**Table 1** The machining information of instance.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Jobs | Features | Alternative operations | Alternative machines | Processing time (minutes) | Precedence constraints |
| crankcase body |  |  | 3,4/1,2 | 21,18/16,19 | Before all features |
|  |  |  | 3,4 | 18,21 | Before |
|  |  |  | 5,6/9 | 23,20/8 |  |
|  |  |  | 3,4 | 13,14 | Before |
|  |  |  | 5,6/9 | 16,19/9 |  |
|  |  |  | 5,6 | 14,18 | Before |
|  |  |  | 5,6 | 11,12 | Before |
|  |  |  | 7,8 | 23,20 |  |
| crankcase cover |  |  | 3,4/1,2 | 19,21/13,16 | Before all features |
|  |  |  | 5,6 | 15,21 | Before |
|  |  |  | 3,4 | 11,9 | Before |
|  |  |  | 5,6/9 | 15,13/8 |  |
|  |  |  | 7,8 | 16,19 |  |
| crankcase side cover |  |  | 3,4/1,2 | 17,19/14,18 | Before all features |
|  |  |  | 5,6 | 7,8 | Before |
|  |  |  | 5,6 | 13,16 | Before |
|  |  |  | 5,6 | 12,15 | Before |
|  |  |  | 7,8 | 20,23 |  |
| crankshaft |  |  | 3,4/1,2 | 16,18/22,19 | Before all features |
|  |  |  | 3,4 | 15,16 |  |
|  |  |  | 5,6/9 | 13,10/9 |  |
| crankshaft bolt |  |  | 1,2 | 16,19 | Before all features |
|  |  |  | 3,4 | 13,18 | Before |
|  |  |  | 5,6/9 | 11,10/8 |  |
|  |  |  | 7,8 | 22,21 |  |

**Table 2** Transportation time

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| machines/machines | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 0 | 3 | 4 | 3 | 2 | 4 | 3 | 2 | 3 | 3 |
| 2 | 3 | 0 | 1 | 2 | 2 | 1 | 3 | 4 | 2 | 3 |
| 3 | 4 | 1 | 0 | 3 | 1 | 2 | 2 | 2 | 1 | 2 |
| 4 | 3 | 2 | 3 | 0 | 2 | 3 | 1 | 3 | 2 | 4 |
| 5 | 2 | 2 | 1 | 2 | 0 | 2 | 3 | 2 | 1 | 2 |
| 6 | 4 | 1 | 2 | 3 | 2 | 0 | 2 | 3 | 2 | 3 |
| 7 | 3 | 3 | 2 | 1 | 3 | 2 | 0 | 2 | 2 | 2 |
| 8 | 2 | 4 | 2 | 3 | 2 | 3 | 2 | 0 | 3 | 3 |
| 9 | 3 | 2 | 1 | 2 | 1 | 2 | 2 | 3 | 0 | 3 |
| 10 | 3 | 3 | 2 | 4 | 2 | 3 | 2 | 3 | 3 | 0 |

Note: Machine 10 represents the warehouse in Table 2.

**Table 3** Related parameters of each machine.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameters/machines | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Cutting power/ KW | 11.15 | 9.36 | 10.74 | 13.29 | 11.34 | 14.12 | 9.86 | 12.45 | 13.78 |
| Idling power/KW | 2.06 | 1.84 | 1.98 | 2.60 | 2.25 | 2.79 | 1.94 | 2.32 | 2.65 |