency sweeps are time-consuming; hence they are unsuitable to use as test methods in a production line. They are however quite sensitive and can be used to detect interesting frequency intervals which can be used for other types of measurements. If damage can be detected using NRUS then it is likely that other nonlinear acoustic methods can be used as well.[7]

DISCUSSION

The quality of polymer components has been evaluated by using two methods of non-destructive testing. The samples which are referred to as damaged are visibly damaged, i.e. the damages could be spotted by the naked eye. This yielded a good initial way to separate samples. However, this do not guarantee that samples that are labeled undamaged are in fact undamaged or does not contain subsurface discontinuities. The population of damaged samples had three different types of damage which resulted in a low effective population, meaning that there was no way to ensure statistical certainty regarding characteristic properties for different damage types. One of the more time-consuming aspects of this work has been the process of calibration as each method had different variables to calibrate, albeit some variables were carried over. The initial calibration which was conducted before the testing methods were applied revolved mainly around finding suitable input signal amplitudes and frequencies. [8]Different setups on the oscilloscope were tested and evaluated to find a suitable frequency and time resolutions. Heavy emphasis was put on finding the resonance frequency which gave the highest response with respect to input signal amplitude, this frequency and an interval around it were carried over for all experiments. Initially, an older model signal generator was used which was unable to deliver sufficiently fine frequency sweeps. This meant that all prior experiments had to be redone which resulted in a shorter effective period of experiments, luckily some parameters could be carried over.

CONCLUSION

Several nonlinear acoustic methods for NDT have been used to inspect polymer components. It was shown that a method depending solely on the generation of Higher Harmonics had difficulties in generating apparent characteristic differences between undamaged and damaged samples even though several harmonics were inspected. This leads the authors to not recommend further work with this specific method. Morover, this does not mean that the method cannot be used to conduct NDT for thin polymer components. A more time-consuming method that indicated damage was NRUS where each frequency sweep took 800 seconds to complete, thus rendering the method unsuitable for production line implementation. This indicates that no further emphasis should be put on this method as a means of testing in such environments. [9]

Thus, NDT allows:

• determine and improve product quality, find out and eliminate the causes of defects

• determine the strength of products

•prevent accidents and improve safety

• reduce the cost of production

•prevent environmental disasters.

In the course of production and operational processes, the technical condition of any facility requires regular assessment. NDT allows carrying out evaluation activities without suspension, dismantling and sampling, which are quite expensive. The use of NDT methods in the inspection of an object does not require forced downtime and makes it possible to detect and eliminate its fatigue and various defects at an early stage. Therefore, the main objectives of NDT are aimed at: Minimizing accident risks and increasing the level of operational safety of equipment at hazardous production facilities.

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