Application of Group Technology Based Integrated Cellular Manufacturing System

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Abstract

This paper is based on a work to assist local manufacturing industries to optimise their production capability through the implementation of Group Technology (GT) concept. The paper reports on a computer program developed based on Prof. Burbidge's Production Flow Analysis (PFA) method. Sample data for the machine-component grouping was obtained from a case study involving a machine shop. The computer program was used to form machine-part grouping. Initially the computer program formed five machine-part groupings. Later detailed study of the groupings resulted in three final cells. Group Loading study was carried on these cells to determine the number of machines of each type to be allocated in each machine group. Finally the proposed layout was simulated using WITNESS software to evaluate and justify the implementation of GT based Cellular Manufacturing (CM) cells on the selected case study.

Keywords: Group Technology, Cellular Manufacturing, Production Flow Analysis, Simulation.

1 Introduction

CM and its forefather GT is not new to the manufacturing sector. It has been used fully or partially in most of the industrial sectors throughout the last 50 years. Even though the early history of GT can be traced back to as early as 1920s [1], detailed research into the application of GT for manufacturing began during the late 1950s.

PFA is a method of machine-component grouping in GT. The PFA method was introduced by Prof. Burbidge to the GT literature world more than 35 years ago [2]. Since then GT and CM, as an application of GT, have come a long way. In recent years, the studies conducted on GT and CM are more concerned with cell formation methodology [3, 4, 5]. PFA method was widely used in some of the research work carried out in the 1980s [6, 7]. For the present study, a computer program was developed based on Prof. Burdbridge 's PFA methodology.

In Malaysia, GT and CM have played a significant role in the development of the manufacturing sector. A recent study has been conducted on the development and the status of GT and CM in Malaysia. It has been known that most of the companies involved in the survey are aware of the benefits and advantages of GT and CM [8].

2 Software Development

The computer program was developed using Visual C++ as the compiler. This language has been chosen because it could run on Microsoft Windows platform, thus enabling the program to be more user friendly. The system requirement for this software is Windows 95 with a minimum of 8MRAM and about 1MB space in the hard disc. The computer program was developed mainly based on the manual group analysis of PFA. The flow chart of this program is as shown in Figure 1.

First, the user needs to input the number of machine types employed, the corresponding quantity and types of parts that are produced. The program will then do a series of interpretation to produce the initial cells. The program will first identify the machine that has the least number of parts produced in order to become the nucleus machine for the first module. The selected machine type and all the parts processed on this machine are stored in the first module. Any other machines used with the nucleus machine to make any of the above listed parts are recalled and also stored in this module. It will then repeat the above process with the remaining machine types, eliminating one machine type each time.

The next stage is what is known as the 'Modular Synthesis'. Here the program will identify the module that uses the largest number of different machine types. In case there is more than one such module, the program will choose the module that includes the

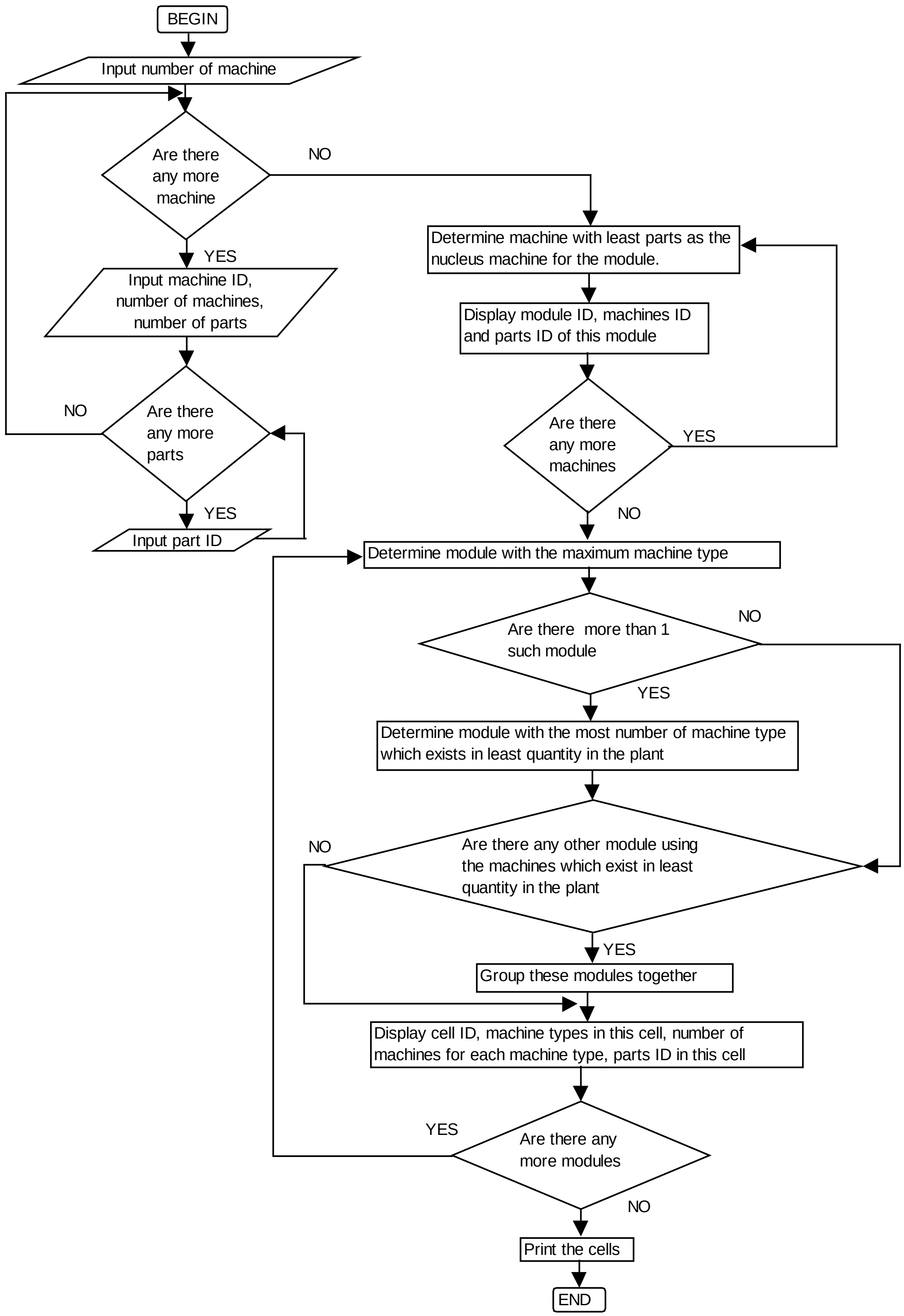

Figure 1. Flow chart of the developed computer program.

greatest number of machine types of which only one exists in the factory. Now the program will recall all the parts and machine types produced and used in that module. The program will also identify if there are any other modules that uses the same machine types of which only one exists in the factory. If there is, then the program will group together those modules with the selected module. This will form the first cell. An output with the information of total cells created and the corresponding machines and parts that will be produced in these cells will be generated. The output can be retrieved using Windows tools such as MSWord, Word Pad and etc.

3 Case Study

The software has been applied in a case study involving the machine shop of a company. The company, which is located in Klang, Selangor, produces a wide range of parts and components for the mould and die as well as jig and fixture industries. Its main customers include some of the well-known multi-national companies.

The machine shop has in all 35 machines. These machines are classified into 8 machine types according to their job function. The machine shop also has other "common" machines such as drilling, tool grinder, press machine and a furnace. Almost all the machines are laid out on the functional basis.

Data required for the CM layout analysis are components machining sequence and their corresponding machining times. These are obtained from the job sheets and part drawings. A total of 102 parts that was produced in the duration of three months have been selected for this study. Based on the data collected, a table containing information of parts, their processes and machining time for each of the processes has been created.

3.1 Group Analysis

The next stage in PFA is Group Analysis. In this stage, machine-part families are formed. Table 1 shows that there are 5 machine-part groups, each with its own group of machines and parts. These machine-part groups form the initial CM cells for this research. It is noted that group 1 (Table 1a) has the most parts whereas the other groups have lesser parts. Similarity co-efficient studies on all the 5 groups show that some of the parts in group 1 could be transferred to the "under-utilised" group 2. Similarly, groups 3 and 4 (Tables 1b and 1c) could be combined to become one cell. It is also observed that group 5 (Table 1e) could be absorbed into Group 2. Hence, 3 cells were finally formed as shown in Table 2.

3.2 Group Loading Analysis (GLA)

Group loading is the stage where the number of machines of each type to be allocated to each machine group is determined. The machines are allocated based on the loading of each machine type in the cells. Table 2 illustrates the final cells with their corresponding machines and parts.

3.3 Line Analysis (LA)

This is the third stage in PFA. LA was carried out in order to arrange the production facilities optimally within the CM cells thus simplifying and minimising the material flow within the cells. The objective of LA is to establish a near flow line production system where the number of backtracking is to be minimised. However, when some components use certain machines in a different sequence, the modified form of a line layout can still be used with minimum backtracking of materials.

The LA is done by listing the number of times each machine in a particular cell is required for the first operation, second operation and so on as applicable for that particular cell. The machine that is most required by the first operation is placed first in the machine layout. Similarly the second machine in the sequence is the one that is required the most by the second operation and so on. The machine sequence formed by LA for this case study is shown in Table 3.

Cell	Machines Sequence/Number of Machines
Cell 1	Milling (7) - Wire Cut (1) - Grinding(3) - EDM (1) - CNCMill (2) - Lathe (1)
Cell 2	Lathe(2) - EDM (1) - Milling (2) - Grinding (1) - Cylindrical Grind (1)
Cell 3	Machine Center (1) - Milling (1) - Grinding (1)

Table 3. Machine layout sequence for each cell and number of machines for each machine type.

4 Simulation

Simulation is used to evaluate the performance of the proposed cellular layout and to compare it with the current functional layout. WITNESS simulation software has been found to be appropriate for this purpose and it is user friendly.

NO	Part No.	MILL	CNC MILL	W/C	EDM	LATHE	GRD
1	B/B5092/2	120	120	240			120
2	K4663	120				480	180
3	K4795/4				60	120	
4	K4916/10	90			150		90
5	K4969	180		90			120
6	K4986/6	120		300			150
7	K4986/8	30		300			90
8	K4986/10	90			150		90
9	K5128/1	360			480		300
10	K5143/10					240	
11	K5204/2	120		240	120		150
12	K5481/6		480				
13	K5499/1	300		180			240
14	K5500/12	60		90	60		60
15	K5500/14	60		90	60	60	
16	K5500/15	60		90	60		60
17	K5500/20	90		300	150		90
18	K5500/43					120	
19	K5504/1	150			180		300
20	K5515/9	120				180	
21	K5529	150		300			180
22	K5539/1	1800		1200			960
23	K5571/1	90				90	
24	K5572/1	120		900			90
25	K5572/2	180		150			120
26	K5586/6	240		240			180
27	K5586/8	210		240			180
28	K5586/13	90		120			60
29	K5586/14	90		120			60
30	K5586/15	90		120		60	
31	K5586/38		60				30
32	K5602/1	15				30	
33	K5606	180		240			210
34	K5607	90		150	120		120
35	K5607/6	180		240			210
36	K5607/11	90		150	120		120
37	K5607/16			120			90
38	K5607/23					90	150
39	K5650/1	150		30			120
40	K5732/1	150		60	120		120
41	K5777/1	90			120		90
42	K5811/1	150		90	120		90
43	K5830		900				
44	M3020/1	300		600	180		720
45	M3406/4	240				900	
46	M3485/18	150			90		120
47	M3546	420			720	210	180
48	M3549/10	180		45		120	
49	M3589/1				240		90
50	M3599				240		150
51	M3606					240	
52	M3665	150			120		300
53	M5015	360		180	270		240
54	M5185	180		60	60		300
55	M5243	180		60	60		210
56	M5245	90		90			120
57	M5246	90		240			210
58	M5273	90		90	60		180
59	M5391		600		240		180
60	M5413/1	180			180		300
61	M5487/1	60			90		90
62	M5487/2					15	
63	M5487/3					30	
64	M5487/4					30	
65	M5503/3-1		120				
66	M5503/4-1		90				
67	M5532/1	150		150			180
68	M5532/2	120		180	120		90
69	M5532/3	180		120	240		120
70	M5532/4	180		210			90
71	M5532/5	300		180	120		120
72	M5532/11	30			30	30	30
73	M5541	120		30			30
74	M5577/1	300	7200				
75	M5553/1			90		15	
76	M5975		150				
77	M6063/11	210		45	60		240
78	M/M4906/2	180			180	150	240
79	M/M4937/13			90	300		120
80	M/M6042/11	90	60				30
81	M/M6049/7	90		120	210		120
82	U5553/19	150		180	240		240
	Total Min	6225	660	6390	2070	1470	5220

Table 1a. Machine-part Group No. 1.

NO	Part No.	EDM	LATHE	GRD
1	K5500/30		120	
2	K5500/33		30	
3	K5500/34		30	
4	K5500/35		30	
5	M5532/23		120	
6	S3718	180	600	
7	S3809/1		120	120
8	S3812/1		120	120
	Total Min	180	1170	240

Table 1b. Machine-part Group No. 2.

NO	Part No.	MILL	GRD
1	K5284/3		600
2	K5586/12	180	120
3	K5586/19	180	120
4	M5602/1	240	90
5	M/M5975	300	60
	Total Min	900	990

Table 1c. Machine-part Group No.

NO	Part No.	MILL	GRD	M/C
1	K5591/1		210	360
2	K5592/2		420	540
3	K5593/3		180	120
4	K5596/1	420	210	60
5	S/SC5208/1		240	2400
	Total Min	420	1260	3480

Table 1d. Machine-part Group No. 4.

NO	Part No.	MILL
1	M5414	150
2	M5554/13	180
	Total Min	330

Table 1e. Machine-part Group No.

NOTE :- M/C - Machine Center
Machining times are in minutes

Table 1. Machine-groups with corresponding parts, machines and machining times.

NO	Part No.	MILL	CNC MILL	W/C	EDM	LATHE	GRD
1	B/B5092/2	120	120	240			120
2	K4969	180		90			120
3	K4986/6	120		300			150
4	K4986/8	30		300			90
5	K5204/2	120		240	120		150
6	K5481/6		480				
7	K5499/1	300		180			240
8	K5500/12	60		90	60		60
9	K5500/14	60		90	60	60	
10	K5500/15	60		90	60		60
11	K5500/20	90		300	150		90
12	K5529	150		300			180
13	K5539/1	1800		1200			960
14	K5572/1	120		900			90
15	K5572/2	180		150			120
16	K5586/6	240		240			180
17	K5586/8	210		240			180
18	K5586/13	90		120			60
19	K5586/14	90		120			60
20	K5586/15	90		120		60	
21	K5586/38		60				30
22	K5606	180		240			210
23	K5607	90		150	120		120
24	K5607/6	180		240			210
25	K5607/11	90		150	120		120
26	K5607/16			120			90
27	K5650/1	150		30			120
28	K5732/1	150		60	120		120
29	K5811/1	150		90	120		90
30	K5830		900				
31	M3020/1	300		600	180		720
32	M3406/4	240				900	
33	M3549/10	180		45		120	
34	M5015	360		180	270		240
35	M5185	180		60	60		300
36	M5243	180		60	60		210
37	M5245	90		90			120
38	M5246	90		240			210
39	M5273	90		90	60		180
40	M5391		600		240		180
41	M5503/3-1		120				
42	M5503/4-1		90				
43	M5532/1	150		150			180
44	M5532/2	120		180	120		90
45	M5532/3	180		120	240		120
46	M5532/4	180		210			90
47	M5532/5	300		180	120		120
48	M5541	120		30			30
49	M5577/1	300	7200				
50	M5553/1			90		15	
51	M5975		150				
52	M6063/11	210		45	60		240
53	M/M4937/13			90	300		120
54	M/M6042/11	90	60				30
55	M/M6049/7	90		120	210		120
56	U5553/19	150		180	240		240

Table 2a. Cell No. 1.

NO	Part No.	MILL	EDM	LATHE	GRD	CYL. GRD
1	K4663	120		480	180	
2	K4795/4		60	120		
3	K4916/10	90	150		90	
4	K4986/10	90	150		90	
5	K5128/1	360	480		300	
6	K5143/10			240		
7	K5500/30			120		30
8	K5500/33			30		30
9	K5500/34			30		30
10	K5500/35			30		30
11	K5500/43			120		
12	K5504/1	150	180		300	
13	K5515/9	120		180		
14	K5571/1	90		90		
15	K5602/1	15		30		
16	K5607/23			90	150	
17	K5777/1	90	120		90	
18	M3485/18	150	90		120	
19	M3546	420	720	210	180	
20	M3589/1		240		90	
21	M3599		240		150	
22	M3606			240		
23	M3665	150	120		300	
24	M5413/1	180	180		300	
25	M5414	150				
26	M5487/1	60	90		90	
27	M5487/2			15		
28	M5487/3			30		
29	M5487/4			30		
30	M5532/11	30	30	30	30	
31	M5532/23			120		180
32	M5554/13	180				
33	M/M4906/2	180	180	150	240	
34	S3718		180	600		360
35	S3809/1			120	120	180
36	S3812/1			120	120	180

Table 2b. Cell No. 2.

NO	Part No.	MILL	GRD	M/C
1	K5284/3		600	
2	K5586/12	180	120	
3	K5586/19	180	120	
4	K5591/1		210	360
5	K5592/2		420	540
6	K5593/3		180	120
7	K5596/1	420	210	60
8	M5602/1	240	90	
9	M/M5975	300	60	
10	S/SC5208/1		240	2400

Table 2c. Cell No. 3.

NOTE :- M/C - Machine Center
Machining times are in minutes

Table 2. Final 3 Cells with corresponding parts, machines and machining times.

4.1 Input data

In order to simulate the cellular layout, the following set of information is required: -

a) parts produced and its quantity
b) machine type and its quantity
c) machining time for each of the process needed to complete a particular part
d) part arrival time (job order)
e) process sequence for each part

The following assumptions have been made in order to simplify the simulation: -

a) machine set-up time is included in machining time
b) parts continue to arrive until the end of simulation
c) parts travelling time between machine is negligible
d) machine breakdown time is not considered for this simulation
e) no parts were scrapped
f) all completed parts were shipped out
g) part arrival time and quantity are based on Triangular Distribution

First, the present condition of the machine shop is modelled. The simulation is run for the duration of 201,600 minutes. This duration is equivalent to a situation where the machine shop is running on a twenty-four-hour production shift per day for 5 months. Next the cellular layout was modelled and simulated. The results obtained from these simulations were analysed and compared. Table 4a illustrates the machine utilisation of the present layout. It is noticed that the Wire Cut machine is 100% utilised in this simulation, as is the case presently faced by the machine shop. The chart also shows that machines such as EDM, Lathe and Milling as being “blocked”. A blocked situation arises when a machine has completed its job but is unable to send the machined part to the next process, due to the fact that the other machine is busy or occupied by parts. So, even though these machines have extra capacity to produce more parts, they could not do so because an increase of parts could further create bottle-neck situation.

In the cellular layout, the Wire Cut machine is placed in Cell No. 1 (Table 4b). Therefore, a similar situation of bottle-neck is faced in this cell. However in Cell No. 2 (Table 4c) and Cell No. 3 (Table 4d) a different situation is observed. These machines have additional capacities that could be fully exploited to increase the production without interrupting the system.

5 Conclusion

The computer program can be used to overcome the main obstacle in using PFA method for cellular layout formation. Previously, the manual method has been very time consuming, some requiring days to accomplish the task. With the help of this program the task could be done in a matter of minutes.

With the use of the simulation software, the evaluation of the impact that GT will bring could be assessed. This could further facilitate the task of implementing GT based Cellular Manufacturing.

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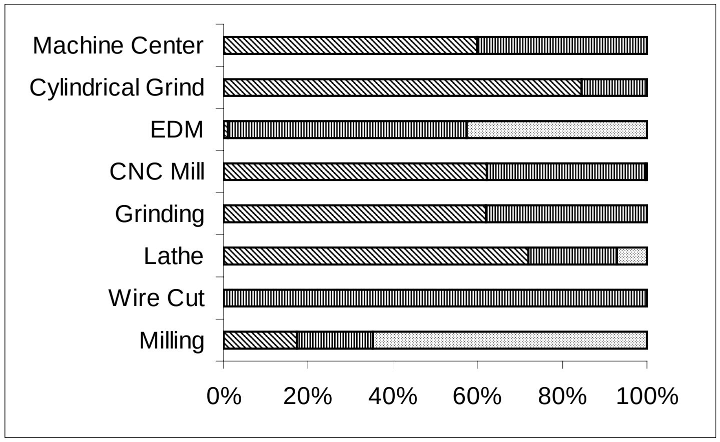


Table 4a. Machine Utilisation of Present Layout.

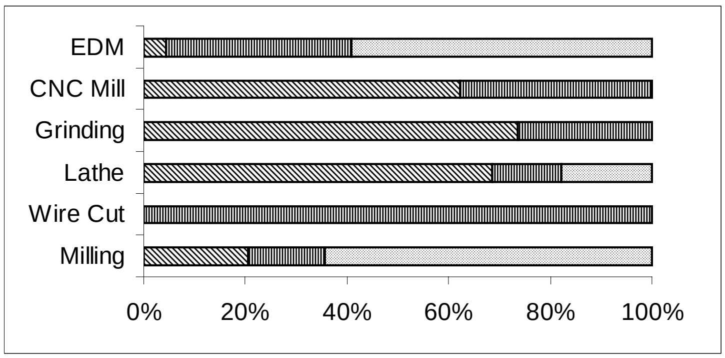


Table 4b. Machine Utilisation of Cell No. 1.

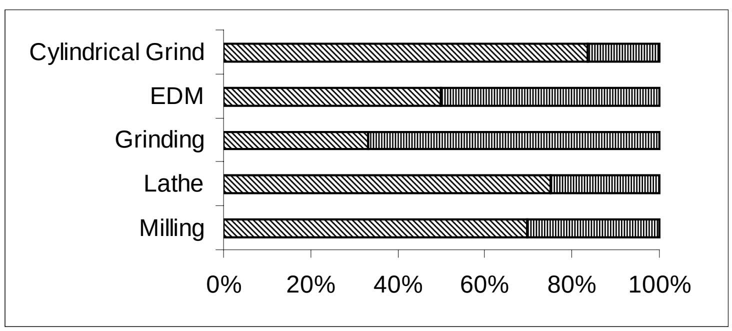
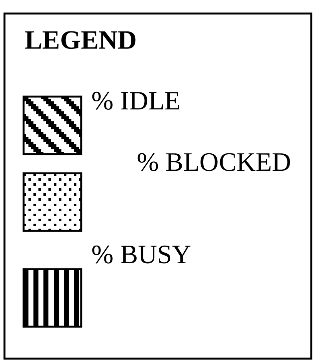


Table 4c. Machine Utilisation of Cell No. 2.



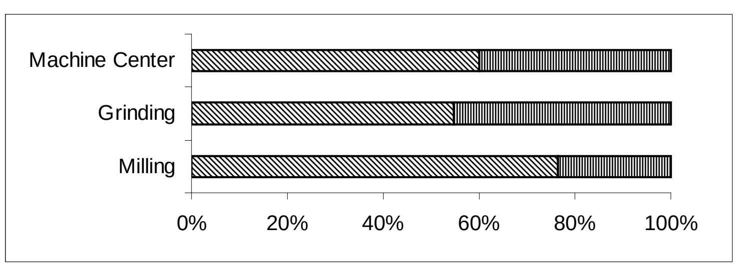


Table 4d. Machine Utilisation of Cell No. 3.