Supplementary File for Paper: Scheduling and Logistics Optimization for Batch Manufacturing Processes with Temperature Constraints and Alternative Thermal Devices

Appendix A
Comparison experiments under the same running time

In this section, we report and analyze the solutions with the same running time as a termination condition, which is $0.1 * I$ minutes. Note that the results of MIP reported in this section are obtained under the termination condition of one hour rather than the same as the termination condition of the test algorithms.

The ranking comparison of the tested methods is shown in Table A.1, which reveals an overview of their performance. Table A.1 indicates that the proposed SA-DC can achieve the highest $\bar{R}$ for all instances. Furthermore, it gets $\bar{R} = 1.0$ for 18 out of 25 instances. Even the worst $\bar{R}$ obtained by it is 1.8. However, ANSA, SAILS, and MNSA can achieve the highest $\bar{R}$ for 5, 7, and 0 instances only. Thus, we conclude that SA-DC is significantly superior to its competitors under the same running time.

The comparisons of metrics 2) - 5) are illustrated in Table A.2, which displays the detailed optimization effects of the tested methods. The following issues can be observed from Table A.2:

a) For those instances that MIP can optimally solve, the proposed SA-DC can also obtain the optimal solutions. For those instances that MIP cannot solve or cannot optimally solve, SA-DC obtains the same solutions as MIP for three instances, i.e., instances 20-1, 20-3, and 30-5, and betters MIP for all other instances. Hence, SA-DC is effective for solving large-scale instances;

b) SA-DC obtains the best $\bar{f}_1$ and $\bar{f}_2$ among the compared methods for all 25 instances. In contrast, ANSA, SAILS, and MNSA can obtain the best ones for only 5, 7, and 0 instances (highlighted in bold), respectively. Besides, SA-DC can find the minimum f_1 value in every experiment, i.e., $C_{f_1^*} = 10$, while the competitors can do this in the experiments of a few instances only. These indicate that SA-DC significantly outperforms these competitive peers under the same running time; and

c) Under the premise that f_1 is minimized, the solutions obtained by SA-DC are significantly more energy efficient than the competitors. Compared with ANSA, SAILS, MNSA, and MIP, SA-DC can save at most 43.03% (instance 50-3), 60.58% (instance 50-4), 61.32% (instance 40-3), and 75.48% (instance 30-3) energies under the given running time. Thus, SA-DC well achieves the goal of saving energy while ensuring high productivity.

TABLE A.1
Ranking comparison under the same running time

Instance	SA-DC	ANSA	SAILS	MNSA	MIP
10-1	**1.0**	**1.0**	**1.0**	3.8	**1.0**
10-2	**1.0**	**1.0**	**1.0**	2.9	**1.0**
10-3	**1.0**	**1.0**	**1.0**	1.2	**1.0**
10-4	**1.0**	**1.0**	**1.0**	1.5	**1.0**
10-5	**1.0**	**1.0**	**1.0**	1.1	**1.0**
20-1	**1.0**	1.2	**1.0**	7.4	**1.0**
20-2	**1.0**	3.0	2.8	8.4	**1.0**
20-3	**1.0**	1.6	**1.0**	6.3	**1.0**
20-4	**1.0**	2.0	2.8	7.4	**1.0**
20-5	**1.2**	3.5	3.8	8.2	**1.0**
30-1	**1.0**	4.0	3.9	12.4	3.0
30-2	**1.0**	6.8	6.3	13.5	6.0
30-3	**1.0**	3.0	3.6	11.5	4.0
30-4	**1.0**	4.1	4.0	12.7	2.0
30-5	**1.0**	5.0	4.7	10.3	**1.0**
40-1	**1.0**	5.7	8.0	20.5	–
40-2	**1.0**	4.5	6.8	18.5	–
40-3	**1.2**	7.0	7.8	18.9	–
40-4	**1.8**	9.2	11.5	23.4	–
40-5	**1.0**	5.4	6.9	16.5	–
50-1	**1.7**	10.3	14.7	27.5	–
50-2	**1.2**	8.1	10.7	23.2	–
50-3	**1.1**	10.3	15.9	26.3	–
50-4	**1.0**	8.0	9.9	23.5	–
50-5	**1.1**	10.8	12.7	26.4	–

TABLE A.2
COMPARISON OF THE DETAILED OPTIMIZATION EFFECTS UNDER THE SAME RUNNING TIME

Instance	SA-DC			ANSA				SAILS				MNSA				MIP		
	$\bar{f}_1$	$C_{f_1^*}$	$\bar{f}_2$	$\bar{f}_1$	$C_{f_1^*}$	$\bar{f}_2$	E	$\bar{f}_1$	$C_{f_1^*}$	$\bar{f}_2$	E	$\bar{f}_1$	$C_{f_1^*}$	$\bar{f}_2$	E	f_1	f_2	E
10-1	**2.0**	10	**695.5**	**2.0**	10	**695.5**	0.00%	**2.0**	10	**695.5**	0.00%	2.0	10	1299.0	46.46%	**2.0**	**695.5**	0.00%
10-2	**1.0**	10	**3478.5**	**1.0**	10	**3478.5**	0.00%	**1.0**	10	**3478.5**	0.00%	1.9	1	3478.5	0.00%	**1.0**	**3478.5**	0.00%
10-3	**1.0**	10	**1680.4**	**1.0**	10	**1680.4**	0.00%	**1.0**	10	**1680.4**	0.00%	1.2	8	1680.4	0.00%	**1.0**	**1680.4**	0.00%
10-4	**1.0**	10	**1985.8**	**1.0**	10	**1985.8**	0.00%	**1.0**	10	**1985.8**	0.00%	1.3	7	1985.8	0.00%	**1.0**	**1985.8**	0.00%
10-5	**1.0**	10	**1486.7**	**1.0**	10	**1486.7**	0.00%	**1.0**	10	**1486.7**	0.00%	1.1	9	1486.7	0.00%	**1.0**	**1486.7**	0.00%
20-1	**2.0**	10	**2534.6**	2.1	9	2534.6	0.00%	**2.0**	10	**2534.6**	0.00%	3.2	0	–	–	2.0	2534.6	0.00%
20-2	**2.0**	10	**3432.8**	2.6	4	3441.3	0.24%	2.5	5	3442.9	0.29%	3.0	1	3632.9	5.51%	**2.0**	**3432.8**	0.00%
20-3	**2.0**	10	**2204.3**	2.3	7	2204.3	0.00%	**2.0**	10	**2204.3**	0.00%	2.8	2	3115.2	29.24%	2.0	2204.3	0.00%
20-4	**2.0**	10	**4278.5**	2.5	5	4278.5	0.00%	2.9	1	4278.5	0.00%	3.0	1	5370.3	20.33%	**2.0**	**4278.5**	0.00%
20-5	**2.0**	10	**2634.0**	2.5	5	2634.0	0.00%	2.5	5	2797.1	5.83%	2.7	3	3495.3	24.64%	**2.0**	**2634.0**	0.00%
30-1	**3.0**	10	**4099.8**	3.9	1	4736.3	13.44%	3.7	3	4524.1	9.38%	4.4	0	–	–	3.0	6742.4	39.19%
30-2	**3.0**	10	**4977.2**	3.8	2	5997.9	17.02%	3.8	2	5844.2	14.84%	4.4	0	–	–	3.0	6293.8	20.92%
30-3	**3.0**	10	**3795.8**	3.4	6	3795.8	0.00%	3.5	5	4219.8	10.05%	4.7	0	–	–	3.0	15479.2	75.48%
30-4	**3.0**	10	**4950.6**	4.0	1	4950.6	0.00%	4.0	0	–	–	4.6	0	–	–	3.0	12902.5	61.63%
30-5	**3.0**	10	**4183.2**	3.9	1	4905.3	14.72%	3.9	1	4326.3	3.31%	4.4	1	8940.5	53.21%	**3.0**	**4183.2**	0.00%
40-1	**4.0**	10	**5088.8**	4.4	6	5093.0	0.08%	4.4	6	8172.0	37.73%	5.7	0	–	–	–	–	–
40-2	**4.0**	10	**4278.3**	4.1	9	4778.3	10.46%	4.0	10	6055.2	29.35%	5.8	0	–	–	–	–	–
40-3	**4.0**	10	**3769.7**	4.3	7	5006.6	24.70%	4.3	7	5887.1	35.97%	5.7	1	9745.1	61.32%	–	–	–
40-4	**4.0**	10	**4246.1**	4.5	5	4400.0	3.50%	4.5	5	6418.1	33.84%	5.3	0	–	–	–	–	–
40-5	**4.0**	10	**2705.6**	4.4	6	4485.7	39.68%	4.5	5	6858.3	60.55%	5.6	0	–	–	–	–	–
50-1	**5.0**	10	**8788.7**	5.7	3	16891.8	47.97%	6.1	1	12758.9	31.12%	7.5	0	–	–	–	–	–
50-2	**5.0**	10	**4773.4**	5.5	5	5092.6	6.27%	5.7	4	9879.8	51.68%	6.8	0	–	–	–	–	–
50-3	**5.0**	10	**4755.4**	5.0	10	8346.5	43.03%	5.3	7	9401.2	49.42%	6.7	1	8912.3	46.64%	–	–	–
50-4	**5.0**	10	**7369.4**	6.0	1	7369.4	0.00%	6.2	1	18694.4	60.58%	7.5	0	–	–	–	–	–
50-5	**5.0**	10	**7969.8**	5.9	1	9390.8	15.13%	6.0	0	–	–	7.3	0	–	–	–	–	–