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# RESOLUTION OF THERMAL STRIPING ISSUE DOWNSTREAM OF A HORIZONTAL PIPE ELBOW IN STRATIFIED PIPE FLOW

by

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## ABSTRACT

A thermally stratified pipe flow produced by a thermal transient when passing through a horizontal elbow as a result of secondary flow gives rise to large thermal fluctuations on the inner curvature wall of the downstream piping. These fluctuations were measured in a specially instrumented horizontal pipe and elbow system on a test set-up using water in the Mixing Components Technology Facility (MCTF) at Argonne National Laboratory (ANL). This study is part of a larger program which is studying the influence of thermal buoyancy on general reactor component performance [1]. This paper discusses the influence of pipe flow generated thermal oscillations on the thermal stresses induced in the pipe walls.

The instrumentation was concentrated around the exit plane of the 90-degree sweep elbow, since prior tests [2] had indicated that the largest thermal fluctuations would occur within about one hydraulic diameter downstream of the elbow exit. The thermocouples were located along the inner curvature of the piping and measured the near surface fluid temperature. The test matrix involved thermal downramps under turbulent flow conditions.

The largest thermal fluctuations were observed to be located in the 9:00-12:00 hour clock positions at about one pipe diameter downstream from the elbow-exit [2]. At these locations as indicated by the surface thermocouples, the wall is subjected to thermal fluctuation as large as 30 to 40 percent of the total temperature change imposed by the thermal ramp at the pipe inlet.

The propensity for thermal striping under severe thermal oscillations near the wall region can be resolved only through a frequency-amplitude content analysis (power spectral density analysis). However, the conventional power spectral density (PSD) analysis is well developed only

for the stationary signals. Therefore, a special and unique technique had to be developed to reduce the unstationary signals from the test section thermocouples to quasi-stationary signals for meaningful statistical information. The typical thermal signal consisted of 15 to 18K data points for each thermocouple. Typically 30-40 thermocouples had to be treated per test for such an analysis. A two stage trend removal which is believed to be unique was developed. In the first stage a sliding window (usually 128, 256, and 512 data points long) removed the DC part from the data rendering it a "trendless AC" signal. However, the resulting signal is still unstationary due to the fact that the transient portion of the signal, which contains the useful data for our purposes is flanked by two integral stationary segments i.e, pre- and post-transient. In the second stage of the data reduction program these two non-transient portions were separated numerically and a statistically averaged PSD analysis was applied.

It should be noted that the window length does not have much of an impact on the results. Figure 1 shows a case where the outlined methodology has been applied with three different window lengths of 128, 256, and 512 data points. The resulting PSDs are very similar in all cases. The only difference observed is the increased bandwidth resolution of PSD with increasing window width. Statistically this finer resolution is not of significance since it is a direct result of the fewer subsets going into the averaging process in obtaining the PSD per spectral bandwidth. Therefore, a compromising choice was made to use only the 256 data point long window in the proposed PSD analysis of the data.

In Fig. 2 a typical statistical sample corresponding to the data of thermocouple #66 in Fig. 3 of Ref. [2] is presented. The power spectral density is plotted against the frequency content of the signal. It is seen that most of the energy in the signal is confined to the low frequencies below 1 Hz. Power decay is nearly exponential with frequency.

The experimental results and theoretical considerations also show that the ratio of peak-to-peak to RMS of the temperature fluctuations is about 6. Furthermore, due to the transient nature of the main event giving rise to the stratification and hence the thermal oscillations, large fluctuations are observed to occur only during 25 percent of the transient duration.

Based on the above observations and the short duration of the statistically important oscillations any deleterious effects from thermal striping downstream of a horizontal elbow will depend on characteristics of the transients, number of occurrences of the event, build up of stratification in the horizontal piping upstream of the elbow and on piping material.

REFERENCES

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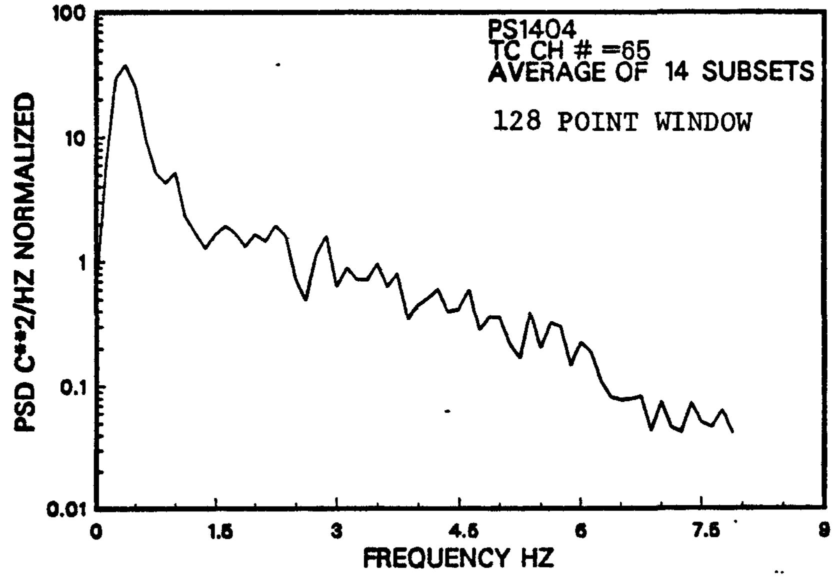
2. Kuzay, T. M. and Kasza, K. E., "Thermal Oscillations Downstream of an Elbow in Stratified Pipe Flow," Trans. Am. Nucl. Soc., 46, 794 (1984).



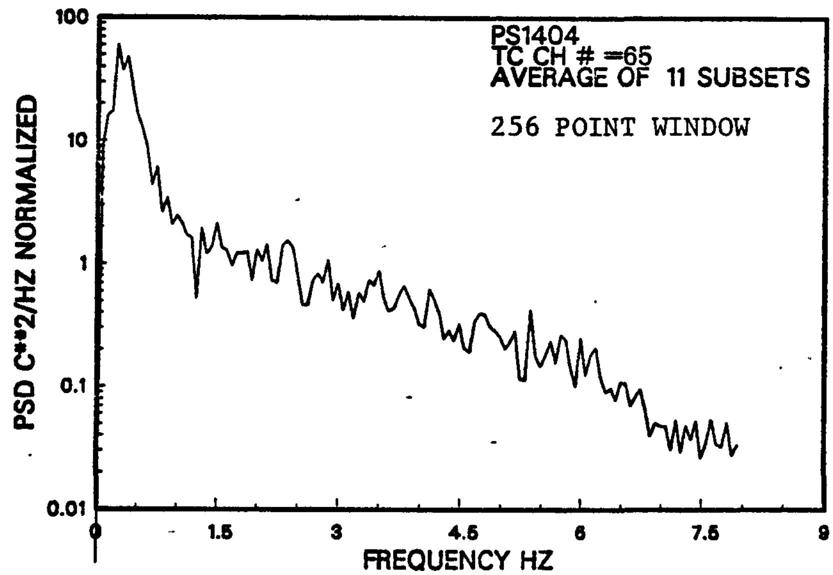
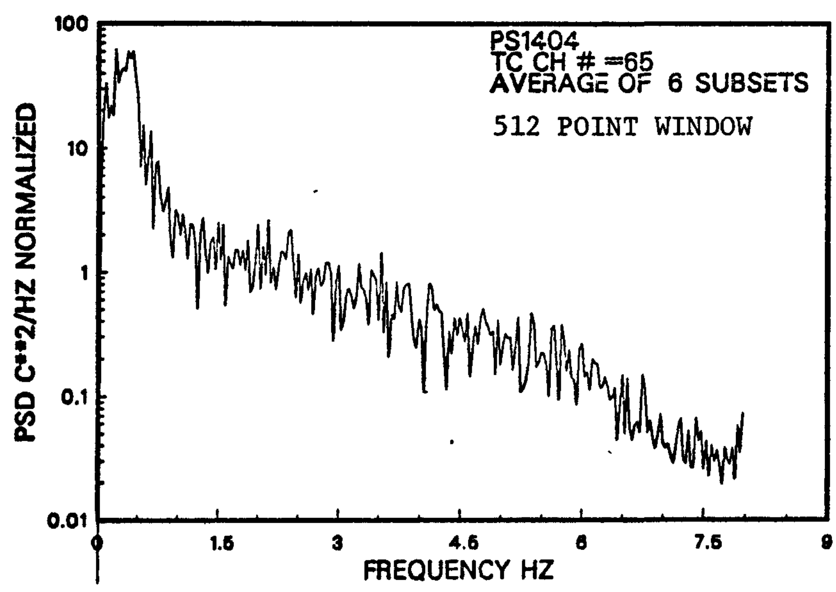




Fig. 1. The Effect of Window Length on the Resulting Power Spectral Density



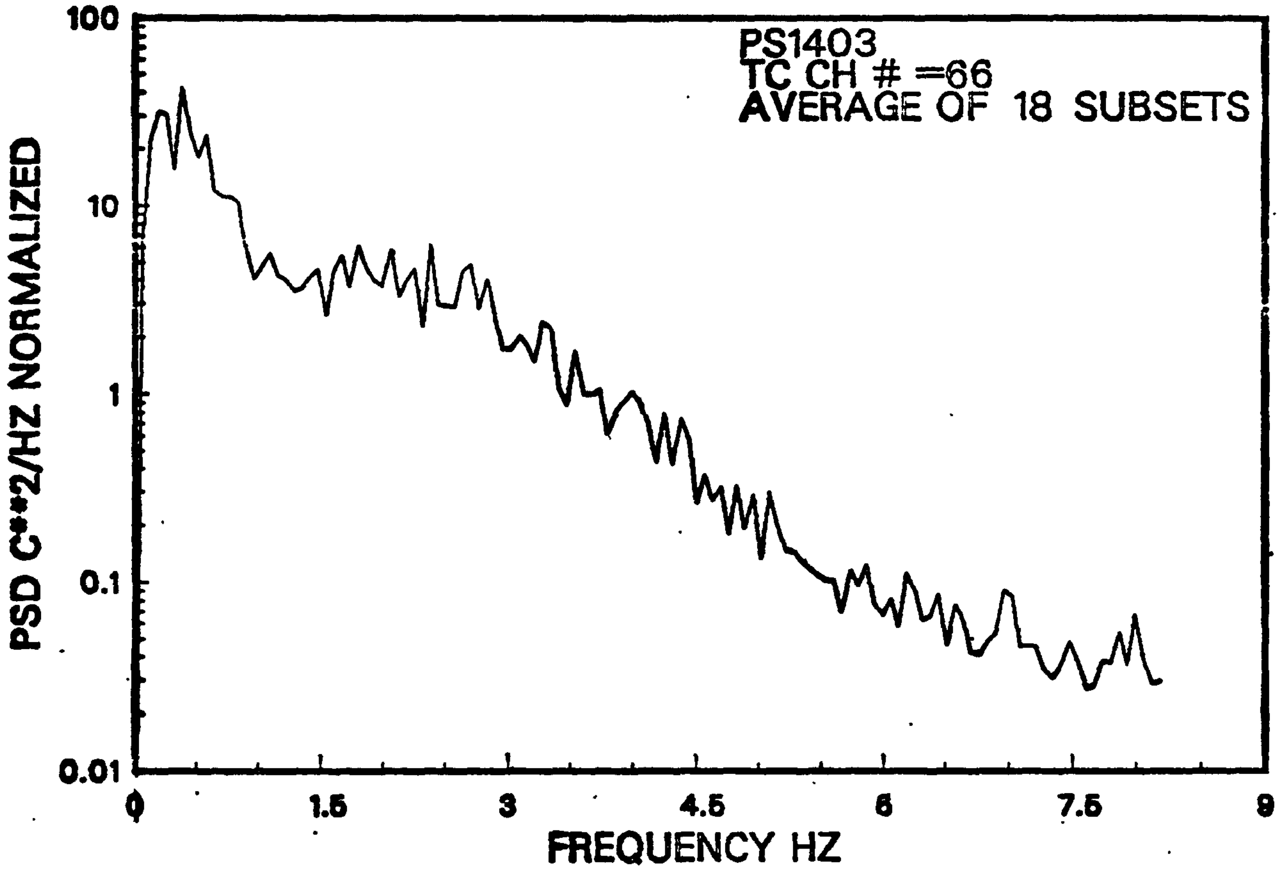



Fig. 2. Power Spectral Density for Thermocouple 66, Ref. [2]

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