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ENTROPY GENERATION ANALYSIS IN TRANSITION CHANNELS

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Abstract*—Abstract** ***Entropy generation of fully developed turbulent flow in a transition duct is investigation in this study. Air was used to study as working flow on entropy generation, flow passing from a rectangular to square channel in turbulent flow conditions, experimentally. Entropy generation was increased according to the equivalent conical angle of the transition duct. The lateral side angle of the duct was varied to investigate its effect on the entropy generation

Keywords— Channel, Entropy generation, Turbulent flow

I. Introduction

Lately times, entropy generation and its minimization are attempted by implementing the second law analyses on various transport operations. Bejan [1-3] presented the entropy generation in fluid flow and heat transfer inside duct. The author illustrated the entropy generation minimization method for heat and fluid flow system.

Entropy generation is directly related to the term thermodynamic irreversibility and it is a concept used very frequently in all heat transfer operations. There are many sources such as heat transfer operations and viscous effects among the sources of entropy generation. Bejan [4] has conducted intense studies on the different reasons of entropy generation in applied thermal engineering. Entropy generation damages beneficial system work. Therefore, engineering studies, which attempt to understand the entropy generation mechanisms, concentrate on irreversibility of flow and heat transfer, have been gradually increasing.

A study on entropy generation in flow conditions within a cylindrical duct was conducted by Sahin [5]. In this study, it was determined that dimensionless entropy generation decreases with the channel length per unit heat increase, on the other hand, the modified dimensionless entropy generation term increases per unit capacity. Also, it was determined that pumping power required for per unit heat capacity decreases with the duct length. Again, another study on entropy generation in flow conditions between two ducts was also conducted by Haddad et al. [6]. In this study, they investigated thermal, viscous and the total entropy generations of different flow parameters at different thermal limit conditions at the range of two intertwined ducts in enforced laminar flow conditions. In that study, researchers also determined that entropy generation increases with an increase in the Eckert number.

Comprehensive studies regarding flow and heat transfer in channels under the same and different geometric conditions in engineering practices were performed by researchers such as White [7], Shah and London [8].

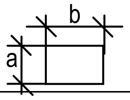
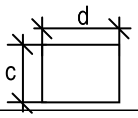
A study to this end was performed by Bejan [9]. In this study conducted, the entropy generation term in circular section ducts was presented with a simple analytical expression under constant heat flux. In a study performed by Sahin [10], the second law analysis of a viscous fluid in a circular duct was conducted in isothermal limit conditions. A study related to flow and heat transfer in non-circular channels was performed by Narusawa [11]. Nag et al. [12] conducted a study involving optimization of the second law in enforced flow conditions throughout a channel under constant heat flux. Investigation of entropy generation throughout a channel in laminar flow conditions was carried out by Sahin [13] in a study as well again under constant heat flux. In that study, it was shown that optimum dimensions of a heat converter or minimum values of fluid inlet temperature can be detected.

In this study, entropy generation, $S_{generation}$, stemming from pressure change in short transition ducts with different conical and lateral side angles was experimentally examined.

II. Experimental Section

Air, which is used as fluid in the system, is sent to the test element through ventilator. Air sent to the system passes through a flow regulator, thereby reducing the rotation effect that ventilator will give to fluid. After a wide section, air enters into an adaptor at sizes 350x350 mm. and then, air, which passes through a channel with 150 mm. length, completes its development.

Table 1. Transition channel and its attributes

Symbol	L_1	L_2	L_3	Input	Output
mm	500	750	1000		
ϕ^0	6	5	4		
α^0	4	3	2		

β^0	8	6	5	
$A_1 = a.b = 0.028\, m^2$				
$A_2 = c.d = 0.056\, m^2$				

In the table above (Table 1), A_1 shows input cross-sectional area of transition channel, A_2 shows output cross-sectional area, ϕ shows equivalent conical angle, α shows the angle that lower and upper sides make with the axis of transition channel and β shows the angle that lateral sides make with the channel axis.At all cross-sections ,the total and static pressures were measured. The pressure measurement operation was conducted at 5 mm. distances from the wall to the axis. Horizontal and vertical-direction local velocity distributions in cross-sections measured were carried out via hot wire anemometer. Air flow rate was determined with a flow-meter connected to the circuit.In this study, transition channel, whose attributes are given in

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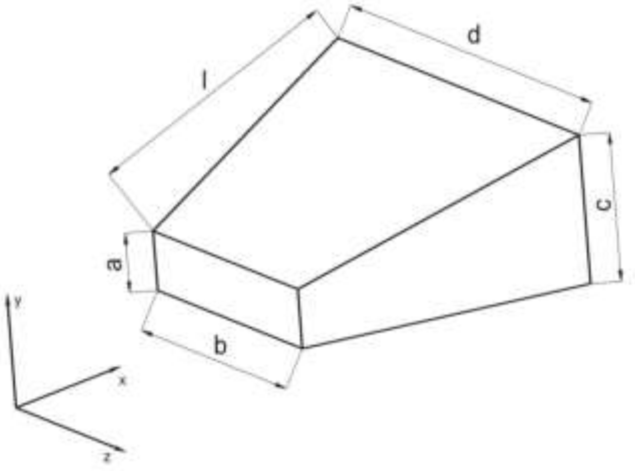

Fig. 1. Transition duct and measurement points

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III. Analysis of the Second Law

There are various performance assessment criteria based on the second law. Detailed information pertaining tothese criteria can be found in issue [12] of Kumar.

In this study, entropy generation, which occurs during the flow of air passing by from a rectangular cross-section channel to a square one, in transition part was investigated experimentally.

Input dimension ratio of the examined rectangular channel are $\delta = a/b$, output dimension ratio is $\sigma = c/d$, and its side angles - the angle that lateral and upper sides make with the duct axis- are α and β , respectively. Conical angle was defined as ϕ .

One of the known phenomena in engineering practices is that there is pressure loss in channels due to friction. For instance, let's address the channel in Figure 1, which is covered, as a short transition duct in steady and adiabatic flow conditions. Pressure in input conditions shall be P_{in} and temperature shall be T_{in} . We know from practical results that pressure in the output of channel is lower than pressure in the input. $P_{out} = P_{in} - \Delta P$

Entropy generation equation is derived for transition duct. All thermal properties are assumed to be uniform along the transition duct. The entropy generation equation can be started by considering the fluid subjected to constant heat flux, as shown in fig.1.

The entropy generations is sometimes given in a dimensionless entropy form as [5]:

$$\psi = \frac{\dot{S}_{gen}}{\left[\dot{Q}/(T_0 - T_i)\right]} \qquad 1$$

Here, as v and T are positive, the entropy generation term is positive as well because, there is a drop in pressure between input and output pressures.

IV. Results and Discussion

It was determined from test results that the entropy generation term changes depending on the Reynolds number, the side angle, conical angle of transition channel and the duct length. It was observed that the entropy generation term increases with the decrease of lateral side angles of the channel.(Figure and Figure 4) As seen in Figure 2, vertical entropy generation takes on higher values than horizontal entropy generation. Although the entropy generation term takes on the value S_{gen} = 11 in horizontal direction in the same point for Re = 6.10^5 andL = 500, this value approximately becomes S_{gen} = 12 in vertical direction. Again, it is seen that the entropy generation term also increases with the increase of duct length. Here, the total pressure drop, ΔP, also increases with the increase of duct length. It is seen that there is a decrease in entropy generation. Its reason is that entropy generation, which occurs due to pressure loss, ΔP, also reduces with the increase of lateral and upper side angles. Also, changes take place in values of entropy that occurs on local points increase with the increase of duct length.

For instance, while the vertical entropy generation term at the point L = 500 and x / L = 0.75 takes on the value 1.2. Approximately for the same Reynolds number, this takes on the value 0.8 for L = 750 provided that other variables are kept constant.

It is seen in figure 5 that local entropy increase is higher in the channel input, x / L = 0.0, and the entropy generation term drops due to flow getting better as well while input cross-sectional impacts, x/L=0, x/L=1, go towards the ends of the channel. Pressure losses occur depending on geometric attributes of the channel in transition channels used and this situation leads to entropy increases. As seen in Figure 6, pressure drops become more evident in short transition channels and also, there is an apparent increase in friction coefficient. But, taking lateral and upper side angles larger becomes effective on this pressure change.

Selecting low Reynolds numbers can also be considered an advantage thermodynamically. Because, in this case entropy generation remains lower in comparison with higher Reynolds numbers.

Friction coefficient, f, was calculated according to the equation (16). As a result of this equation, comparisons of friction coefficients with the Re number and the covered channel configurations are presented in Figure 6. As also seen in the figure, it was determined that lateral channel angles are effective in pressure drop and also, pressure coefficient increases with shortened duct length and increasing values of the Re number. The aspect ratio of the duct was varied from 0.4 to 3.2 so as to study its effect on the entropy generation. The parameter lateral side angle and conical angle were fixed. It can see in fig. 7 that dimensionless entropy generation rapidly decreases when aspect ratio increases.

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V. Figures and Tables

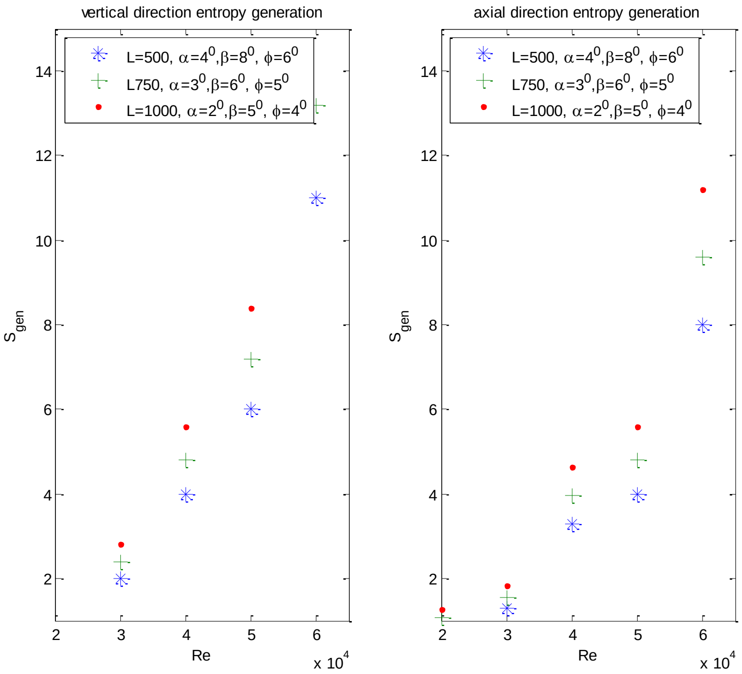

Figure 2. Entropy generation vertical and horizontal versus with the Re number

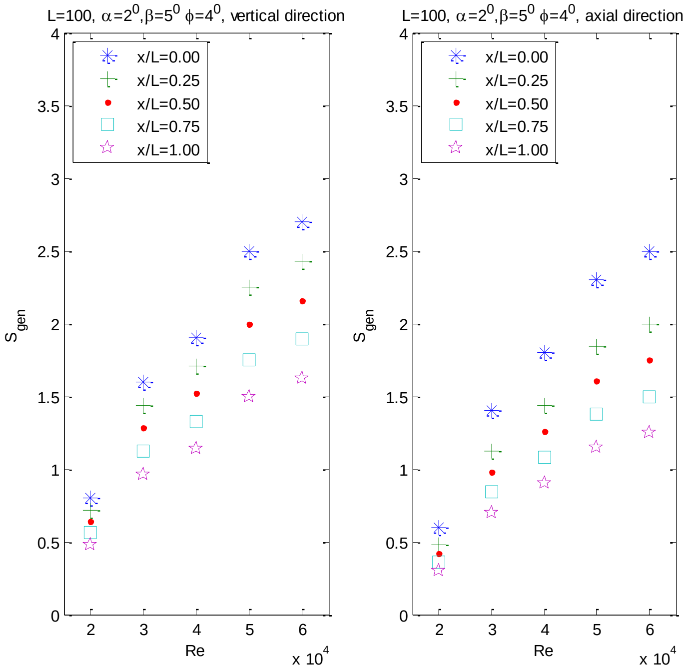

Figure 3. Local dimensionless entropy generation with the Re number

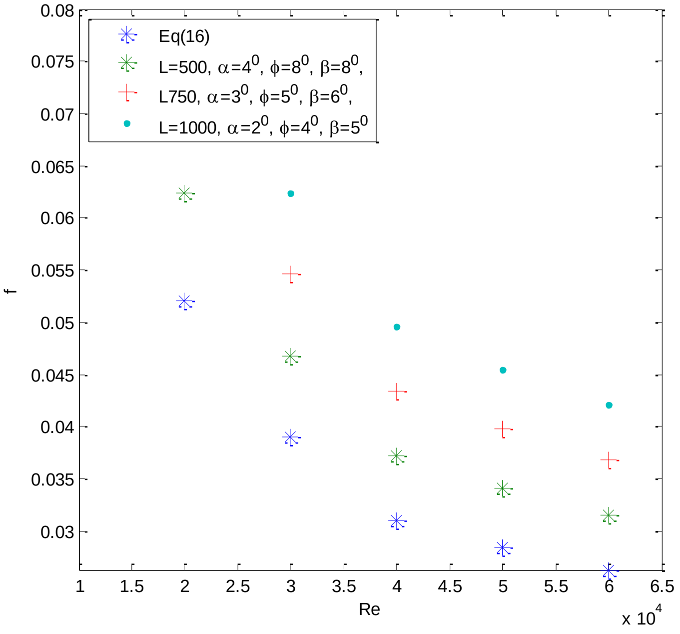

Figure 4. Horizontal and vertical alteration of friction coefficient for the transition channels L_1, L_2, L_3

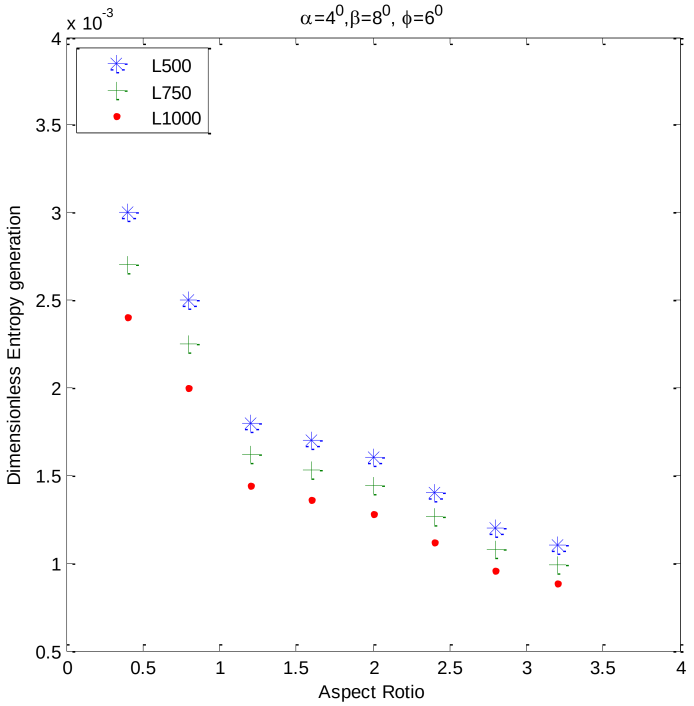

Figure 5. Dimensionless Entropy generation versus duct aspect ratio

VI. References

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