Loss effect analysis of irreversible Stirling cycle refrigerator

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INTRODUCTION

The design of a Stirling refrigerator requires the understanding of the processes. Different numerical models have been developed to design the Stirling refrigerator and to evaluate the overall performance of the machine. However, the shares of each loss have not been investigated in detail so far. The share of share of each type of loss at different operating condition will help in optimal designing of machine components and operating conditions. In this research work, a non-ideal second order model called modified simple model with different losses incorporated and developed by the author [1] have been used to investigate the share of different losses.

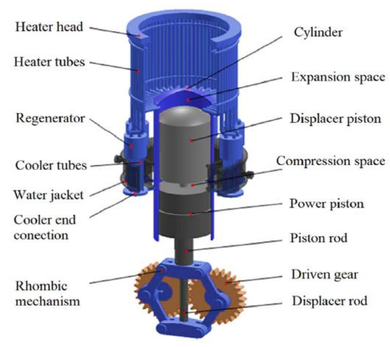


Fig. 1 : Components

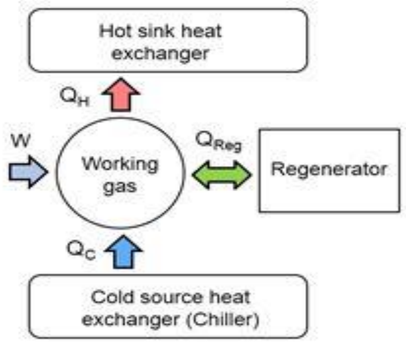


Fig. 2 : Schematic diagram

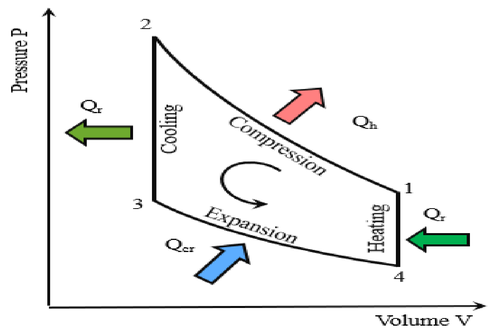


Fig.3. Ideal P-V diagram

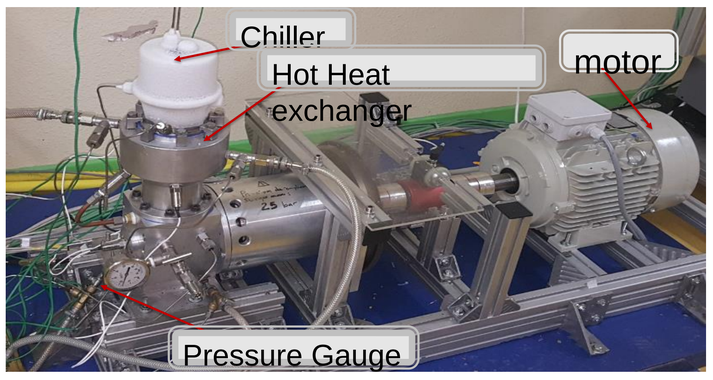


Fig. 4: Beta-type Stirling refrigeration machine at cooling stage

MATERIALS AND METHODS

Materials

After the model have been validated with experiment using FEMTO 60 machine, analysis of losses have been conducted. The losses have been classified as power losses and heat losses.

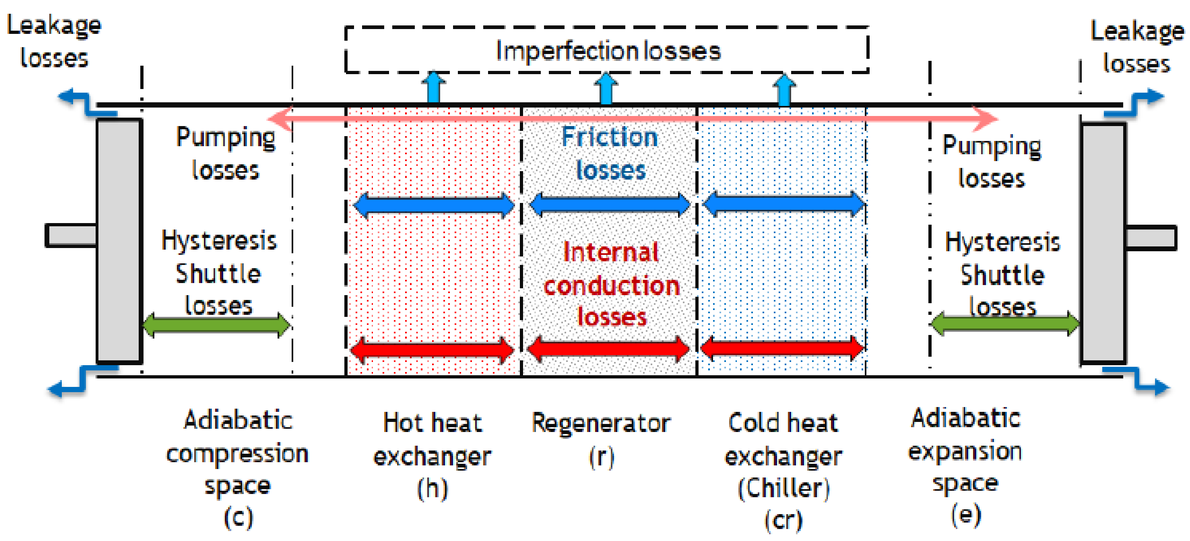


Fig. 5 : Mapping of different losses

Methods

A non-ideal second-order numerical model is simulated using the FEMTO 60 engine model in a reverse condition as shown in Fig. 2. MATLAB code is used to simulate the numerical model. The values of different losses have been recorded at different operating conditions.

$$COP = \frac{Cooling\ load}{Input\ power\ requirement}$$

Heat Losses

Power Losses

Simulation at different parameters → Evaluating the share of losses and COP → Remarks & conclusions

RESULTS AND DISCUSSION

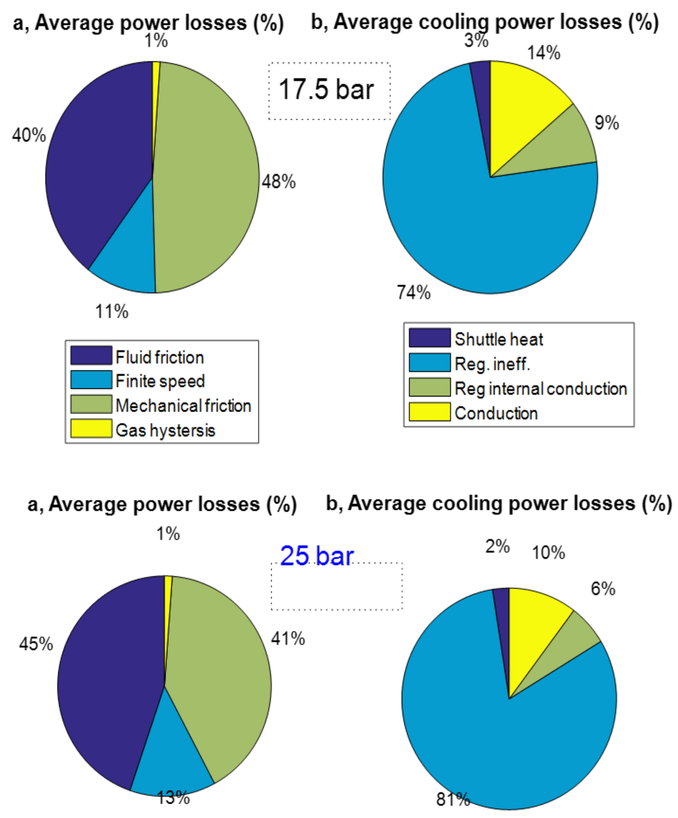
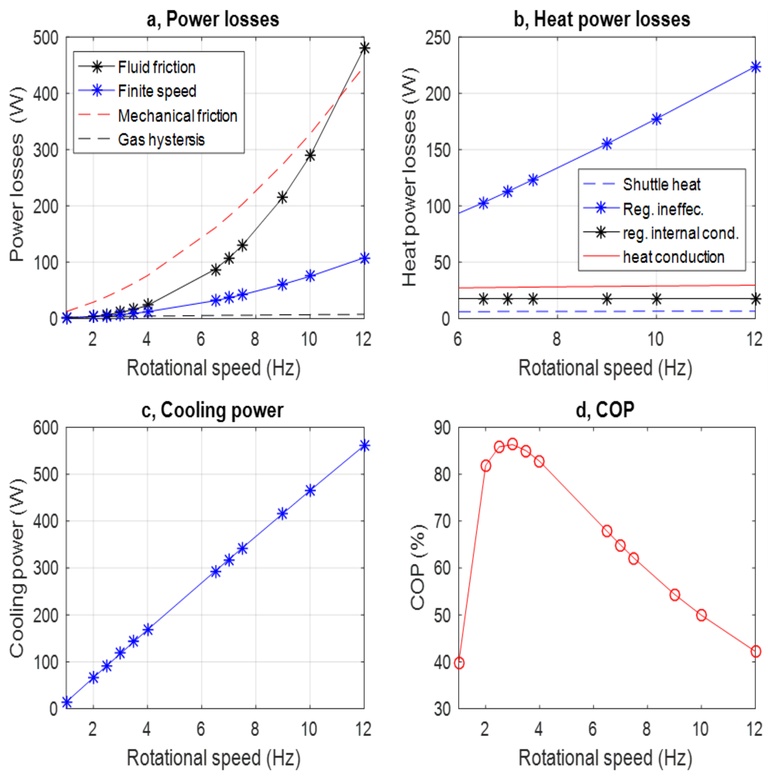


Fig. 6 : Analysis of the percentage of losses at different pressure

- The major power losses are mechanical friction loss and fluid friction loss
  &
- The major heat loss is loss due to regenerator imperfection

- The percentage share of fluid friction loss and loss due to regenerator ineffectiveness increase with increase in charging pressure
- At higher pressure more concern shall be given to the reduction of fluid friction and regenerator imperfection losses.



- Except for gas hysteresis power loss all power losses are majorly affected by rotational speed
- Except regenerator imperfection loss all other heat losses remain unchanged

- Cooling power increases due to increase in number of cycles per unit time

Fig.7: Trend of major losses and refrigeration performance with respect to operating speed

Conclusions

- Fluid friction power losses and regenerator imperfection losses are found as the two most losses that are mostly affected by charging pressure and operating speed.
- The shares of these two losses (fluid friction and regenerator imperfection losses) over their respective total losses increase with an increase in operating speed as well as with charging pressure.
- During design and development of Stirling machines, critical investigation shall be made on range of operation of the machine so that we could select appropriate component so as to minimize the major losses and then the total losses.

Reference

1. M. Z. Getie, F. Lanzetta, S B´egot, B. T. Admassu, S. Djetel-gothe, A non-ideal second order thermal model with effects of losses for simulating Beta-type Stirling refrigerating machine, International Journal of Refrigeration, (2021). https://doi.org/10.1016/j.ijrefrig.2021.05.018 .
2. S. Djetel, Mod´elisation et r´ealisation d'une machine r´eceptrice de Stirling pour la production de froid, Th`ese de l'Universit´e Bourgogne Franche-Comt´e de Belfort, 2020.

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