

AXIAL CONDENSER OPTIMIZATION

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Abstract: Construction of condenser plays important role for efficient operation of energy systems. In this system a heat pipe is utilized for heat transfer. The condensation part of the heat pipe is situated on top of the heating zone. The condenser is placed in the heating zone and is used for efficient heat transfer from one medium to another. The thermal oil is used as cooling medium in the condenser. This paper analyzes the effect of different operation condition of thermal oil to thermal performance. From the collected results it is obvious that the larger mass flow and higher temperature cause better thermal performance and lower pressure drop.

Keywords: CONDENSER, HEAT PIPE, EFFICIENCY

1. Introduction

The energy captured by the waste heat recovery unit is used for a variety of heat processes such as heating of oil, water, water/glycol for processing oil and gas, and gas regeneration. Waste heat can also be used for heating of living quarters and other heating purposes. There are many different commercial recovery units for the transferring of energy and heat pipe is very good thermal conductor.

Heat pipe has the ability to transfer heat hundred times more than copper and can be used, for example, in energy conservation, such as heat recovery in hot exhaust gas system, and for use in domestic and industrial applications. Solar heating is also another example for the application of heat pipes [1 and 2]. For example, heat pipe solar collector is widely used now days [3 and 4].

Optimization of condenser plays important role in efficient operation of the system. In order to improve the performance of condenser it is required to elaborate thermal analysis for different mass flows and temperatures. In this article different power of condenser in regard to various mass flows and the temperatures on the heat pipe of condenser are investigated.

2. Numerical simulations

Numerical simulation offers objective and quantitative data enabling a far more exact analysis of the task. All the important parameters for simulation (boundary conditions of the simulated model, i.e. initial oil temperature, temperature of the heat pipe, initial mass flow, etc.) has to be supplied in order to solve a task.

The heat power and pressure drop of condenser are calculated in this section. The investigated system consists of the condenser (see Fig. 1). Condenser is placed on the heating zone of heat pipe and is used for efficient heat transfer from one medium to another. The water is used as a working fluid in the heat pipe and in the condenser is used thermal oil as cooling medium, which is pumped through the connection (see Fig. 1).

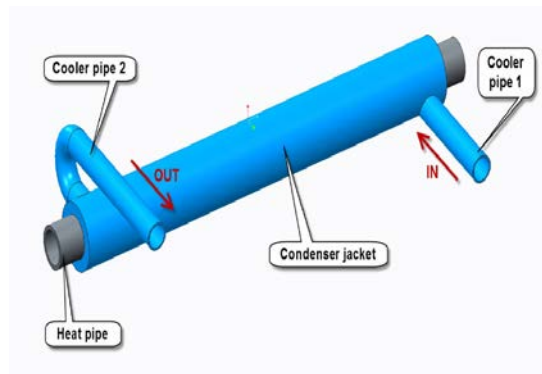


Fig. 1 Heat pipe condenser.

The main objective of this research was to identify the pressure build-up in the condenser made from carbon steel (dP), the outlet temperature of the thermal oil (T_{out}) and the output effect (quantity kW added to the thermal oil). These tasks were done for the different temperature on the heat pipe 100-200-320 °C (the temperature is constant over the whole surface), with flow 10, 20, 30 and 40 g/s of thermal oil (Paratherm NF), with fixed inlet temperature on 80°C.

Physical model

A thermal analysis is done for axial condenser with the connections 180° offset. The condensation part of the heat pipe is attached to the top part of the evaporation area. The model of condenser was created based on the supplied drawings and subsequently was modified to be able to use simulations in finite volume. Numerical model consists of cooling fins, jacket and oil (see Fig.2). Figure 3 shows detailed construction of the condenser.

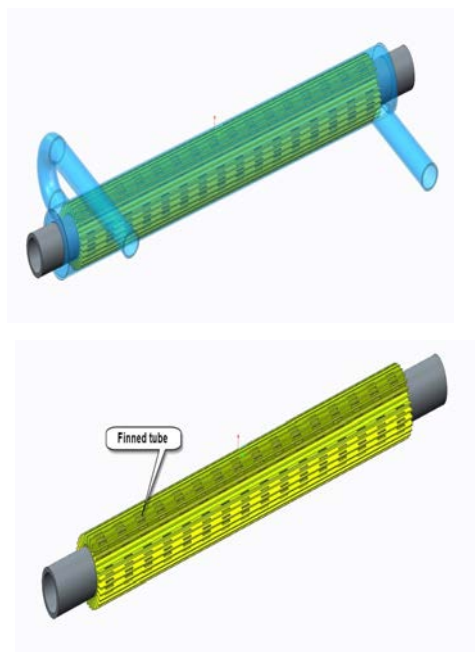


Fig. 2 Condenser jacket (up) and Finned tube (down).



Fig. 3 Axial condenser.

In the table below are shown boundary conditions that were set at the inlet of condenser. Initial conditions: The system was for all cases set to 80°C at the beginning of the simulation.

Table 1: Boundary conditions

Name	Type	Setting of parameters	
		Mass flow (kg/s)	Temperature (°C)
IN	Mass-flow-inlet	0.01-0.02-0.03-0.04	80
OUT	Pressure-outlet	-	-
Surface of the heat pipe	Wall	0	100 - 320

3. Analysis of Results

The results of numerical calculations for the axial condenser made from carbon steel and aluminium are presented in this section. The purpose was to analyse the pressure build-up in the axial condenser and thermal power of the condenser for different temperature on the heat pipe. The calculations performed for condenser made of carbon/stainless steel (316L) are presented in the following section.

Axial condenser made from carbon steel

This thermal analysis was done in order to evaluate the effects of different factors in numerical simulations of the axial condenser. The influence of mass flow and surface temperature are highlighted in the following cases:

Case 1:

- Numerical simulations for mass flow of thermal oil 0.01 kg/s
- Temperature on the heat pipe was set as follow: 100°C - 200°C - 320°C.

Results of case 1:

In the Table 2 are presented results of five different simulations for following parameters:

- Output temperature of the thermal oil (Tout)
- Heat power of the condenser (Q)
- differential pressure over the condenser (dP)

Table 2: Case 1

Parameter	Mass flow		Tin		dP
	0.01	kg/s	80	°C	
Units	T - Heat Pipe		Tout	Q	
	°C		°C	W	Pa
1	100		98	405	51
2	200		184	2516	27
3	320		279	5332	18

Figures 4 and 5 show the results of numerical prediction for case 1-1 (Temperature on the heat pipe is 100°C) and case 1-3 (Temperature on the heat pipe is 320°C) respectively. As shown in Figure 4, the output temperature of the thermal oil is approximately 98°C.

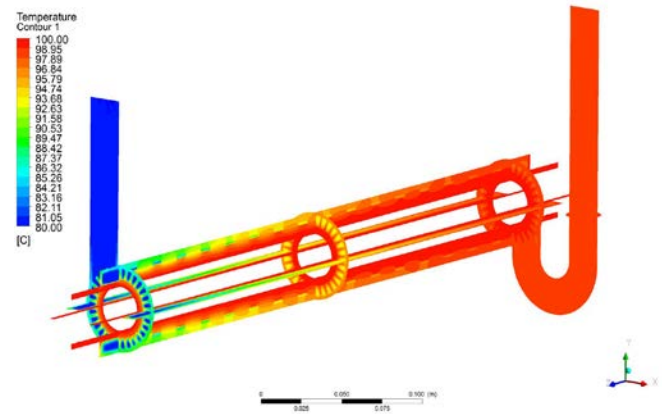


Fig. 4 Temperature field inside the axial condenser (Heat pipe temp.-100°C).

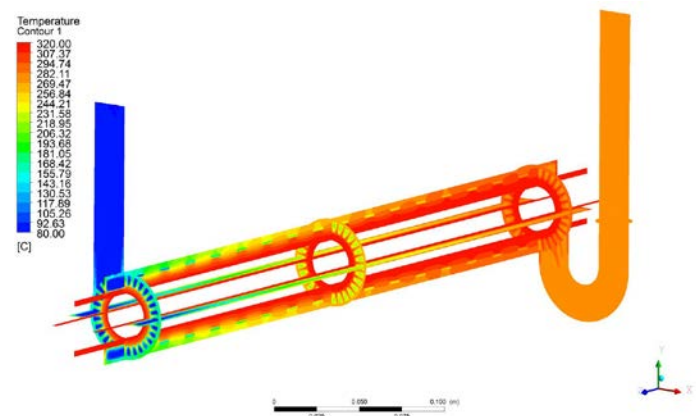


Fig. 5 Temperature field inside the axial condenser (Heat pipe temp.-320°C).

Different surface temperature of heat pipe has significant influence on output temperature of oil, resulting in higher heat power. It can be observed (Figure 5), that the average temperature on the outlet of condenser is 279°C.

Case 2:

- Numerical simulations for mass flow of thermal oil 0.02 kg/s
- Temperature on the heat pipe was set as follow: 100°C - 200°C - 320°C.

Results of case 2:

The Table 3 summarizes the factors and their impact to the results.

Table 3: Case 2

Parameter	Mass flow		Tin		dP
	0.02	kg/s	80	°C	
Units	T - Heat Pipe		Tout	Q	
	°C		°C	W	Pa
1	100		95	646	103
2	200		163	3922	66
3	320		237	8025	40

Case 3:

- Numerical simulations for mass flow of thermal oil 0.03 kg/s

- Temperature on the heat pipe was set as follow: 100°C - 200°C - 320°C.

Results of case 3:

The Table 4 summarizes the factors and their impact to the results.

Table 4: Case 3

Mass flow		Tin			
0.03	kg/s	80	°C		
Parameter	T - Heat Pipe	Tout	Q	dP	
Units	°C	°C	W	Pa	
1	100	92	791	158	
2	200	149	4755	114	
3	320	209	9594	81	

Case 4:

- Numerical simulations for mass flow of thermal oil 0.04 kg/s
 - Temperature on the heat pipe was set as follow: 100°C - 200°C - 320°C.

Results of case 4:

The Table 5 summarizes the factors and their impact to the results.

Table 5: Case 4

Mass flow		Tin			
0.04	kg/s	80	°C		
Parameter	T - Heat Pipe	Tout	Q	dP	
Units	°C	°C	W	Pa	
1	100	90	888	90	
2	200	138	5308	138	
3	320	189	10635	189	

Increasing the surface temperature on the heat pipe leads to the following result: the outlet temperature of the oil increases and consequently the heat power is higher and pressure drop is lower.

Summary - Axial condenser made from carbon steel

Figures 6 and 7 show dependence of the thermal power and the pressure difference of condenser for different flow.

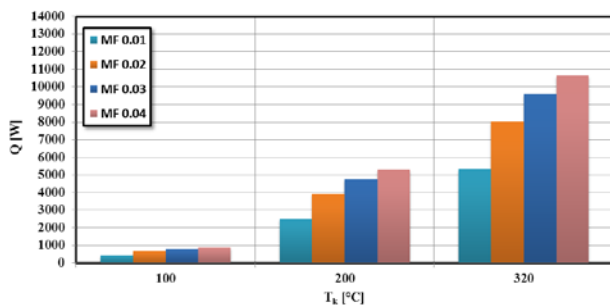


Fig. 6 Thermal power of condenser for different Mass flow (MF).

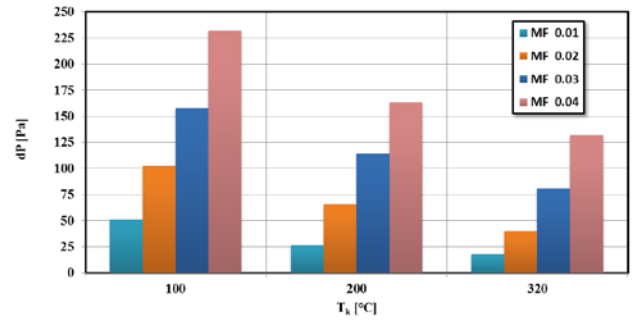


Fig. 7 Differential pressure over the condenser for different Mass flow (MF).

In Figure 6 is shown the impact of mass flow on thermal power. The power is higher by increasing flow to the condenser as well as the temperature on the heat pipe. The pressure drop decreases when surface temperature increases (Fig.7).

4. Conclusions

The aim of this article was to evaluate the effect of different factors to the parameters of the axial condenser. The influence of different mass flows and the temperatures on the heat pipe of condenser were investigated and following conclusions have been reached.

- The highest thermal power was observed in the case 4 (mass flow 0.04 kg/s and temperature on the heat pipe 320°C).

- The lowest differential pressure over the condenser was noticed in the case 1 (mass flow 0.01 kg/s and temperature on the heat pipe 320°C)

The thermal powers of the axial condenser reached a maximum value at the temperature 320 °C. By decreasing the temperature on the heat pipe the power of condenser was reduced. When the flow of thermal oil is rising, the condenser has better heat performance. This effect can be very well observed, when the temperature on the heat pipe is 320 °C and the flow rate is 0.04 kg/s.

In the pressure drop Fig. 7 can be observed that combination of high mass flow and high temperature causes low pressure drop. In regards to both thermal power and differential pressure, higher temperature and mass flow is better.

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