











**Table 5:** Flow time of jobs in respective machines

Job	M <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	M <sub>4</sub>	M <sub>5</sub>	M <sub>6</sub>	M <sub>7</sub>	M <sub>8</sub>	M <sub>9</sub>	M <sub>10</sub>
14	0-5	5-7	7-8	8-11	<b>11-19</b>	19-21	21-27	27-28	28-37	37-45
08	5-10	10-11	<b>11-18</b>	18-19	19-26	26-29	29-35	35-41	41-43	45-47
11	10-15	<b>15-17</b>	18-19	19-26	26-32	32-35	35-42	42-47	47-54	54-58
12	<b>15-17</b>	17-23	23-29	29-34	34-40	40-47	47-49	49-50	54-62	62-65
17	17-24	24-29	29-31	34-36	40-43	47-52	52-53	53-59	62-64	65-68
15	24-31	31-37	37-40	40-42	43-49	52-54	54-59	59-66	66-67	68-71
20	31-38	38-39	40-44	44-46	49-53	54-60	60-62	66-68	68-74	74-81
16	38-47	47-49	49-56	56-59	59-63	63-64	64-69	69-72	74-82	82-83
04	47-54	54-59	59-65	65-68	68-70	70-73	73-75	75-79	82-84	84-86
13	54-57	59-63	65-67	68-74	74-75	75-80	80-84	84-91	91-97	97-102
01	57-62	63-65	67-70	74-79	79-86	86-95	95-102	10-11	11-11	11-11
06	62-65	65-72	72-77	79-81	86-88	95-96	102-107	11-11	11-11	11-12
18	65-73	73-75	77-82	82-86	88-97	97-100	107-109	11-11	11-12	12-13
09	73-80	80-88	88-94	94-103	10-10	10-11	112-114	11-12	12-12	13-13
07	80-87	88-90	94-98	10-10	10-11	11-11	119-120	12-12	12-13	13-14
03	87-88	90-92	98-100	10-11	11-11	11-12	126-128	12-13	13-13	14-14
19	88-90	92-97	10-10	11-11	11-12	12-12	128-133	13-13	13-14	<b>14-14</b>
05	90-96	97-104	10-10	11-12	12-12	12-13	133-136	13-14	<b>14-15</b>	15-15
10	96-100	10-10	10-11	12-12	12-13	13-13	136-139	<b>14-15</b>	15-15	15-16
02	10-10	10-11	11-11	12-13	13-13	13-14	140-145	15-15	15-16	16-16

The jobs which are affected by implementation of breakdown times are highlighted.

J14 on M5, J08 on M3, J11 on M2, J12 on M1, J19 on M10, J05 on M9, J10 on M8

The initial breakdown causes some changes in second one.

Implementation of Breakdown times:

**Table 6:** Flowtime of jobs with breakdown in respective machines

Job	M <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	M <sub>4</sub>	M <sub>5</sub>	M <sub>6</sub>	M <sub>7</sub>	M <sub>8</sub>	M <sub>9</sub>	M <sub>10</sub>
14	0-5	5-7	7-8	8-11	<b>11-21</b>	21-23	23-29	29-30	30-39	39-47
08	5-10	10-11	<b>11-20</b>	20-21	21-28	28-31	31-37	37-43	43-45	47-49
11	10-15	<b>15-19</b>	20-21	21-28	28-34	34-37	37-44	44-49	49-56	56-60
12	<b>15-19</b>	19-25	25-31	31-36	36-42	42-49	49-51	51-52	56-64	64-67
17	19-26	26-31	31-33	36-38	42-45	49-54	54-55	55-61	64-66	67-70
15	26-33	33-39	39-42	42-44	45-51	54-56	56-61	61-68	68-69	70-73
20	33-40	40-41	42-46	46-48	51-55	56-62	62-64	68-70	70-76	76-83
16	40-49	49-51	51-58	58-61	61-65	65-66	66-71	71-74	76-84	84-85
04	49-56	56-61	61-67	67-70	70-72	72-75	75-77	77-81	84-86	86-88
13	56-59	61-65	67-69	70-76	76-77	77-82	82-86	86-93	93-99	99-104
01	59-64	65-67	69-72	76-81	81-88	88-97	97-103	103-111	111-113	113-120
06	64-67	67-74	74-79	81-83	88-90	97-98	103-108	111-114	114-116	120-126
18	67-75	75-77	79-84	84-88	90-99	99-102	108-110	114-120	120-121	126-134
09	75-82	82-90	90-96	96-105	-106	-114	-116	-121	-121	-140
07	82-89	90-92	96-100	105-111	111-116	116-121	121-122	122-124	127-132	140-142
03	89-90	92-94	100-102	111-112	116-119	121-128	128-130	130-135	135-139	<b>142-148</b>
19	90-92	94-100	102-106	112-114	119-125	128-130	130-135	135-137	139-145	-151
05	92-98	100-106	106-107	114-122	125-131	131-135	135-138	<b>138-149</b>	149-155	-159
10	98-102	106-109	109-114	122-130	131-134	135-136	138-141	149-157	157-160	160-167
02	102-104	109-115	115-119	130-132	134-140	140-142	<b>142-149</b>	157-159	160-166	167-168

Hence Cmax = 168  
 Completion time for B3= 88.  
 Completion time for B2= 142.  
 Completion time for B1= 168.  
 Common Due date of the batches = 135  
 Early Batches = B3.  
 Tardy Batches =B1, B2.  
 Early cost = 47  
 Tardy cost = 7+33= 40.  
 Total cost = 40+47=87.  
 Calculation of Total flow time for m machine without breakdown:

$$\bar{E}_w = \frac{\sum_{i=1}^n w_i f_i}{\sum_{i=1}^n w_i}$$

$\sum w_i f_i = 45+(47-5)+(58-10)+(65-15)+(68-17)+(71-24)+(81-31)+(83-38)+(86-47)+(102-54)+(119-57)+(125-62)+(133-65)+(139-73)+(141-80)+(145-87)+(148-88)+(155-90)+(163-96)+(164-100).$

$=45+42+48+50+51+47+50+45+39+48+62+63+68+66+61+58+60+65+67+64.$   
 $=1099.$

$\sum w_i f_i = 1099$

$F_w = 1099/20 = 54.95.$

Calculation of Total flow time for m machine with breakdown:

$$\bar{E}_w = \frac{\sum_{i=1}^n w_i f_i}{\sum_{i=1}^n w_i}$$

$\sum w_i f_i = 47+(49-5)+(60-10)+(67-15)+(70-19)+(73-26)+(83-33)+(85-40)+(88-49)+(104-56)+(120-59)+(126-64)+(134-67)+(140-75)+(142-82)+(148-89)+(151-90)+(159-92)+(167-98)+(168-102)=$

$47+44+50+52+51+47+50+45+39+48+61+62+67+65+60+59+61+67+69+66$   
 $=1110$

$\sum w_i f_i = 1110.$

$F_w = 1110/20 = 55.5.$

## 7. Conclusion

In our paper we considered the major constraint as breakdown times of the machines. We are dealing with the jobs which are having the distinct job size. The major objective considered here is make span and mean weighted flow time of jobs. From our results it is proved that the mean weighted flow time varies slightly while compared between the processing with breakdown times and without breakdown times. Professor Michael L. Pinedo's Lekin Scheduling system 2.4 contributes more in our paper. All the Gantt charts are made with the help of Lekin scheduling systems. Lekin provides the solution for m machine problems through Local search Heuristics method. Another software tool used in our paper is Lisa

(Library of Scheduling Systems) to find the optimality. Hence we complete our objective in our paper successfully.

## 8. Future Scope

In future the manufacturing trend is mostly flow based advanced production scheme with the use of production algorithms and high tech computers usage in production line apart from in design work. Even though machine break down is minimum it will not be totally unavoidable. Global competition force manufacturers go for advance production shop practice in that context our work is a small plat form to think about it in near and long future

## Reference

- [1] Johnson .S .M. Optimal two and three stage production schedules with setup time included.,Naval Research Logistics Quarterly1(1954) 61-68.
- [2] Garey.M.R,Johnson.D.S.,The Complexity of Flowshop and Jobshop scheduling, Mathematics of operations research 1 (1976) 117-129.
- [3] Rajendran.C.,Zeigler.H., An efficient heuristics for scheduling in a flowshop to minimize total weighted flowtime of jobs.
- [4] Lee.C.Y., Chen.Z.L. Machine scheduling with deliveries to multiple customer locations, European Journal of Operational Research 164(2005) 39-51.
- [5] Simchi- Leve.D ., New worst case results for bin-packing problem, Naval Research Logistics 41 (1994) 579-585.
- [6] A.B.Chandramouli., Heuristic approach for N job 3 machine flowshop scheduling problem involving transportation time,Breakdown times and Weightage of jobs.,Mathematical and Computer application vol 10 pp.301-305,2005.
- [7] T.C.E. Cheng, Z.-L. Chen, M.Y. Kovalyov and B.M.T. Lin, Parallel-machine batching and scheduling to minimize total completion time, IIE Transactions 28 (1996) 953-956.
- [8] Chang.Y.C et al Machine scheduling with job deliver coordination, European Journal of Operational Research 158 (2004) 470-487.
- [9] Guzin ozdagoglu A simulated annealing application on flowshop sequencing problem:A comparative case study.

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