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APPLICATION OF ACOUSTIC EMISSION IN PUNCH PRESS MONITORING

The authors of this paper analysed Acoustic Emission (AE) signal generated in different stages of punch process, emitted from crank PMSC – 12 punch press. The details of the instrumentation used are described. The experimental part describes the influence of feedstock thickness and hardness to the intensity of the emitted signal. The final part of the investigation presents the changes of AE signal caused by simulated tool abrasive wear. The possibilities of AE monitoring of punching of thin plates are also discussed.

1. Introduction

The stress wave caused by the energy release in stressed solids is called the Acoustic Emission (AE) effect. The AE sources are crack formations, generation or annihilation of dislocations and friction processes. The AE technique has been developed for monitoring the processes in various branches of industry. Application of acoustic emission in punch press monitoring is focused to avoid catastrophic failures of tools and machines and to reduce expensive machine downtime and tooling cost by an early detection of any abnormal condition. The advantages of application of AE technique versus traditional method of strain gauge punching force monitoring appear more clear when thin plates are subject of press processing. The application of AE measurements in punch press working was described in various papers. Among them [1] and [2] can be recommended as detailed research descriptions. AE monitoring of friction processes caused by deep drawing of sheet metal is

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discussed in [3]. Some information about the principles of AE technique applied to control friction processes can be found in [4].

The aim of the authors of the presented paper is to point out the influence of feedstock sheet thickness and hardness on the intensity of the emitted AE signal. The other part of the investigation presents the changes of AE signal caused by simulated tool abrasive wear. This allows for detection of process failure. In the final part of the presented paper, the authors stated what is the thickness range of the stock possible to monitoring using the typical AE instrumentation.

The investigation of punching process described below was performed using 5 ton capacity, pneumatic crank PMSC – 12 punch press. The steel rod of 20 mm in diameter and 100 mm long was attached to the press die-set at the position found experimentally. At the end of this rod the wideband 90 – 900 kHz AE transducer, manufactured by American Physical Acoustic Corporation, was fixed using metal bands and screw joints. The steel rod acted as a waveguide for the measured AE signal. Stress wave transmission of the waveguide was poor for the lower frequency band, generated by the press driving engine parts. Therefore, the rod had much better efficiency in transmission of the stress wave frequencies higher than 50 kHz and generated in worktool-stock contact zone. The AE signal was processed in a custom – made AE analyzer. The AE analyzer was capable to compute the root-mean-square (*U RMS*) of the registered electric signal what can be also described as deriving a square root of the AE signal energy. The *U RMS* parameter was calculated separately for the lower frequency band (50–100 kHz) and for the highest frequency band possible to receive (400–900 kHz). The AE analyser transmitted the both values of the AE signal activity, together with the current level of the force measured at the punch, using the strain gauge method, to the PC computer every 2 milliseconds via parallel port. The instrumentation described above enabled the authors to control the process with sufficient time resolution and to compare the intensity of the registered AE signal generated in low (*U RMS L)* and in high (*U RMS H)* frequency bands, separately.

2. Experimental

The authors of the presented paper have found that the registered AE signal generated during the process of punching consists of three components: initial impact, shear fracture and the noise evoked by pulling the punch off the sheet. Two first components are often recordable as one uninterrupted pulse train. The maximum of the AE intensity appears when plastic deformation zone reaches its greatest volume in the processed detail. At the conditions arranged in the investigation described below, the AE signal intensity registered during first two punch movement phases was similar as that registered by pulling-off the worktool from the sheet. However, the AE signal generated in high frequency band (*U RMS H)* during first two punch movement phases has higher intensity and shorter period than *U RMS L*, registered at the same time. This can be useful to recognize the process phases by means of AE signal monitoring. The following feedstock samples were used in the investigation: *st 3* mild steel one and three millimetres thick, three millimetres thick stainless steel, 0.3 millimetres thick transformer (silico-manganese), and 0.3 millimetres thick stainless steel. After completing the introducing experiments the investigation included four samples of each stock type.

Fig. 1 presents AE signal *U RMS L* registered for three punching processes of 1 mm thick mild steel sheet processing, marked as squares, circles and

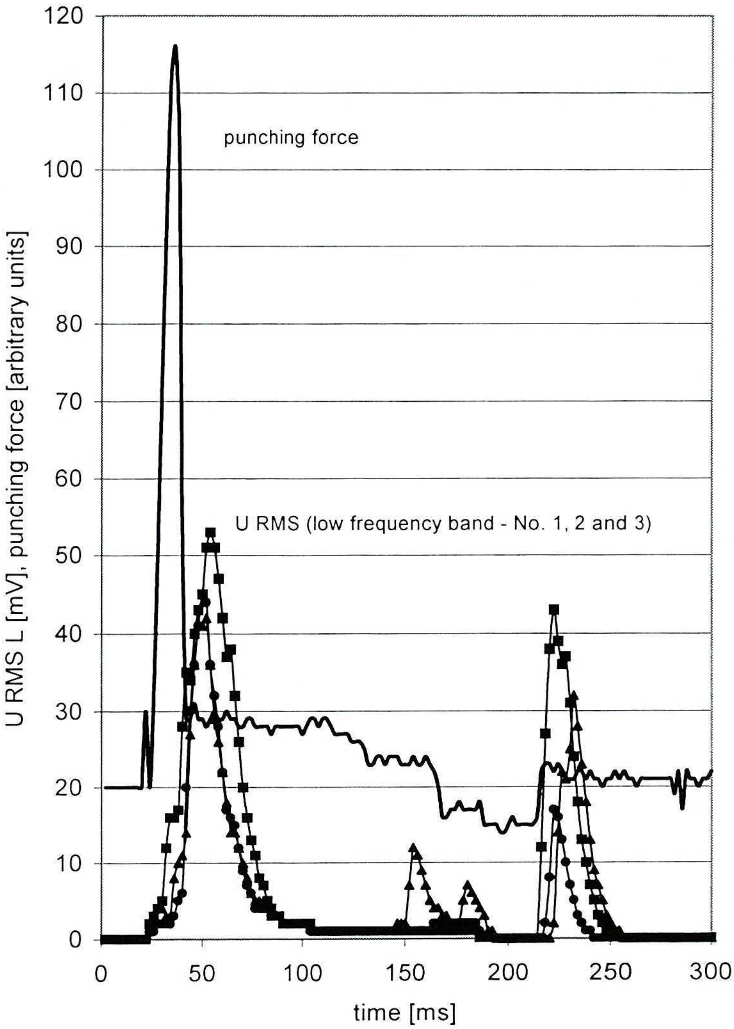

Fig. 1. Punching of 1 mm thick mild steel sheet. Root-mean-square of AE signal in lower frequency band registered for three punching processes (marked as suqares, circles and triangles) and punching force (thick line), both parameters measured in one punch travel cycle

triangles. The thick line denotes punching force, both parameters measured in one punch travel cycle. It is worth of mention that the differences in the AE signal level measured in three separate cycles do not exceed 20 % of its current value. The first peak of AE signal intensity is delayed to the punch force increase and is evoked by the plastic deformation processes. The second small burst of AE signal activity probably denotes the separation of the blank from the stock. The third peak of AE signal intensity is related to the noise evoked by pulling the punch off the sheet.

Fig. 2 presents the comparison between *U RMS L* and *U RMS H* registered during punching processes of 3 mm thick mild steel sheet processing. Time function of punching force applied in the experiment is shown in upper part of

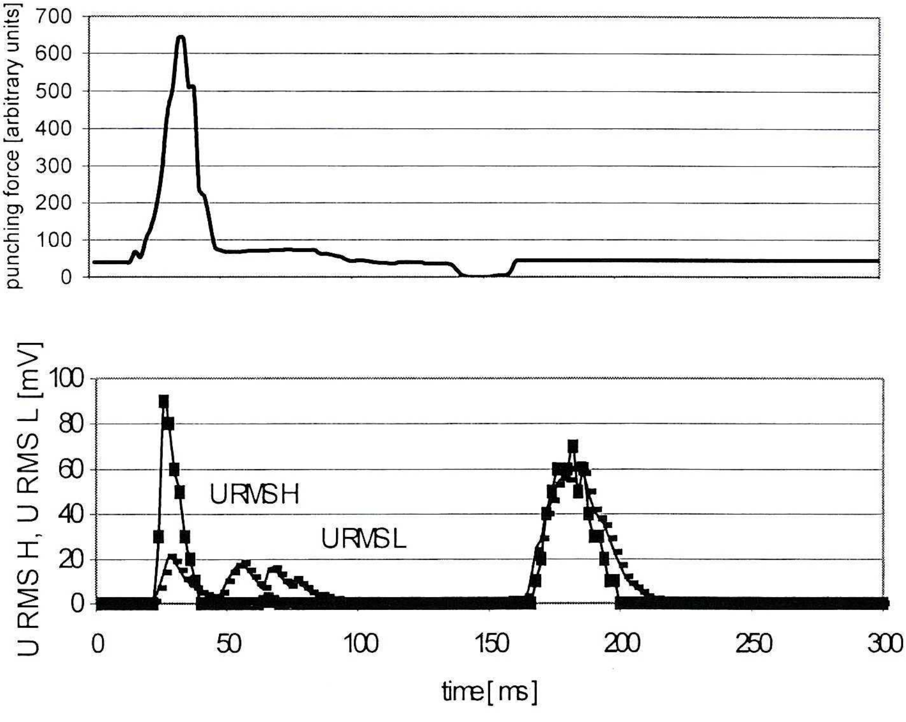

Fig. 2. Punching of 3 mm thick mild steel sheet. *U RMS H* (squares) and *U RMS L* (horizontal dashes) and punching force (upper part of the Figure). High frequency activity of AE signal appears in early phase of stock plastic deformation

the Figure. High frequency activity of AE signal (the line marked with squares) appeared in early phase of punch intrusion into the sheet volume. During the phase of pulling the punch off the sheet, the levels of *U RMS L* and *U RMS H* were nearly equal. Fig 3 shows that the low and high frequency waveforms registered during punching of 3 mm stainless steel processing both present longer duration as it was registered for mild steel. The noises generated by the intensive extrusion of the blank from the sheet is remarkable. The blank separation also produces an AE signal. High and low frequency activity of AE signal appears at the same time. It can lead to the conclusion that the material presenting longer plastic deformation behaviour effects in generating stronger AE signal.

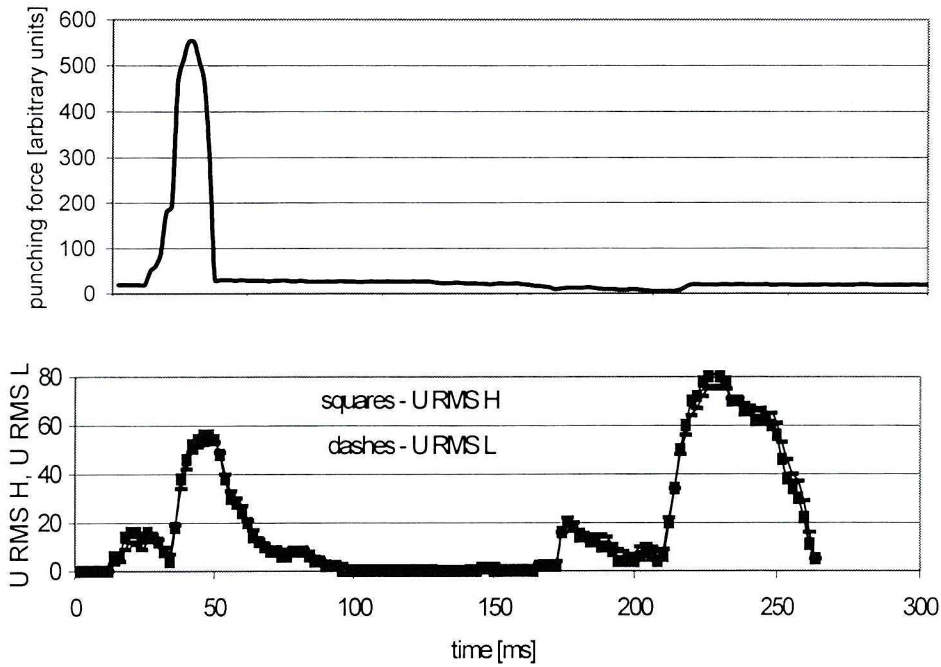

Fig. 3. Punching of 3 mm thick stainless steel sheet. *U RMS H* (squares) and *U RMS L* (horizontal dashes) and punching force (upper part of the Figure). High and low frequency activity of AE signal appears in the same time in this process of increased plastic deformation

Fig. 4 presents the comparison between *U RMS L* and *U RMS H* registered during punching processes of thin (0.3 mm) sheet plates. The intensity of registered acoustic emission signal was 20 dB (10 X) weaker than that registered in thick plates. To make the proper process registration possible, an additional 20 dB increase of signal amplification was arranged. A punching force registered by tensometric strain gauge was also ca. 10 times lower than that registered in previous cases. The resolution of the used sensor did not allow us to measure the force evoked by pulling the punch off the plate, what appeared at about 160 ms delay after the intrusion phase. The positive peak at the right side of punching force plot denotes the stress wave generated at the crank movement break. The central part of Fig. 4 shows AE waveform registered during punching the stainless steel plate. There is a significant signal burst during the plastic deformation phase. It is worth of mention that AE signal generated in high frequency band rises on and fades faster than low frequency component, and therefore it can more precisely determine the process of punching. The small peak at about 80 ms delay is probably caused by shear fracture. The lower part of Fig. 4 shows AE waveform registered during punching the harder transformer steel plate. *U RMS H* burst amplitude is doubled if compared with the waveform registered in stainless steel. In this latter case there is no AE burst generated by shear fracture, but there are small peaks in the region when the punch is pulled off the plate. AE signal burst generated at plastic deformation phase seems to be 20% shorter as the burst registered in more ductile stainless steel case.

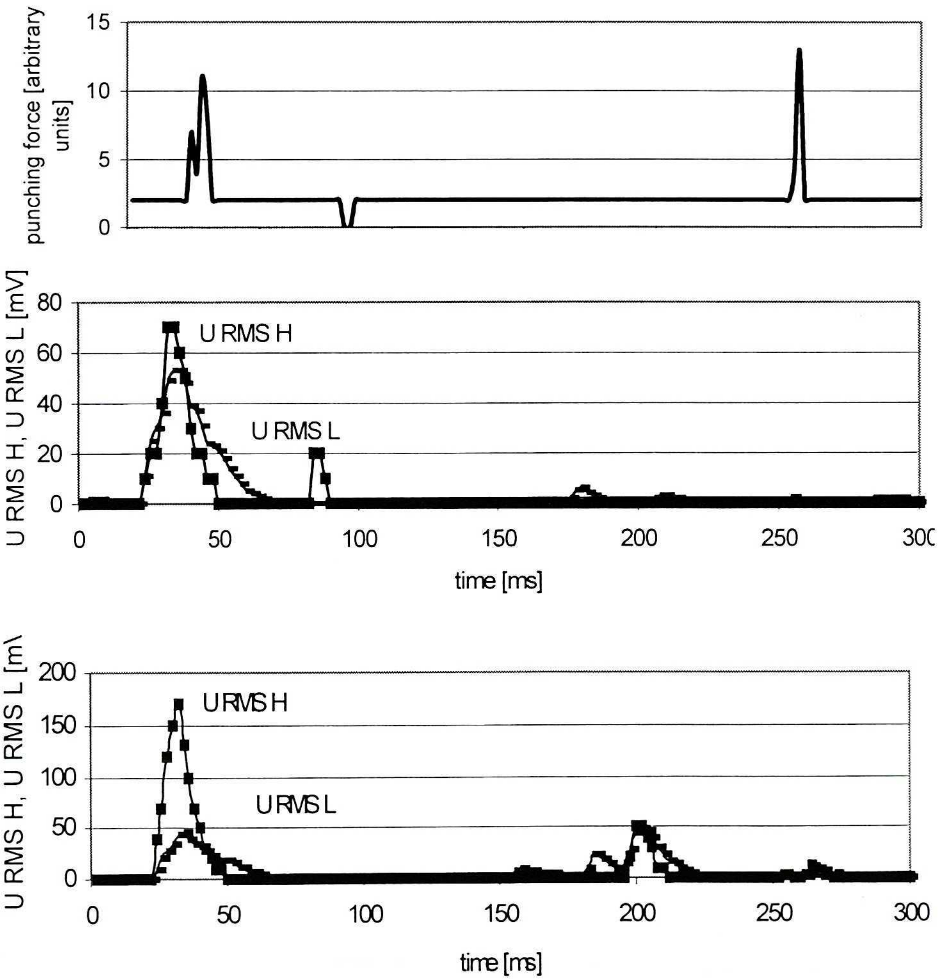

Fig. 4. Comparison between *U RMS L* and *U RMS H* registered during punching processes of thin (0.3 mm) sheet plates of stainless steel (central part) and silico-manganese steel

The last part of the investigation was aimed at registering the AE activity at the abnormal press operating condition. The experiments were performed with 0.3 mm sheet stainless and transformer steel plates processed with the worktool with dull-edged face. In this case, the excessive plastic deformation process appeared prior to separation of the blank. A long 'fin' of metal at the edge of the blank was drawn out, causing the additional friction component during punch extrusion. The processes described above are shown in Fig. 5. The ductility differences between two investigated steel compositions resulted in the presented AE signal intensity. Peak AE signal level, registered in transformer plate and shown in lower section of the Fig. 5 is twice as high as that measured in stainless plate (shown in central section of the Figure).

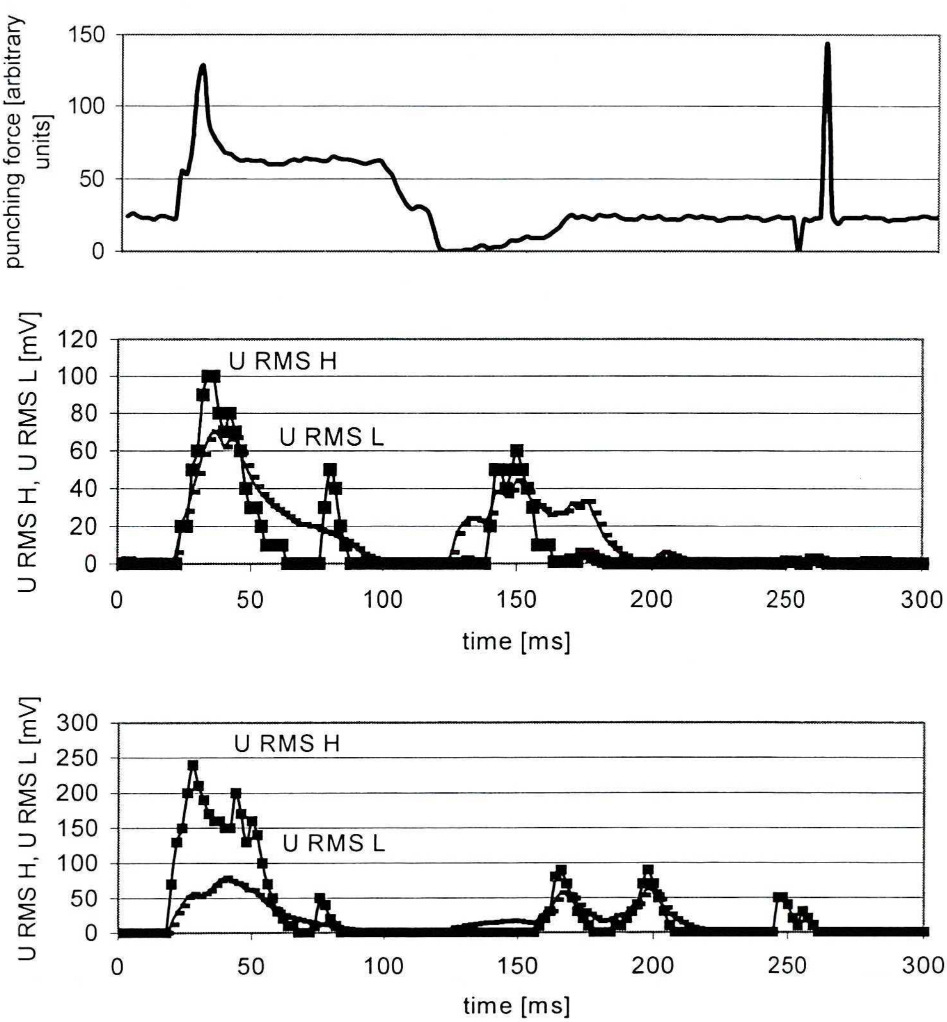

Fig. 5. Punching made in the material shown in Fig. 4, applying the worktool with dull-edged face. Longer duration of the AE activity reflects the excessive plastic deformation process, prior to separation of the blank. Peak AE signal level, registered in transformer plate (lower section) is twice as high as that measured in stainless plate (central section of the Figure)

There were three ranges of specimen thickness applied in the reported investigation, i.e. 3, 1 and 0.3 mm. The AE signal level decrease was noticed together with reduction of specimen thickness. Acoustic Analyser gain was modified to keep the proper recording conditions. 60 dB recording level was used for the measurements of 3 mm plates and 80 dB was adjusted for the 0.3 mm plates. For the majority of avaiable AE recording systems, the maximal useful amplification level equals 100 dB. Higher amplification requires more restricted signal filtering procedures to avoid the system instabilities and to suppress the background noise.

The authors present the dependence between the punched plate thickness and required AE analyser gain level in Fig. 6. The presented relation suggests that it is possible to register AE signal evoked in punching the plate 0.1 mm thick and therefore it is possible to apply the AE technique to control the manufacturing processes of fine elements.

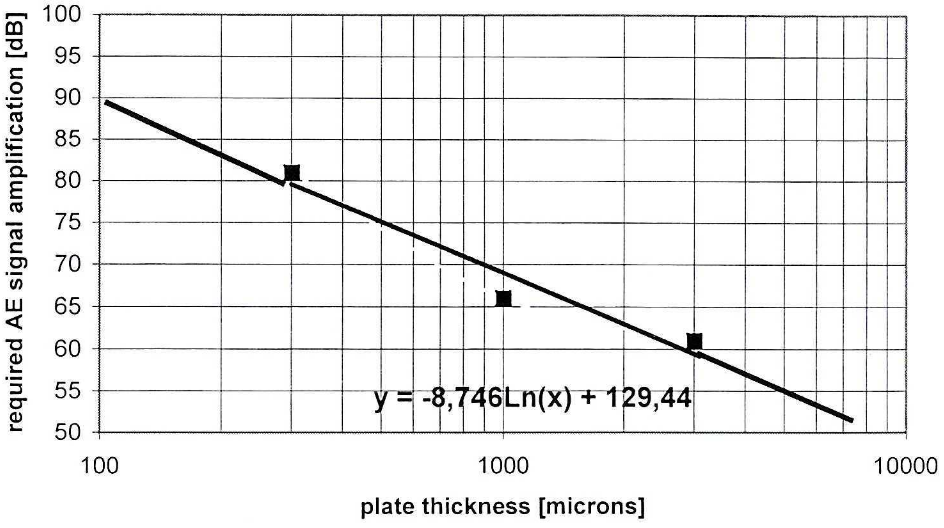

Fig. 6. The dependence between the punched plate thickness and the AE analyser gain level used in the investigation

3. Conclusions

AE signal measurements can be applied for monitoring of punch press operation. It is possible to analyse such phases of the press stroke as: worktool intrusion and related stock plastic deformation effects, blank separation and worktool extrusion off the sheet. The level of the registered AE signal depends on plate thickness and hardness of the processing material, however, it is possible to register the signals generated in 0.1 mm plate. The failures of tools, such as its abrasive wear, causing the abnormal AE signal intensity increase, can also be detected. The AE signal waveforms generated in higher frequency band (500–1000 kHz) present short rise- and decrease- time periods and therefore are most useful to characterise the phases of punching.

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REFERENCES

[1] Kim B.S.: Punch Press Monitoring with Acoustic Emission (AE) Part 1: Signal Characterization and Stock Hardness Effects. J. of Engineering Materials and Technology, 105, 1983, pp. 295÷304.

[2] Wilcox A.J., Baggs D. R. H., Shirvani B.: Acoustic Emission in Press-working. Records of Faculty of Engineering and Computer Technology University of Central England, 1990, pp.295÷303.

[3] Skare T., Thilderkvist P., Stahl J.: Monitoring of friction processes by the means of acoustic emission measurements – deep drawing of sheet metal. J. of Materials Processing Technology, 80 – 81 (0), 1998, Elsevier Publ., pp.263÷272.

[4] Marczak M., Marczak R, Ranachowski Z., Senatorski J.: Application of Acoustic Emission Method to Determine the State of Friction Process of Metal Collaborating Pairs – Preliminary Results, The Archive of Mechanical Engineering, XLVI, 1, 1999, Warsaw, pp. 80÷84.

Zastosowanie metody emisji akustycznej do monitorowania procesu wykrawania blach

Streszczenie

W niniejszym artykule przeanalizowano postać sygnału emisji akustycznej (EA), generowanego w procesie wykrawania blach. Generacja tego sygnału zachodzi w trakcie procesu formowania się strefy odkształceń plastycznych w obrabianym materiale, przy odrywaniu się wykrojonego detalu oraz przy wyciąganiu stempla z blachy przy ruchu powrotnym suwaka. Pomiary prowadzono przy obróbce blachy konstrukcyjnej, stopowej i transtormatorowej (krzemowo-manganowej), o trzech różnych grubościach. W ramach badań zasymulowano wystąpienie sytuacji awaryjnej. Przy użyciu dwóch rodzajów najcieńszych blach zademonstrowano zapisy sygnału zarejestrowane w trakcie wykrawania wykrojnikiem o stępionych krawędziach. W tym przypadku generowany sygnał EA miał dwukrotnie wyższe natężenie w stosunku do warunków normalnych, a czas trwania jego generacji w fazie odkształceń plastycznych był również dwukrotnie dłuższy.