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Analysis of Regenerator for Reversed Stirling Cycle Which Various Geometry

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Abstract

Analysis of regenerator deals with assumptions made for analysis and different equation use to predict the performance of regenerator Problem and sample calculation deals with problem and calculation of various parameter such as geometrical parameter heat transfer co-efficient and effectiveness, pressure drop loss of refrigerator effect due to ineffectiveness and pressure drop and other type of regenerator losses Result and discussion deals with the effect of mass flow rate mesh size standard wire gauge inner diameter of regenerator motor r.p.m. on effectiveness of regenerator and pressure drop. Various type of graphs plotted against effectiveness and pressure drop v/s above parameter

Keywords: Phillips liquid nitrogen plant, penetrates , heat conduction, effectiveness of regenerator, pressure drop ,porosity, filling factor

Introduction

When a wire screen is used as a material for regenerator matrix, heat will be stored within a wire element. Heat transfer during heating or cooling by a body is dependent on both internal resistance and surface resistance.

Figure1.1 shows a model of heat conduction in the section of wire element. The following three different cases are possible:

(a) If diameter dw is too small, heat penetrates to the center of wire before the blow time expires. In this case, although the total volume of wire has been used effectively, but effective heat storage volume is insufficient and will result in additional load at the cold end, therefore to augment the heat storage capacity, number of screens must be increased. In case the numbers of screens are more, the flow losses will be increased considerably.

(b) If the wire diameter dw is too large, heat does not penetrate to the center of the wire element within the blow time. Thus, some domain of the sectional area does not contribute to the heat storage.

(c) If the wire diameter dw is selected such that heat just penetrates to the center of the wire element within the blow time, then the desired heat storage capacity would be achieved.

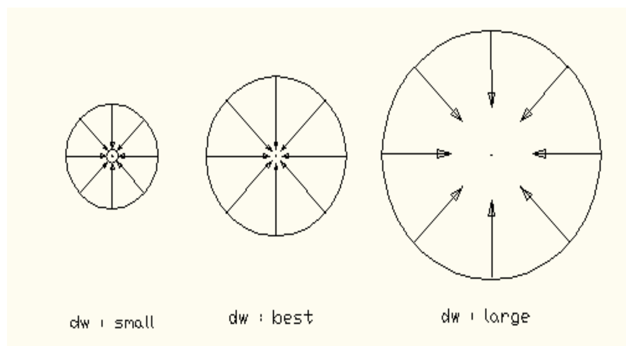

Fig1.1 heat conduction in wire element

Assumptions made for theoretical analysis:

a) The working fluid obeys perfect gas law
b) Constant mass flow velocity
c) Negligible heat conductivity of the matrix and the fluid in the direction of flow
d) One dimensional flow (for half cycle
e) Constant heat transfer coefficient between the matrix and fluid
f) Constant temperature of the fluid at the inlet of matrix
g) Mesh screens are closely stacked

Design Procedure

1- Calculation for Effectiveness of the regenerator

$$E' = 1 - \frac{1}{1 + NTU_0}$$

2- Calculation for pressure drop:

$$\Delta p = \frac{n * f * G^2}{2 * \rho_{mean}}$$

3- Calculation for loss of refrigeration effect due to pressure drop:

$$\frac{\Delta Q}{Q_{ideal}} = 10.21 * (1 - E')$$

4- Calculation for regenerator losses

$$Q_{l,th} = m_0 * C_p * (1 - E') * (T_h - T_o)$$

Case Study

Regenerator effectiveness and various performance parameters is calculated for regenerator of reversed stirling cycle(Phillips liquid nitrogen plant-106) having liquid nitrogen production capacity 6.5 liter per hour under standard operating condition.

The regenerator of installation is in annular shape having inner diameter of matrix 78mm, outer diameter of matrix 101.5 and length of matrix 45 mm. matrix materials is phosphorous bronze. Cryogenerator operates at higher pressure 40 bar and lower pressure 6.45 bar. Working fluid is Helium

A steady state method for determining the effectiveness of regenerator was adopted.

Following gas flow rates and mesh size and SWG is used for theoretical investigations.

Material of matrix:	**Phosphorous bronze**
Gas flow rate:	**42.61kg/hr**
Inner diameter	**78**
Mesh size	150, 200, 250, 300, 350, 400
SWG	47, 48, 49, 50

Table3.1
Effectiveness for different mesh size and swg at constant mass flow rate 42.61kg/hr

SWG	MESH SIZE					
	150	200	250	300	350	400
47	0.9892	0.9936	0.996	0.9976	0.9986	0.9993
48	0.9886	0.9929	0.9953	0.9968	0.9978	0.9985
49	0.988	0.9923	0.9947	0.9962	0.9971	0.9979
50	0.9878	0.9921	0.9944	0.9959	0.9969	0.9976

Chart3.1

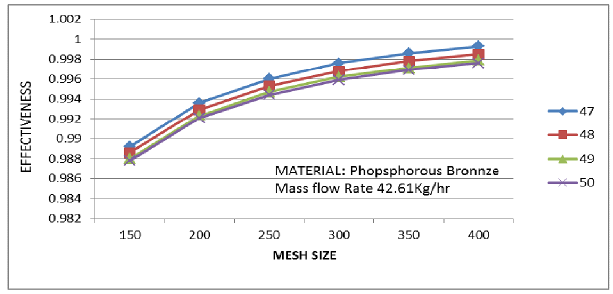

Table3.2 Pressure Drop In Bar For Different Mesh Size And Swg At Constant Mass Flow Rate 42.61kg/Hr

SWG	MESH SIZE					
	150	200	250	300	350	400
47	0.0113	0.0186	0.0313	0.0567	0.1184	0.3403
48	0.0123	0.0185	0.0277	0.0422	0.066	0.1124
49	0.0143	0.0202	0.0279	0.0382	0.0522	0.0721
50	0.0162	0.0222	0.0297	0.039	0.0508	0.0661

Chart3.2

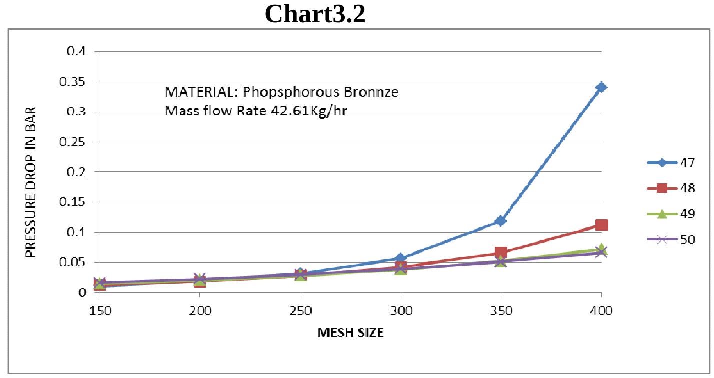

Table3.3
Effectiveness for different swg and mesh size at constant mass flow rate 42.61 kg/hr

MESH SIZE	SWG			
	50	49	48	47
150	0.9878	0.988	0.9886	0.9892
200	0.9921	0.9923	0.9929	0.9936
250	0.9944	0.9947	0.9953	0.996
300	0.9959	0.9962	0.9968	0.9976
350	0.9969	0.9971	0.9978	0.9986
400	0.9976	0.9979	0.9985	0.9993

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Chart3.3

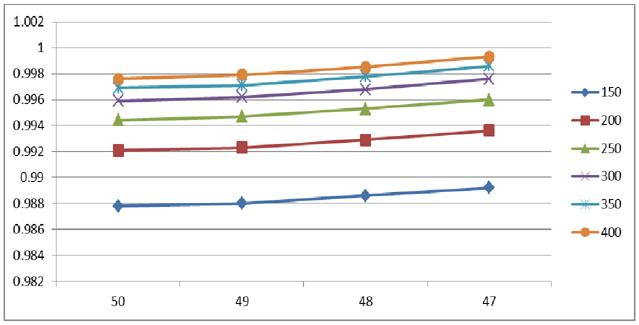


Table3.4
Pressure drop in bar for different swg and mesh size at constant mass flow rat 42.61 kg/hr

MESH SIZE	SWG			
	50	49	48	47
150	0.0162	0.0143	0.0123	0.0113
200	0.0222	0.0202	0.0185	0.0186
250	0.0297	0.0279	0.0277	0.0313
300	0.039	0.0382	0.0422	0.0567
350	0.0508	0.0522	0.0666	0.1184
400	0.0661	0.0721	0.1124	0.3403

Chart3.4

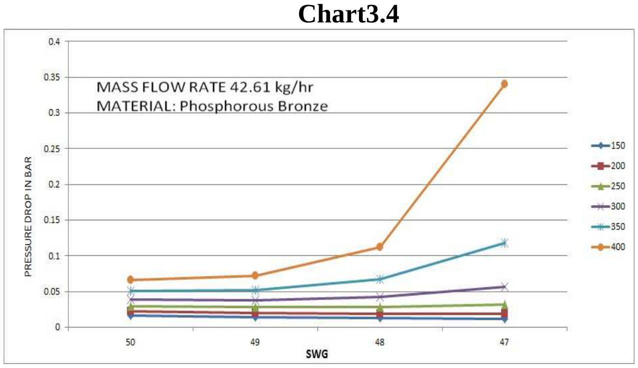
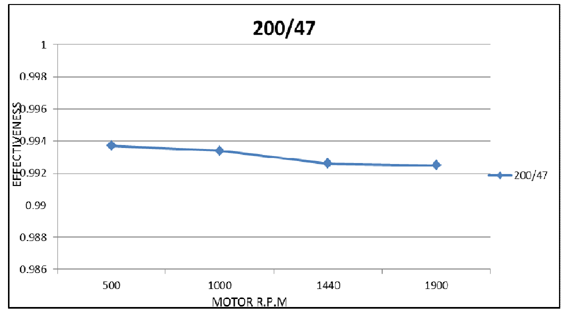


Chart3.5
Effectiveness for different rpm and constsnt mass flow rate and constant swg

MESH SIZE	MOTOR RPM			
	500	1000	1440	1900
200/47	0.9937	0.9934	0.9926	0.9925

Chart 3.5



Conclusions

- As mesh size increases the effectiveness of regenerator increases and the value of pressure drop is also increases
- As SWG decrease the effectiveness of regenerator is increase and value of pressure drop is increase
- For lower mesh size effectiveness is affected by mass flow rate where for higher mesh size effectiveness is not affected by mass flow rate
- As motor r.p.m. decrease the effectiveness of regenerator is increase. For higher mesh size the effectiveness is little affected by motor r.p.m.
- For lower mesh size the losses due to pressure drop are negligible as compare to other losses ,but at higher mesh size losses due to pressure drop increase
- Losses due to ineffectiveness and thermal losses are considerably more for lower mesh size and they decrease with increase in mesh size
- By suitably selected parameter such as mesh size, wire diameter, mass flow rate, motor r.p.m. and inner diameter of regenerator considerable increase in effectiveness can be achieve.

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