Analytical modelling of the acoustical interaction effect between multiple out-of-phase compressor reed valves

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ABSTRACT

Most industrial reciprocating compressors involve multiple reed valves that periodically open and close at various moments of the compressor cycle. Each reed behaves as a vibro-acoustic source whose spectrum of vibrations is excited by the flow through the valve. Since suction and discharge sets of valves have similar behaviours, investigation of interactions for a set of six discharge valves is done here. Non homogeneity of the reed geometry is accounted for in the mathematical developments by considering a variable width. Analytical approach allows quick prediction to weak geometric modifications of the multiple valve system response.

The angular frequency of the piston that compresses the gas is noted Ω. It is directly related to and imposed by the rotational frequency of the engine. Every valve has identical geometry and so vibrates at the same frequency noted w (corresponding to the first eigen-frequency of the valve). Depending on the values of the ratio w/Ω, there is either a risk of acoustic amplitude amplification propagating outside the vehicle or inside the cabin.

A single reed valve is modelled as a Timoshenko beam whose width varies with the exponential characteristic length d and considered in free vibrations so as to calculate its eigen-frequencies. An original non-dimensional form of the Timoshenko's equations is conducted (in the same way as Bideau *et al.* [1]) involving only three dimensionless parameters. Assuming modal description of the beam vibration allows a similar formulation of the dispersion equation to the homogeneous beam (constant width) to be found, whatever the value of the characteristic parameter d. Eigen-frequencies are then calculated for a cantilever beam, justified since the valve tip is free during the elevation and declination motion in the discharge cycle, before impacting the retainer or the valve seat (upper and lower limiters respectively).

The forced vibrations problem is eventually stated and developed within a linear decomposition on the eigen-modes and application is done for a timed rectangular pulse signal excitation whose period matches with the piston cycle one. This has been conducted in order to simulate the force of the fluid on the valve.

The acoustical pressure field generated by the 6-valve system is then formulated accounting for a phase shift for the aperture/closing cycles equal to the sixth the piston period. Amplification of the acoustical pressure amplitude is observed for specific values of the ratio w/Ω, equal or close to the number of valves (six here). Besides, controlling the risk of such an interaction is shown to be possible by weak modifications of the geometry, changing the characteristic length d, *i.e.* the eigen-frequency w.

REFERENCES

[1] N. Bideau, L. Le Marrec, L. Rakotomanana, “Influence of a finite strain on vibration of a bounded Timoshenko beam”, *Int. Journ. Solids Struct.,* Vol. **48**, pp. 2265–2274 (2011)