CHAPTER VII

APPLICATION OF PRESENT MODEL

In the previous chapter, the present generic model has been already validated against a full-scale industrial pneumatic conveying drying of cassava flour. In this chapter, the model will be applied to the search for a more suitable operating condition for the present production (drying) capacity and for a suitable operating condition for a 20 % increase in drying capacity.

Generally, there are many variables that affect the drying capacity and product condition. However, in practice, it is convenient to manipulate the inlet air temperature and the mass flow rate of air to improve the dryer's performance. For example, it is sometimes possible to reduce the operating cost while maintaining the product quality and drying capacity. Here the inlet air temperature and the mass flow rate of air are varied to find a suitable operating condition that reduces the operating cost. The major operation costs, which are related to the inlet air temperature and the air flow rate, are the heat necessary to raise the ambient air temperature and the electricity used to operate the air blower. Furthermore, the conditions predicted by the present model are also compared with those obtained from the previous model (W. Tanthapanichakoon and C. Srivotanai, 1996).

7.1 Optimization of operating condition for the existing drying capacity

The sixth set of operation data in Table 5.1 is used as the reference case in this application. The operating conditions and pertinent parameters of this case are used in the comparative simulations except the inlet air temperature and the mass flow rate of air, which are to be varied to find their effects. Since there are two variables to vary, the approach to find the suitable operating condition is to vary one variable at a time while the other one is fixed. In this application, the inlet air velocity is varied between 20 and 35 m/s while the inlet air temperature is fixed at 463, 478 and 493 K. Since the air temperature is known to have much less effect on the equilibrium moisture content than the relative humidity, the intrinsic equilibrium moisture content is assumed here to remain constant throughout these simulations. As mentioned above, the values of all the other model parameters used in this application are the set of values that have been proved suitable to the pneumatic conveying drying of cassava flour, as summarized in Table 6.3 along with the dryer configuration and flour properties.

Figures 7.1 to 7.3 reveal the relations of the predicted outlet moisture content and temperature of flour versus air velocity at a constant inlet air temperature for the present and previous models. The desired product moisture content is set to be 15 % dry basis and shown as the horizontal dash line in the figures. The outlet flour temperature predicted by the present model is also shown to indicate possible adverse effect of high product temperature on the final properties of flour. As expected, a rapid increase in the flour temperature occurs after the model switches over to the internal moisture diffusion controlled model.

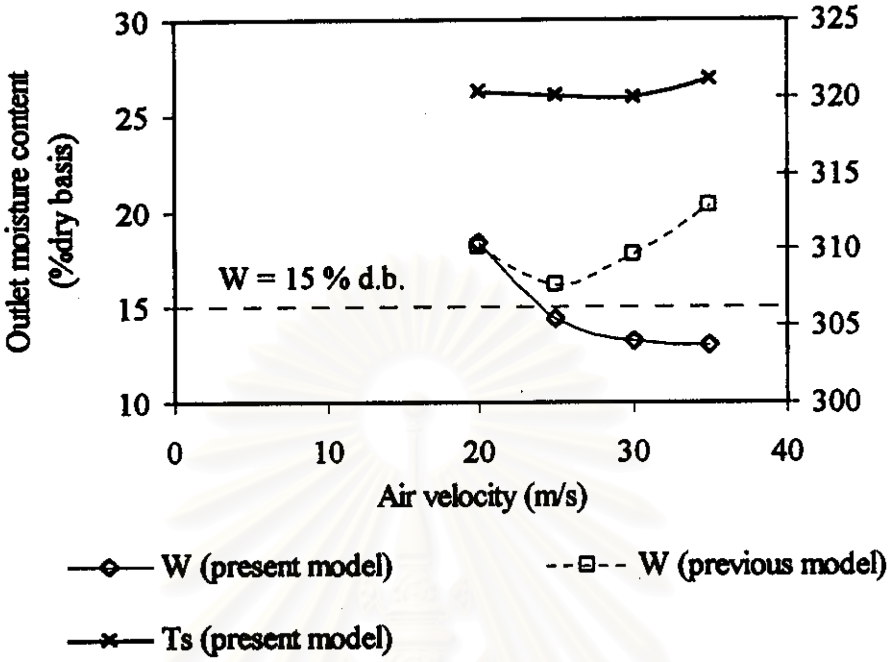

Figure 7.1 Relations of the outlet moisture content and temperature of flour versus the inlet air velocity ($T_{a,0}$ = 463 K and G_s = 5759 kg/hr)

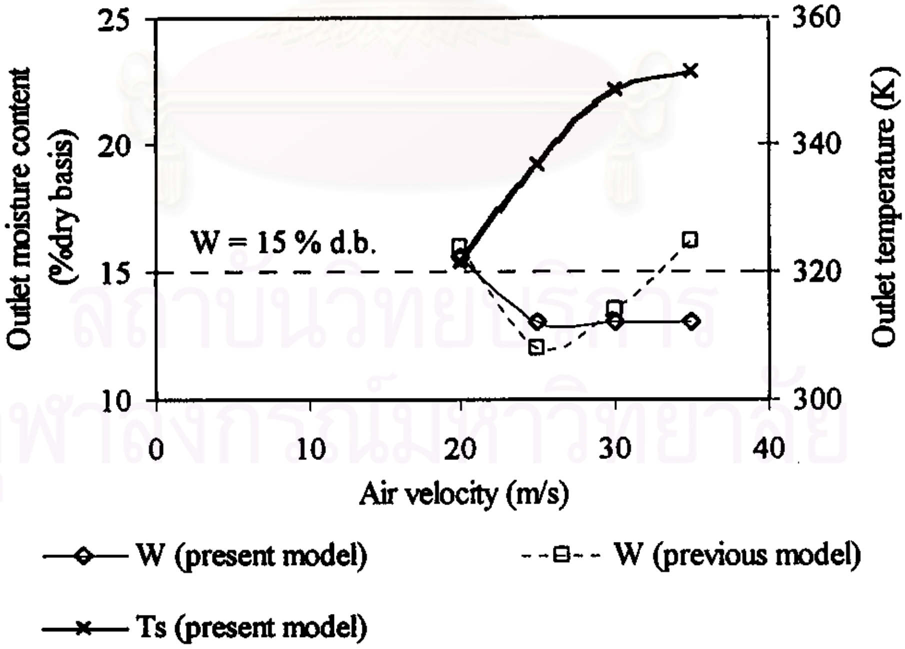

Figure 7.2 Relations of the outlet moisture content and temperature of flour versus the inlet air velocity ($T_{a,0}$ = 478 K and G_s = 5759 kg/hr)

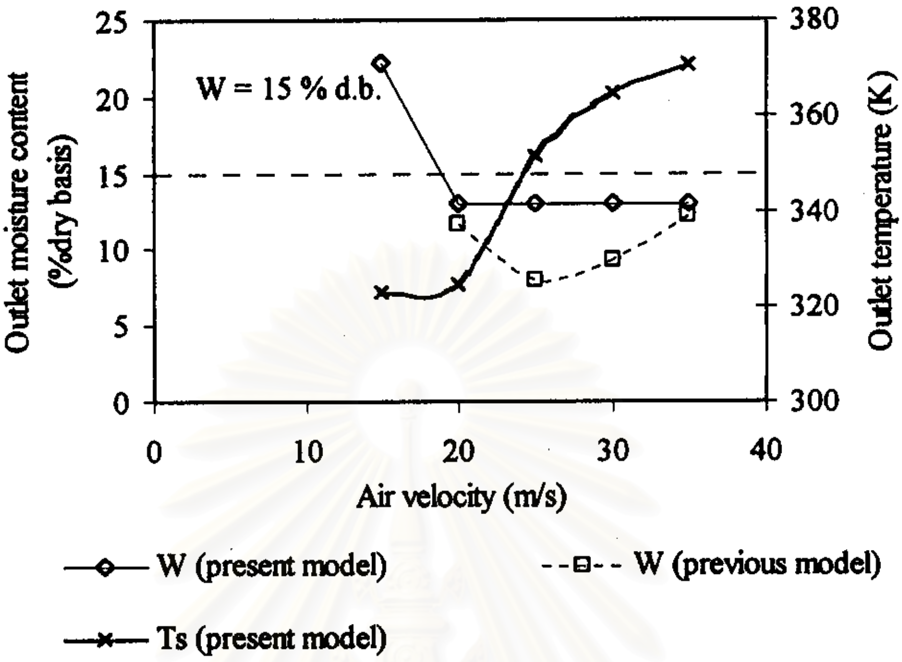

Figure 7.3 Relations of the outlet moisture content and temperature of flour versus the inlet air velocity ($T_{a,0}$ = 493 K and G_s = 5759 kg/hr)

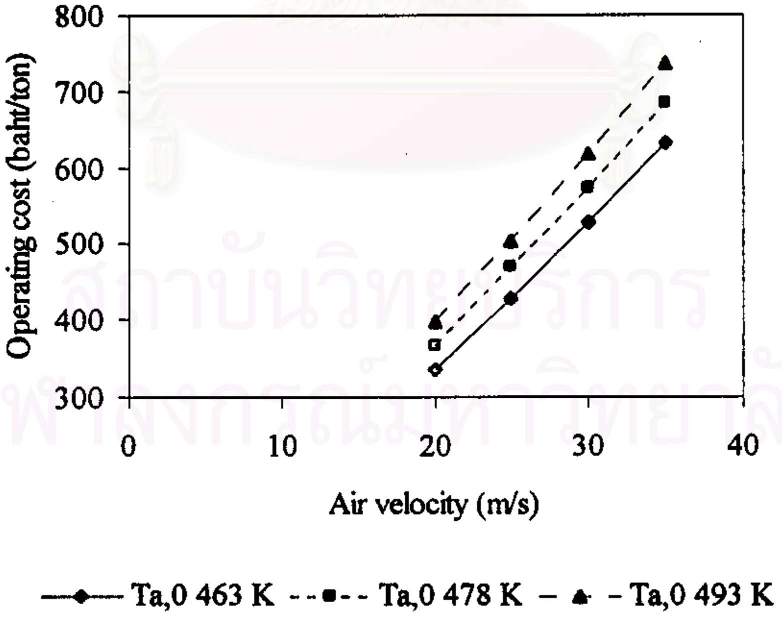

Figure 7.4 Relation of operating cost versus inlet air velocity (open symbols mean 15 % dry basis can not be achieved)

It can be seen from the figures that the outlet moisture content predicted by the present model tends to become higher than that obtained from the previous model as the inlet air temperature increases. At a low inlet air temperature, the outlet moisture content is not close to the equilibrium moisture content, 13 % dry basis, of the present model, so the outlet moisture content predicted by the present model is lower than the previous model. On the other hand, when the inlet air temperature is high, the outlet moisture content approaches the 13 % equilibrium moisture content, and model switching occurs in the simulation of the present model, so the drying rate falls and the outlet moisture content predicted by the present model becomes higher than the previous one.

From the figures, at constant inlet air temperature the outlet moisture content predicted by the present model generally decreases as the inlet air velocity increases but quickly approaches an asymptote, especially when the inlet air temperature is high. According to the present model, the minimum allowable inlet air velocities that satisfies the desired outlet moisture content of 15 % dry basis at each inlet air temperature is as follows:

1. For the inlet air temperature 463 K, the minimum inlet air velocity is 25 m/s.
2. For the inlet air temperature 478 K, the minimum inlet air velocity is about 22 m/s.
3. For the inlet air temperature 493 K, the minimum inlet air velocity is slightly below 20 m/s.

In practice, the minimum allowable air velocity should be adopted to achieve the lowest operating cost. An increase from 363 K to 393 K in the inlet air temperature allows a decrease of 5 m/s in the inlet air velocity. Therefore an evaluation of the heating cost and electricity cost in the industrial pneumatic conveying dryer is required. The expenditure equations for calculating the heating cost and electricity cost are as follows (W. Tanthapanichakoon and C. Srivotanai, 1996):

$$\text{Heating cost} = \frac{G_a * C_{p,a} * (T_{in} - T_{amb})}{\eta * \text{Heating value of fuel}} * \text{fuel cost rate} \tag{7.1}$$

$$\text{Elect. cost} = \frac{\text{Air vol. flow rate} * \text{pressure drop in dryer} * 0.0098}{\text{Efficiency of fan}} * \text{Elect. cost rate} \tag{7.2}$$

C-grade fuel oil is the heating fuel. The heating value and cost of fuel oil are 9800 kcal/lit and 3.5 baht/lit, respectively. The overall efficiency of the air heater and combustor (η) equals 55 % while the efficiency of the blower equals 80 %. The electricity cost rate is 1.07 baht/kW-hr. The direct operating cost is the summation of the heating cost and electricity cost, as shown in Figure 7.4.

The figure reveals that increasing the inlet air temperature by 30 K causes less operating cost than increasing the inlet air velocity by 5 m/s. Thus, a high inlet air temperature of 493 K can lead to a sizable saving in operating cost. Hence the optimum inlet air temperature and velocity within the studied ranges are 493 K and 20 m/s, respectively, for the present model prediction which also agree with conditions indicated by the previous model. Compared to the actual condition of 473 K and 34.9 m/s, the inlet air temperature should be increased to 493 K and the inlet air velocity should be decreased to 20 m/s. These suggested change would result in a decrease of 45 % in the mass flow rate of air and it can reduce operating cost by 250 baht/ton.

7.2 Optimization of the increased drying capacity

The present model is next applied to the case of increasing in the drying capacity. The sixth set of operation data is used once again as reference case but the objective is to increase drying capacity by 20 %, which is 6910 kg dry flour/hr. The range of variation of the inlet air velocity and temperature studied are the same as in section 6.1. So are the dryer configuration, flour properties and model parameters used in this application.

Figures 7.5 to 7.7 reveal that the minimum allowable inlet air velocity at a constant inlet temperature is as follows:

1. For the inlet air temperature 463 K, the minimum inlet air velocity is much higher than 35 m/s or does not exist.
2. For the inlet air temperature 478 K, the minimum inlet air velocity is 30 m/s.
3. For the inlet air temperature 493 K, the minimum inlet air velocity is 25 m/s.

Compared to the former drying capacity, the minimum allowable inlet air velocity at the inlet air temperature 478 K and 493 K should each be increased about 5 m/s. Thus, the mass flow rate of air is increased by 20-25 %.

In conclusion, the economically optimum inlet air temperature and velocity for a 20 % increase in the drying capacity are 493 K and 25 m/s, respectively.

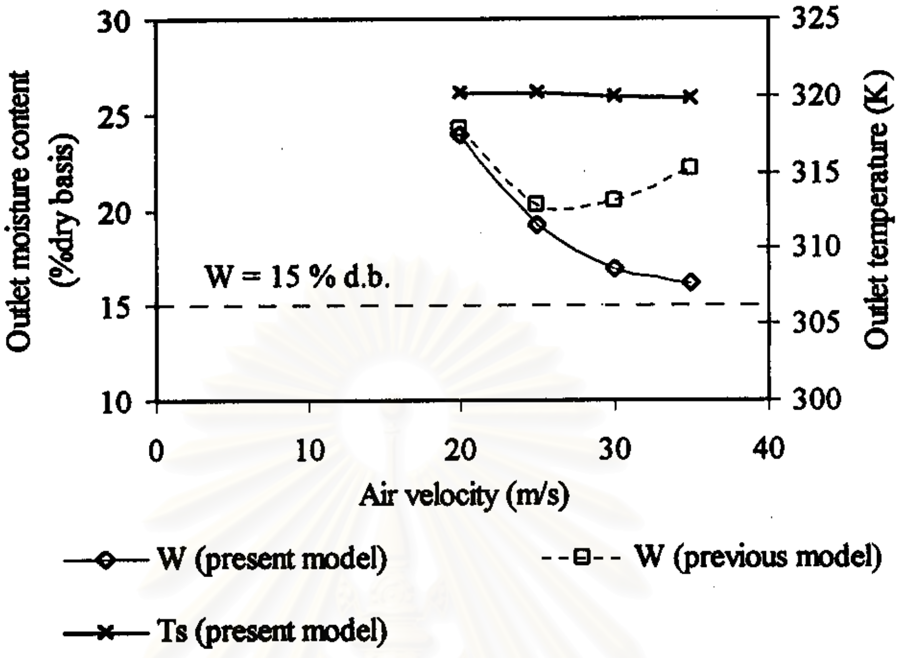

Figure 7.5 Relations of the outlet moisture content and temperature of flour versus the inlet air velocity ($T_{a,0}$ = 463 K and G_s = 6910 kg/hr)

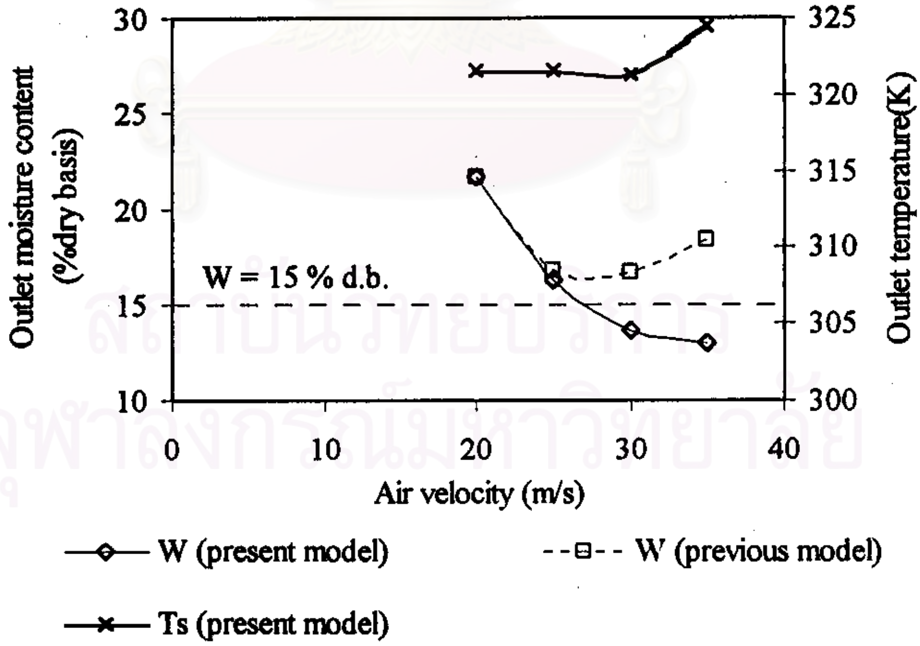

Figure 7.6 Relations of the outlet moisture content and temperature of flour versus the inlet air velocity ($T_{a,0}$ = 478 K and G_s = 6910 kg/hr)

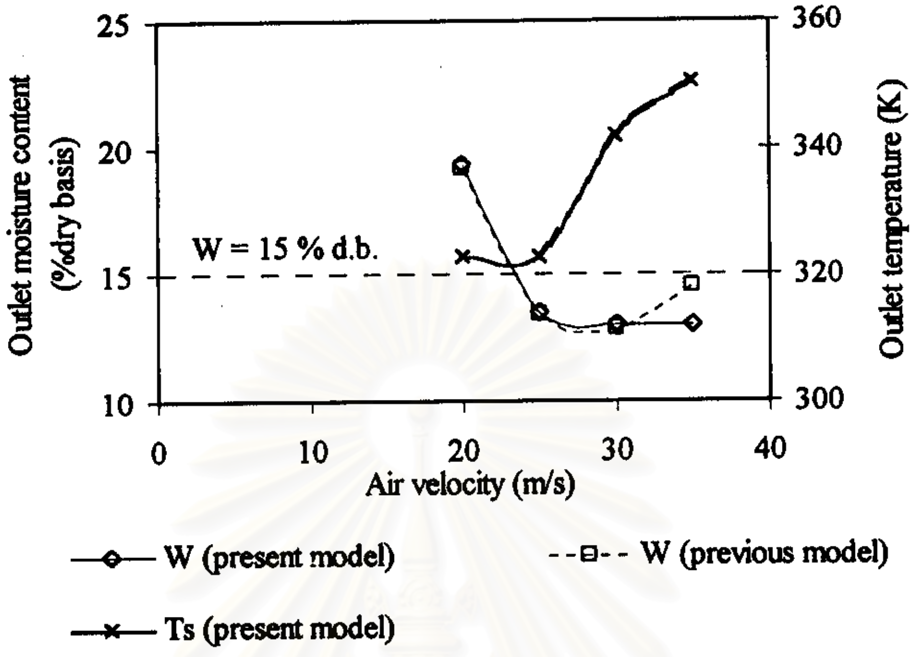

Figure 7.7 Relations of the outlet moisture content and temperature of flour versus the inlet air velocity ($T_{a,0}$ = 493 K and G_s = 6910 kg/hr)