Supplementary material for *Solving many-objective reentrant hybrid flowshop scheduling problem considering uncertainty factors in Thin-film Transistor Liquid Crystal Display*

The model presented comprises of 8 jobs, with 13 machining processes each, and 5 production stages. The production stages correspond to the following sequence of processes: PVD→PH→WET→CVD→CVD→PVD→PH→WET→DRY→WET→DRY→WET→CVD. There are 3 machines in PVD, 3 in CVD, and 3 in DRY, as well as 4 machines in both PH and WET. The processing time and the delivery time of 8 jobs are shown in Table 1. The various states of the machine are presented in Table 2, with their corresponding switching time and power. Triangular fuzzy numbers of transportation time are represented in Table 3. Failure rates for each machine state are presented in Table 4. Furthermore, Table 5 details the respective energy consumption of each machine state, including processing and idle energy consumption. The energy consumption of transportation is determined to be 2.4 kW, while delay and inventory costs are valued at 2 and 4, respectively. Finally, the carbon emission factor for electrical energy is recorded as 0.54 kgCO2/kWh.

**Table 1** The processing time and the delivery time of each job（min）

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Processing path | Delivery time | PVD | PH | WET | CVD | CVD | PVD | PH | WET | DRY | WET | DRY | WET | CVD |
| job1 | 540 | 21 | 25 | 22 | 20 | 22 | 21 | 27 | 20 | 18 | 22 | 20 | 20 | 19 |
| job2 | 475 | 22 | 25 | 20 | 22 | 33 | 22 | 23 | 18 | 20 | 25 | 22 | 21 | 23 |
| job3 | 590 | 30 | 35 | 23 | 25 | 23 | 30 | 26 | 22 | 16 | 26 | 12 | 28 | 22 |
| job4 | 665 | 41 | 38 | 25 | 26 | 25 | 45 | 40 | 25 | 24 | 22 | 20 | 25 | 25 |
| job5 | 580 | 32 | 30 | 22 | 23 | 22 | 30 | 32 | 26 | 28 | 25 | 25 | 26 | 26 |
| job6 | 730 | 40 | 38 | 20 | 35 | 32 | 38 | 35 | 25 | 20 | 21 | 26 | 25 | 32 |
| job7 | 510 | 45 | 36 | 30 | 45 | 40 | 42 | 38 | 32 | 24 | 28 | 16 | 25 | 35 |
| job8 | 610 | 38 | 28 | 26 | 32 | 28 | 26 | 26 | 25 | 20 | 26 | 22 | 29 | 30 |

**Table 2** Machine state switching time（min）/ power（102/kW）

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Stage  Machine state | PVD | |  | PH | |  | WET | | | |  | CVD | | |  | DRY | |  |
| 1 | 2 |  | 1 | 2 |  | 1 | 2 | 3 | 4 |  | 1 | 2 | 3 |  | 1 | 2 |  |
| 1 | 0/0 | 12/0.9 |  | 0/0 | 8/1.3 |  | 0/0 | 10/1 | 12/1.5 | 12/1.3 |  | 0/0 | 10 | 20/2.2 |  | 0/0 | 50/4.5 |  |
| 2 | 12/0.9 | 0/0 |  | 8/1.3 | 0 |  | 7/0.9 | 0/0 | 7/0.8 | 22/2.5 |  | 10/2 | 0/0 | 20/2.2 |  | 30/2.8 | 0/0 |  |
| 3 |  |  |  |  |  |  | 10/1.2 | 12/1.4 | 0/0 | 10/1.1 |  | 100/8.5 | 100/8.5 | 0/0 |  |  |  |  |
| 4 |  |  |  |  |  |  | 12/1.5 | 14/1.7 | 7/1 | 0/0 |  |  |  |  |  |  |  |  |

**Table 3** Triangular fuzzy numbers of transportation time()

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Stage | | PVD | | |  | PH | | | |  | WET | | | |  | CVD | | |  | DRY | | |  |
| Machine  Number | | 1 | 2 | 3 |  | 4 | 5 | 6 | 7 |  | 8 | 9 | 10 | 11 |  | 12 | 13 | 14 |  | 15 | 16 | 17 |  |
| PVD | 1 | 0 | 3 | 5 |  | 17 | 19 | 21 | 23 |  | 17 | 19 | 21 | 23 |  | 9 | 12 | 12 |  | 28 | 30 | 32 |  |
| 2 | 3 | 0 | 3 |  | 15 | 17 | 19 | 21 |  | 15 | 17 | 19 | 21 |  | 8 | 10 | 10 |  | 26 | 28 | 30 |  |
| 3 | 5 | 3 | 0 |  | 13 | 15 | 17 | 19 |  | 13 | 15 | 17 | 19 |  | 6 | 8 | 8 |  | 24 | 26 | 28 |  |
| PH | 4 | 17 | 15 | 13 |  | 0 | 3 | 5 | 7 |  | 3 | 5 | 7 | 9 |  | 8 | 6 | 15 |  | 14 | 16 | 16 |  |
| 5 | 19 | 17 | 15 |  | 3 | 0 | 3 | 5 |  | 5 | 3 | 5 | 7 |  | 12 | 10 | 19 |  | 12 | 14 | 14 |  |
| 6 | 21 | 19 | 17 |  | 5 | 3 | 0 | 3 |  | 7 | 5 | 3 | 5 |  | 14 | 12 | 21 |  | 17 | 19 | 19 |  |
| 7 | 23 | 21 | 19 |  | 7 | 5 | 3 | 0 |  | 9 | 7 | 5 | 3 |  | 16 | 14 | 23 |  | 8 | 10 | 10 |  |
| WET | 8 | 17 | 15 | 13 |  | 3 | 5 | 6 | 9 |  | 0 | 3 | 5 | 7 |  | 8 | 6 | 15 |  | 12 | 14 | 14 |  |
| 9 | 19 | 17 | 15 |  | 5 | 3 | 5 | 7 |  | 3 | 0 | 3 | 5 |  | 10 | 8 | 17 |  | 10 | 12 | 12 |  |
| 10 | 21 | 19 | 17 |  | 7 | 5 | 3 | 5 |  | 5 | 3 | 0 | 3 |  | 12 | 10 | 19 |  | 8 | 10 | 12 |  |
| 11 | 21 | 21 | 19 |  | 9 | 7 | 5 | 3 |  | 7 | 5 | 3 | 0 |  | 14 | 12 | 21 |  | 6 | 8 | 8 |  |
| CVD | 12 | 10 | 8 | 6 |  | 8 | 12 | 14 | 16 |  | 8 | 10 | 12 | 14 |  | 0 | 3 | 8 |  | 28 | 30 | 30 |  |
| 13 | 12 | 10 | 8 |  | 6 | 10 | 12 | 14 |  | 6 | 8 | 10 | 12 |  | 3 | 0 | 10 |  | 19 | 21 | 21 |  |
| 14 | 12 | 10 | 8 |  | 15 | 18 | 21 | 23 |  | 15 | 17 | 19 | 21 |  | 8 | 10 | 0 |  | 26 | 28 | 28 |  |
| DRY | 15 | 28 | 26 | 24 |  | 14 | 12 | 17 | 8 |  | 12 | 10 | 8 | 6 |  | 28 | 19 | 26 |  | 0 | 3 | 8 |  |
| 16 | 30 | 28 | 26 |  | 16 | 14 | 19 | 10 |  | 14 | 12 | 10 | 8 |  | 30 | 21 | 28 |  | 3 | 0 | 10 |  |
| 17 | 32 | 30 | 28 |  | 16 | 14 | 19 | 10 |  | 12 | 12 | 12 | 8 |  | 30 | 21 | 28 |  | 8 | 10 | 0 |  |

Note：，

**Table 4** Failure rate of machines in different states (10-2)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Machine state | | PVD | | |  | PH | | | |  | WET | | | |  | CVD | | |  | DRY | | |  |
| 1 | 2 | 3 |  | 4 | 5 | 6 | 7 |  | 8 | 9 | 10 | 11 |  | 12 | 13 | 14 |  | 15 | 16 | 17 |  |
| 1 |  | 1 | 0.5 | 0.8 |  | 1.2 | 2.1 | 1.9 | 1.5 |  | 1.3 | 0.8 | 0.5 | 1.4 |  | 2.5 | 3 | 1.4 |  | 3.4 | 1.6 | 2.3 |  |
| 2 |  | 1.5 | 1 | 1.2 |  | 2 | 1 | 1.1 | 1.6 |  | 0.7 | 0.4 | 1 | 1.2 |  | 2.2 | 2.4 | 1.1 |  | 2.6 | 2.9 | 1.8 |  |
| 3 |  |  |  |  |  |  |  |  |  |  | 0.7 | 0.2 | 1.1 | 0.9 |  | 1.3 | 0.8 | 0.5 |  |  |  |  |  |
| 4 |  |  |  |  |  |  |  |  |  |  | 0.8 | 0.5 | 0.9 | 0.7 |  |  |  |  |  |  |  |  |  |

**Table 5** The idle/processing power of the machine in different states (102/kW)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Machine state | PVD | | |  | PH | | | |  | WET | | | |  | CVD | | |  | DRY | | |  |
| 1 | 2 | 3 |  | 4 | 5 | 6 | 7 |  | 8 | 9 | 10 | 11 |  | 12 | 13 | 14 |  | 15 | 16 | 17 |  |
| 1 | 1.2/3 | 1/3.2 | 1.4/2.5 |  | 1.2/2.2 | 1.1/2.3 | 0.9/2 | 1.5/1.9 |  | 0.7/1.2 | 0.8/1.1 | 0.8/1.3 | 0.9/1.5 |  | 2/3 | 1.9/3.6 | 2/3.2 |  | 1.6/2.6 | 1.8/2.8 | 1.5/2.4 |  |
| 2 | 0.9/2.5 | 1.3/3.8 | 1.6/1.8 |  | 1.5/1.8 | 1.8/2.5 | 1.3/2.4 | 1.7/2.1 |  | 0.9/1.2 | 0.6/1.5 | 0.7/1.3 | 1/1.2 |  | 2.1/3.1 | 1.8/3.3 | 1.6/3.6 |  | 2/3.2 | 1.8/2.9 | 2.2/3.5 |  |
| 3 |  |  |  |  |  |  |  |  |  | 1.1/1.5 | 0.9/1.2 | 0.8/1.4 | 0.9/1.6 |  | 2/4.1 | 2.2/4.3 | 2.1/4.2 |  |  |  |  |  |
| 4 |  |  |  |  |  |  |  |  |  | 0.8/1.2 | 0.9/1 | 1/1.6 | 0.7/1.2 |  |  |  |  |  |  |  |  |  |