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Research Paper

Acoustic emission—A promising and challenging technique for process monitoring in sheet metal forming

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ABSTRACT

Acoustic emission (AE) is a non-destructive testing method with a high potential for quality and process monitoring in sheet metal forming. In this paper the possibilities and limitations of this testing method with regard to sheet metal forming are presented. For this purpose several rectangle cups were manufactured from the low carbon (DC06) as well as the dual-phase steel (HCT600X) by deep drawing. The analysis of the measured acoustic emissions was focused on two objectives. First, a correlation between the cracking and the acquired resulting acoustic emissions were created. The second objective of the analysis was to verify the suitability of the AE-technique for process monitoring. The results have shown that acoustic emissions arised during the deep drawing process enable not only the detection of crackings, but also different process deviations such as lacking lubrication and wrong material. But it has to be considered that the feasibility of the acoustic emission technique as a process monitoring tool depends from the material ductility which limits the fields of application.

1. Introduction

The sheet metal industry has to fulfil increasingly higher demands on parts and processes. This especially concerns the automotive industry which is the largest manufacturer and customer of sheet metal parts. As more and more materials are used with high strength, the processing complexity has risen. One example in the automotive industry is the application of lightweight design by using thinner metal sheets made from high strength steels [1]. Therefore several manufacturing methods are close to the process boundaries whereby the reliability decreases. Due to many influence factors, for example batch variations of the material or changing tribological conditions, sporadically unavoidable defects or disruptive influences within the sheet metal forming could occur. Because the period between the occurring, the detection and the removal from production faults can take a long time, the manufacturing of defective goods cannot be prevented. Therefore an automated fault detection during the forming process would be beneficial, particularly with regard to the "industry 4.0". Industry 4.0 is a future project of the German government for an advanced manufacturing (e.g. smart productions with autonomous machines).

Therefore, in the era of industry 4.0 the automation of industrial processes is becoming increasingly important. The automation technology enables an increase of the productivity with a simultaneous reduction of costs. Furthermore, higher production and process qualities can be ensured through industry 4.0. For many entrepreneurs, regardless of the industry sector, the idea of a fully autonomous factory is still very attractive. Due to the higher quality requirements of the products and the more complex tools and processes the need for 100% inspection in the forming industry increases, too.

A very promising method to combine the quality requirements and the automated process monitoring is the acoustic emission technique [2].

2. Basics of acoustic emission

Acoustic emissions are elastic waves which are emerged due to the spontaneous release of energy in a solid state during cracking [3]. For the identification of defects within a solid body or for the verification of the material properties and the structural stability in practice, for example microstructural transformation, cracking or material fatigue, sound waves from the middle ultrasonic range are suitable [4].

The acoustic emissions are transient signals, which propagate as body waves through material, and can be acquired on the surface by sensors. The mainly applicated AE sensors are piezoelectrical sensors. Overall AE assesses not the condition of a part, but the

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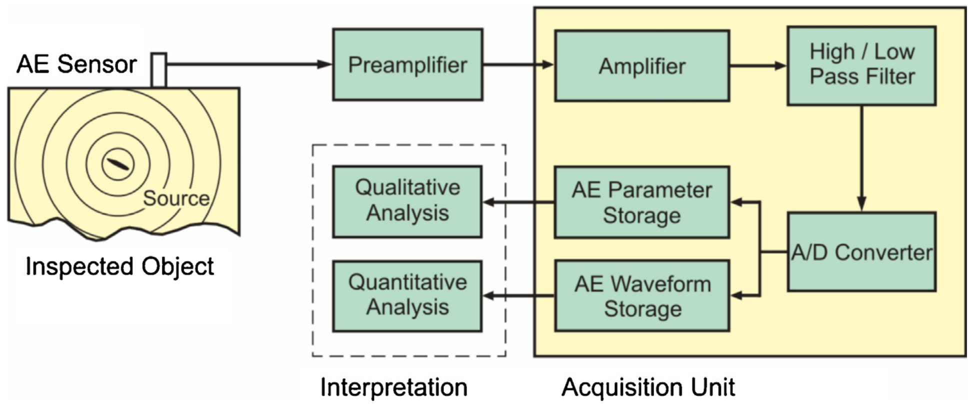

Fig. 1. Principle of acquisition and analysis of acoustic emission (referring to [5]).

changing of the condition, which occurs during the damage and not afterwards. For this reason a dynamic, temporal progress describing analysis of the damage is possible. A disadvantage of the AE technique is the reproducibility of the measured signals, because the phenomenon which generates acoustic emission appears once and can only be detected at the time of the occurrence.

The main elements of an AE measuring system are shown in Fig. 1.

The analysis of the recorded signals can basically carry out qualitatively and/or quantitatively. In the qualitative analysis of acoustic emissions signal parameters are calculated and stored in real-time. Some commonly used AE-parameters are shown in Fig. 2.

Based on these parameters it is possible to describe the temporal development of the AE activity and assign the acoustic emissions to defects or process noise. The identification of a crack with the qualitative analysis is only feasible up to a certain level. In the quantitative analysis, however, the complete waveform is considered. In this method, the entire signals are evaluated in time and frequency domain. Therefore, it is necessary to record all AE signals in digital form.

In the field of metal forming the acoustic emission technique was primarily used to characterise a material behaviour. Therefore ordinary test results were correlated and analysed with the AE signals occurring during the tests. For example tensile tests [8], upsetting tests [9] and bending tests [10] were investigated. Skåre [11] demonstrated that different friction conditions in sheet metal forming can be monitored with AE. Changes of the tribological influencing factors such as the contact pressure, the surface quality and the relative velocity between the friction partners could be determined with the help of the acoustic emission technique. Haupt [10] monitored the cracking in a tube forming process, which was used for manufacturing torsion profiles, in a frequency range up to 500 kHz with the AE.

Results of several studies showed that particularly the acoustic emission analysis is suitable for the online monitoring of hot and cold forming, especially for forging. In [9] differences in the crack initiation and crack growth could be detected in compression tests of magnesium specimens. Furthermore the feasibility of monitoring an industrial bulk metal forming process with the AE technique was shown in [12]. Drive bevel gears could be classified based on the distribution and analysis of simple signal parameters into cracked and accurate parts. In a further study the potential of the AE technique was examined for three different aluminium alloys (EN AW 5083, EN AW 7075, EN AW 6082) [13]. The alloy EN AW 7075 is suitable for crack detection up to a specimen temperature of 150 °C, while in contrast the alloy EN AW 6082 and EN AW 5083 only at room temperatures showed a clearly identifiable AE activity when a crack occurs in a specimen. The investigations indi-

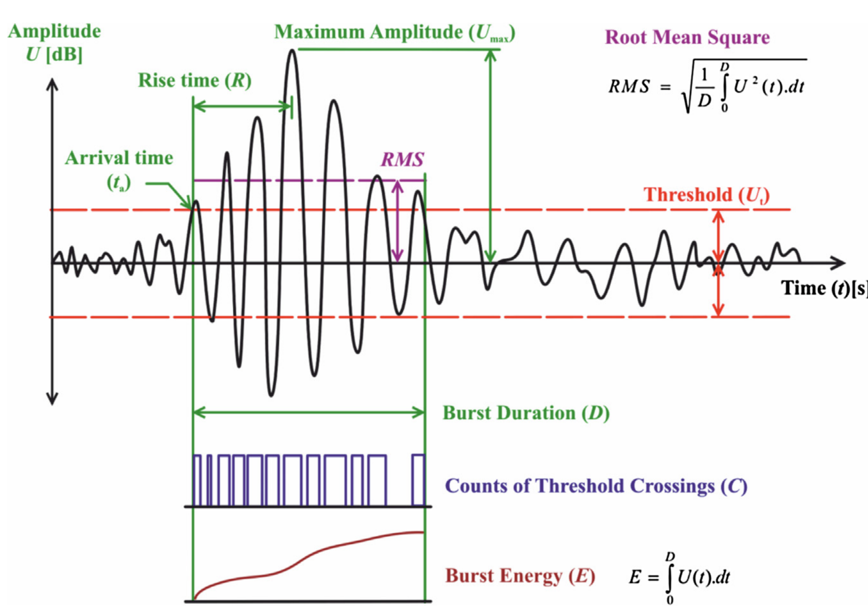

Fig. 2. Outline frequency used signal parameters for the qualitative analysis of acoustic emissions [13].