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Detection of the onset of galling in strip reduction testing using acoustic emission

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Abstract

Galling is an important issue in metal forming of tribologically severe materials such as high strength steel, stainless steel, Al- or Ti-alloys, since it leads to poor surface quality of the formed components, production stops and possibly deterioration of tools. The onset of galling is difficult to detect, since it is either based on the operator's personal judgement or indirect measuring techniques. The application of acoustic emission measuring technique for characterization of onset of galling in sheet metal forming is discussed in the presented paper. The strip reduction test, which emulates the ironing process, has been examined in order to evaluate onset of galling and how this is related to the generated acoustic emission parameters. Preliminary investigations have shown that differences can be found in the acoustic emission signal parameters depending on the frictional conditions between the tool and the workpiece surfaces. A correlation to the severity of galling is found. This is inspected through observations of tested workpiece surfaces in SEM and measurements of the surface roughness. The acoustic emission measuring technique is found to possess promising aspects for online monitoring of galling in metal forming processes.

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Keywords: Acoustic emission; Strip reduction testing; Galling; Surface roughness; Online monitoring;

1. Introduction

Acoustic emission (AE) testing is a non-destructive testing method based upon measurement of dynamic surface motion induced due to a rapid release of elastic stress waves [1-3].

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Elastic waves may be generated suddenly in solids in the ultrasonic frequency regime (typically reported to be in the range 100 kHz - 300 kHz) [4-6] due to
different failure mechanisms caused by static or dynamic loading. Such failure mechanisms are e.g. crack propagation or debonding of corrosion products etc. The occurrence of such events in the solids are experienced as dispersed elastic energy propagating as elastic waves, which can be detected using piezoelectric sensors.
The ability to detect abnormalities non-destructively has caused extensive use of AE testing as a tool for monitoring structural health and processing. The AE testing method has thus been implemented in a variety of different fields, e.g. evaluation of resistance spot welding processes, structural health monitoring of wind turbine systems, detection of defects in bearings etc.

As regards to sheet metal forming the prevented access to the sheet/tool contact interface requires indirect measuring to detect the onset of galling. Conventional techniques, e.g. measurement of the friction force, have typically been found to have too limited sensitivity. AE measuring has, on the other hand, been successfully applied as an online monitoring technique for evaluation of different tribological characteristics in metal forming operations [7-12]. Behrens et al. [13] have concluded that acquisition and analysis of AE signals allows for online assessment of production conditions and deviations in production processes. Skåre [14] similarly noted that energy analysis of the AE signals allows for an evaluation of the quality of lubrication and detection of process defects in sheet forming such as the stick-slip effect, cracking etc. Mostafavi and Pashmforoush [7] successfully applied the AE technique for detecting the onset of galling, noting a direct relation between the wear mechanism and AE peak amplitudes. However further investigations are needed in order to correlate the AE signals with the experienced failure mechanisms. The current study therefore aims at exploring the possibility to apply the AE testing methodology for detection of the threshold sliding length for lubrication breakdown and the subsequent onset of galling.

1.1. Acoustic emission parameters and signal characterization

AE signals generally occur in the two distinguishable forms; namely as burst signals or continuous signals. Burst-type emissions are characterized by being individual emission events of very short duration and large amplitudes. A continuous AE signal is on the other hand defined as having a sustained signal level, which is produced by rapidly occurring AE events. Common waveform parameters are defined in ISO 12716: 2001 for characterization of AE signals. The common purpose of AE testing is to characterize AE events and parametrize these in order to adequately describe the occurring event. For such analysis, the following characteristics are commonly applied:

- AE event counts above a voltage threshold.
- Averaged signal intensity (root mean square of the voltage signal).
- Peak amplitudes
- AE energy
- Duration and rise time of AE events
- Frequency spectral analysis.

Assessment of the listed parameters is commonly applied for analysis of the time domain for real time monitoring applications.

2. Experimental procedure

2.1 Strip reduction testing

The strip reduction test in figure 1 is a testing method used to emulate the ironing process [15]. A strip is placed on a supporting plate and both are fixed in a pair of jaws, while a circular cylindrical tool pin is loading the top of the strip with a defined height reduction. The strip is subsequently pulled with constant speed. The test is developed as a simulative test, which emulates the tribological conditions in the interface between a die and a can wall during ironing. Evaluation of the tribological conditions of the process can be performed by measurement of 1) the horizontal drawing force, 2) the surface roughness of the strip after reduction [16] and 3) AE events.