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Analysis of Acoustic Emission Signal for the Detection of Defective Manufactures in Press Process

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***Abstract*—** Small cracks or chips of a product appear very frequently in the course of continuous production of an automatic press process system. These phenomena become the cause of not only defective product but also damage of a press mold. In order to solve this problem AE system was introduced. AE system was expected to be very effective to real time detection of the defective product and to prevention of the damage of the press molds.

In this study, for pick and analysis of AE signals generated from the press process, AE sensors/pre-amplifier/analysis and processing board were used as frequently found in the other similar cases. For analysis and processing the AE signals picked in real time from the good or bad products, specialized software called cdm8 was used. As a result of this work it was conformed that intensity and shape of the various AE signals differ depending on the weight and thickness of metal sheet and process type.

***Keywords*—**press, acoustic emission, signal processing

I. INTRODUCTION

As industries flourishes, production systems adopt more automation system and accordingly unmanned system for increase of their efficiency. And in recent production systems, various inspection processes having been mainly depended on skilled personnel are replaced by automated equipments like sensor integrated inspection systems. From these trends, the traditional inspection system for various types of defective products even in the press process is replaced by automated inspection system using various sensors, and its related researches are well on the way to progresses [1].

In the present press process, a method of image checking after pressing is most widely used as an automatic inspection method for defective products. But, there are many cases to which image checking method is difficult to be applied due to the speed of inspection or the size of a product or its shape.

In addition, because such inspection method requires expensive process or equipments or ample spaces, it is very difficult to be justified economically. Eventually new method that escapes from the above restrictions becomes needed. Taking into account all the above points, an inspection system of defective products in the press process using AE sensors was designed, and in this work as a preliminary effort to develop it to the stage of actual application. AE signals produced from both the good and bad press products were analyzed considering the press load, number of products and other parameters.

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II. THEORY

A. Acoustic emission

The acoustic emission (AE) signal can be divided into successive type signal and sporadic type signal. This type of AE signals are analyzed through the signal processor in the form of variables such as the existence of a signal generation or the shape of signal etc. excepting the signal of special case.

Therefore, in the signal processor, the critical voltage is set up for the signal processing. And the acoustic emission would be regarded to be generated if it exceeds the critical voltage.

B. The measurement of the acoustic emission

As shown in Fig1, the displacement of one point x in the external domain by the surface traction or the body force (volume stress) at the micro area is expressed as follows using the Green function [2].

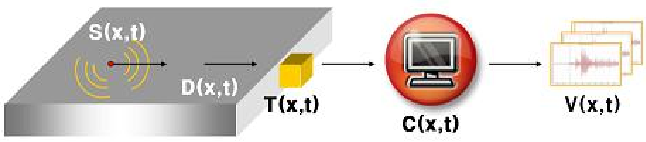

Fig. 1 Transfer function.

$$u_i(x,t) = \int dx' \int G_{ij,k'}(x,x',t-t')\Delta\sigma_{jk}(x',t')dt' - \int dS'_{k'} \int G_{ij}(x,x',t-t')\Delta t_{jk}(x',t')dt' \quad (1)$$

It is usually called transfer function. This function consists of many sub transfer functions as follows.

$$G(x,t) = D(x,t) * T(x,t) * C(x,t) \quad (2)$$

It can express as the convolution integral of each transfer functions by the mold (D), the converter (T) and computer (C). On the other hand, the output V (x, t) that is to be visibly recognized is expressed as a function of G and S as follows.

$$V(x,t) = G(x,t) * S(x,t) \tag{3}$$

In the most experiment, it is confined only to the case that the direction of force is applied to the vertical to the surface of the test piece. Generally, as a force generation source, the break-down of the point of a pencil lead or the glass capillary tube, or the drop of a ball is used. The flat board in which the calculation of the Green function becomes theoretically available is used as the medium [3-4].

C. *The interpretive method of the acoustic emission*

The interpretation of the AE signals can be classified into the activity method represented by the excess of the acoustic emission and the method of the waveform analysis that relates to the shape of the signal. A method by the acoustic emission activity evaluates variables including the event number, the ring-down count, the peak amplitude and energy, and etc. And there is a direct relation with the size and frequency of the acoustic discharge source.

The method by the waveform analysis compares how the waveform of the acoustic emissions was drawn. There are variables, used in this case, such as the rise time, the event duration, the rising slope and frequency spectrum etc.

The example of the evaluation using Event and ring-down count observes the Kaiser effect, and the Felicity ratio and creep phenomenon. The Kaiser effect (Kaiser 1953) has been applied as to know the initial stress condition of rock materials. Based on the Kaiser effect, T. Fowler proposed the Felicity ratio, which can show the damage quantitatively in tank structures. The Felicity ratio was established because of the following fact. The Kaiser effect can only hold in the stable condition of the materials. As to progress the internal instability, the Kaiser effect is gradually breaking down, As a result, AE activity starts to be observed even under lower stress than that of the maximum stress experienced [5-6]. The development of creep along with the uniform event increase or the uniform ring-down count increase can occur in the test piece under constant stress. And in this case, it can estimate that the advance of damage is taking place in the test piece. The rise time, the event duration, and a slope and frequency spectrum can be used in the observation of the waveform characteristics, based on the idea that the acoustic emission occurred from the special deformation mechanism has the special waveform characteristics. And it is possible to verify the special failure mechanism by processing these parameters statistically. As the parameters used for signal characteristics, not only the variables used in the specialized equipment for acoustic emission signal analysis but also the various variables which could be regarded as even a feeble feature of the generated signals are being used [7].

III. LABORATORY DEVICE AND METHOD

A. *Laboratory device*

A specialized equipment was designed and constructed for the detection of defective products appeared in the press process. This equipment can be attached to a press system, and consists of three main parts. One is AE sensor that can be attached to the press die and used in sensing the AE signals generated from a work piece and the die. Another is pre-amplifier that filters and amplifies the AE signals which generally includes not only the target signals but also various noises. And the other is a PC that contains required software and analyzes the signals fed to it from the pre-amplifier and displays the results in readable form so that they can be useful to determine the good and the defective.

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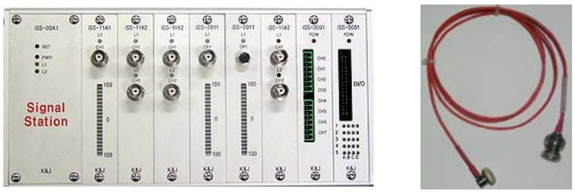


(a) Integrated Signal Board **(b) AE sensor**
(750kHz, 16-bit, 16-ch A/D, 4-ch 16-bit D/A)

Fig. 2 Equipment in the experiment.

B. *Experimental method*

(1) The sensing system adhering to the AE Sensor to the press apparatus

The AE signal detection sensor is attached to the press die for the collection of the acoustic signals in the organized system. An exclusive magnetic clamp was designed for the stable signal collection and fixes the AE sensor firmly to the die. The signal collected from a sensor that has already been filtered is sent to the control computer after being amplified through the pre-amplifier. The generated acoustic signal is collected during the press work. The defective product is determined through the process including the amplification - filtering - amplification -A / D-conversion - FFT analysis, and etc.

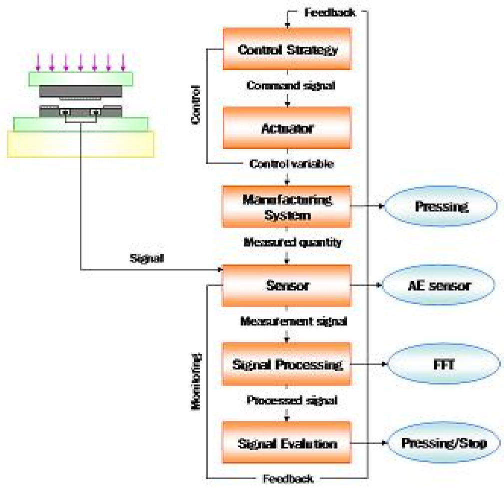


Fig. 3 Algorithm of the system.

(2) The acoustic signal process and the defective judgment technique generated in the AE Sensor.

Material parameters (a material, the thickness, a shape, and etc.) and session parameters (the press load, the work speed, the processing method, and etc.) required for data analysis were collected through the field test using the already mentioned equipment system. The data collected from the field test is output in wave form from the cmd8 program. The output value in the wave form is transformed into text file and stored in the computer memory, and by utilizing the commercial programs such as Excel, Origin, and etc. and the Voltage change vs. the press work time is confirmed. Because there was no standard of signal data pre-existing for distinction of the good and the defective, the signal generated when the good were produced was established as normal signal (wave). The great quantity of signal data was secured from the field experiment. The signal data that comes from the good product were analyzed and normalized, and then was set up as the standard wave. The database for the normal signal wave was constructed from vast amount of signal data gathered and analyzed and used as the standard for distinction of the good and the defective. The examples of the good product and the defective are shown in the Fig. 4-6. For each case, the signal data of the normal and defective products are collected, graphed, compared and analyzed. In the case of the industrial press which is engaged in actual production environment, it is usually very close to its neighbor press and influenced in AE signal by its neighbor. However, through this study, it was confirmed that the standards of the normalized wave differs depending on the press weight, the shape of the molds, the methods of process, and the quality and thickness of a material
.

(a) Normal product **(b) Defective product**

Fig. 4 Material of Experiment NO.1 (with 110ton press)

(a) Normal product **(b) Defective product**

Fig. 5 Material of Experiment NO. 2 (with 150ton press)

(a) Normal product **(b) Defective product**

Fig. 6 Material of Experiment NO. 3 (different product with 150ton press)

IV. RESULT AND ANALYSIS

A. The product NO.1 production in 110ton press (the thickness =0.7mm, the temperature =0 , material = cold rolled steel sheet)(Fig. 4, and Fig. 7 reference)

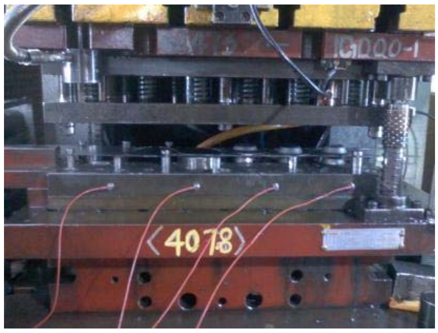
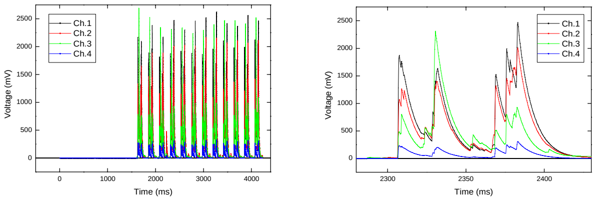


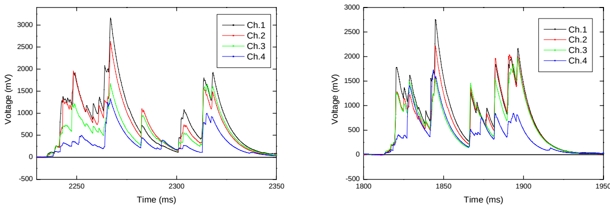
Fig. 7 Photograph set up a sensor to 110ton press (CH-1, 2, 3, 4 from the left side)

It shows the value within the maximum V=+2,600mV in the case of the normal product as shown in Fig. 8 (a), (b). And It shows the value within the maximum V=+3,000mV in the case of the defective product as shown in Fig. 9 (a), (b). But, the minimum value of the signal amplitude of the defective product and the maximum value of the normal product are very close to each other. Therefore, it is not suitable to determine the standards for distinction of the normal and the defective product. But if only the signal of a ch-4 is considered, a voltage more than 400 mV in the normal product was not measured and a voltage more than 1,000 mV in the defective product was measured. Therefore, the conclusion that it could be regarded as the defective if the measured signal of the ch-4 exceeds 800 mV could be drawn. That is, in the actual production environment, if the signal from one sensor that is mounted on the ch-4 exceeds 800mV, it could be regarded as the defective. This would be regarded as the most effective way to determine the defective.



(a) Whole graph. (b) Graph which partially expands.

Fig. 8 Graph of the normal product.



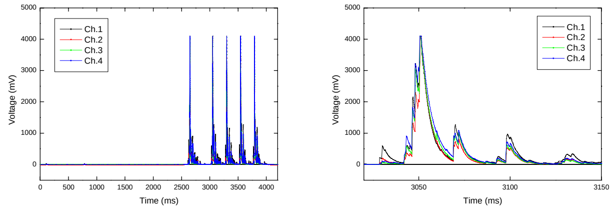
(a) Defective product NO. 1. (b) Defective product NO. 2.

Fig. 9 Graph of the defective product.

B. the product NO.2 production in 150ton press (the thickness =1mm, the temperature =0℃, material = cold rolled steel sheet, Fig. 5 and Fig. 10)

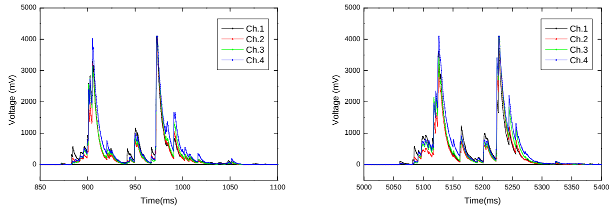
Fig. 10 Photograph set up a sensor to 150ton press (CH-1, 2, 3, 4 from the left side)

It shows the value within the maximum V=+4,300 mV in the case of the normal product as shown in Fig. 11 (a), (b), while it shows a value more than the maximum V=+4,300 mV in the case of the defective product as shown in Fig. 12 (a), (b). And there are nearly no difference between the maximum value of the signal amplitude at the defective good and the maximum value of the normal product. Hence, the good/defective determination criteria have to be set up as being different to the previous case. In this case, the second high peak values must be compared. When being the normal product, the signal is about +1,500 mV or less. And when being the defective, the signal is about +3,800 mV or greater. And at this time, similar signals from all channels were obtained. Therefore, the conclusion that the sensors could be mounted on any channel because the shape and the amplitude of the signals are almost same was drawn.



(a) Whole graph. (b) Graph which partially expands.

Fig. 11 Graph of the normal product.



(a) Defective product NO. 1. (b) Defective product NO. 2.

Fig. 12 Graph of the defective product.

C. The product NO.3 production in 150ton press (the thickness =1mm, the temperature =0℃, material = cold rolled steel sheet, Fig. 6, and Fig. 13)

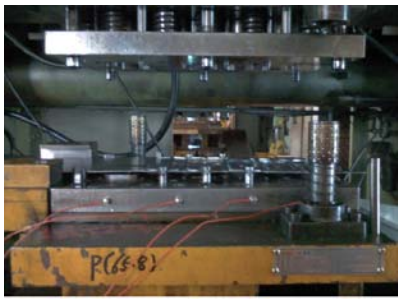
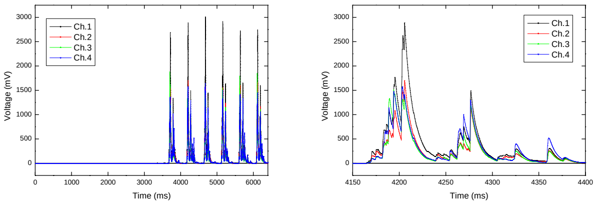


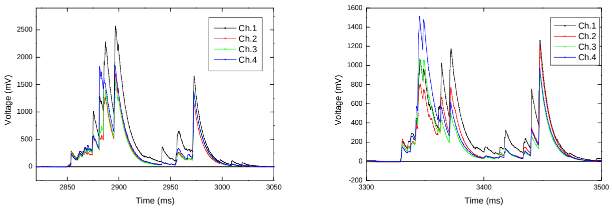
Fig. 13 Photograph set up a sensor to 150ton press (CH-1, 2, 3, 4 from the left side)

It shows the value within the maximum V=+2,900 mV in the case of the normal product as shown in Fig. 14 (a), (b). It shows a value more than the maximum V=+2,600 mV in the case of the defective product as shown in Fig. 15 (a), (b). Because there is almost no difference between the maximum signal value of the normal product and the maximum signal value of the defective product, and because there is the part where the maximum signal value and minimum signal value of each channel are similar to each other, it is almost impossible to determine the defective by use of only one channel signal. Therefore, the signals from at least two channels must be compared for the determination of the defective. If the difference of the maximum values of the channel 1 and channel 4 is +1,000 mV or greater, it could be possible to determine that the product would be normal. From the above result, it could be found that sensors at the location 1 and 4 were required in the case of this type of product for the normal/defective determination.



(a) Whole graph. (b) Graph which partially expands

Fig. 14 Graph of the normal product.



(a) Defective product NO. 1. (b) Defective product NO. 2.

Fig. 15 Graph of the defective product.

V. Conclusion

The use of AE signal was applied to the pressing process in order to determine the defective product. Many kinds of data were considered for comparison analysis. But eventually the results were drawn from the bases of the data on the voltage vs. time. All data were considered to be concerned with time. The reason why the time dependant data is regarded as important is because the normal/defective product must be determined in real time from the data obtained in real time in the actual production system. And in order to find out the most proper number and position of the AE sensor, many sensors of different positions were tested, thereby it became possible to determine the normal/defective product using the least required number and the most proper positions of sensors depending on the product of the press processes. Even though there is the trend to analyze the data with the spectrum about a specific frequency in the field of same subjects and in the related paper, the real time determination of the normal/defective product in the press process was made to be possible by analyzing various time dependant data in this paper. However, it would be required more time and experiments to develop more reliable system for the normal/defective product determination in the press process because of its production characteristics.

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