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Various parameters affecting the performance of a regenerator

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Abstract—main objective of this review paper is to show how various parameters affect the performance of regenerator. Performance of regenerator is very important parameter to design it.varius parameter which affects the performance of regenerator has been discussed.

***Keywords**-regenerator,parameter*

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I. INTRODUCTION

A regenerator is a very efficient compact heat exchanger which is used in cryogenic systems such as the Stirling cycle, Gifford-McMahon cycle, Solvay cycle, Vuilleumier cycle, and pulse tube refrigerator types. It is constructed of a matrix material that has the capability of quickly transferring and storing heat from a gas, which passes through it. It is also highly resistant to heat flowing along its longitudinal direction.

As compared to the counter-flow heat exchanger, the regenerator does not require simultaneous continuous flow of two physically separated fluids. The regenerator transfers heat to and from the same gas by the intermediate heat transfer with the regenerator material each time the gas direction is cyclically reversed. For an equivalent thermal efficiency, the regenerator can be made much smaller and lighter than its counter-flow heat exchanger counterpart (R. A. Lechner).

The regenerator has several distinctive advantages: It can be made relatively small; its efficiency is very high; matrix material is readily available; its construction is simple; and as a result, its cost is comparatively low. In normal operation, the regenerator is relatively insensitive to plugging by impurities in the gas stream. It does not require the physical separation of the gas stream.

All cryogenic refrigerators require a heat exchanger, which separates the high temperature gas from the low temperature gas. Figure 1 shows the relative position of the heat exchanger in a cooling system. The use of regenerator in this position allows a large temperature difference to be produced, with the advantage of simplicity, small physical size, and high efficiency.

The action of a regenerator can be seen as represented by figure 1.

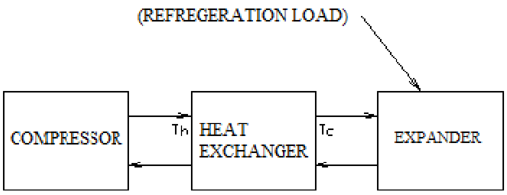

Fig 1 Cry cooler system Diagram

During the steady state operation of the regenerator, for one cycle, the warm gas from a compressor at temperature Th, passes through the regenerator, from point 1 to point 2, and progressively transfers to the matrix material until the gas temperature approaches the refrigeration temperature Tc. The gas is further cooled by the refrigeration process, from point 2 to point 3, after which it returns to the regenerator.

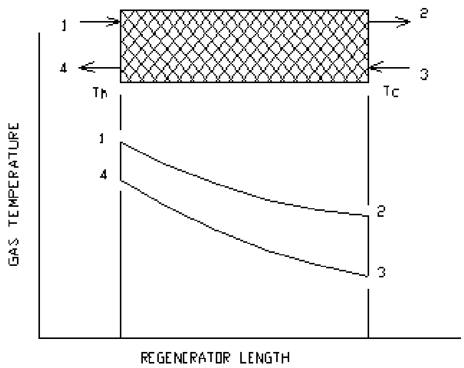

Fig. 2 Regenerator Temperature cycle

Progressively rising in temperature, from point 3 to point 4, the gas leaves the regenerator slightly colder than when it first started the cycle. The regenerator is never quite able to cool the incoming gas stream down to the refrigeration temperature, nor is it able to warm up the outgoing gas stream quite to the incoming gas temperature, because of heat losses and irreversibility. Lower the refrigeration temperatures, the greater the effect of losses. This makes heat exchanger efficiencies of 97% and higher, a necessity for most cryogenic applications.

Losses in regenerators have been categorized and described. These effects, such as property variations with temperature, longitudinal heat conduction, wall effect, feed gas flow effect, and end effect, all combine to provide the total heat loss which reduces the regenerator's overall efficiency.

Various types of matrix materials can be used in a regenerator, according to the characteristics desired, but certain properties are required. Resistance to gas flow should be low to minimize the energy required to move the gas through the regenerator. The construction should provide a large heat transfer area to enable the gas to experience intimate contact with the matrix material. The heat capacity and thermal conductivity should be large to enable rapid transfer of large amounts of heat.

II. VARIOUS PARAMETERS AFFECTING THE PERFORMANCE OF A REGENERATOR

The various parameters affecting the performance of a regenerator are:

Void volume
Longitudinal conduction
Variable specific heat
Pressure cycling
Wall effect
Impact of heat capacity and geometry of matrix
Pressure drop

VOID VOLUME

Void volume also called, as dead volume of the regenerator, is the volume occupied by the gas within the matrix due to its porosity. Regenerators using wire screen of mesh 300 has porosity 58.6%, so more than half of the space is occupied by the regenerator dead volume. If wire screen of mesh 10 is used, its porosity is 84%. There is little chance of minimizing void/dead volume by screen size selection, when using wire mesh geometries (N. Nag raja).

AXIAL/LONGITUDINAL CONDUCTION

It is one of the important factors affecting the performance of the regenerator. The length of cryogenic regenerator is usually small (50 to 150 mm), though the temperature gradient across the regenerator is quite large. It results in conduction namely, Longitudinal conduction along the wall of the regenerator containment tube and along the regenerator matrix. The heat thus gained at the cold end forms an additional heat load, which adds to the thermal loss. Conduction losses are relatively small if the regenerator length is more than 100 mm and diameter is less than 25 mm.

Heat loss due to conduction along the wall can be minimized by the use of a long thin wall, small diameter cylinder of low conductivity materials. Stainless steel is favoured because it has strength, toughness and relatively low thermal conductivity. It is impermeable to gases, relatively easily worked and readily available at reasonable cost (P.A. Rios & J.L. Smith Jr.).

VARIABLE SPECIFIC HEAT

The specific heat of materials decreases with temperature, while of gases it increases. Rea and Smith (P.A. Rios & J.L. Smith Jr.) using finite difference method studied the influence of variable specific heat of the matrix. The results indicate a decrease in effectiveness with decrease in the cold end temperature. This effect was relatively small at higher warm end temperature. It is observed that between the temperature variations of 300 K to 80 K there is relatively small change in specific heats of matrix materials and gas. So considering the specific heat of matrix and gas at mean temperature will give quite good results.

PRESSURE CYCLING

In regenerator of Stirling machine blow times are very small, so the time required for an element of gas to pass through, which is known as "residence time" is not shorter compared to blow time and it is possible for some gas particles to remain always within the regenerator. Mass flow rate and pressure is not constant within the regenerator (P.A. Rios & J.L. Smith Jr.).

WALL EFFECT

Heat flows through the wall of outer cover and inner cover of the regenerator is known as wall effect. The matrix temperature gradient carries some axial conduction loss, but for the regenerator of short length used for the cryogenic refrigerator, this loss is much more and so effectiveness is greatly affected (P.A. Rios & J.L. Smith Jr.).

IMPACT OF HEAT CAPACITY AND GEOMETRY OF THE MATRIX

Andean gives analytical and experimental results of, shows that for regenerative refrigerators providing cooling above about 70 K, the primary concern should be the matrix characteristics size. The Specific matrix chosen (mesh particulate etc) has a direct impact on the efficiency and the performance of regenerative system and should be chosen depending upon the demands to be placed upon the system. However, for end expander with reasonable swept volume and cycle rate, the matrix material and volumetric heat capacity is virtually of no consequence. Also, axial variations in the characteristic size of the regenerator matrix can improve performance.

PRESSURE DROP

The effect of pressure drop on refrigeration capacity can be gauged from the work diagrams for expansion and compression spaces as shown in figure 3. The shaded areas are the reduction in area of expansion space diagram due to regenerator pressure drop. The refrigeration capacity is decreased approximately by the same proportion as the area of work diagram (N. Nag raja).

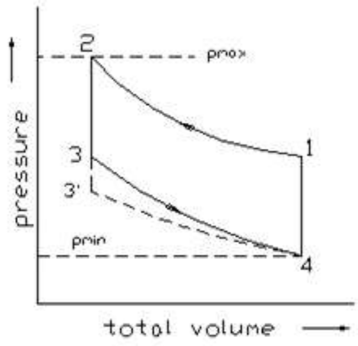

Fig 3 Reduction in refrigeration effect due to pressure drop

III. CONCLUDED REMARKS

Paper show how various parameters affect performance of a regenerator and it is necessary to optimize these parameter to optimize performance of regenerator.

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