MONITORING OF CENTRIFUGAL CAST ROLLS USING ACOUSTIC EMISSION

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Abstract

The seven centrifugal cast rolls were on-line monitored by using acoustic emission (AE) method till seven days after pouring. AE technique is suitable method, since the signal is generated naturally by abrupt localized changes in stress in a solid [1]. The aim of this work was to optimize the cooling rate and to investigate the effect of scrap quality (for melting process) on the internal quality of rolls. The evaluation of AE records (counts rate versus time) revealed, that the quality of rolls is affected mainly by:

1/ phase transformations

2/ generation of thermal and transformation stresses during cooling

All experiences are summarized at the end of this paper and new topics for further research are outlined.

Keywords: counts rate, phase transformation, residual stress, cooling rate

Introduction

The quality of centrifugal cast rolls is usually controlled at the end of manufacturing process. In the course of the technological process no data, which could reveal the development of defects, are usually recorded. The knowledge of the mechanisms of the stress generation during both solidification and cooling of rolls is necessary for:

1/ modification of the manufacturing process in order to minimize the formation of defects.

2/ determination, which steps of the production process are critical for the development of defects.

Acoustic emission (AE) is an excellent tool for on-line monitoring of long-term processes. The results of AE evaluation have to be checked by using other nondestructive testing methods, e.g. ultrasonic or magnetic methods.

Experimental procedure

The centrifugal cast rolls consisted of two layers. The outside working layer was formed by a high alloy chromium cast iron (about 18% Cr), the body of rolls was made of a low alloy gray cast iron.

Fig.1 shows the experimental assembly for on-line AE monitoring of centrifugal cast rolls. This assembly consists of three essential parts:

1/ detection of AE signal

2/ analog data processing

3/ digital data processing

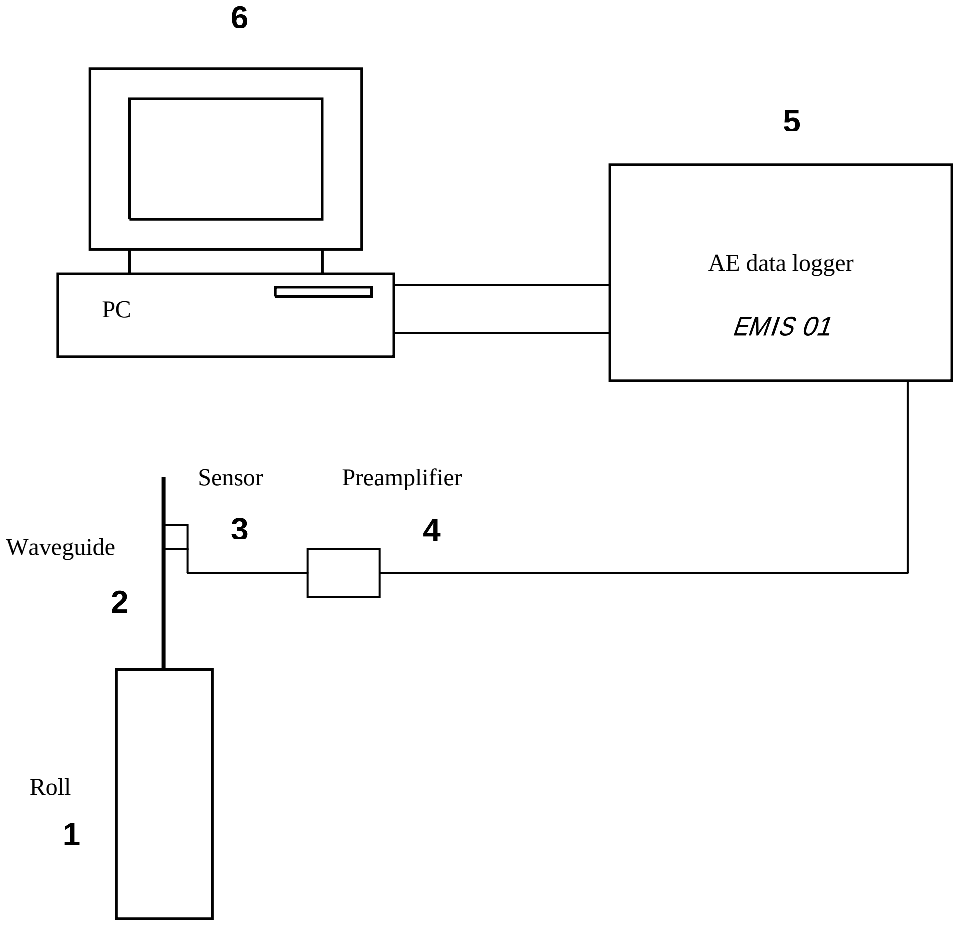

Fig.1
The experimental assembly for on-line AE monitoring

The signal is detected by using AE-sensor (3) fixed at the end of waveguide (2). The waveguide, which was put into liquid metal on the upper side of roll (1), enables use of piezoelectric AE sensor. The recommended working temperature for this type of sensor is to 80 °C.The output from sensor is passed to the preamplifier EM_1 (4) in which is the signal amplified, first frequency filtered and converted for transmission (on low output impedance) to AE-data logger EMIS_01 (5).The cca 50 meters long coaxial cable serves for connection between preamplifier EM_1 (4) and data logger EMIS_01 (5).

A data logger EMIS_01 (5) is essentially a device for performing amplifying, frequency filtering and amplitude distribution of signal by sorting it into 7 amplitude windows. The gain of whole electronic chain was set on 60 dB. The signal is in EMIS_01 digitalized and in the form count rate transferred to PC (6) by using serial transfer line RS485. The evaluation is done in the form counts rate for all seven amplitude windows. The trends on figures 2 to 8 represent the relation between counts rate versus time for all counts higher than 200 μV (related to sensor output).For detailed analysis of all amplitude windows was not enough space in this paper.

Experimental results

The technological process of the centrifugal cast rolls production was on-line controlled up to 165 hours after pouring. An evaluation of the rolls quality during solidification and cooling was performed using count rate versus time records. The AE monitoring started approximately 25÷30 hours after pouring of the roll body. At this moment the waveguide was put into liquid metal. The evaluation of the AE monitoring can be divided into three time intervals :

1. period: from 25-30 hours to 65 hours after pouring (Figs.2 and 3)
The dominant processes taking place during this time period are phase transformations. The phase transformation dynamics depends on the cooling rate, which determines the evolution of temperature gradient in castings and the start and finish temperatures of transformations. The AE records indicate that small surface cracks can form in this time period.

2. period: from 65 hours to 137 hours after pouring (Figs.4 and 5)
Thermal and transformation stresses develop in the course of cooling. In this period the stress releasing is possible due to sufficient plasticity of the metal matrix.

3. period: from 137 hours to 168 hours after pouring (Figs. 6 and 7)
Further cooling is accompanied by a decrease of plasticity of the metal matrix and by aging reactions. The periodically repeated bursts of elastic energy in Fig. 6 demonstrate that in this period cracks can form in the rolls.

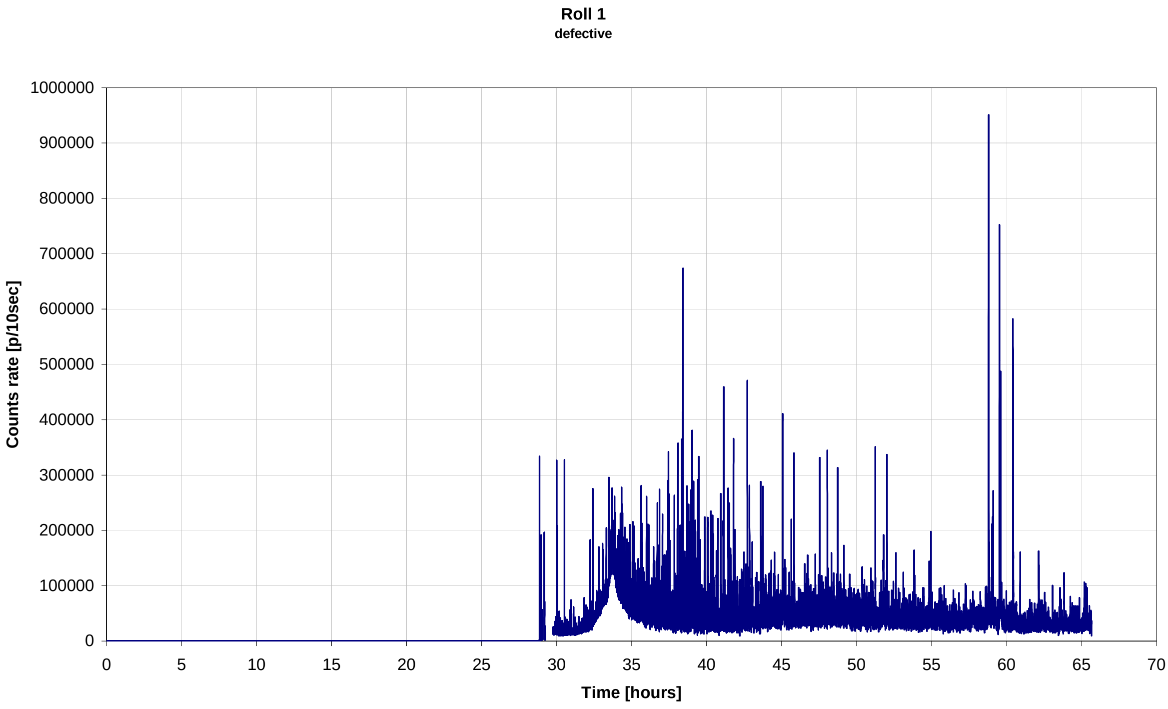

Fig.2
Typical relation counts rate versus time for defective roll (period 1)

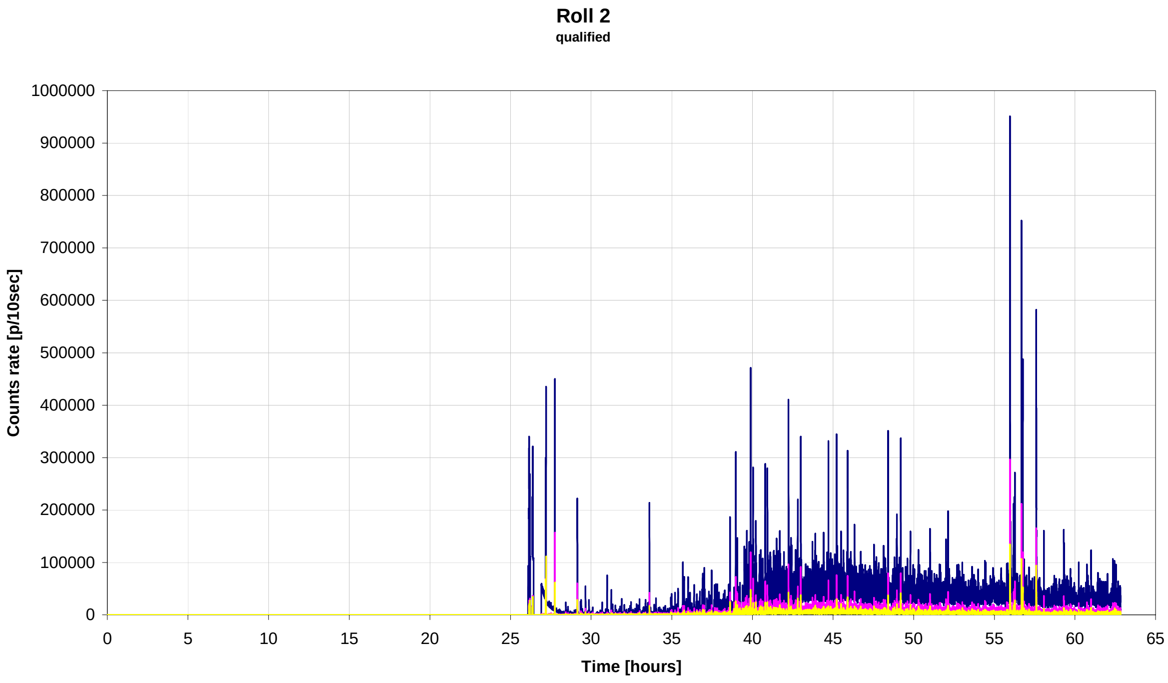

Fig.3
Typical relation counts rate versus time for qualified (non defective) roll (period 1)

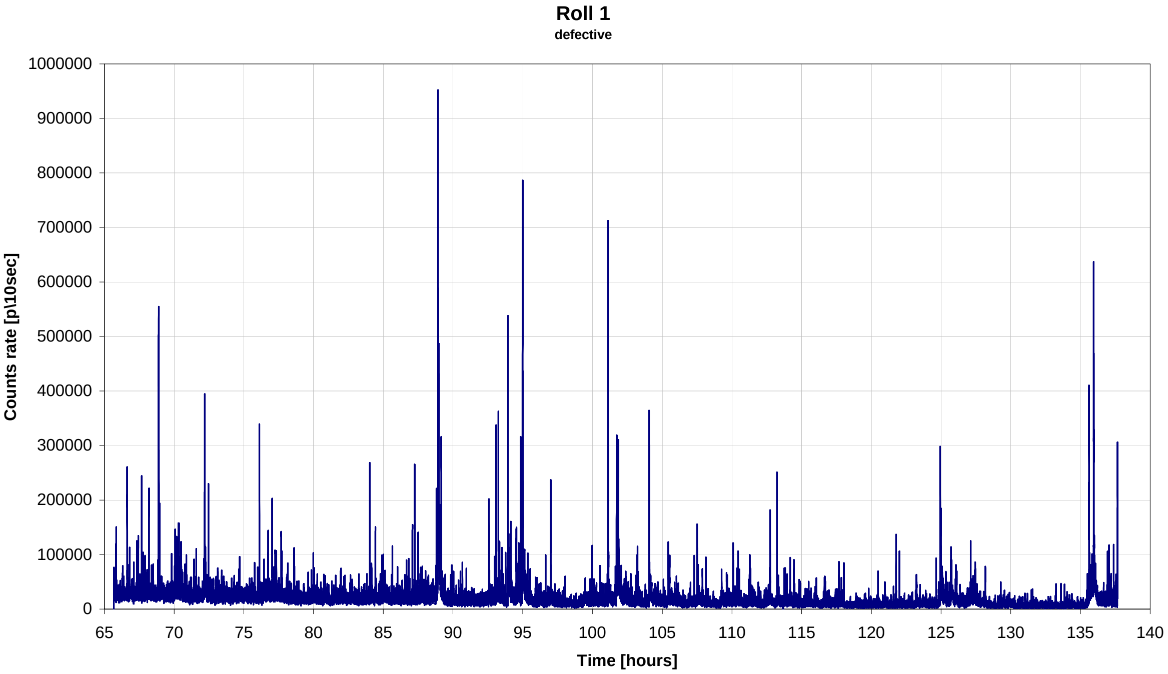

Fig.4
Typical relation counts rate versus time for defective roll (period 2)

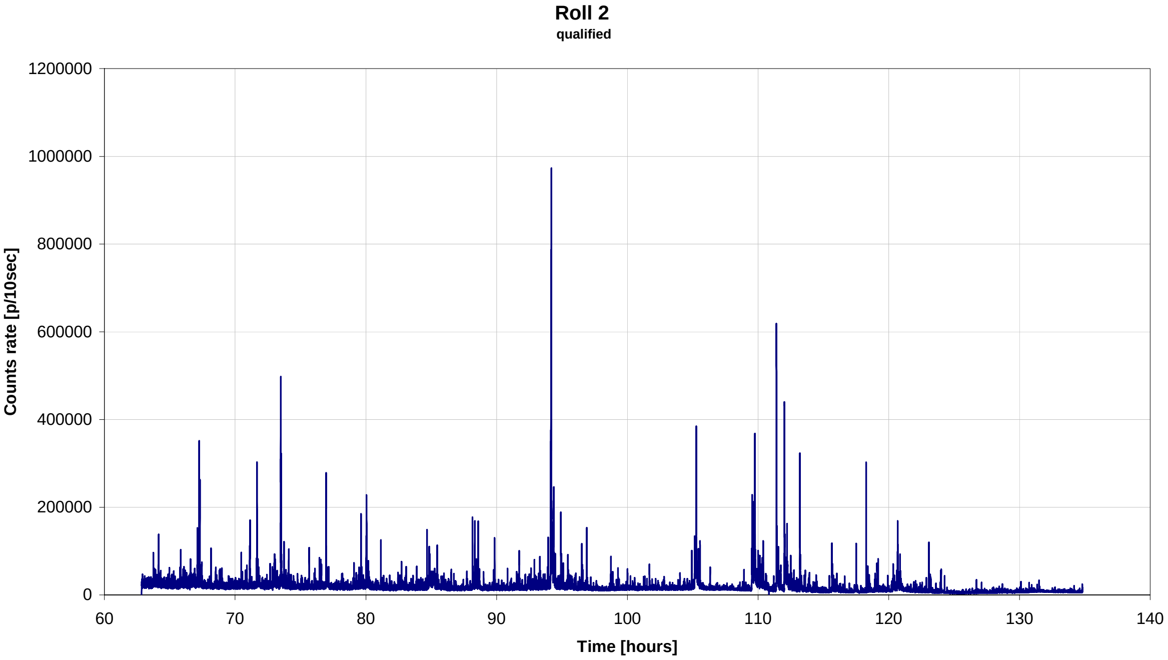

Fig.5
Typical relation counts rate versus time for qualified (non defective) roll (period 2)

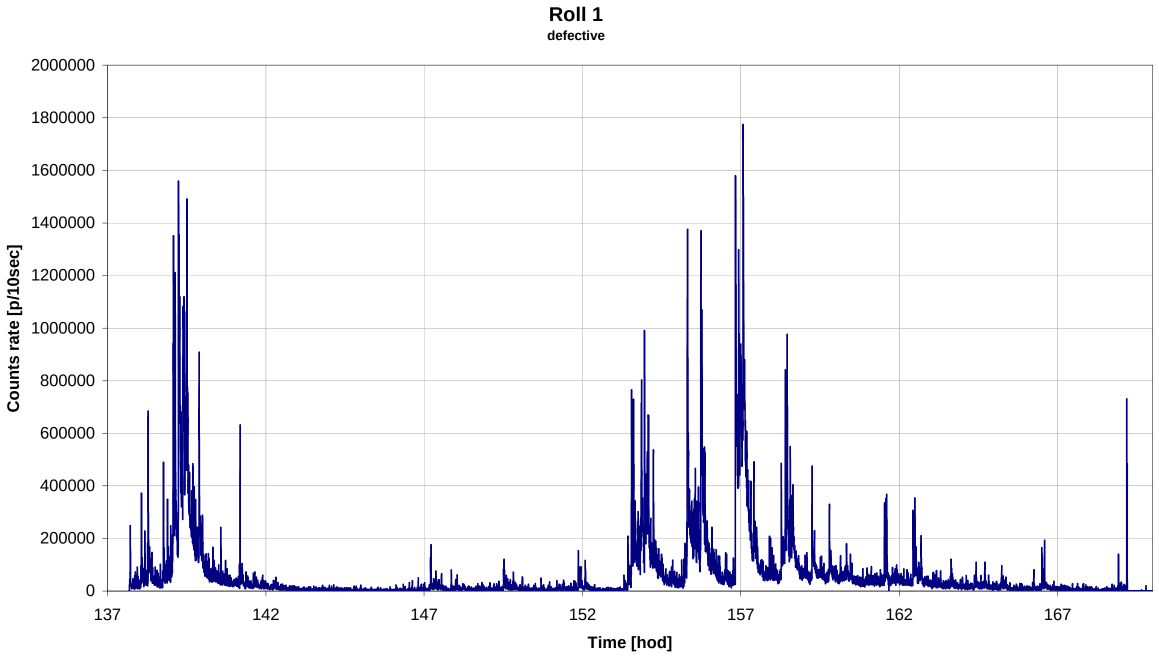

Fig.6
Typical relation counts rate versus time for defective roll (period 3)

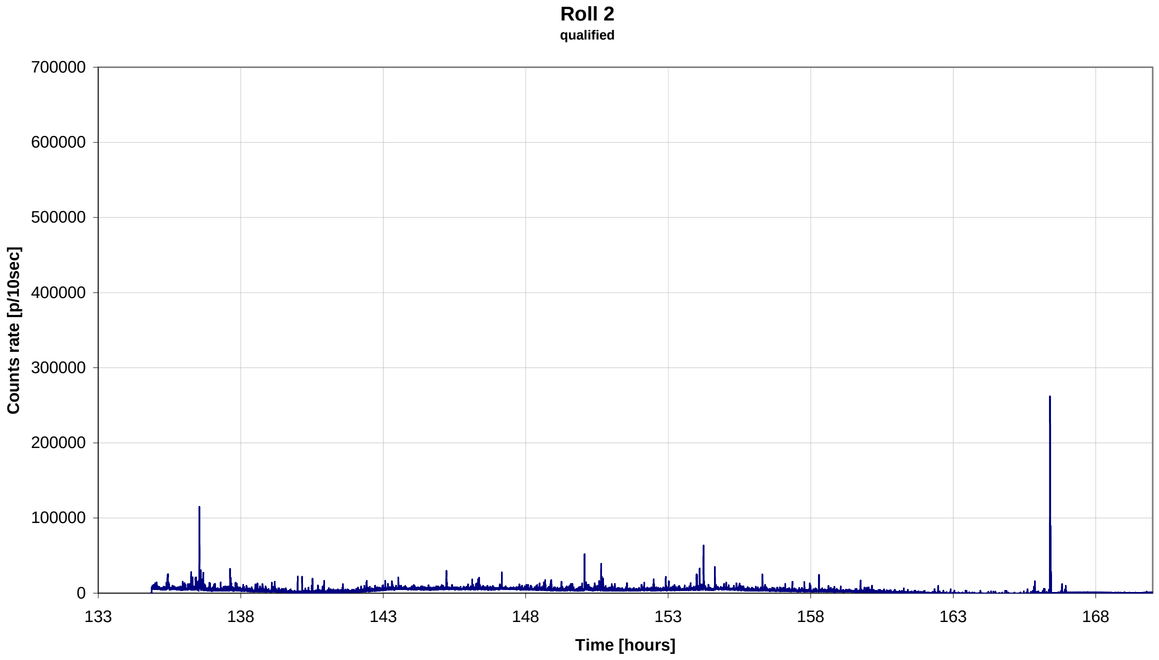

Fig.7
Typical relation counts rate versus time for qualified (non defective) roll (period 3)

Conclusion

The count rate versus time records in Figs. 2 and 3 show, that the internal quality of rolls is strongly affected by phase transformations. In the case of defective rolls phase transitions took place about 3 to 5 hours earlier in comparison with defect free rolls. It is expected that phase transformations and temperature gradient across the rolls generated tensile stresses in the surface layer of the rolls. In the time interval of 30 to 60 hours after pouring (1. period) small surface cracks, so called " spider`s web cracks", are formed. The propagation of these surface cracks towards the roll center was restricted due to the change of tensile into compressive stresses in the surface layer of rolls. This interpretation is based on the experience obtained during previous investigations on heavy forgings and castings (2,3).

The releasing and rearranging of residual stresses are the principal processes taking place in rolls at cooling times over 60 hours after pouring, Figs. 4-7. The temperature fall was accompanied by the drop of plasticity of the metal matrix and by aging processes, which resulted in embrittlement of the rolls. The severity of embrittlement depends on the chemical composition of material and on the cooling rate, which is important for development of residual stresses. At slow cooling rates the releasing of elastic energy took place continuously. This reduced the tendency for initiation and propagation of cracks. As can be seen in Figs. 6 and 7 the faster cooling rate of the roll No. 1 in comparison with the roll No. 2 was associated with pronounced periodical bursts of elastic energy. A visual inspection of rolls at room temperature revealed small surface cracks in the roll 1, while no defects were found in the roll 2.

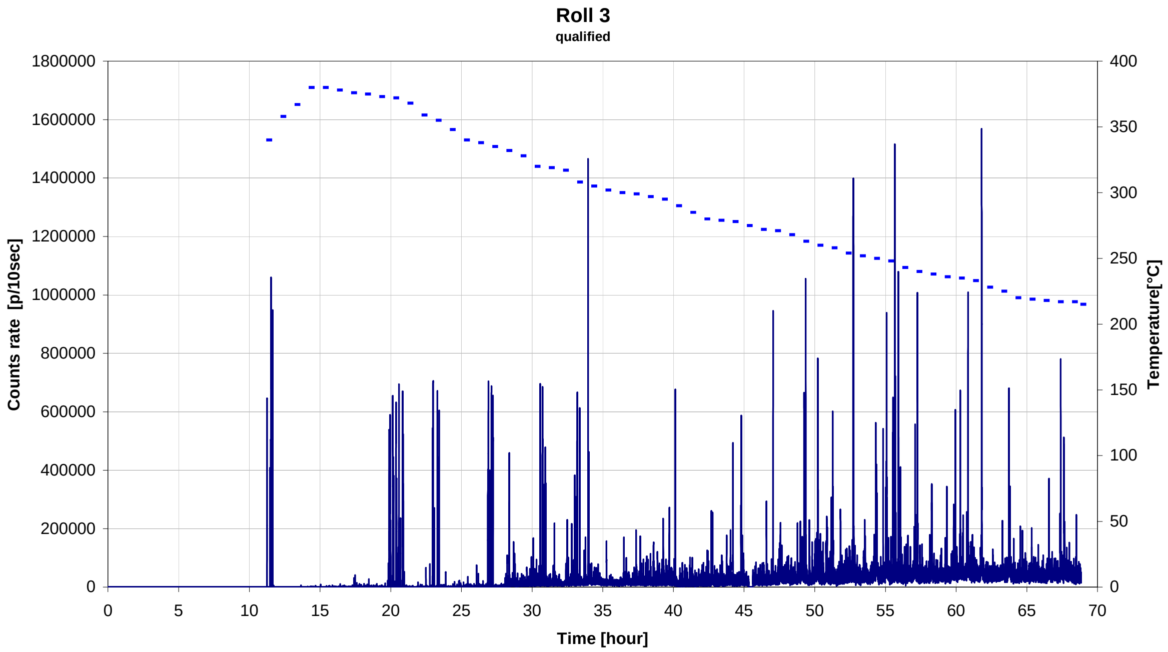

Fig.8
Typical relation counts rate versus time for qualified (non defective) roll (period 1) slow cooling rate

One of the rolls namely roll 3 (Fig. 8) was held under slow cooling rate. The releasing the internal stress is performed continuously so aging processes are suppressed. No cracks were found at the end of manufacturing.

The remaining obstacles to the implementation AE method are techniques to separate defect signal from noise reliably and to characterize flaw severity for accept-reject output criteria. Many supporting studies and experiments of role of metallurgical and manufacturing variables ought also to be carried out to determine the bounds of sensitivity AE. This includes temperature, ultrasonic and eddy current measurements in manufacturing process. All conclusions must be controlled by laboratory experiments and studies.

On-line AE monitoring is very useful tool for the control of technology. For many physical and metallurgical processes, which can not be simulated in laboratory environment, provides this method necessary data. There are only several potential techniques that show promise for in- process control, one of them is AE.

Additional theoretical suppor of this workwas provided by the Grant Agency of the Czech Republic under No. 106/04/1334.

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