OPTIMIZATION OF THE LOOP IN A TRAVELLING-WAVE THERMO-ACOUSTIC ENGINE

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Introduction

A number of experimental realizations of thermo-acoustic engines that use an acoustic loop to feed energy back to a regenerator have been reported, mostly of the Thermo-Acoustic Stirling Heat Engine (TASHE) type. An alternative configuration is the simple wavelength loop with the linear alternator in a short side-branch, but with close to travelling-wave phasing on both sides of it. The advantage over the TASHE is that a great deal more power can be extracted for the same stroke-length of the alternator. However, a difficulty with this configuration lies in maintaining the optimum conditions in the regenerator, particularly when the temperature at the hot-end is changing. Attempts by the author to achieve consistent power generation with atmospheric air and a radiative heating system that would be cheaply realizable with a wood-burning stove have been frustrated, with very variable performance, and a thermal to electrical conversion efficiency of less than 1% [1].

This contribution focusses upon finding the optimum acoustic path in the loop feeding the regenerator, so as to give the most favourable conditions within it. Computations with a model of the regenerator have proved capable of reproducing the pressure distribution around the loop with reasonable accuracy [2]. However, attempts to use the model to determine the best loop configuration have been negated by the complex interaction of the parameters. An alternative, semi-empirical approach is described here.

Method for Loop Optimization

Bannwart et al. [3] characterised the regenerator separately from the rest of the loop through calculation of its transfer function from two experiments with different boundary conditions. They then computed the response when this regenerator was placed in a loop with variable length legs on either side of a variable length of branch pipe, and thus identified an optimum configuration, albeit without power extraction.

The approach here is similar, but the optimisation of the boundary conditions for the regenerator is carried out through a procedure recently outlined by Holzinger et al. [4]. They derived the gain in acoustic power from the scattering matrix (Σ) of a two-port element, which here includes the regenerator. The coefficients of Σ can be derived from the coefficients of the transfer matrix, as determined by the two-source method. Computing the eigenvalues of the product of Σ and its adjoint yields the maximum possible amplification factor and power gain relative to the total incident power, and the acoustic impedance required at the two boundaries to achieve this.

Because of the need for at least two-microphones on each side to assess the energy flows, the boundary planes were as shown in Figure 1. To implement the 'two-source' method, the loop was closed with a plate in two different places. Thus energy flowed in different directions through the regenerator and around the loop to an open termination, which was given extra real impedance by inserting a Rockwool plug. Measurements were made for the unheated case, and for three levels of heating, with three frequencies of excitation.

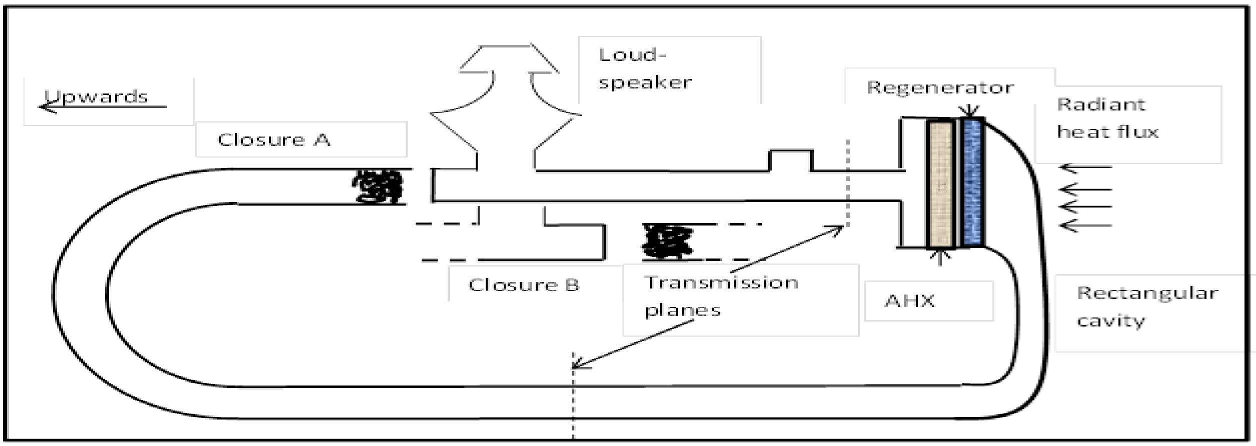

Figure 1: *The loop configuration, showing chosen transmission planes and the two pipe closures*

Results

The maximum and minimum acoustic power gains were thus computed:

Table 1: *Computed Results for the Potential Acoustic Gains of the Regenerator based on Transfer Function Measurements*

T_h	f=68Hz		f=74Hz		f=80Hz	
	Max	Min	Max	Min	Max	Min
295-297K	0.07	-0.25	0.10	-0.25	0.14	-0.33
690-780K	0.47	-0.35	0.37	-0.29	0.35	-0.28
860-920K	0.45	-0.32	0.23	-0.40	0.22	-0.38
1010-1060K	0.40	-0.36	0.38	-0.49	0.26	-0.40

It is seen that for the unheated cases, the deduced gains centre on negative values, because of dissipation, although errors in measurement suggest erroneously that some positive generation could take place. When the temperature of the hot end of the regenerator (T_h) was increased by radiation, maximum potential gains of about 0.4 were deduced, and these values are consistent with those computed in [4] from first principles for the present Womersley number of 0.4. However, the general trend to a reduced maximum gain with temperature is not in accord with theory, and the fall in gain with frequency is too rapid.

References

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