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FREQUENCY SINKS ON TRANSIENT PERIODIC SIGNALS

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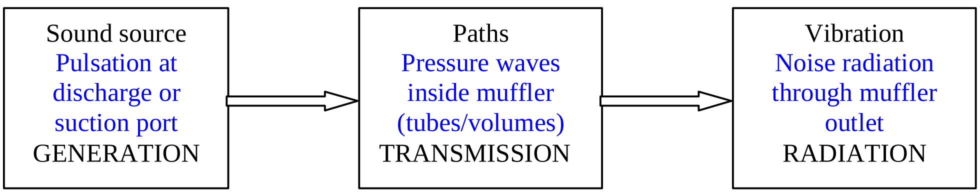
Abstract

Several industrial machines radiate noise due to fast periodic transient vibration or gas pulsation, such as hammers, compressors and others. As transient phenomena, the noise spectrum trends to be flat over frequency, but with lobs and sinks. When this transient pulse is also periodic, a spectrum containing harmonics will overlap the transient spectrum. By analyzing these kind of transient signals on time, it is possible generate "sinks" on specific frequencies. Using a parametric study of a suction pulsation signal, it is possible to point out what variables should be changed to achieve higher attenuation on specific frequencies. An example will be shown on a real transient signal.

INTRODUCTION

The mechanism of noise generation inside any machine can be explained by the single picture above :

When dealing with any pumping machine, like refrigeration compressors, one of the most important sources are the acoustical excitation coming from suction and discharge transient. Commonly to reduce this excitation, several machines apply an acoustical muffler. For example, this mufflers can be seen itself as a mechanical/acoustical system :



So, in order to design a machine with a good acoustical performance, it is extremely important to study the pulsation time history at discharge or suction instant and comprehend its mechanism of noise generation. The goal is to achieve a pulsation that has low acoustical energy at audible frequency range, especially at frequencies coincident with shell and parts resonances.

PULSATION TIME HISTORY

Gas pulsation are non harmonic cyclic repeating signals. Therefore, that implies that they are periodic, and as it, generates a frequency spectrum composed of harmonics of fundamental frequency, which is the same as machine speed. Any work aimed the understanding of relation between time history of a periodic signal and its frequency spectrum should start by analyzing the different regions of these periodic signal and how it differs of a pure harmonic signal.

Typically, a gas pulsation transient can be composed by two different time periods : one is when the fluid is pumped, or in other words, when there is mass flow through ports and valves are open; the other is when those valves are close. The first time period is characterized by sudden pressure variations, while second period is characterized by pressure standing waves from muffler components resonances.

The figure 1 shows a actual gas pulsation on a reciprocating compressor. On the same figure are illustrated the main features of a typical gas pulsation time history.

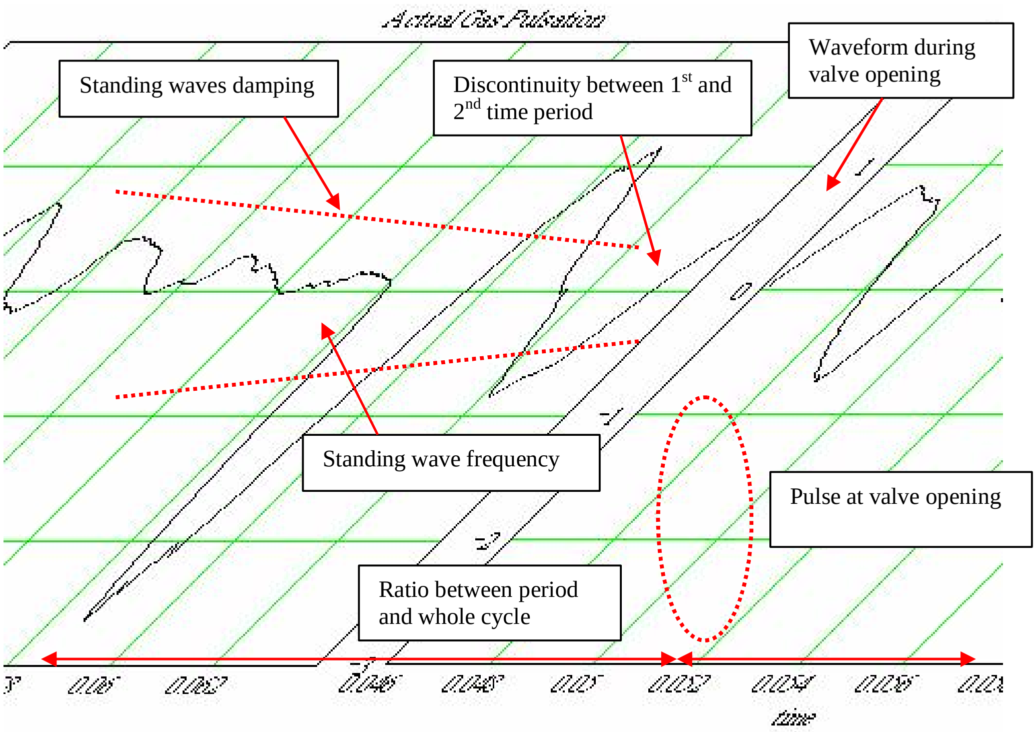


Figure 1 – Typical gas pulsation time history.

PARAMETRIC STUDY

To avail which characteristic of pulsation signal could affect its frequency spectrum, a parametric study was proposed. As independent variables, were chosen :

- Frequency of standing wave when valves are close;
- pulsation transient induced by valve opening;
- waveform type of this pulsation transient;
- acoustical damping after valve closing;
- non continuity at valve opening instant;
- amplitude ratio between standing waves and induced pulsation;
- time duration ratio between these two pulsations.

As objective functions the were chosen the magnitude level in a certain frequency. The study was done using both Fourier Integral and FFT in order to express better the sinks and pulsation particularities.
The technique for studying those variables was to vary each one independently, fixing the other ones to a known value.The Figures 2 to 8 represent the a built time history of a typical pulsation in which one of the above mentioned variables were studied. Beside the time history, the frequency spectra of those signals are shown

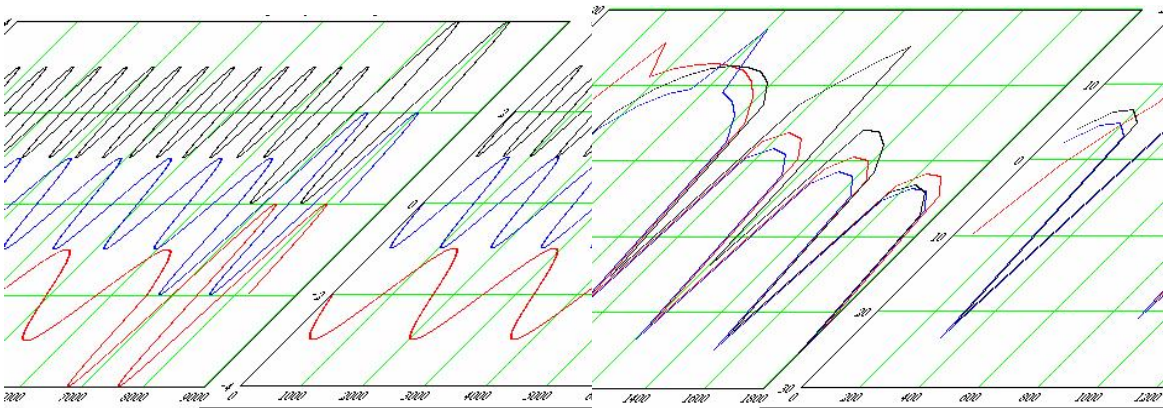


Figure 2 – Time history and frequency spectra varying the frequency of standing wave

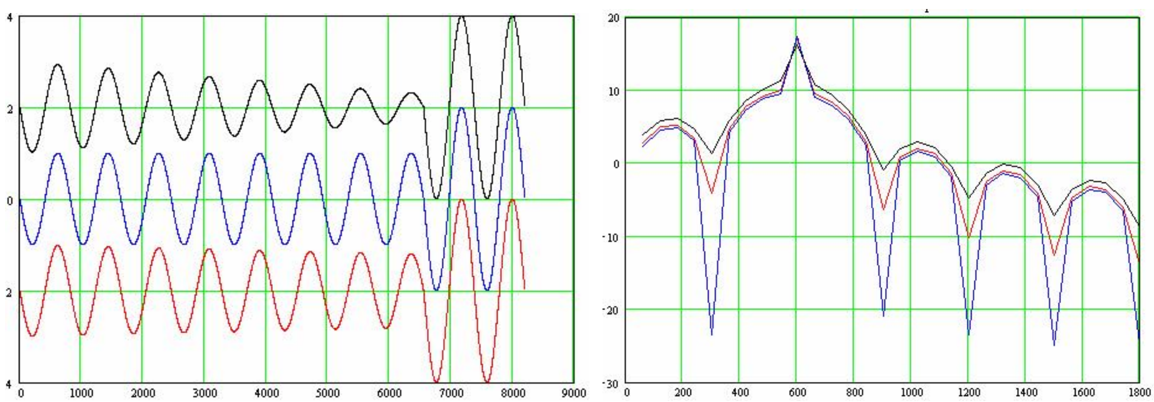


Figure 3 – Time history and frequency spectra varying the damping of standing wave

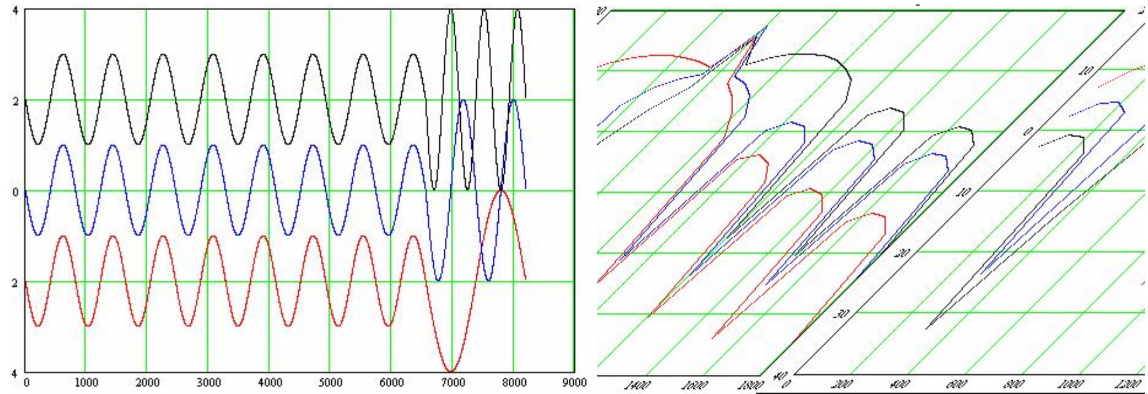


Figure 4 – Time history and frequency spectra varying the frequency of pulsation during valve opening

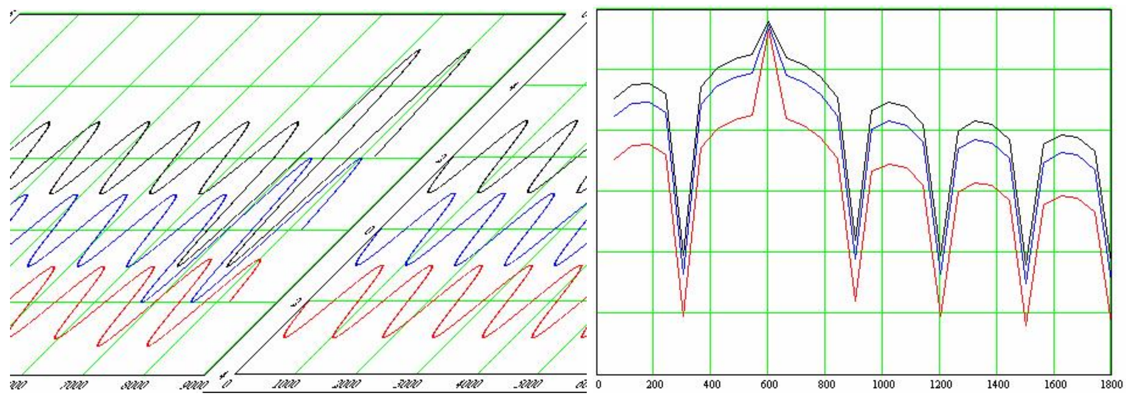


Figure 5 – Time history and frequency spectra varying the ratio amplitude between pulsation during valve opening and standing wave

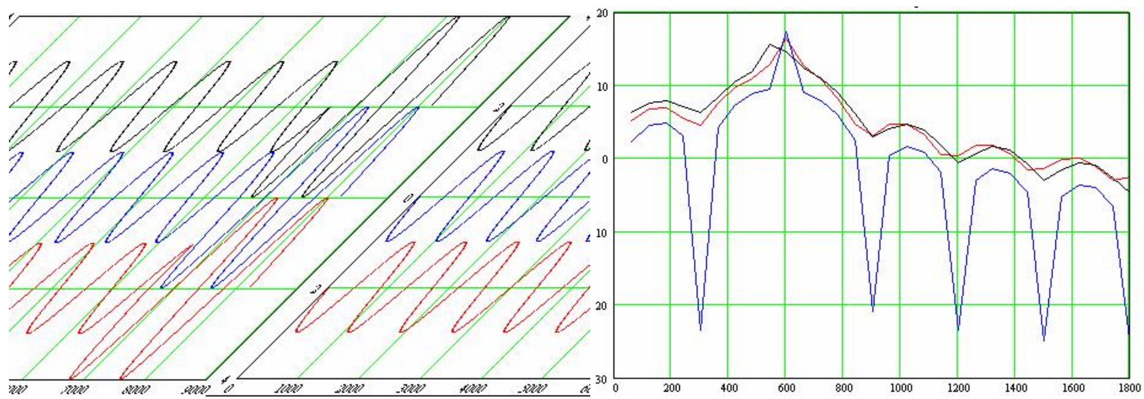


Figure 6 – Time history and frequency spectra varying discontinuty between pulsation during valve opening and standing wave

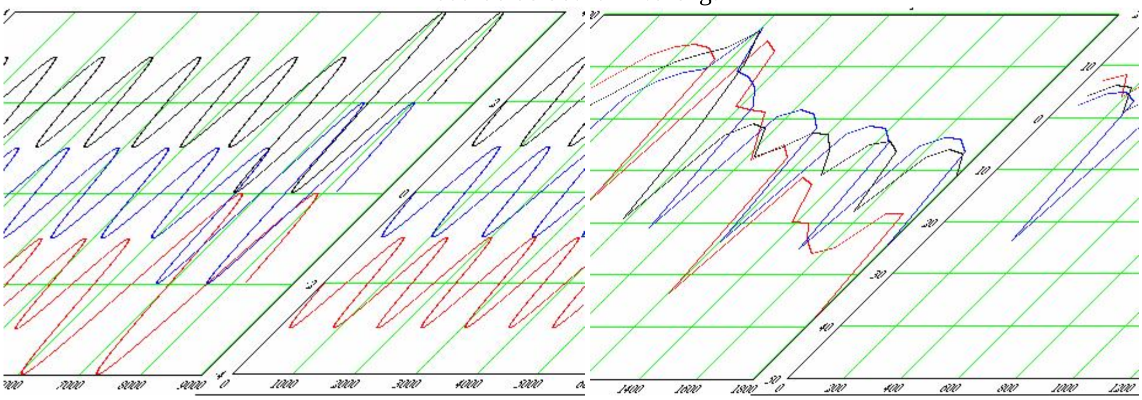


Figure 7 – Time history and frequency spectra varying the ratio between duration of pulsation during valve opening and duration of standing wave

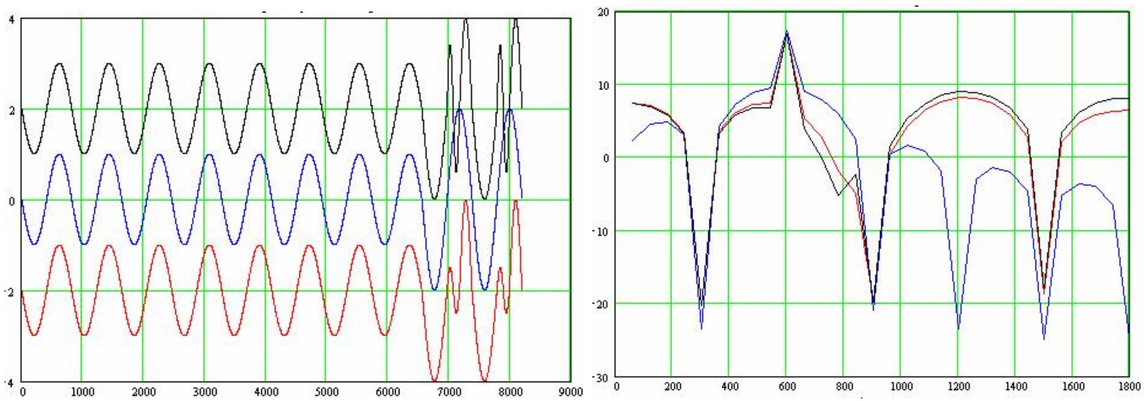


Figure 8 – Time history and frequency spectra varying the waveform of pulsation during valve opening

RESULTS ANALYSIS AND CONCLUSION

The frequency spectrum analysis of pulsation time history proves that some “sinks” must be achieved at specific frequencies, provided that they are harmonic of fundamental frequency. At those sinks, the acoustical energy is extremely low, well below the excitation level of other harmonics components.

This is quite important when dealing machines that operates under fluid pumping excitation. If the suction or discharge system could be designed such as these sinks are coincident with structural or acoustical resonances of the machine parts, a quieter machine will be achieved. In practice, it will be tuning a high response with a very low excitation.

From the analyzed factors, the most important are the ones that could determine if those frequency sinks are present or not and its position on frequency spectrum. Those factors are:

a) Discontinuity at final of standing wave period and start of pressure pulse due to valve opening;
b) ratio between period from standing wave and pressure pulse due to valve opening;
c) frequency of both pulsation;
d) waveform of pressure pulsation during valve opening.

Among those, the ones that apparently are more important of all is the ratio between time duration of each pulsation and whole cycle and pressure slope(discontinuity) at valve opening instant. The other variable are important because they could suppress the sinks at certain harmonics.
The damping of standing wave and amplitude ratio between are no significant concerning frequency spectra.

BIBLIOGRAPHY

[1] Hamilton, J F, “Measurement and control of compressor noise”- West Lafayete, Purdue University, 1988.