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GENERATION OF AE SIGNALS AND ITS WAVEFORM CHARACTERISTICS OF GAS LEAKAGE EMANATED ON PIPE WITH SPECIFIC DEFECTS OF DIFFERENT GEOMETRICAL SHAPES

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ABSTRACT

Acoustic Emission testing method is now widely recognized as the most appropriate tool to determine the flaws from material structure as a non-destructive technique (NDT). In this study, we have used this method to determine the characteristics of the generated AE signals and analyze its waveforms relative to time and frequency domain at various gas pressures. We have considered four different geometrical shapes of pinhole such as straight-type, stepwise-type, slit-type and cone-type. All these defects were artificially made on conventional pipe (JIS SGP20A) commonly used for gas pipeline. The experimental results described common behavior of AE waveforms for each type of the specific defect. As in the case of straight-type pinhole, the pressure shock occurred above the critical pressure at 220kPa and eventually screech tone was generated while pressure increases until it reached to 500kPa primarily because of unstable gas flow and turbulent flow. For stepwise-type, we observed different characteristics of AE waveform. Apparently, a monotonic increase of amplitude took place at the onset since self-excited vibration of the acoustic signals within the flow structure occurred. Also, sudden dropped of amplitude over the critical pressure was recorded. On the other hand, the slit-type defect showed a rapid fluctuation of acoustic signals because of strong energy released by gas leak so its amplitude became higher in magnitude. Lastly, for cone-type pinhole showed other distinct characteristics at which unusual sound was observed. It seems that this type of orifice have similar pattern with that of stepwise pinhole relative to its peak frequency values. In general, a unique behavior of acoustic signals was mainly caused by the large-scale instability of flow of the gas leakage emanated on specifically defective pipe with various geometrical shapes.

KEY WORDS - *Acoustic emission, fast Fourier transform, gas leak, pipe*

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1. INTRODUCTION

Nondestructive leak testing deals with the leaking of liquids or gases in pressurized or evacuated components or systems as a result of pressure differential and a report of G. Anderson and A. Anastasopoulos, et.al, showed that acoustic emission (AE) is widely used for leak detection [1,2]. Thus, **acoustic emission** technique is extremely the best tool to determine the flaws from material structures. Over the years, **AE** testing method has been applied in monitoring and inspection of flaws specifically on gas leakage from pipeline installations through research in the field and laboratory. Its application is considered as an efficient and cost-effective process among other relevant methods. In actual **pipeline installations, identifying** the leak is a common problem that usually happens specifically when it is buried underground. Several research works have been carried out using **this method** to characterize and analyze the flaws from pipeline installations. Such method could also be used to locate the leak source and could effectively characterize the development of defects such as deformation, corrosion, cracks, etc. **A report by R.K. Miller, et.al, showed** that it is desirable to study small leak rates so that we could characterize them in the laboratory and **reproduced as well** in the field since the leakage rate is important in the context of environmental protection regulation [3]. Another study reported that the characteristic frequency of acoustic emission due to gas leakage is 10 kHz [4]. Acoustic emission studies **conducted by Kenichi Yoshida, et.al,** on the attenuation of elastic waves in pipelines and the acoustic noise environment associated with leak detection have been conducted on the basis that the AE amplitude is proportional to the leak energy as mentioned [5-7]. The critical pressure at 220kPa was calculated based on the assumption that the flow velocity reached to its sound velocity [8]. The screech tone is characterized, as **reported in the study of Young-Kill Yu, et.al,** as the feedback loops driven by large-scale instability of waves of airflow [9].

The main objective of this study is to characterize and analyze the generated AE signals from gas leakage on pipe with **created specific defect**. It is essential to follow certain procedures, **especially the specified signal filtration process and heuristic threshold level.** A pressurized air cylinder has been used in order to eliminate the associated noise from the surrounding environment dissipated by moving parts and the mechanical equipment. We made several types of **defects with well-defined geometries** such as straight-type, stepwise-type and cone-type pinhole. The process of evaluation on gas leakage has been continuously performed to perfectly determine the defects in material structures but it seems a lot of complexities come across during monitoring and inspection. Thus, this paper will enhance in establishing an appropriate procedure to resolve such problem.

2. METHODOLOGY

The same set-up of the experiment and methods have adopted from previous study as shown in Fig.1. The specimen has an inside diameter and an outside diameter of 27mm and 21mm, respectively and the corresponding length is about 150mm. The AE sensor (M5W, Fuji Ceramics), was attached to the flat surface of pipe prepared with a reduced pipe wall thickness and it was mechanically polished with #1000 grain sander where pinhole was formed using Electro-Discharge Machine (EDM). In order to isolate the generated AE signals from

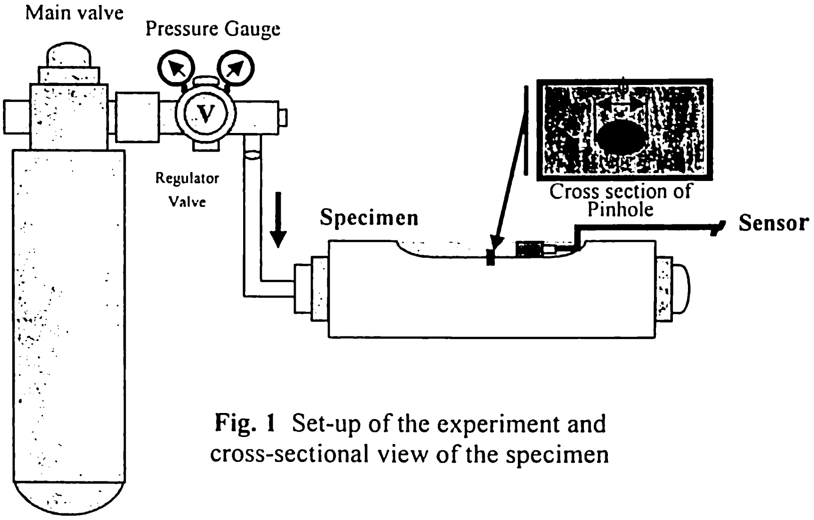

Fig. 1 Set-up of the experiment and cross-sectional view of the specimen

unwanted noise emitted from the surrounding environment a heuristic threshold level was set to 40dB. The total gain of 60dB and a wideband pass filter ranging from 100kHz to 1200kHz were considered in signal filtration. The AE signals were detected continuously at varying pressures from 100kPa to 500kPa. A pressurized cylinder filled with air was used in order to eliminate the associated noise coming from the surrounding environment dissipated by the moving parts and the mechanical equipment. It was assumed to be at normal operating conditions all throughout the test run. And then regulating the pressure valve controlled the flow of air coming from the cylinder. In this experiment we have used three different sensor locations at a distance of 10.0mm, 20.0mm and 30.0mm from the artificial defect. At the middle portion of the specimen several **specific** defects of different geometrical shapes such as straight-type, slit-type, and cone-type pinhole with 1.0mm wall thickness and stepwise-type at two different wall thicknesses were considered as can be seen in Fig.2. It is essential to follow certain procedures and especially the signal filtration process for proper acquisition of AE signal. And then, after all the parameters were **configured, and data were** recorded using MISTRAS 2001 and eventually **were analyzed by using entirely FFT** process as shown in Fig.3.

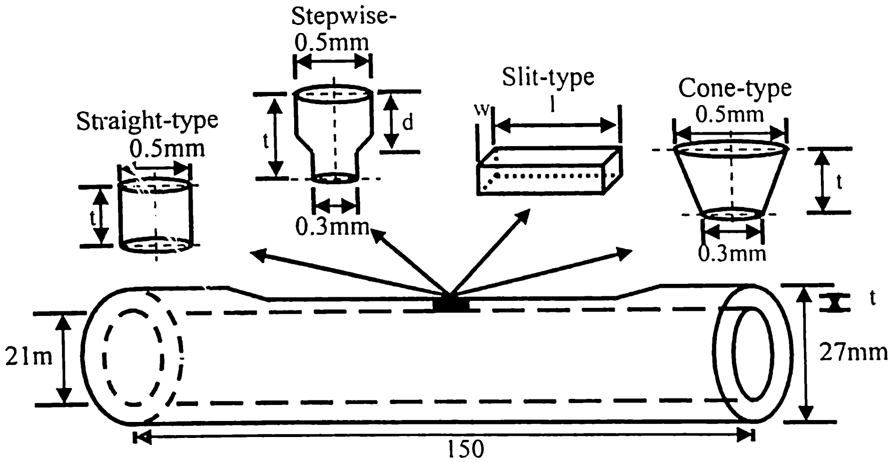

Fig. 2 Details of several artificial defects.

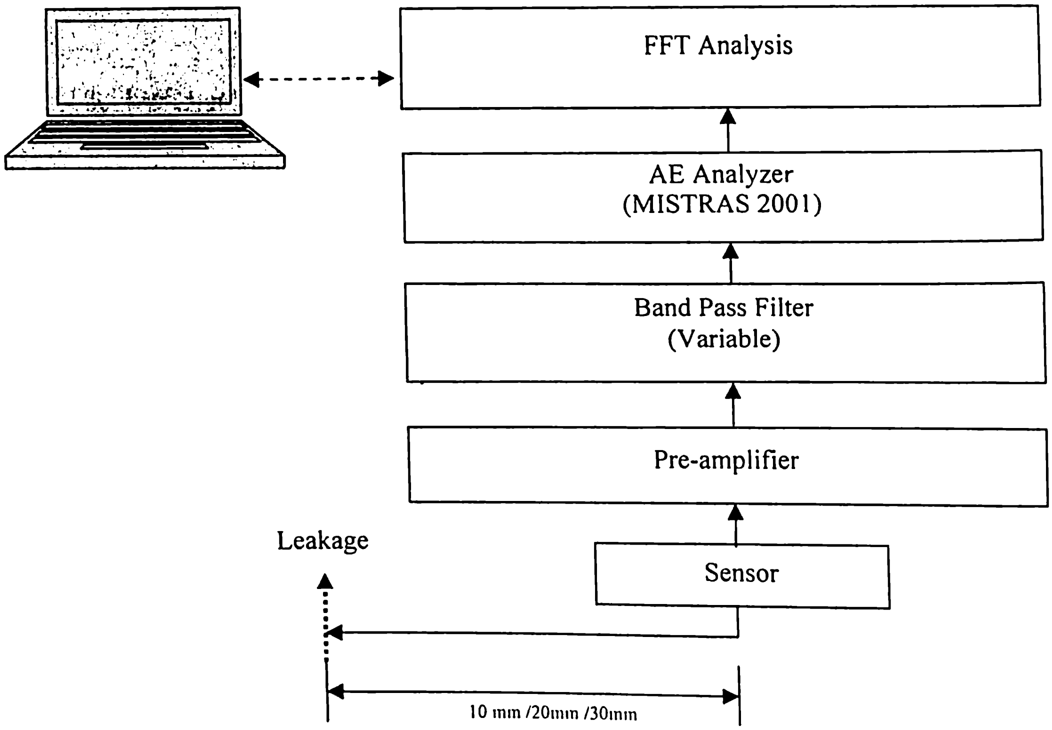

Fig. 3 Data Flow Analysis

3. RESULTS AND DISCUSSION

The leak in pipeline generates acoustic waves propagating along the pipe wall. Analysis of the results of the generated acoustic signals indicated that each type of defects showed its common and unique characteristics. From the three different sensor-source locations we have observed that attenuation of signals was due to the effect of the sensor-source distance when the gas escapes from the pipe through the artificial defect. Their effect demonstrates a sharp dropped off of amplitude at a farther distance. Further the attenuation of signal in the material structure depends upon the frequency of the stress wave and also the amplitude and frequency spectrum of the generated stress waves are also dependent on material characteristics [10,11]. Other factors that affect the acoustic signal are size and the nature of defect mechanism and the material properties. In this present study, we encountered difficulty in detecting acoustic signals emanating from the leakage especially when the sensor-source distance is about 20mm and 30mm. Thus, we decided to employ the threshold level of 40dB for data acquisition all throughout the experiment.

3.2.1 *Attenuation of acoustic signals as a function of sensor-source distance*

It can be seen that the sensor-source distance affects the generation of acoustic signals during gas leakage. Further the pipe wall thickness has greatly influenced on the generation of acoustic signal from the escaping gas in pipe defect. In Fig.4 and Fig.5 we could observe the behavior of the generated acoustic signals at three different sensor locations for stepwise-type defect taken at 500kPa at two different pipe wall thicknesses. It was about 75% decrease in magnitude of amplitude when the sensor was located 10mm apart from the source. However, there was no significant difference of amplitude between 20mm and 30mm sensor locations. At 10mm distance the amplitude was about 6.5mV while at 20mm it was 1.6mV and then when the sensor was a little bit farther of about 30mm from the source the amplitude was only 1.0mV for stepwise-type defect with d=1.5mm at wall thickness of 2.0mm. Whereas, when d=0.3mm with t=1.0mm the amplitude was recorded as follows 8.2mV at 10mm, 2.02mV at 20mm and 1.2mV at 30mm distance from the source. These attenuations clearly indicated the effect of the sensor-source location on the generated acoustic signals emanated on pipe with specific defect of different geometrical shapes.

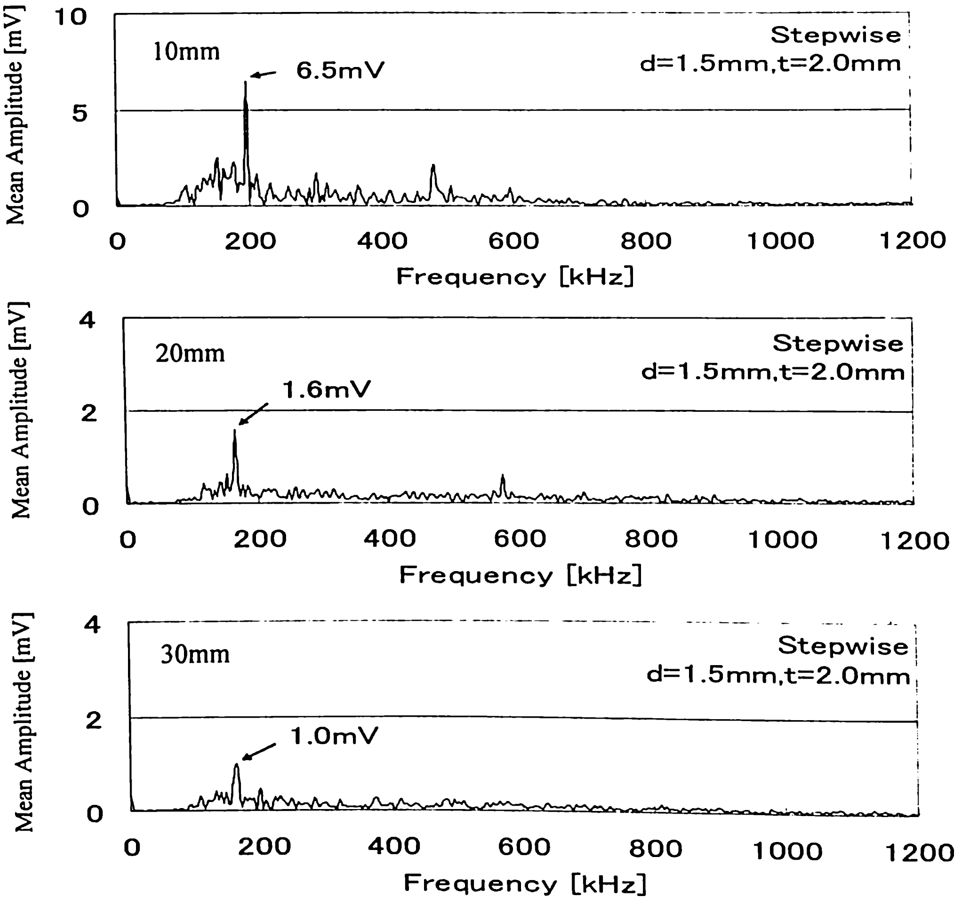

Fig. 4 Attenuation of acoustic emission signals at different sensor-source location.

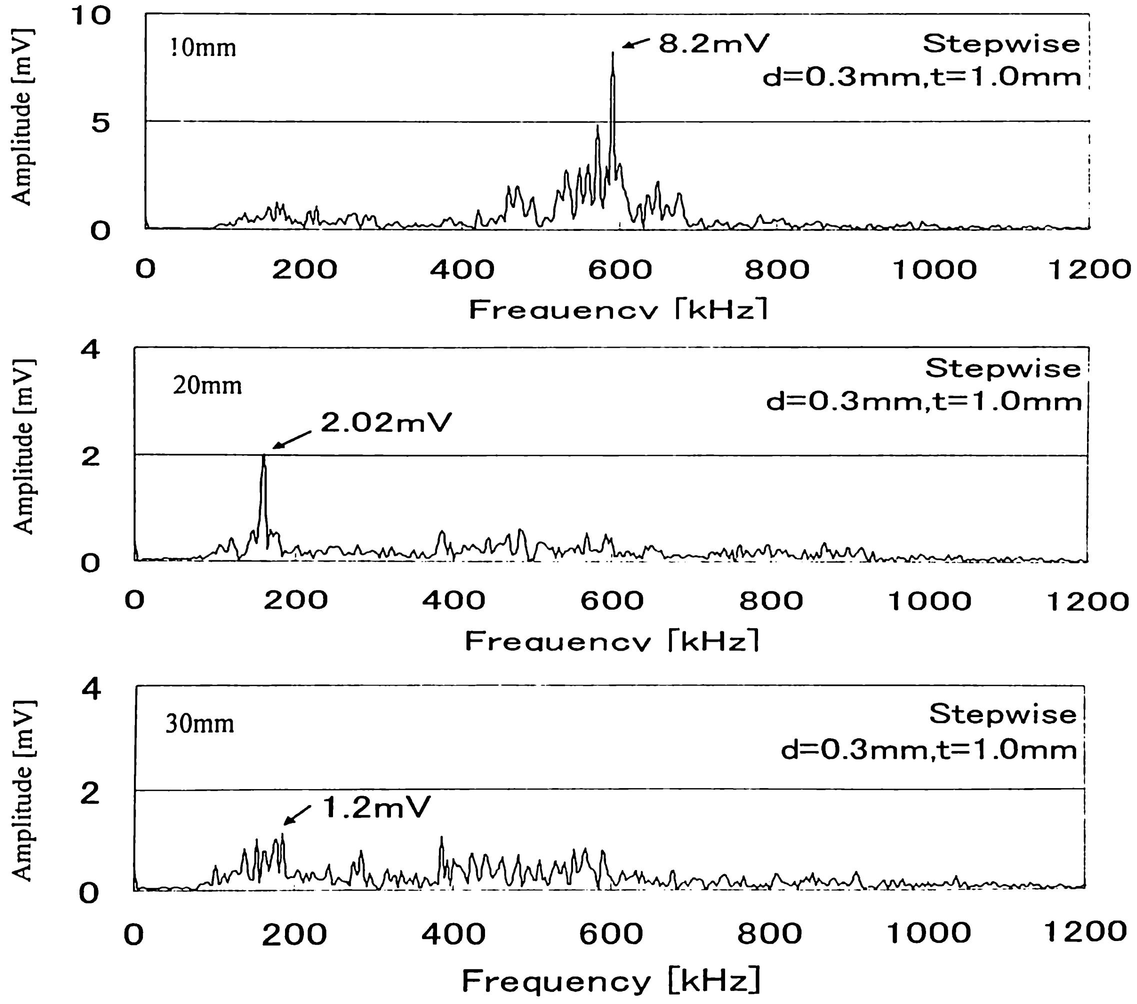

Fig. 5 Attenuation of acoustic emission signals at different sensor-source location.

3.2.2 *Mean amplitude difference of various defects with different geometrical shapes*

In this case the mean amplitude demonstrated unique characteristics for each type of pipe defects. Figure 6 showed the mean amplitude relative to gas pressure wherein the slit-type defect recorded highest amplitude at higher pressure while the cone-type and straight-type defects have almost similar values when the pressure was less than 350kPa for 20mm sensor-source distance. This means that greater the leak rate the larger the acoustic power could be detected during leakage. At the early stage where the pressure is about 120kPa slow propagation of acoustic signals have been recorded for straight-type pinhole while at higher-pressure the burst signals have dominantly observed, which was caused by the sensor location and the large-scale turbulence of flow. And then as the gas pressure increases the amplitude increases as well. For slit-type defect it was observed again the development of unusual noise at higher pressure because of high energy released as the gas escapes from the defect. Whereas the stepwise-type defects with different depths (Figs.7a,b,c) we could see other common and unique characteristics of the generated

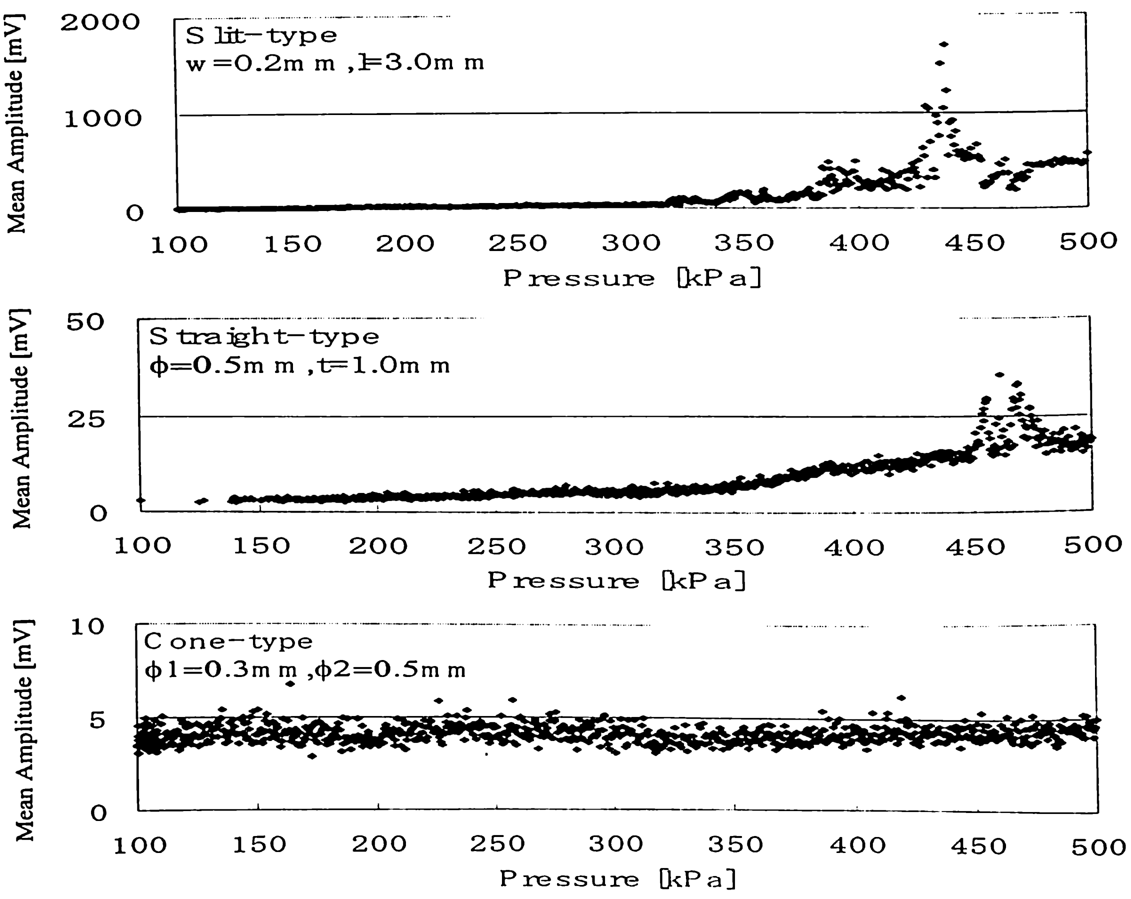

Fig. 6 Mean amplitude in relation with air pressure at different defects for t=1.0mm.

AE signals during gas leakage. We also recorded a monotonic increase of amplitude at the onset seemingly because of self-excitation of acoustic signals within the flow structures. It was clear also the effect of stepwise deviation as evidently seen in their respective waveforms when the gas pressure increases continuously to 500kPa. However, when the depth is 0.3mm at t=1.0mm there was no substantial effect of stepwise wherein it follows a similar pattern with that of straight-type defect. The sharp dropped off of the amplitude at critical pressure might probably be the effect of choking at the throat of the pinhole because of the unstable flow of air due to large-scale turbulence during transition of flow. Since according to the report, this states that if the pressure drop across the orifice is sufficiently high, the flow through orifice will be choked [12]. It was also mentioned that the amplitude of the acoustic output may not be independent of orifice size.

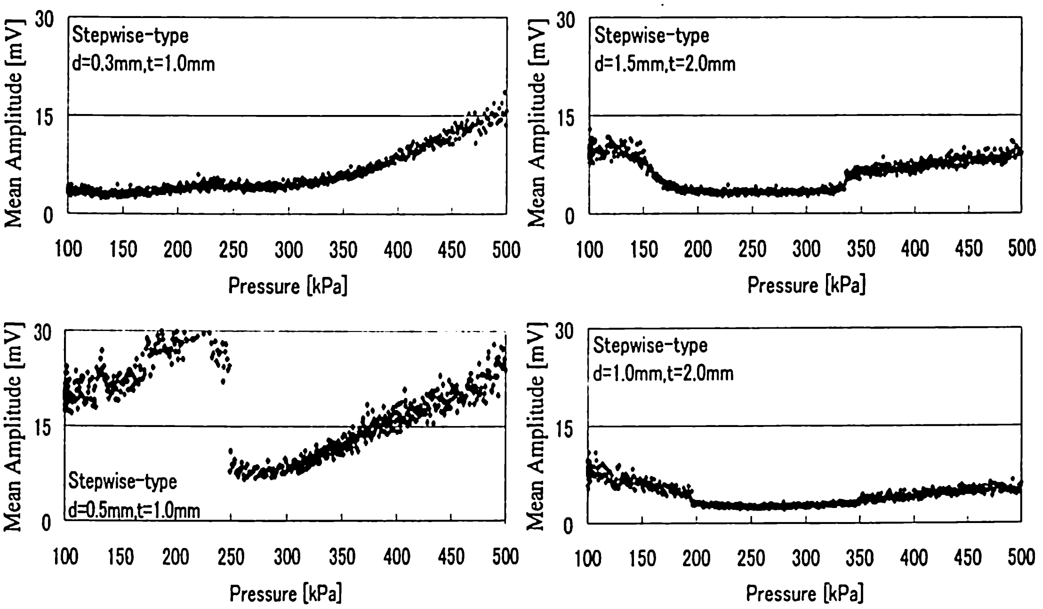

Fig. 7a Mean amplitude in relation with air pressure for stepwise-type defect at 10.0mm sensor-source location.

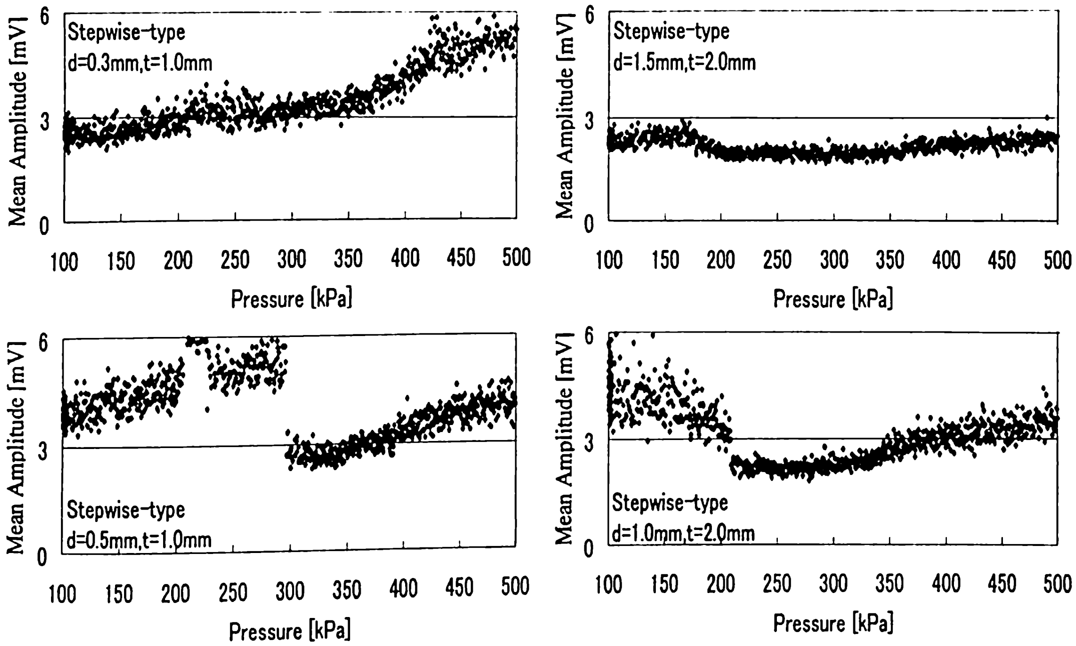

Fig. 7b Mean amplitude in relation with air pressure for stepwise-type defect at 20.0mm sensor-source location.

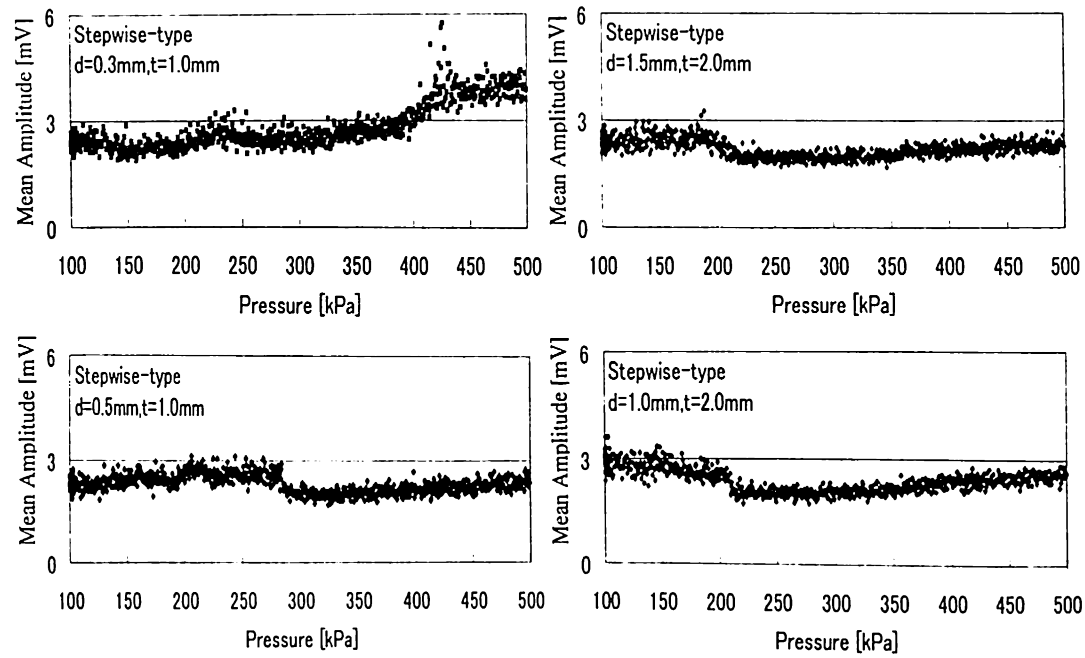

Fig. 7c Mean amplitude in relation with air pressure for stepwise-type defect at 30.0mm sensor-source location.

In other words, the propagation of acoustic signals has been a function of many factors such as the sensor-source location, size and the nature of defect mechanism, mechanical properties of the materials and the amount of the energy released. Accordingly, studies showed that the acoustic power is the function of density of the gas in the jet, cross-sectional area of the jet and the ambient sonic velocity [11,12].

3.2.3 *Spectral analysis of acoustic signals emanated on various defects*

It was reported that the signal generated by the turbulence of gas in the pipeline was found to be wide band signal having less than 600kHz frequency [13]. In this study, based on their respective peak frequency values almost all specimens have nearly recorded the same frequency range from 150kHz to 600kHz except for slit-type defect in which above 150kPa unusual acoustic sound occurred with high frequency which could be attributed to the screech tone characteristics development. This was due to the high energy released from the escaping gas. The maximum peak frequency of the screech tone was about 478kHz and then banished when the pressure was above 40kPa (Fig. 8). Similarly, in the later part of the flow the characteristics of screech tone appeared for straight-type defect, which has a peak frequency of 572kHz and some discrete frequency values above critical pressure. In the case of cone-type defect the peak frequency relative to air pressure has almost similar values with that of stepwise-type. Furthermore, the stepwise-type defect shows screech tone characteristics in the later part of the flow when depth is equal to 0.3mm with t=1.0mm. All others show a discrete frequency values caused primarily by self-excited acoustic signals. Generally, for three different sensor-source locations the peak frequency values have shown the same range as mentioned previously. And it was dominantly observed and recorded at about 200kHz.

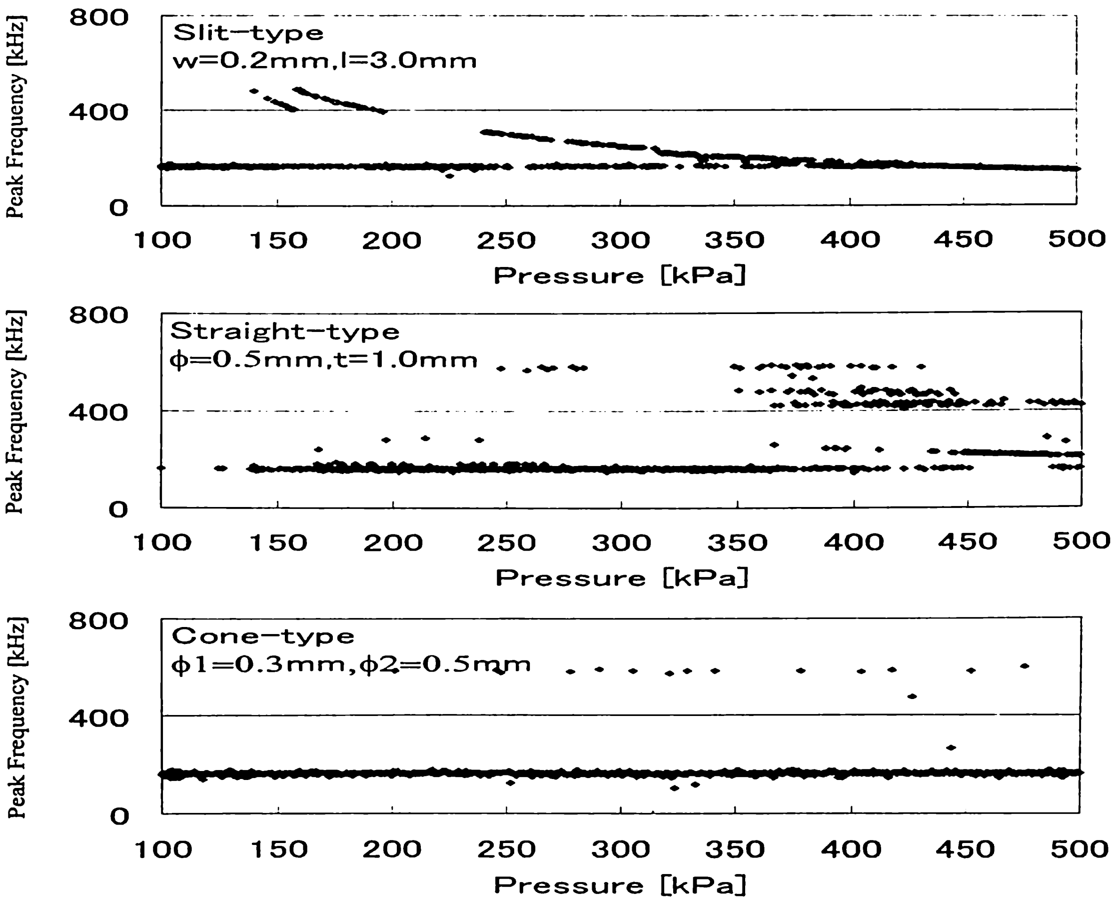

Fig. 8 Peak frequency for different types of defects with t=1.0mm at 20mm sensor-source distance.

4. CONCLUSIONS

The AE signals generated during gas leakage has been evaluated at different sensor-source locations. It was indicated that among the three locations the nearest distance has more strong acoustic power than when the sensor was located far from the source. The transient occurrence of unusual sound signifies for screech tone characteristics only developed for straight-type and slit-type defects. However, other types of defects such as stepwise-type and cone-type demonstrated a discrete frequency values because of self-excitation of the emitted signals. And also, the unique behavior is a clear indication that every AE event has its own distinct waveforms. The stepwise deviation affects primarily the acoustic signals and eventually traces a common waveform in some depths. The large-scale turbulence of the flow at higher gas pressure generally was the cause of all those unique characteristics as the air escapes from the leakage. And finally, the shock cell was developed near the nozzle lip region especially for straight-type of defect.

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