Recurrence Analysis of Dynamics of a Square Natural Circulation Loop

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As a passive heat removal system, natural circulation loop (NCL) can be used for its capability of transferring heat without the help of any active device. In NCL, the loop fluid absorbs heat from a heat source at a lower elevation and ejects it to a heat sink at higher elevation. For this passive nature of heat transfer NCL is being used in various practical applications like nuclear reactor core cooling, solar water heaters etc. According to the applications NCL is associated with the safety of the systems. Due to this reason it is very important to characterize the flow dynamics properly so that we can design proper control mechanism to control the flow dynamics. As NCL has low hydrodynamic head its makes NCL inherently less stable and can cause the instabilities in the flow dynamics. These instabilities may cause the failure of the system.

Due to this flow dynamic instability associated with the NCL and characterization of this dynamics is the major research interest for past few years [1]-[4]. In the present study, we are trying to characterize the flow patterns which were found from the numerical study done by the help of MATLAB based Simulink model [5]. With the increase in heater power fluid flow dynamics in NCL have been changed. To characterize the flow dynamics recurrence plot [6] along with recurrence quantification as the nonlinear dynamic analysis tool and complex network approach have been used. Proper quantification of the flow dynamics is highly essential to distinguish between possibly chaotic systems, which are deterministic in nature from those dominated by noise, which is stochastic in nature. From the numerically obtained time series data for a small scale square NCL set-up, we found that for heater power less than 625 watt flow pattern shows stable steady state nature and with the increase in heater power flow pattern first changes to oscillatory regime and then with increase in heater power further flow pattern changes to flow reversal regime.

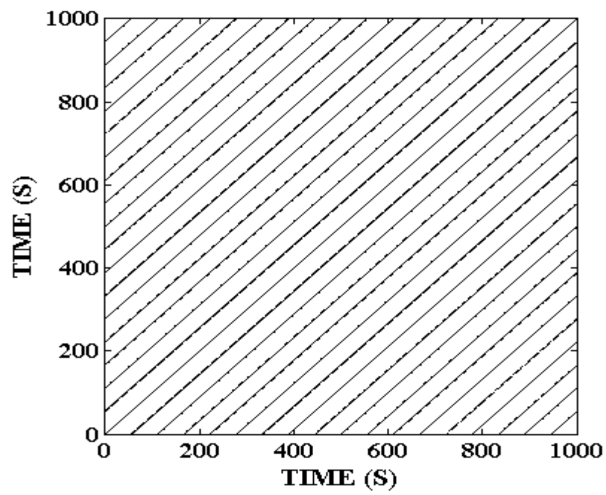

Figure 1:- Recurrence Plot at 705 W.

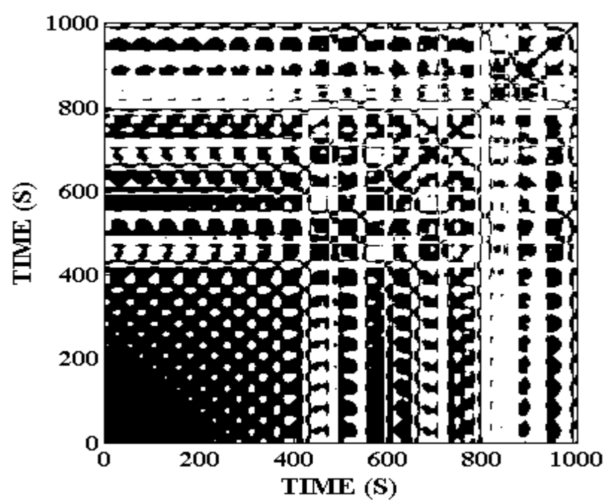

Figure 2:- Recurrence Plot at 770 W.

Fig. 1 shows the Recurrence plot for the 700 watt heater power. From the figure we can see that it shows diagonal line structure with equal spacing which signifies periodic nature. We find similar results for all the heater powers in the oscillatory regime. It confirms that the oscillation we get at the oscillatory region is purely periodic. Fig. 2 shows the Recurrence plot for the 770 watt heater power. From the figure we can see that it shows box like structure which signifies the chaotic nature. We get similar results for entire flow reversal region. It confirms that the fluid flow dynamics at the flow reversal region is chaotic.

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