CONTRIBUTION OF ACOUSTIC EMISSION INTO OPTIMAL BEARING LUBRICATION

Burkhard Ziegler

University of Applied Sciences
D. 35390 Gießen, Wiesenstr. 14
Phone: + 49 641 309 2226 ; Fax: +49-641-309-2911
e-mail: Burkhard.Ziegler@mmew.fh-giessen.de

Abstract

This article describes the bases of the acoustic emission analysis to make successful applications in the range of the tribological problems, especially at machinery slide journal bearings. Acoustic emission differs from ultrasonic testing, which actively probes the structure; Acoustic emission listens for emissions from active defects and is very sensitive to defect activity when a structure is loaded beyond its service load. During detecting and analysing the generated acoustic emission we earn information about the behaviour, state or quality of these acoustic emission sources. A lot of different sources are generating acoustic emission (e.g. corrosion processes, fluid friction, cracks, cutting processes). This paper shows the acoustic emission sources, the wave propagation, the mode conversion, the damping, the design of a typical transducer and the whole measurement chain. The piezoelectric disc, the "heart" of a typical acoustic emission transducer, converts the incoming mechanical wave into a corresponding electrical signal. Every transducer has its own characteristic, if this is unknown we can test it with difficult methods e.g. so called reciprocal method. On the end of this paper the signal parameters (burst-count, rise-time, signal-duration, signal peak amplitude, signal energy and root-mean-square) will be discussed.

Keywords: *non-destructive testing, acoustic emission*

Zusammenfassung

Dieser Artikel beschreibt die Grundlagen der Schallemissionsanalyse um erfolgreiche Anwendungen im Bereich der Tribologie, speziell bei Gleitlagern in Maschinen, zu erstellen. Die Schallemissionsanalyse unterscheidet sich von dem aus der Werkstoffprüfung bekannten Ultraschallverfahren. Das Ultrasachallverfahren leitet aktiv Ultraschall in die Proben ein. Die Schallemissionsanalyse empfängt aus der Probe die dort erzeugten Schallemissionen in Form von Ultraschallwellen. Durch das Empfangen und Auswerten der erzeugten Schallemissionen erhält man Informationen über das Verhalten, den Zustand oder die Qualität der Schallemissionsquelle. Die Schallemissionsanalyse ist ein zerstörungsfreies Prüfverfahren. Es gibt eine große Anzahl unterschiedlicher Schallemissionsquellen (z.B.: Lagerreibung, Gelenkreibung, Korrosionsprozesse, Brüche). Um die Schallemissionsanalyse exakt anwenden zu können, muss man mit deren Mechanismen vertraut sein. Dieser Artikel führt ein in die Schallemissionsquellen, die Ausbreitung der Wellen, die Modenwandlung, die Dämpfung, den Aufbau der Sensoren und erklärt die Messkette. Die Piezokeramik ist das „Herz" eines typischen Schallemissionssensors, sie wandelt (aufgrund des piezoelektrischen Effektes) die einfallende mechanische Welle in ein korrespondierendes elektrisches Signal um. Jeder Sensor hat seine spezielle Charakteristik (Übertragungsfunktion). Ist diese unbekannt, kann man sie durch verschiedene Methoden messen und daraus ableiten. Die Signalparameter (Impulsrate, Anstiegszeit, Signallänge, maximale Amplitude, Signalenergie und RMS - Wert), die der Bewertung der Schallemissionsquelle dienen, werden zum Schluss des Artikels besprochen.

Schlüsselwörter: *zerstörungsfreie Werkstoffprüfung, Schallemissionsanalyse*

1. Introduction

Acoustic emission (AE) differs from ultrasonic testing, which actively probes the structure; AE listens for emissions from AE sources and is very sensitive to detect activity when (e.g. in a proof test) a structure is loaded beyond its service load [3]. During detecting and analysing the generated acoustic emission we earn information about the behaviour, state or quality of these acoustic emission sources. Acoustic emission is defined as transient elastic waves generated from rapid release of strain energy caused by deformation or damage within or on the surface of material [8]. The frequency ranges from 30 kHz up to 2 MHz. We can also use the AE, generated from the fluid friction inside the bearing gap of slide bearings, to characterise there lubricant conditions.

2. Acoustic emission sources

The following sources are generating acoustic emission:

- Fluid friction (plain and slide journal bearings, biobearings, tubes),
- Boundary friction (microbearings, biobearings),
- Corrosion processes (ships, vessels, welding seams),
- Cracks and crack growth (structures under stress),
- Crack bank friction (crack opening, sliding and tearing),
- Cutting processes (lathing, milling, drilling),
- Solid friction (gliding),
- etc.

3. Acoustic emission waves and wave forms (modes)

In the field of acoustic emission we have general two groups of wave forms:

1. The wavelength is less than the thickness of the material (Fig. 1a),

- Longitudinal waves (oscillations in propagation direction),
- Transversal waves (oscillation perpendicular to the propagation direction),
- Rayleigh waves (Surface wave, combination of a) and b) the oscillation depending on the depth).

2. The wavelength is greater or equal than the thickness of the structure. These waveforms are existing in thin plates and waveguides (Fig. 1b),

- Strain wave (symmetrical wave),
- Bending wave (antisymetrical wave).

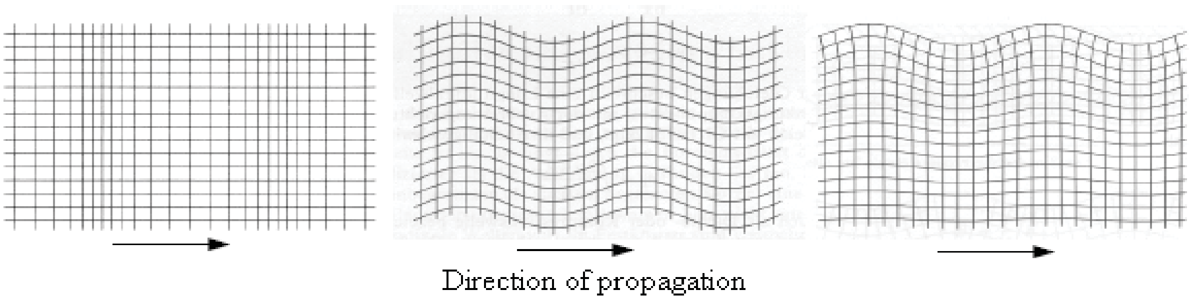

Fig. 1a. Wave forms (Wavelength less than material thickness) Longitudinal-, Transversal-, Rayleigh wave

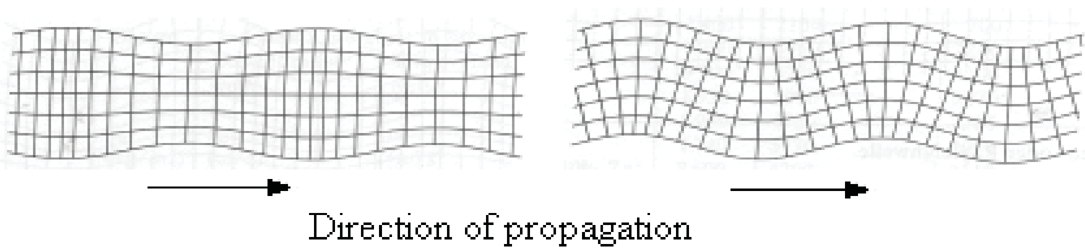

Fig. 1b. Wave forms (Wavelength greater or equal than material thickness): strain wave, bending wave

4. Wave propagation

By propagating from the source to the surface (where the AE sensor is mounted) the AE wave can change its characteristic. Depending on the wave frequency and the damping-coefficient of the material in which the wave propagates the energy of the mechanical wave disappears by friction and dispersion (Fig. 2).

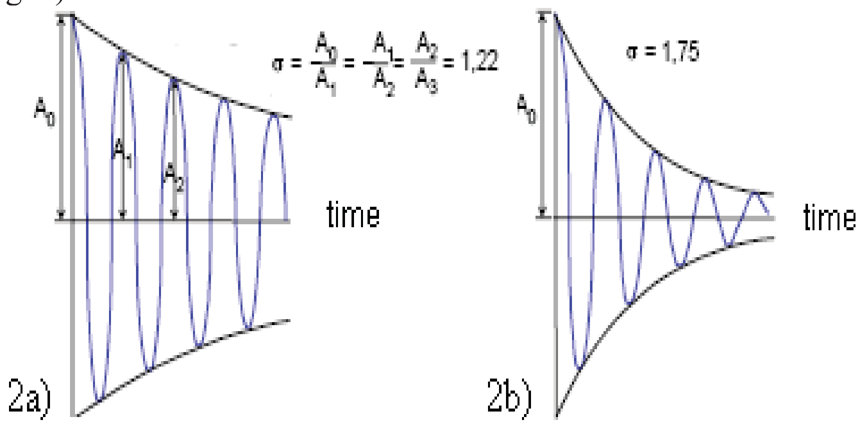

Fig. 2a. Weak wave damping Fig. 2b. Strong wave damping

If the mechanical wave has passed an interface between two materials, the wave can be transferred broken or can even be reflected. With the general law of refraction (Snell's law) it is possible to calculate the angle of reflection or refraction. A mode conversion is also possible (Fig. 3).

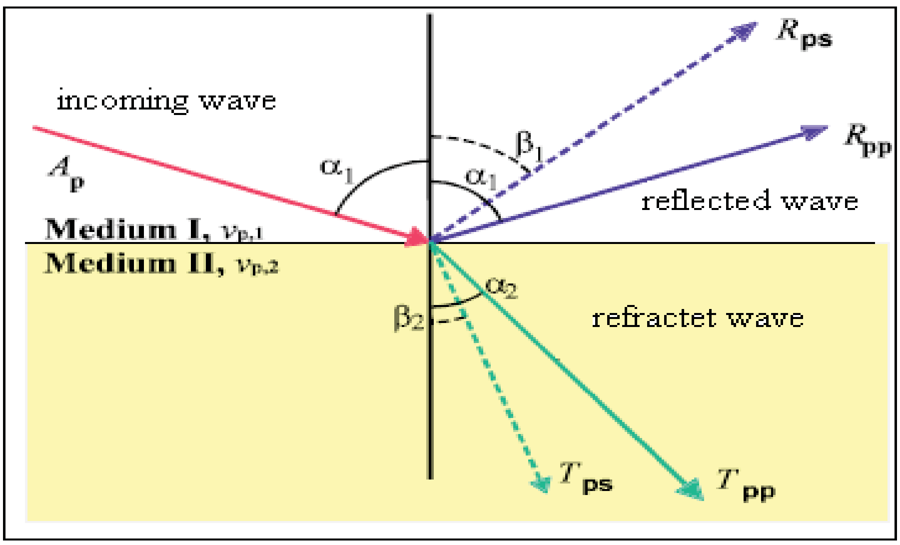

Fig. 3. Reflection and refraction of a plane wave at the interface between Medium I and Medium II. The incoming wave can be reflected (R_{ps}, R_{pp}) or transferred broken (T_{ps}, T_{pp})

5. Acoustic emission transducer

The piezoelectric disc is the "heart" of a typical acoustic emission transducer (Fig. 4). The piezoelectric disk converts (by using the piezoelectrical effect) the incoming mechanical wave into a corresponding electrical signal. In front of the transducer there is a thin plate to protect the piezoelectric disk. The housing contains also a connector to derive the electrical signal generated from the piezoelectric disk.

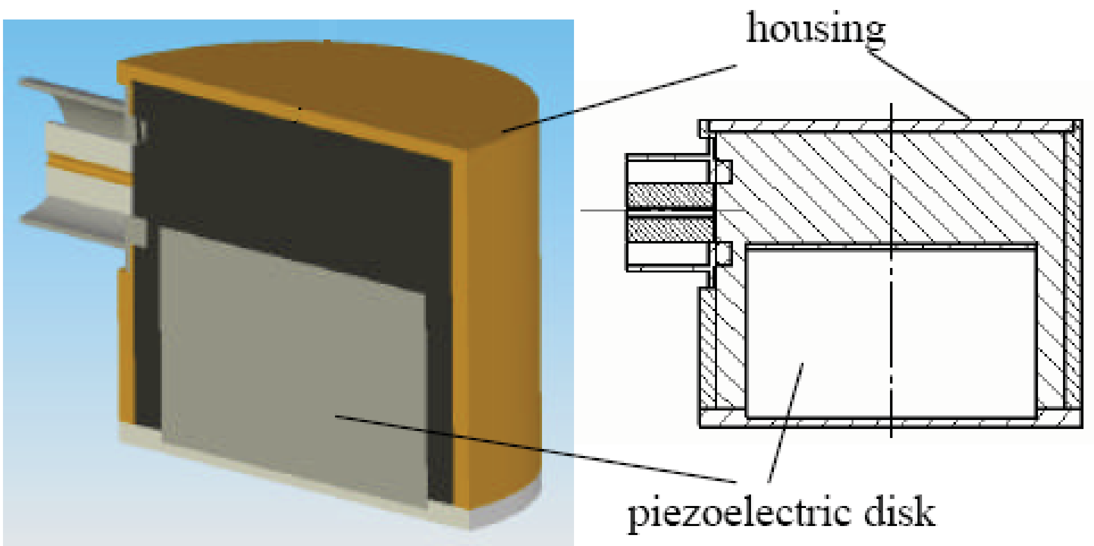

Fig. 4. Design of a typical AE transducer. The piezoelectric disk converts the incoming mechanical wave into a corresponding electrical signal

Depending on the physical dimension, the shape, the material constants and the damping layer on the backside of the piezoelectric disk, every transducer has its own characteristic. Fig. 5 shows a typical frequency response function from a transducer under test, his frequency ranges from 30 kHz up to 150 kHz. The sharp peaks of the response function show us the different resonate frequencies of the transducer.

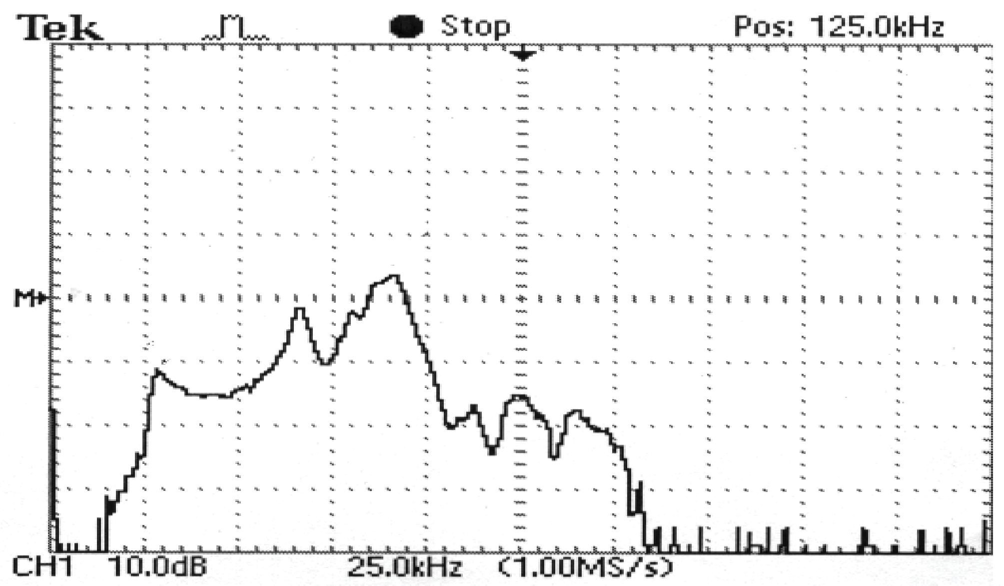

Fig. 5. Response function of an AE transducer (frequency domain). The sharp peaks of the response function show us the different resonate frequencies of the transducer

If a transducer characteristic is unknown we can test it with difficult methods or we compare the performance of the several transducers [1]. Fig. 6 shows the scheme of a so called reciprocal method. The transducer under test receives the mechanical wave transmitted from a sender transducer. The sender transducer supplied by an arbitrary function generator with a delta – impulse, to generate a wide band mechanical wave.

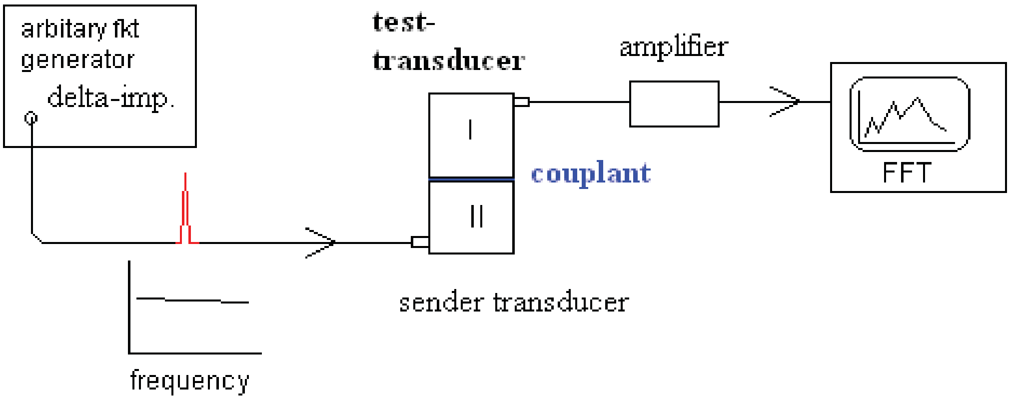

Fig. 6. Scheme of the so called reciprocal method (face-to-face). The test-transducer received a wide band mechanical wave which was generated from the sender transducer. The response of the test-transducer can be evaluated

Fig. 7a shows the test method with the so called Beatti block. The sensor under test is contacted (with couplant) at a conical " Nonresonant" block. A nozzle at the opposite site of the block generates mechanical waves by a gas jet. The conic geometry and the lack of any parallel surfaces shown in Fig. 7b reduce the number of mechanical resonances that the block can support [1].

a)

b)

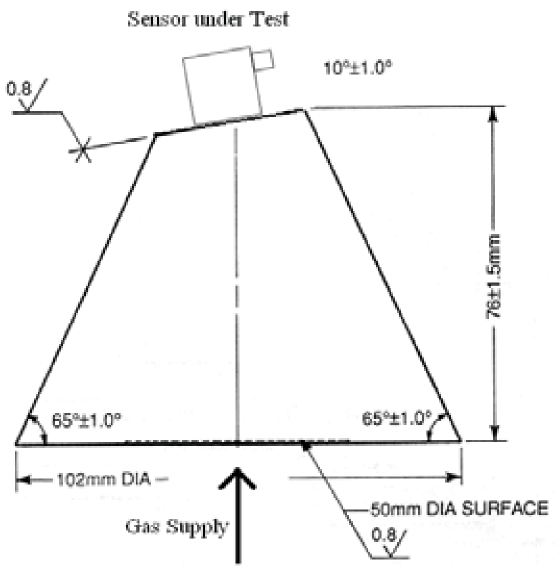

Fig. 7a. Real Beatti – Block test stand for acoustic emission transducer
Fig. 7b. A drawing of the conical non resonant block according to ASTM E 976-94

6. Acoustic emission measuring system

Fig. 8. shows schematicly a simple acoustic measuring system. The mounted AE transducer generates an electrical signal corresponding to the incoming mechanical wave. It is very important to couple the AE transducer on the specimen or workpiece with a couplant (a liquid, grease, paste or pliable solid) to permit transmission of ultrasonic energy between them [3]. If there is no possibility to mount the transducer directly on the workpiece, the mechanical waves can be transmitted by a wave guide to the remoted transducer [4]. Waveguides can be wires, rods or a jet

of water [6]. The electrical signal will be amplified and conditioned before it appears on an oscilloscope or will be registrated in a computer. It is necessary to separate the acoustic wave emissions, originating from within the material, from external signals, such as environmental noise, mechanical noise (vibrations), electrical noise (background noise, electromagnetic compatibility), etc. This will be achieved by careful filtering of the received AE signals. Best practice would be to identify and remove as many sources of extraneous noise as possible before testing [3]. The disturbing vibrations can be damped by using materials such as Pertinax®, Teflon®, etc. The background noise (electromagnetic compatibility) can be damped by using short coaxial-connecting-cables and electrically isolation material, etc. To protect capacity variations in the connecting-cables, it is necessary to fix them [7].

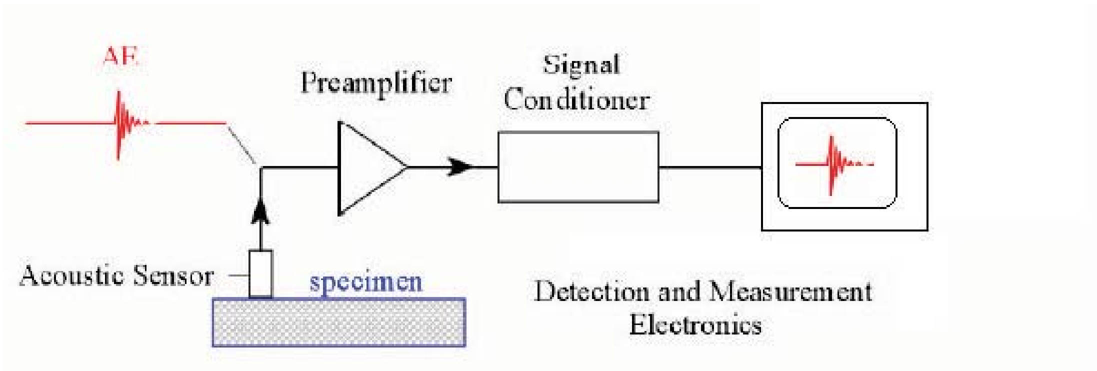

Fig. 8. Simple acoustic measuring system(scheme)

7. Acoustic emission signal forms

There are two acoustic emission signal forms: the continuous AE (Fig. 9) and the bursts (Fig. 10). The continuous AE are generated during friction processes. The Burst signals are generated by releasing elastic energy caused by cracks. The elastic energy can be stored in several ways in different materials or specimen. The Burst signal shown in Fig. 10 is generated by a micro crack into a human femur, it is characterized by a very short rise time and an exponential decrease of the amplitude. The frequency of the crack initiations depends on the load and the state of health of the femur (osteoporosis). The Burst was localized in the interface between the compacta and the spongiosa of a human femur, they both have different compliances. During e.g. an knee bending the shear stress into the interface arises and a crack of a trabecular is possible. The generated elastic wave propagated through the femur and will be detected with a special AE sensor (BoneDiaS®) at the epicondylus lateralis [2].

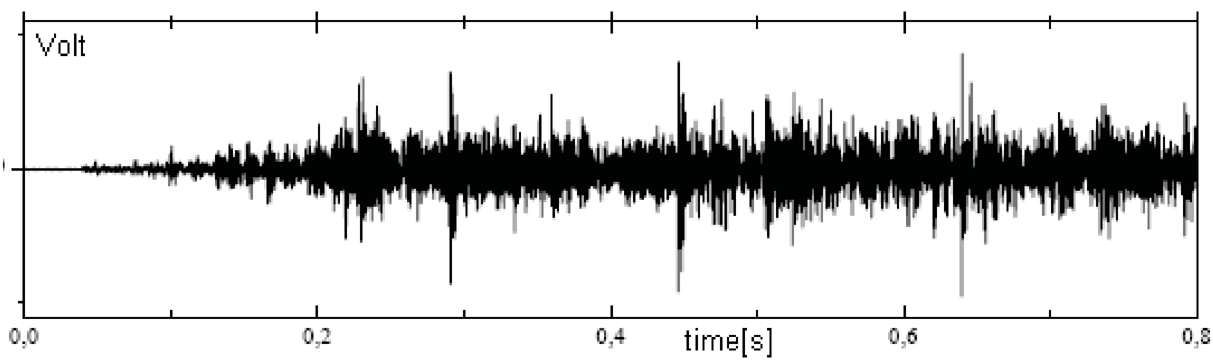

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Fig. 9. Continuous acoustic emission from a friction process

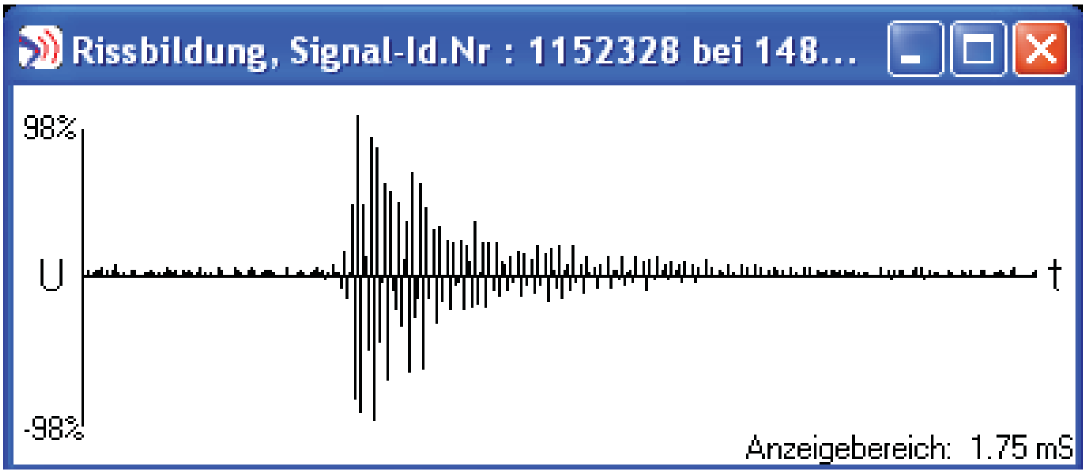

Fig. 10. Burst type signal generated by a micro crack into a human femur, characterized by a very short rise time and an exponential decrease of the amplitude [2]

8. Acoustic emission parameters

To evaluate and compare AE signals, it is necessary to have numerical parameters. Fig. 11 shows the parameters of a burst signal corresponding to AE rules of the German Society for non-destructive testing. Usually the following parameters describe an AE signal:

- burst count (number of detected burst signals crosses the detecting threshold),
- signal duration (interval between the first and the last time between threshold exceeding by a burst),
- signal peak amplitude (maximum absolute amplitude within the duration of the burst signal),
- signal rise-time (time interval between the first threshold crossing and the maximum peak amplitude of the burst signal),
- signal energy (square of signal amplitude).

To compare continuous AE we need an energy equivalent parameter. The **r**oot – **m**eans – **s**quare chip computes a complex ac input signal and gives an equivalent dc output level [7]. All these parameters are used to identify the nature of the source.

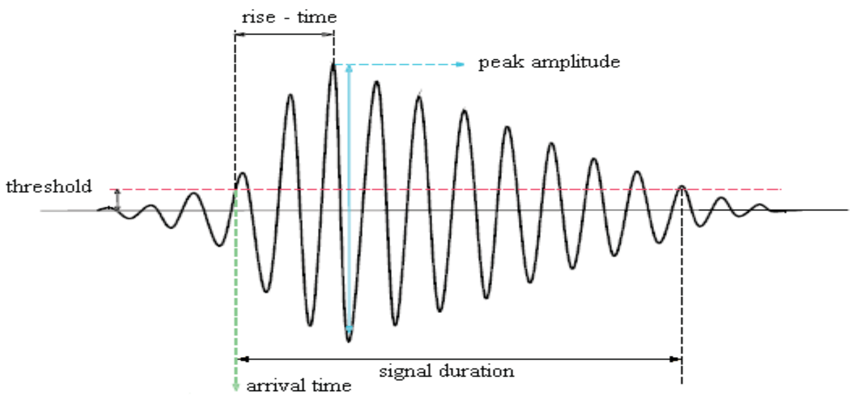

Fig. 11. Parameters of a burst signal corresponding to AE rules of the German Society for non-destructive testing

9. Conclusion

To make successful applications in the range of machinery slide journal bearing based on the acoustic emission analysis, it is necessary to know how it works. This article describes the bases of this non destructive testing and monitoring method:

- Acoustic emission sources,

- Acoustic emission waves and wave forms,
- Wave propagation,
- Acoustic emission trancducer,
- Acoustic emission measuring system,
- Acoustic emission parameters.

Acknowledgement

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