MACHINE LOADING AND MACHINE SHOP SCHEDULING – A CASE STUDY

Thesis submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF ENGINEERING IN MECHANICAL ENGINEERING

(INDUSTRIAL ENGINEERING)

of BHARATHIAR UNIVERSITY

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During the year 1999 – 2000

18/12/2000
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Date : 18.12.2000

Submitted for viva – voce examination held at
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(To whomsoever it may concern)

This is to certify that **Mr.J.PADMANABAN**, a post graduate student specialising in Industrial Engineering of Kumaraguru College of Technology, Coimbatore-641 006, undertook a project work **"MACHINE LOADING AND MACHINE SHOP SCHEDULING – A CASE STUDY"** as a part of his academic requirement from June 2000 to November 2000 in our organisation.

It requires a systematic analysis of the present scheduling system, which is taken for the project work to find the solution. This project is of high order and the software is very useful to the organisation.

This project was successfully completed and performance of the same was good. The interest and conduct of the student were found to be good.

For LAKSHMI MACHINE WORKS LIMITED.

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Many people deserve to be acknowledged and to be obliged. The author is indebted to

Dr.K.K.Padmanabhan, Principal and **Dr.A.Mohanakrishnan**, HOD, Mechanical Engineering Department, Kumaraguru College of Technology, Coimbatore who have provided the opportunity for doing this project.

Mr.M.Loganathan, Deputy General Manager, HRD, Lakshmi Machine Works Limited, Coimbatore for being kind enough to do this project work at his organisation.

Prof.N.Gunasekaran ME, MISTE, MIIIE, Internal Guide, Kumaraguru College of Technology, Coimbatore for providing the timely assistance and encouragement throughout the project work and without whom this project would not have become a great success.

Dr.E.Vallinayagam, Professor, Department of Mechanical Engineering, Kumaraguru College of Technology for his critical comments in shaping up this project work.

Mr.S.Govindaraj, Senior Manager, Cylindrical cell, External guide and the Project Co-ordinator **Mr.Balagurusamy**, Senior Manager, Logistics for their valuable suggestions and for having provided the necessary facilities.

Mr.Sivanandam, Engineer, Cylindrical cell, **Mr.Pugazhendhi**, Foreman, Cylindrical cell, **Mr.Ravi**, Foreman, Cubical cell and **Mr.Venkatesh**, Superintendent, Cubical cell for being helpful to complete this project work.

The author sincerely expresses his gratitude to his family members for co-operating with him throughout this project work.

Last but not least, the author owes his thanks to all the persons who have directly or indirectly involved in doing this project.

The author will hold his grateful feelings for the above forever.

J.PADMANABAN

The scheduling becomes a complex phenomenon in a manufacturing environment, when the demand changes. This fluctuation in demand is shattering the scheduled activities of a system. The operational control can be made simple if proper scheduling is made taking into account the dynamic changes in the management of manufacturing system.

On the other hand schedule serves as a guide for production and establishing manufacturing resource requirements in terms of facilities and machine capacity. The scheduling is very important as it must accomplish its objectives namely due dates, flow times and work center utilisation. Scheduling becomes a very significant area where the fluctuation in demand causes the disparity in due dates of all the jobs and the availability of machines.

Textile machinery manufacturing companies find it very difficult to cope up with the dynamic nature of the demand and delivery time. Everything gets changed in the shop floor when the schedule is changed with respect to demand and delivery. Cubical cell is taken for the study, which has 44 machines and 135 components. Daily scheduling is followed at present. But when the demand changes for a particular product model of the company, the priorities for the components get changed. Hence the present schedule needs a thorough change.

An attempt has been made in this project work to address the above said scheduling problem with the application of computers. The existing problem is analysed and a heuristic algorithm is developed with a typical front end and back end tools to aid the dynamic scheduling.

The developed software package will display the load chart. The data are stored in the database, which can be accessed in the front end from where the load chart will be displayed. The shop supervisor is aided now with the utilisation and idle time of each machine used. The trial orders spare orders can be accommodated in the idle time available in the load chart.

This software will be helpful for the company in a better way to visualise the scheduling problem such as reacting to a fluctuating demand, change in priorities and fluctuation of due dates. The generated load chart clearly depicts the idle time of each machine where the trial and spare orders can be accommodated.

Further research can be made that there is likelihood in the fluctuation of demand, which cannot be met, in the idle time available in the load chart.

CONTENTS

1.1 MACHINE LOADING AND SCHEDULING

Machine shop loading [9] involves the assignment of jobs to various processing centers in a way that satisfies some stated objective such as minimising the total processing time or cost. In other words, shop loading is a resource allocation process.

Loading [4] is defined as the assignment of work to a facility without specifying when the work is to be done and in what sequence. It results in a tabulated chart indicating the planned utilisation of machines or workstation. The objective is to maintain an uptodate picture of available capacity in that plant.

It is necessary to schedule jobs on machines in any workshop environment to ensure that certain jobs get machine allotted for their specific operations.

A schedule [5] may be defined as a plan with reference to that sequence of and time allotted for each item or operation necessary to its completion. The entire sequence of operations, the time estimates for each activity, the necessary sequential constraints and the required resource capacities for each activity are inputs to the development of the detailed plan or schedule.

It can also be thought as a process. The schedule is prepared, actual performance is observed and the rescheduling takes place, as uncertain events become resolved [10].

Scheduling occurs prior to shop floor activity. The need for rescheduling is governed by the accuracy and amount of flexibility in the original schedule and in the environment.

Scheduling handles the ordering of tasks identified in the plans and the association of specific time spans and resources with specific operations and jobs are handled through scheduling. A combination of selection rules, time availabilities are required for scheduling.

A programme with which the suitable delivery may be estimated is known as scheduling [4]. The scheduling may be a long term scheduling or aggregate scheduling and a short term scheduling.

Long term scheduling or aggregate scheduling provides the necessary condition of activities for multiple function areas. It identifies the product batch sizes to meet a particular target such as a monthly forecast, which is followed in this project.

Short term scheduling controls demand over the course of each day. It provides a way to check progress towards achievement of production targets set by the master schedule. Targets include meeting the required delivery dates for completion of all work on the jobs; minimising in-process inventory by minimising the overall manufacturing lead time and minimising machine and labour utilisation.

Scheduling decisions allocate workloads to specific work centers and determine the sequence in which operations are performed within the available capacity.

1.2 COMPANY PROFILE

Lakshmi Machine Works Limited famously known as **LMW** was established by Cavalier G.K.Devarajulu in the year 1962.

LMW is one of the three leading manufacturers of textile machinery's in the world. A multi product company, LMW represents the actualisation of a dream shared by the founding fathers of the group. And the basis of the industry that literally clothes the world. Technology, infrastructure and turnover are the measures of the company's competitiveness. Over the years a conscious effort has been made for vertical integration.

There are totally 9 units of LMW and all are in TamilNadu. Unit-I of LMW is located at Periyanaickenpalayam and Unit-II is situated at Kaniyur. Unit-I holds the major share of the LMW group. Some of the other sister concerns are as follows.

1. Machine Tool Division (MTD), Arasur.
2. Lakshmi Electricals and Control System (LECS), Arasur.
3. Lakshmi Automatic Looms (LAL), Hosur.
4. Lakshmi Synthetic Machines (LSM).
5. Lakshmi Ring Travelers (LRT).
6. Lakshmi Card Clothing (LCC).
7. Lakshmi Precision Tools (LPT).

LMW holds a leading position in the textile machinery-manufacturing field and can take legitimate pride in bringing the latest technology to the textile mills in India and abroad. Even in a protected economic environment, its success was due to quality, fair commercial practice and service. The special way LMW technology touches life is through its sophisticated latest generation textile machinery which spins fibers and yarns ultimately going into the production of fabrics and ready made garments. Its production infrastructure has been kept uptodate with regular modernisation.

The acquisition of ISO 9000 accreditation has helped LMW to test its work practices and also to fill gaps, if any. It is only a first step in the march of LMW towards Total Quality Management (TQM).

LMW is of a conglomerate with a solid core competence in engineering. LMW will be able to absorb and implement advanced technologies in the world with a knowledgeable human resource.

1.2.1 PRODUCT RANGE:

LMW manufactures the entire range of cotton spinning machinery meeting to the demands of mills in India and abroad. In fact, LMW meets 60% of the demand generated in India. The list of products that are manufactured in LMW are shown in Table 1.

Table No: 1 PRODUCT LIST OF LMW

S.No	PRODUCT NAME	PRODUCT MODEL
1	Carding	LC1/3, LC300, LC300A
2	Draw frame	LDO6, RSB851
3	Comber	LK250, LK250/2
	Sliver lap	LE2/4A
	Ribbon lap	LE4/1A
4	Speed frame	LF1400A, LF1465, LFS1660
	Open End Spinning	LM1/2
	Pirn Winder	LMSL40

The sister concerns of LMW are manufacturing the Ring frame machines, Blow room accessories of the textile machinery and CNC machines.

LMW is having more than 1500 customers. The premier customers are,

1. Reliance Spinning mills, Nepal.
2. Bombay Dyeing and Manufacturing Company, Mumbai.
3. Mother textiles, Indonesia.
4. Birla textile mills, Chambal.
5. Gujarat Ambuja Cotton mills, Gujarat.
6. Jaipur Polyspin ltd.

1.2.2 LMW - A BRAND NAME FOR QUALITY:

Quality is LMW's most visible asset. And it's greatest contribution to industry at large. All round upgradation of quality has been possible because of continuous improvement of its quality. The end result is most gratifying when you gauge the remarkable improvement in quality of finished yarns and finished goods of the customers who have used the LMW machineries. Bureau Varitas Quality International **(BVQI)** has given the ISO 9001 certificate for LMW in the year 1994.

1.2.3 AWARDS RECEIVED:

LMW's commitment to quality standards has won laurels and awards. The company standardisation in 1995 from the institute of standards engineers recognises LMW's concerns for improving quality standards, increasing productivity and reducing cost. In 1988-89, LMW received engineering export promotion council's **Regional Top Exporter Shield**. The prestigious **ET-HBSAI** award not only recognises financial performance of the organisation but also its contribution to the general economic development and other socio-economic aspects. The federation of Indian textile engineering industry gave the **Top Exporter Award** for the year 1990-91. In the same year LMW received the award for export excellence.

1.2.4 LAYOUT:

Product layout is adopted in LMW. It is divided into 4 groups and 2 cells. Groups are formed based on its products namely,

1. Carding.
2. Draw frame.
3. Comber and
4. Speed frame.

Cells are classified according to the geometry of the products which acts as internal sub contractor namely,

1. Cubical cell for processing non-cylindrical components and
2. Cylindrical cell for processing cylindrical components.

1.3 INTRODUCTION ABOUT THE PROJECT:

It is needless to mention that the critical aspect of the manufacturing industries is shop floor scheduling. The resources must be utilised to their fullest extent to ascertain the maximum productivity as the companies are facing stiff competition in the market. The resource allocation has to be done properly to achieve this. Hence, machine loading plays a vital role since it is the basis of the resource allocation in a manufacturing environment.

It is to be performed in accordance with the scheduling. But, scheduling of the jobs on the machines is a tedious task in a complex environment such as the cubical cell.

The number of components and the machines in this area are more so that no mathematical model will yield a better solution. Hence, scheduling should be taken care to meet the delivery date. The customer satisfaction is achieved only when we produce the products in time and they are dispatched at right time.

The scope of this project is to prepare a schedule which results in timely delivery which in turn leads to customers satisfaction.

2.1 LOADING WITH A GANTT CHART [9]:

A Gantt chart represents the oldest, simplest and most widely used method for scheduling various activities. With reference to the shop loading, the construction of the chart requires listing the various processing centers as rows and placing jobs in each row plotted against a time axis, for the fabrication of a machine part.

To know the progress of a particular project, this chart is helpful. Hence, this mechanical Gantt chart [4] is also known as "**Progress chart**".

The Gantt chart [4] represents the relationship between load and capacity at all places where the work is carried out. It provides an information

1. To ensure the efficient utilisation of the plant in a factory.
2. To help in setting of reliable delivery.
3. To assist in forward planning of purchase of the new plant.

FACTORS AFFECTING SCHEDULING:

The factors affecting in a manufacturing environment is broadly classified [4] into two groups namely,

(i) External factors

(ii) Internal factors.

External factors:

1. Customers demand.
2. Delivery dates and
3. Stock of goods already lying.

Internal Factors:

1. Stock of finished goods.
2. Time required to produce a component, sub assembly and assembly.
3. Availability of equipment and machinery.
4. Manpower.
5. Production facilities and
6. Economic production run.

Information that is known in advance serves as input to the scheduling function. Three basic pieces of information that help to determine the jobs in the system are (i) Processing time, (ii) Ready time and (iii) Due date.

1. Processing time:

The forecasted estimate of how long it will take to complete a task. This estimate includes any setup time that might be required. Actual processing time is a forecasted value. For task 'i', it is denoted by 't_i'.

2. Ready time:

The point of time at which job is available for processing, is denoted by 'r_i'.

3. Due date:

The established deadline for a task beyond which it would be considered tardy. It is assumed that some kind of penalty for being tardy exists. It is denoted by 'd_i'.

Information that is generated as a result of scheduling decisions represents output from the scheduling function. One such information is the completion time.

Completion time:

The span between the beginning of work on the first job, which time is referred to as 't=0' and when the time when a task 'i' is finished. The span is denoted by 'C_i'.

Quantitative measures for evaluating schedules are usually functions of job completion times. Two important quantities are as follows:

1. Flow time:

The time span between the point at which a task is available for processing and the point at which it is completed i.e., the amount of time, a job spends in the system. Thus, it equals the processing time plus the time that the task waits before being processed. It is denoted by 'F_i'.

2. Lateness:

The amount of time by which the completion time of job exceeds its due date. Lateness measures the conformity of the schedule to a given due date and it is important to note that the negative lateness quantity takes on negative values whenever job is completed early.

Negative lateness represents better service than requested, while positive lateness represents poorer service than requested.

In many situations, distinct penalties and other costs will be associated with positive lateness, but no benefits will be associated with negative lateness. Therefore, it is often helpful to work with a quantity that measures only positive lateness. Lateness is denoted by 'L_i'.

The important terms that are necessary for machine loading [4] are explained in detail.

(i) Routing:

The routing means the various operational steps through which each part is supposed to pass through.

(ii) Current Shop situation:

It means that the machine hours available at current stage. Capacity is defined as the time available expressed in machine hours for work at work centers.

(iii) Tools and Equipment available:

It means that the types of tools and the numbers along with the equipment available at any instant.

(iv) Manpower available:

Manpower required for the work in terms of quantity.

(v) Materials:

Various materials required for this project in terms of type and quantity.

(vi) Work Authorisation.

Some of the other definitions related to scheduling [5] are as follows.

1. Tardiness:

It is defined as the measure of positive lateness. If the task is early, it has negative lateness but zero tardiness. If the task has positive lateness, it has equal positive tardiness.

2. Maximum Flow Time or Make span:

For a finite set of tasks the utilisation of resources is inversely proportional to the time equivalent to accomplish all the tasks. This time is referred to as the make span or maximum flow time of the schedule.

If the make span of the schedule is constant, the sequence that reduces mean flow time also reduces mean in process inventory.

3. Turn around time:

Flow time measures the response of the system to individual demands for service and represents the interval a job waits between its arrival and its departure. This interval is sometimes called as the turn around time.

4. Slack:

A measure of the difference between the remaining time to a task's due date and its processing time. It is denoted by 'SL_i' where $SL_i = d_i - t_i$.

It is not feasible to ensure adequate level of machine utilisation and throughput time in large shop environments by manual scheduling methods when there are large number of jobs in the system.

3.1 INTRODUCTION:

LMW produces all the important components of Carding, Draw frame, Comber and Speed frame. Its sub contractors or vendors manufacture some of the components. The vendors are selected based on scientific rating and systematic analysis is done on the components to be manufactured. All supports are rendered to the vendor by LMW.

The two cells in LMW, which acts like internal sub-contractors are namely (i) Cylindrical cell and (ii) Cubical cell.

Based on the geometry of the objects or jobs, they are sent to these cells. Circular components like shafts, lickerin rollers, grooved rollers, doffing rollers and fluted rollers are processed in cylindrical cell and the other components such as frames and spring piece are processed in cubical cell.

Cubical cell is divided into two groups namely

1) Heavy machines section and
2) CNC section.

There are 24 machines available in heavy machine section and 20 machines in CNC section, whose layouts are shown in figures 1 and 2.

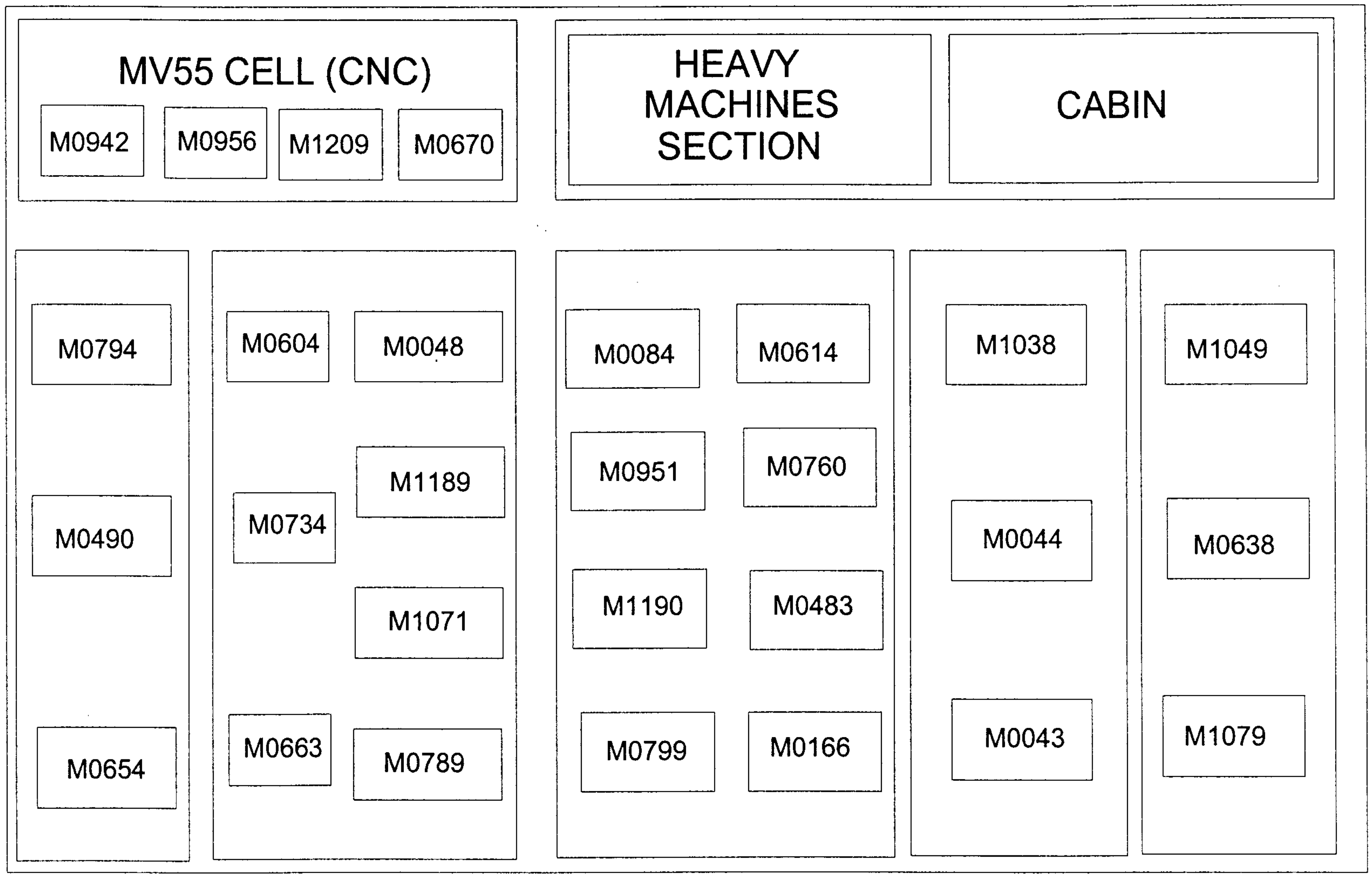

Fig 1. **CUBICAL CELL – HEAVY MACHINES SECTION - LAYOUT**

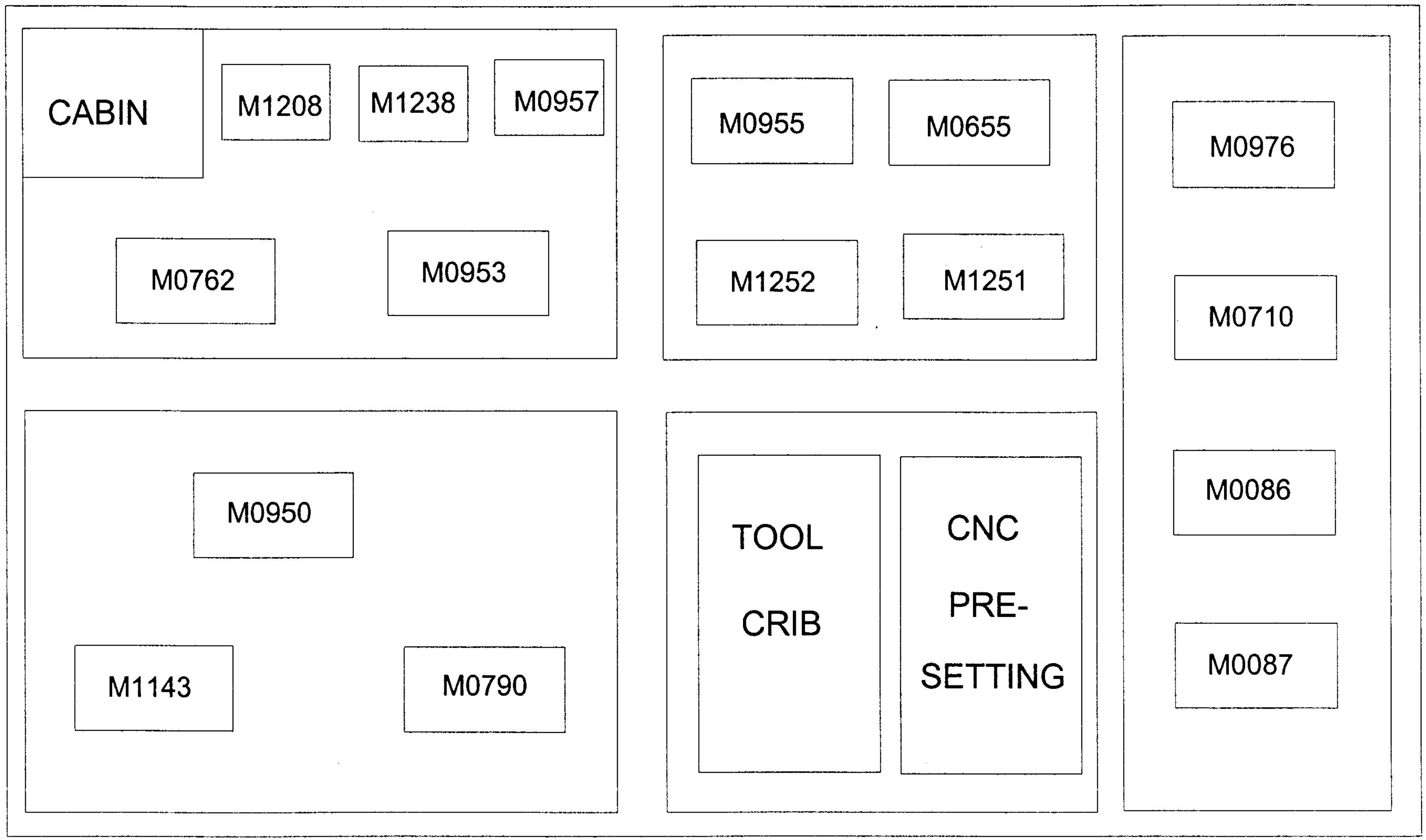

Fig 2. **CUBICAL CELL – CNC MACHINES SECTION - LAYOUT**

3.2 EXISTING SYSTEM OF SCHEDULING:

The world over, the industries are facing recession then and there. The demand for any product is highly fluctuating. However the demands are forecasted with a scientific basis.

Whatsoever be the forecast, the scheduling spread across the year is more dynamic. There are standard scheduling procedures provided the demand is known and constant. The reality is totally different. The number of attempts made in for solving the situations with dynamic nature is very minimal.

At present the scheduling is done according to the daily requirement. Scheduling of components takes place at the time of urgency and the machines are loaded to avoid idleness. Components are loaded when there is urgency. No scheduling system is followed at present. In this case scheduling becomes a problem due to the following reasons.

1. Fluctuation of demand:

When there is a change in the demand, the scheduling needs a thorough change. In this case the components for the machines that are required urgently are being processed. This is done in accordance with the delivery time of those machines.

2. Inclusion of trial and spare orders:

When a new product model is going to be launched, its pilot batch items have to be machined. Those orders must be processed in the shop floor. And, the spares for the textile machinery's are also in request some times. This too should be accommodated. The present system cannot accommodate as and when these orders arrive. Without a change in the schedule these orders cannot be processed. A part of the capacity is left for these orders so that the productivity will not be affected. And if required the machines are made to run for the additional shifts if these orders are not able to meet by the existing system.

3. Shortage of raw materials:

The uncertainty of demand changes and trial and spare orders causes the shortage of raw materials.

4. Breakdown of the machines and labour absenteeism:

Breakdown and the labour absenteeism exist in the entire manufacturing environment. Generally, 15% of the machine capacity are left to compensate these factors. Since the existing system follows urgent scheduling there is no significant effect of this reason over the delivery time.

3.3 PROBLEM DEFINITION:

The focussed area of the project is the cubical cell of LMW. The problems identified in this cell are as follows.

1. Process delay:

Customer's requirement is not met on time. Lead-time of the process is increasing and hence the delay in process takes place. So, the components are not finished in time so that the timely delivery becomes a hectic.

2. Priority:

Since the demand is changing, fixing the priority for the components is a quite tedious task.

3. Low inventory turn over:

There is a standard index for the inventory turn over. If the index is ±100, it is said to be high inventory turn over. Likewise, if the index is ±50, it is medium and it is said to be low inventory turn over when the index is ±30.

Inventory turn over is defined as "the rate of conversion of inventory into sales".

4. High throughput time:

Throughput time is defined as "the time taken for a job between the beginning of its first operation and the time it comes out of the last operation".

This is high for the existing system because of the improper scheduling.

5. Queue:

In all the machines, the jobs are forming a queue that delays the process. The Capacity Constraint Resources (CCR's) are the reason for this.

6. **Heavy inventory of semi finished components** and

7. More bottleneck.

The above mentioned problems are occurring due to the present scheduling system.

3.4 GOAL OF THE PROJECT:

The problems are studied for its causes and its effects are also analysed. The analysis gives a clear identification of what is required for the system. This project mainly aims at two points. They are (1) Monthly scheduling and (2) Load chart.

1. Monthly scheduling:

At present, daily scheduling is followed which is unable to meet the requirements. Hence, preparation of monthly scheduling in accordance with the assembly requirement that serves the purpose is the main objective of this project.

2. Load chart:

In order to visualise the process inside the shop floor, it is necessary to plot the jobs in a chart with respect to their operation sequence. A software package is required to create the load chart because it can incorporate all the changes and in reply it will produce the chart.

3.5 OBJECTIVES OF SCHEDULING:

There are many scheduling objectives. The most important is to increase the utilisation of the resources i.e., to reduce the resource idle time. For a finite set of tasks, the utilisation of resources is inversely proportional to the time required to accomplish all the tasks. This time is referred to as the make span or maximum flow time of the schedule. In a finite problem, the resource utilisation is improved by scheduling the set of tasks so as to reduce the make span.

Another important scheduling objective is to reduce in process inventory i.e., to reduce the average number of tasks waiting in a queue while the resources are busy with another tasks. If the make span of a schedule is constant, the sequence that reduces mean flow time also reduces mean in process inventory.

One final objective for scheduling is to reduce some function of tardiness. In many situations, some or all the tasks have due dates and a penalty is incurred if a task is finished after that date. There are several ways to look at this tardiness objective. One can reduce the maximum tardiness or one can reduce the number of tasks that are tardy.

In simple words, these objectives are expressed as,

a) Achieving high efficiency of operations by using machines optimally.

b) Maintaining low inventories for in process and raw materials.

c) Maintaining short flow time of the product.

The advent of computing using computers has made us to attempt and to resolve the problem using a software package.

4.1 LOADING:

The cubical cell is the focussed area of the study. The details of the machines in that cell are studied very carefully for developing an effective scheduling system. The machine list in this cell is taken and categorised into five groups. The total number of machines in this cell is 44. It is shown in Table 2.

Table No: 2 MACHINE GROUPS

S.No	Machine groups	Number of machines
1	Radial Drilling	9
2	Jig Boring	5
3	Surface Grinding	8
4	Machining Center	10
5	Milling	12

The load for each machine is calculated using the formulae,

Load per machine = (Set up time / Schedule per month) +(Operation time per unit * (NPMr + NPMe / 2)). → (1).
Load per month = Load per machine * number of machines. → (2).

Equation (1) and (2) are used to calculate the load for all the machines for a month based on the forecasted schedule. Sales forecasting is being done for every six months. From this forecast, the schedule will be made for all the products per month. The set up time is fixed and the operation time is known and available.

4.1.1 SAMPLE CALCULATION:

Number of components are processed through all the machines. Load per month of each component is calculated from which load per month of all the machines can be calculated. The sample calculation for the component number 4 is explained here.

The component's name is Bevel gear support. It has two operations namely bottom mill straightness and machining in the machines 41 and 33 respectively. In machine number 41 the set up time is 0.830 and the operation time is 19.4 for hundred pieces of the component and it is 1.49 and 40.2 for the same in machine number 33. This component is a part of LC 1/3 product. The schedule per month for this product is 10 (from sales forecast). NPMr is 1.

So, Load per month is calculated as follows:

Machine 41:

Load per machine = (0.830 / 10) + ((19.4/100) * 1) = 0.277.

Load per month = 0.277 * 9

= **2.493 hours.**

Machine 33:

Load per machine = (1.49 / 10) + ((40.2/100) * 1) = 0.551.

Load per month = 0.551 * 9

= **4.959 hours.**

The load per month for the two operations of the selected component is calculated. This value becomes the load for the respective machines in which the component is processed. Likewise the load per month is calculated for all the components. And the load details of all the machines are also calculated with the help of those values.

Each product of LMW consists of approximately 2000 components. Out of these, some components are given for sub-contract work and the remaining are manufactured inside the shop floor except the bought out items. The requirement for a particular model of a product may vary from customer to customer i.e., the accessories of the textile machine are manufactured according to the requirement.

NPMr denotes the Number Per Machine-regular i.e., the number of same component required for the production of a single product that is regular for the model and **NPMe** denotes the Number Per Machine-eventual i.e., the number of parts required for a specific customer. This will vary according to the requirement of individual customer but NPMr is fixed for a product. With the help of the available details load per machine is calculated which in turn used to calculate the load per month. The list of machines with their capacities and the load per month are shown in Table 3.

From the calculated load details, the machines are analysed for over load and under load.

The load, which goes beyond the machine capacity, is called over load and those machines are called over loaded machines. The load for a machine, which lies than its capacity, is called under load condition.

These load details are shown in figure 3. As stated already, the machines are clubbed according to its category and the total utilisation for all the groups are calculated. Also the load details of various groups are shown in figures 4,5,6,7 and 8.

While calculating the capacity of a machine, 200 hours is considered per shift i.e., 25 days a month and 8 hours/shift. If a machine runs for 2 shifts, its capacity is taken as 400 hours and for 3 shifts it is 600 hours.

Table No: 3 MACHINE LIST WITH CAPACITY AND LOAD DETAILS.

S.No	Machine Number	Machine Capacity(hours)	Load per Month
1	23609	400	16.94
2	23611	400	173.82
3	24001	400	138.81
4	24002	400	893.27
5	24006	400	318.15
6	26002	400	331.13
7	26009	400	261.23
8	26101	400	272.36
9	26102	400	427.59
10	26103	400	205.34
11	26301	400	252.0
12	26302	400	209.92
13	26402	400	454.92
14	26403	400	443.3
15	26404	400	190.47
16	26406	400	287.01
17	26407	400	442.18
18	26409	400	309.61
19	26501	**600**	754.71
20	26503	400	64.68
21	26504	400	230.38
22	26505	400	397.52
23	26705	400	241.08
24	26711	400	407.22
25	26712	400	264.44
26	26806	400	101.71
27	26807	400	547.47
28	26810	400	472.33
29	37102	**600**	617.49
30	37105	**600**	485.54
31	37110	**600**	117.63
32	37201	**600**	544.17
33	37202	**600**	545.9
34	37203	**600**	78.75
35	37301	400	352.98
36	37401	400	92.03
37	37602	400	455.85
38	37603	400	254.63
39	37604	400	278.92
40	38811	**600**	454.59
41	38812	**600**	655.05
42	38814	400	459.5
43	38815	400	91.65
44	38822	400	515.2

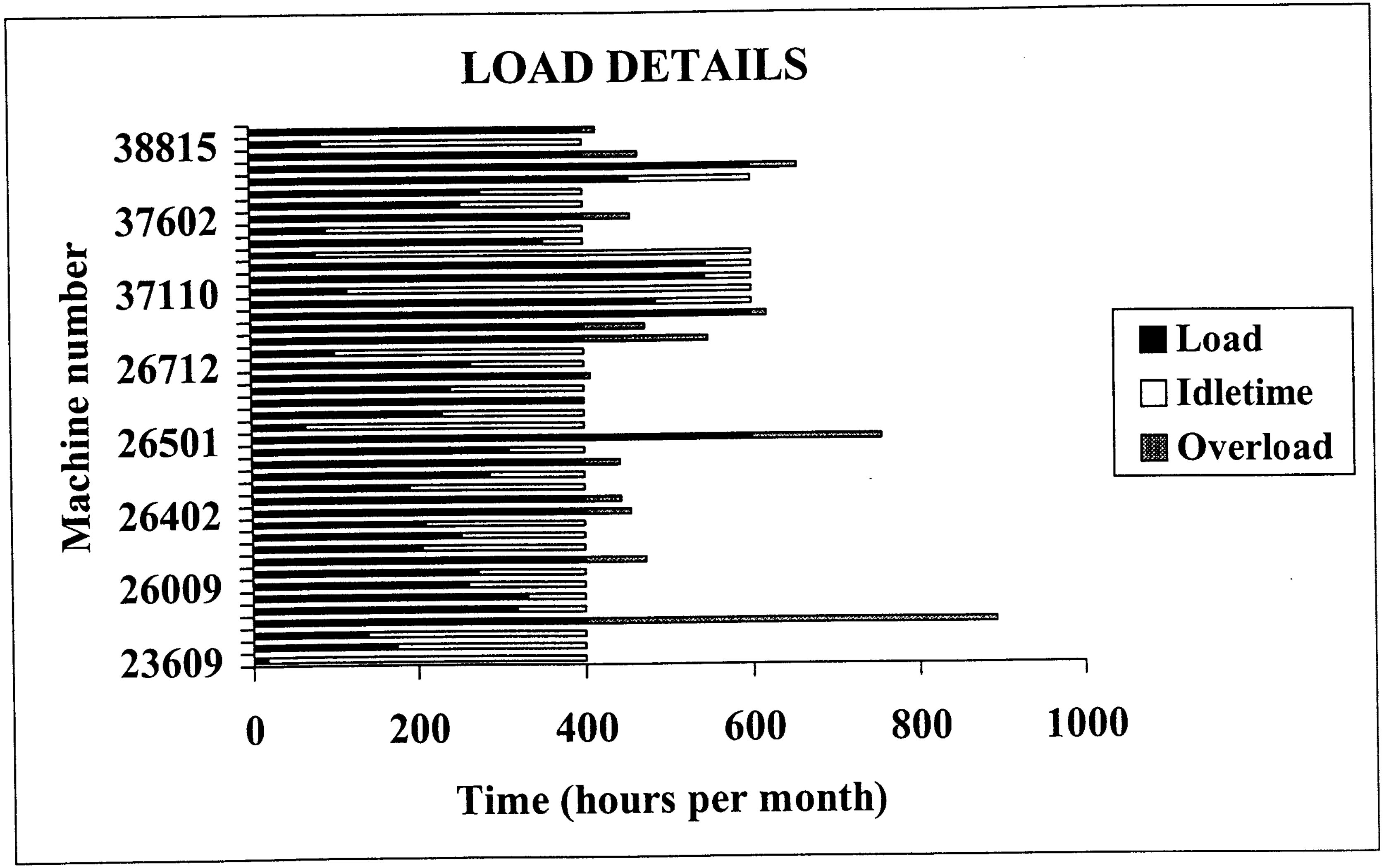

Fig 3. CUBICAL CELL - LOAD ANALYSIS

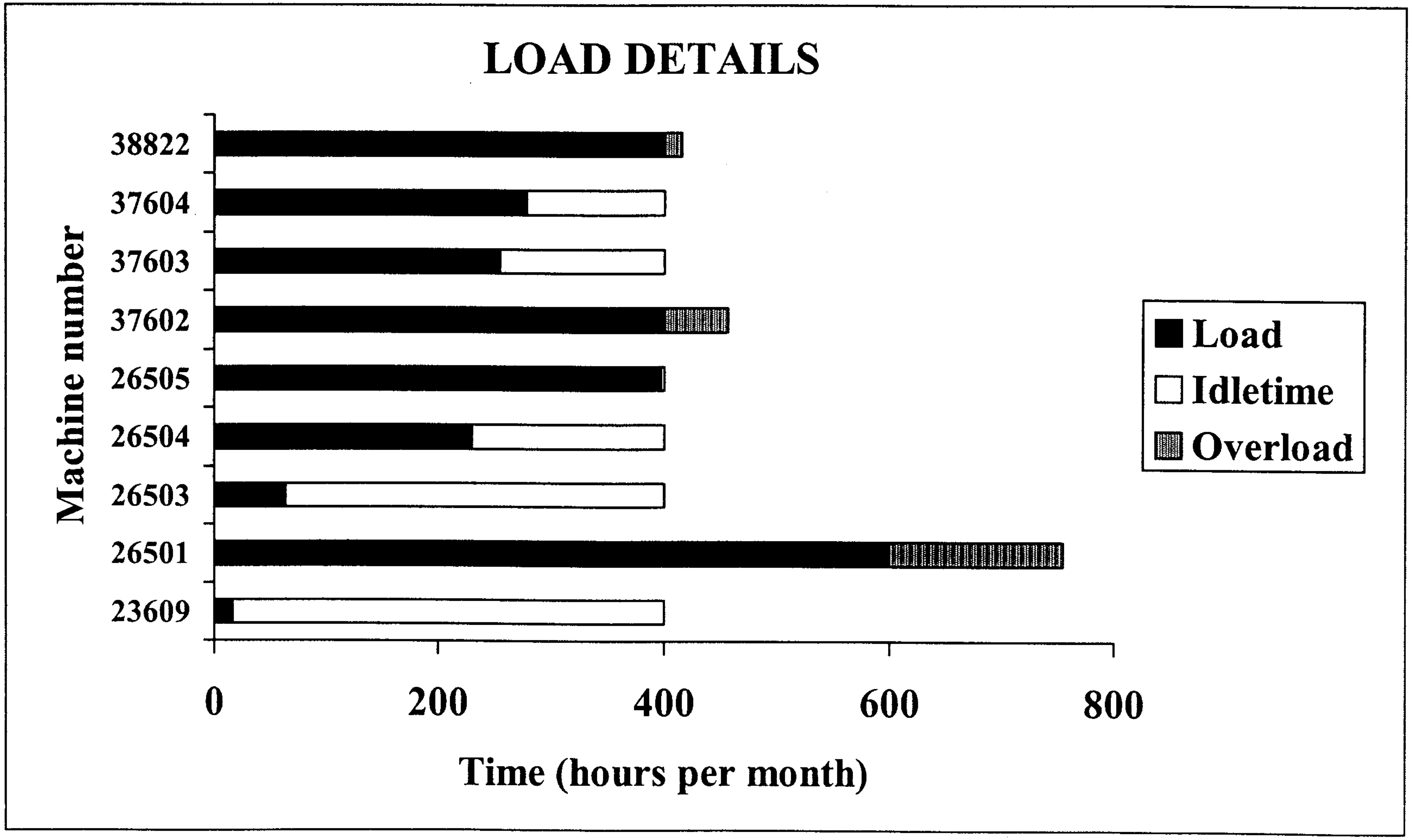

Fig 4. RADIAL DRILLING - LOAD ANALYSIS

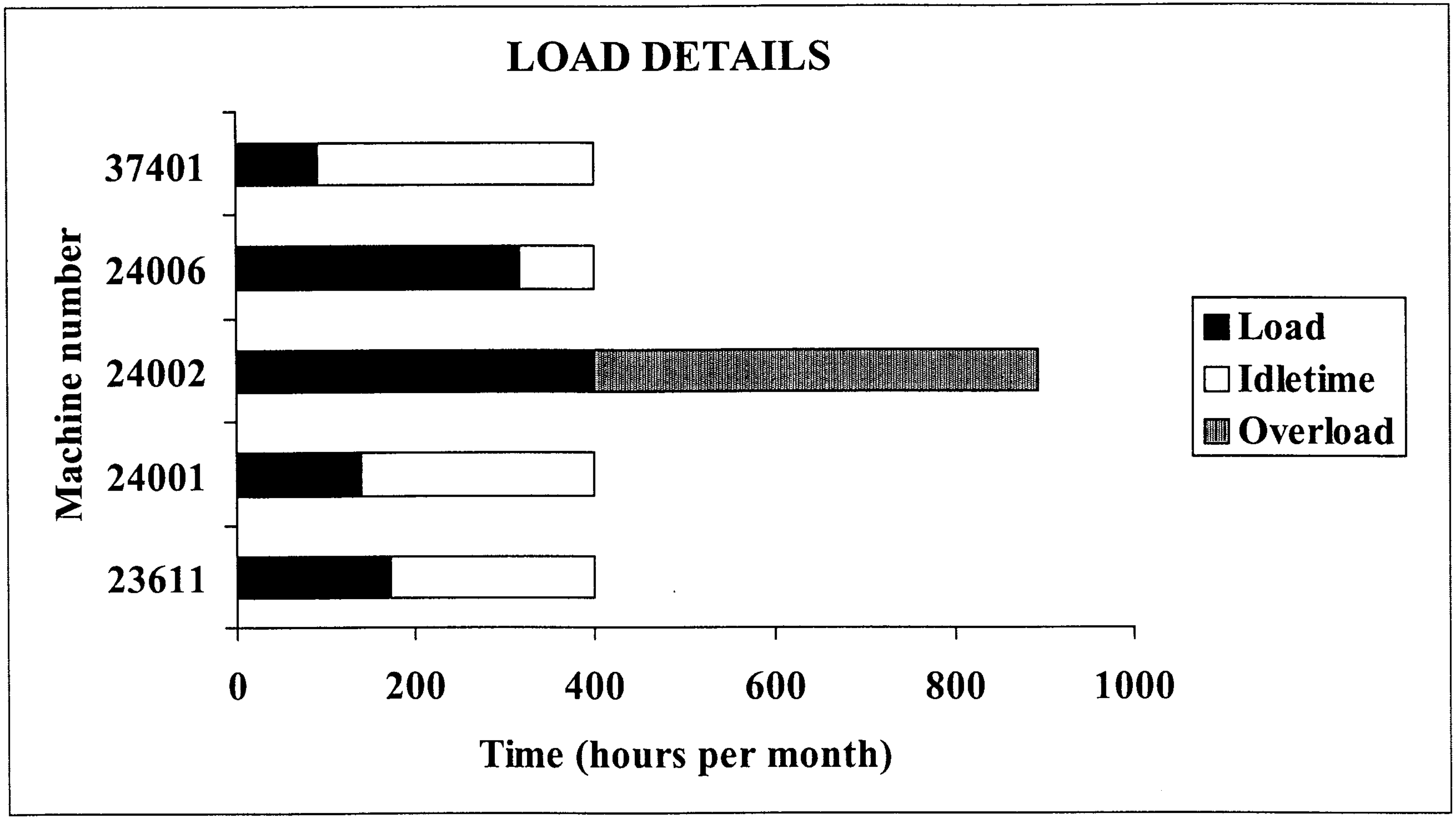

Fig 5. JIG BORING - LOAD ANALYSIS

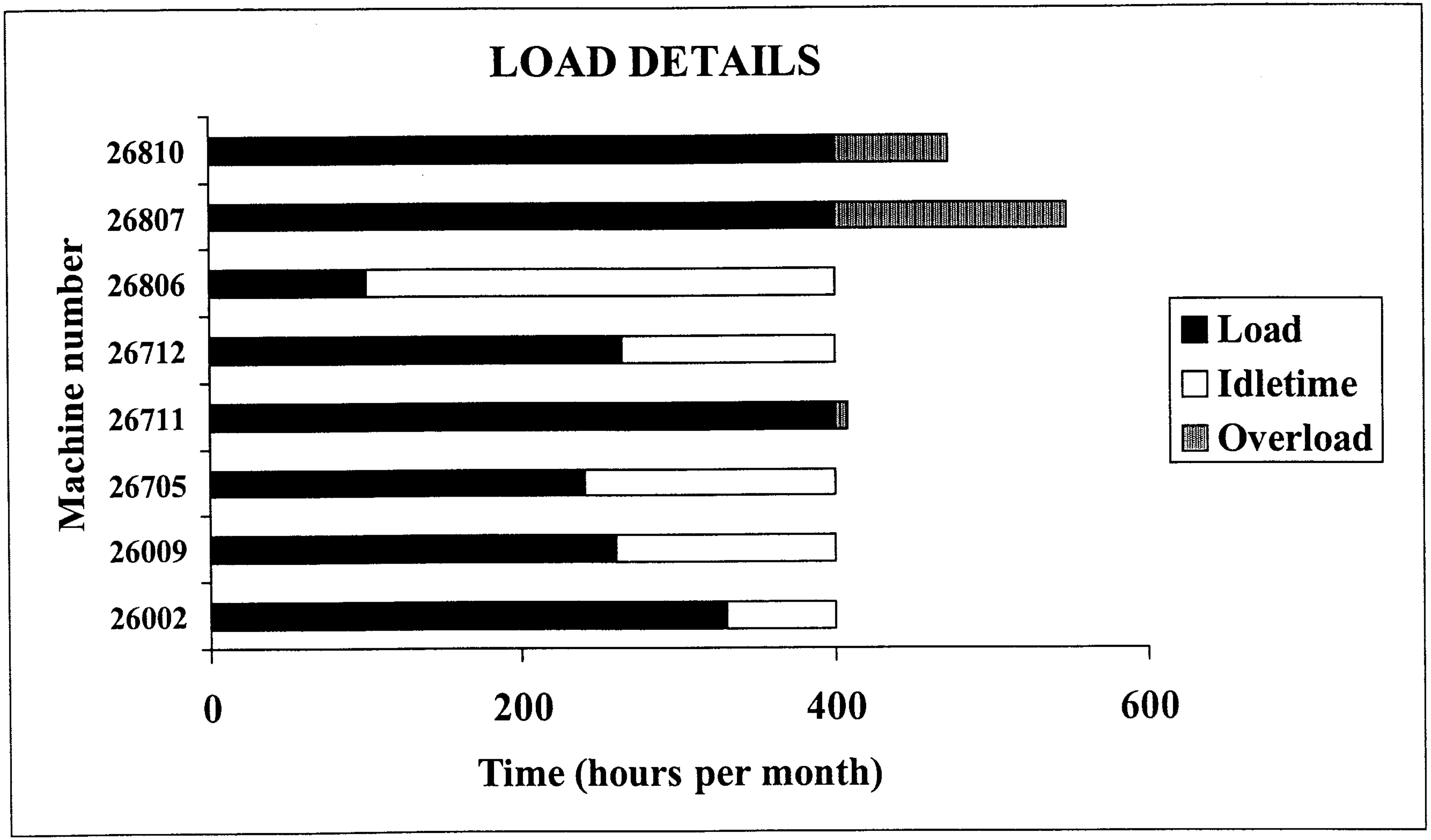

Fig 6. SURFACE GRINDING - LOAD ANALYSIS

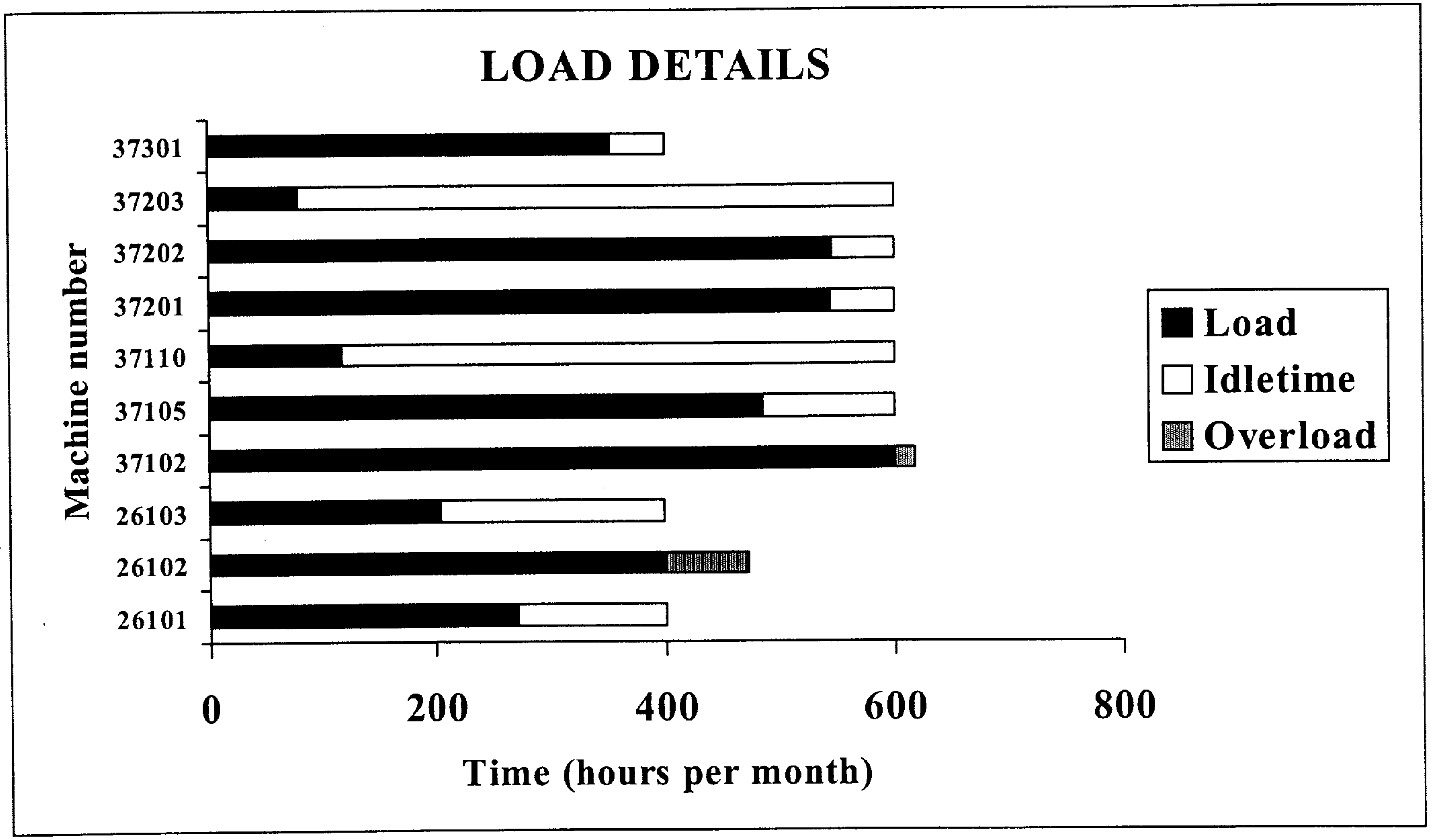

Fig 7. MACHINING CENTER-LOAD ANALYSIS

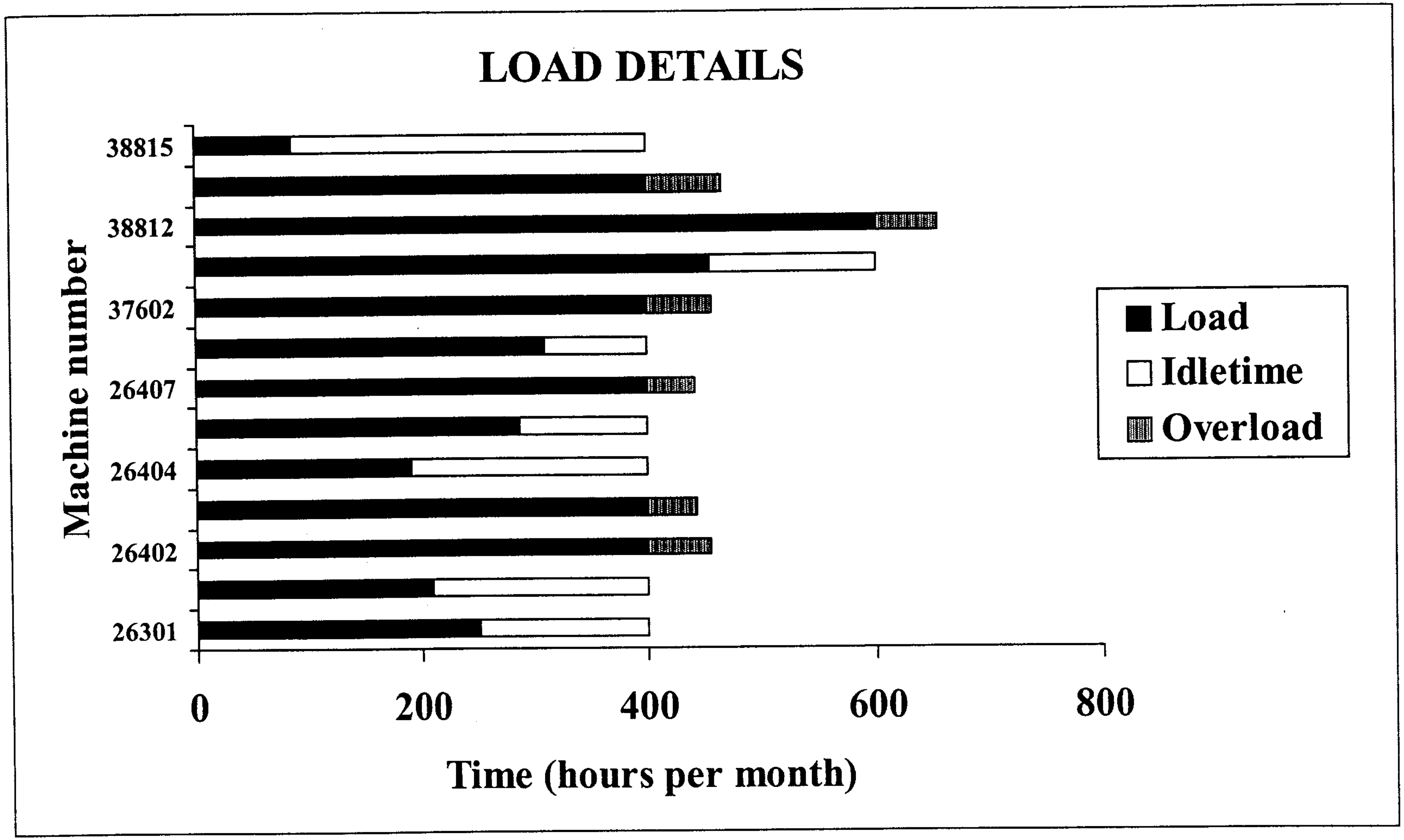

Fig 8. MILLING - LOAD ANALYSIS

The percentage utilisation of all the groups are calculated using the formula,

Percentage utilisation = Sum of load of all machines in that group / Sum of capacities of all the machines in that group.

It is given in Table 4. The same is depicted in the figure 9 for better visualisation.

Table No: 4 PERCENTAGE UTILISATION OF GROUPS

S.No	Machine Group	Capacity	Load	% Utilisation
1	Radial Drilling	3800	2968.33	78.13
2	Jig Boring	2000	1616.08	80.80
3	Surface Grinding	3200	2626.63	82.08
4	Machining Center	5200	3647.35	70.15
5	Milling	5200	4280.20	82.31

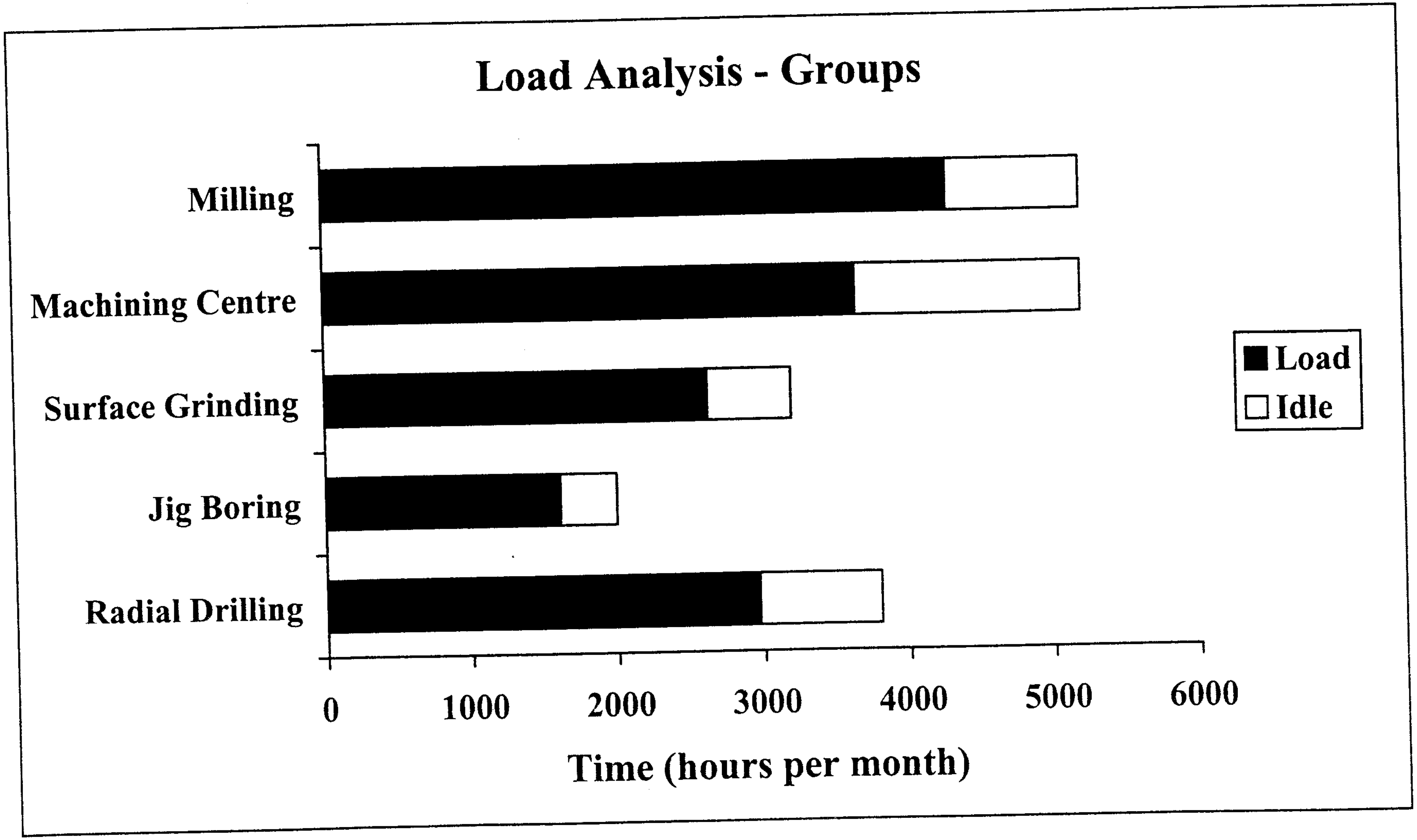

Fig 9. UTILIZATION - A GRAPHICAL VIEW

4.2 SCHEDULING:

The components in the cubical for which the scheduling is to be done is listed. It is shown in Table 5. The processing time of each operation of all the components are taken from the time study department.

Manual scheduling is in force. The following assumptions are made for the existing conditions of the system to carry out this scheduling.

4.2.1 ASSUMPTIONS:

1. Each job is an entity:

Although the job is composed of distinct operations, no two operations of the same job may be processed simultaneously.

2. No pre-emption:

Each operation once started must be completed before another operation may be started on that machine.

3. No cancellation:

Each job must be processed to completion.

4. Each set up time is sequence dependent:

The time taken to adjust a machine for a job is independent of the job last processed.

5. Time to move jobs between machines are taken into account i.e., at least two hour gap is given in between two operations to allow inspection and closing and material handling.

6. In process inventory:

Jobs may wait for their next machine is free. This is not a trivial assumption. For some components, the processing will be continuous from operation to operation.

7. These may be more than one of each type of machine:

For some machines, the alternative machines are available for processing the jobs. In this case, bottleneck is avoided. But the machines, which don't have alternatives, can not be duplicated.

8. No machine may process more than one operation at a time.

9. Machines may be idle:

While placing the jobs in the machines, idle time may take place. This can not be avoided.

10. There is no randomness. In particular,

(i) The number of machines is known and fixed.

(ii) The processing times are known and fixed.

(iii) All other quantities needed to define a particular problem are known.

These are the assumptions made for the scheduling of cubical cell machines and no relaxation is allowed from this.

22	502198080
23	502198240
24	502199720

67	504491822
68	504492140
69	504499960

112	542192620
113	542192640
114	542192720

4.2.2 HEURISTIC ALGORITHM:

The shop supervisor or scheduler can deal with sequencing problems in a variety of ways. The simplest approach is to ignore the problem and accomplish the tasks in any random order. The most frequently used approach is to schedule heuristically according to the predetermined "rules of thumb".

Heuristic algorithm is defined as the sequence of scheduling steps, usually iterative in nature that will allow a schedule to approach optimality but will not guarantee an optimal solution.

In other words, Heuristic is a problem solving procedure or rule of thumb that has been shown to produce good results but can not guarantee optimal results [5].

For our case, a heuristic algorithm has been developed. The major steps are as follows.

1. List out the components.

2. List the operation numbers along with its machines and the operation time for the components in order.

3. Locate the components in the respective machines according to their operation sequence.

4. Give at least two hours in between the successive operations for all the components.

5. Longest Processing Time (LPT) rule is applied wherever required i.e., for the components, which have the same operation sequence.

6. Alternate machines are preferred when
   a) A machine is loaded beyond its capacity.
   b) A machine is not available for a component at any particular time.

7. Check for all the components to see whether all the operations have been performed in sequence or not.

8. Display the load chart for all the machines.

The scheduling process starts from the first operation of the first component. The component will be placed in the specified machine. The second operation of the same component takes place in another machine in which the component is placed such that the starting time of the component in the second machine is at least two hours later than the completion time at the first machine. It is followed for all the operations.

The scheduling process continues in the similar fashion as the first component gets processed in the cell. When the specified machine is not available at any time the components are processed in the alternative machines. It is also followed when a machine is in over load condition. Alternate machine list of cubical cell machines is shown in Table 6.

Based on the above mentioned steps scheduling has been done in the cubical cell. Manual scheduling for that cell is shown in Appendix A.

Table No: 6 ALTERNATE MACHINE LIST (CUBICAL CELL)

<table>
<tr><th>MACHINES</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th></tr>
<tr><td>RADIAL DRILLING</td><td></td><td></td><td></td><td>23609
26501
26503</td><td>26504
26505
37602</td><td>37603
37604
38822</td><td></td><td></td><td></td><td>-</td><td>-</td></tr>
<tr><td>JIG BORING</td><td>23611</td><td colspan="4">24001
24002
37401</td><td>24006</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>MILLING</td><td colspan="2">26301
26302</td><td>26402</td><td colspan="2">26403
26404</td><td>26406</td><td>26409</td><td colspan="2">38811
38812</td><td colspan="2">38814
38815</td></tr>
<tr><td>MACHINING CENTER</td><td colspan="2">26101
26103</td><td>26102</td><td>26407</td><td colspan="2">37102
37110</td><td>37105</td><td colspan="2">37202
37203</td><td>37201</td><td>37301</td></tr>
<tr><td>SURFACE GRINDING</td><td>26009</td><td colspan="3">26002
26705
26712</td><td colspan="2">26711
26807</td><td>26806</td><td>26810</td><td>-</td><td>-</td><td>-</td></tr>
</table>

4.2.2.1 Sample Scheduling:

Machine Number

Component Number	**24006**	**26711**	**37110**	**37604**	**38814**
502180320	7.78 / 2 (5.7 – 9.48)	0	0	2.07 / 3 (11.5 – 13.57)	3.6 / 1 (0 – 3.6)
502195321	0	27.44 / 1 (0 – 27.44)	42.15 / 2 (30 – 72.15)	0	0

The sample shows the scheduling of two components of the cubical cell in their respective machines. Operation time and the number of operation are represented for each component and the time in which this component is undergoing the process in the respective machine is also shown. Between two successive operation of all components minimum of two hour is given for the following reasons.

1. Inspection and closing
   a) Visual Inspection
   b) Random inspection
   c) Quantity checking
   d) Pad closing

2. Material handling

Once the operation is completed in a machine, the component can not be placed in the next machine for operation. It has to undergo a process before being processed in the next machine.

After the operation gets completed, the component is visually inspected for the damages which may takes place while processing. It is followed by the random inspection in which the quality of the component is checked i.e., whether the component is with in the tolerance limit or not. Then the quantity of the batch is verified. Finally, the pad is closed which is the authorised report to proceed further.

At the end of the above said process, the jobs are placed at the exit bins from where they have to be moved to their work centers. Here, the material handling equipment should be available in time. The commonly used material handling equipments are forklift, crane, pallet trucks and battery operated vehicles. Cranes are used to move the jobs inside the shop floor. It 's capacity ranging from 210 – 310 tons. Battery operated vehicles are used to carry light loads. Shop to shop transport is done with the help of forklift. Since the cubical cell's shop floor is divided into two areas all types of material handling equipments are required. The availability of the material handling devices can not be predetermined.

4.2.3 FLOW CHART:

In order to understand the process of scheduling in a better way, the flow of the process is represented in a chart form and it will be helpful for computerising the scheduling problem. The flow chart for the scheduling of cubical cell components is shown in figure 10.

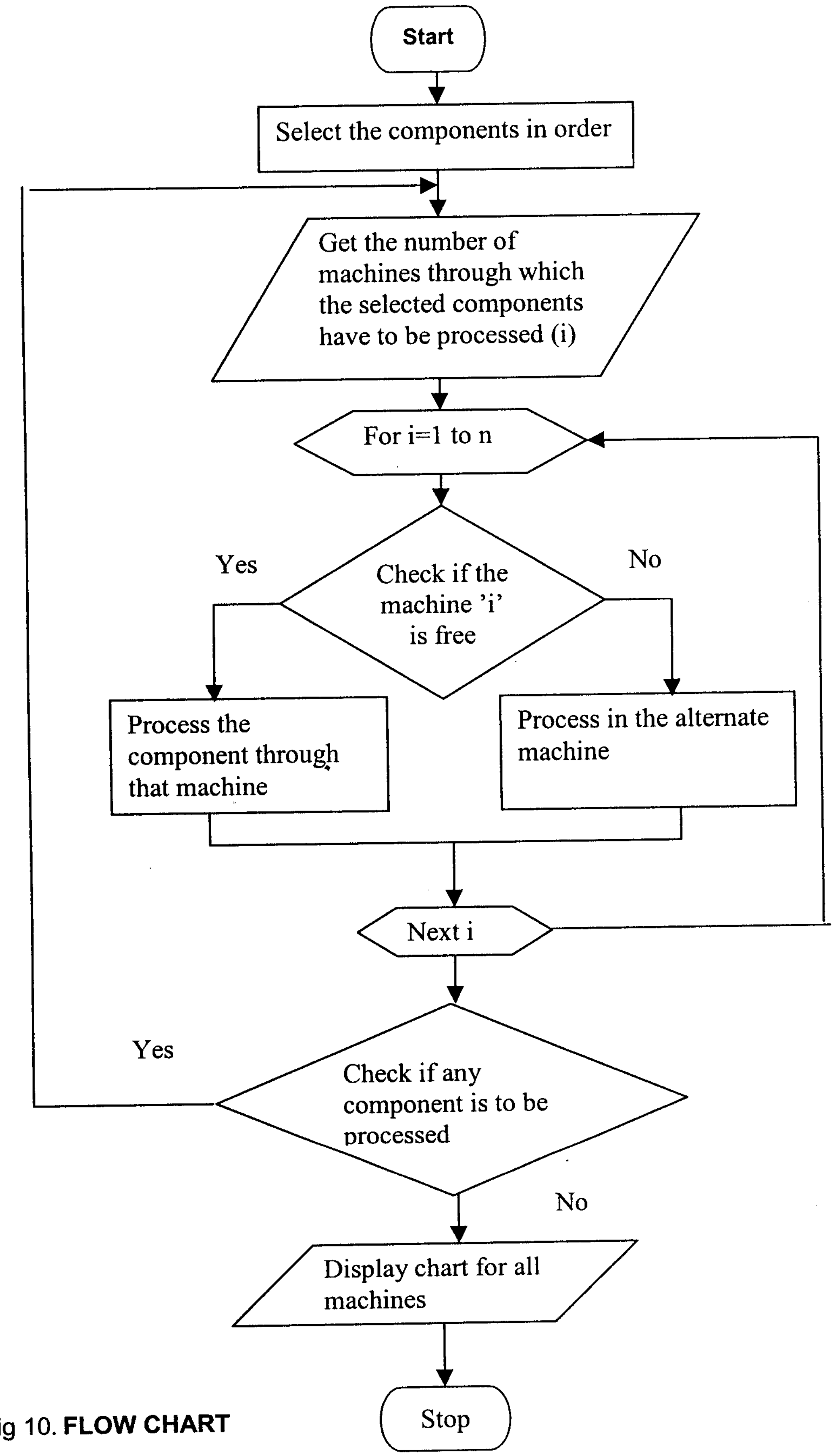

Fig 10. **FLOW CHART**

5.1 INTRODUCTION:

Manual scheduling becomes a tedious process when there is any change in the system in the process. Hence computerisation is necessary to do scheduling in a simple way. A software package is proposed, developed to resolve the problem.

Visual Basic 6.0 is used as a front end and Microsoft Access 97 as a back end tool.

5.1.1 FEATURES OF VISUAL BASIC:

Visual Basic is a tool of choice when programming in windows. There are few programs that take Visual Basic into areas that we may not have thought possible. The salient features are as follows. Visual refers to the method used to create the graphical user interface. Rather than writing numerous lines of code to describe the appearance and location of interface elements, pre-built objects are simply added into place on screen.

1. It is a very user-friendly GUI (Graphic User Interface) language.

The tray icon property holds the icon that will be displayed in the system tray. It holds a string of text that will be displayed above the icon in the tool bar, when the mouse pointer hovers over the icon for about a second or so.

2. Building screen savers.

This constitutes of creating the display portion, declaring module level variables, displaying the form in full screen mode, Adding a configuration form, Adjusting the program's properties and adding a module and a sub routine.

3. Creating forms dynamically.

The most fundamental object in a visual basic program is the form collection. This object contains one property count and one method item.
To demonstrate the techniques for using the form collection and creating forms dynamically, this program performs three basic tasks namely,

a) Create new forms.
b) List all the forms in the application.
c) Delete all the newly created forms.

4. It is easy to connect with MS office application.

The final requirement is the chart that is displayed in the MS Excel form. By adding a command button to the form with events this can be done.

5. Easy for coding.

6. Easy file accessibility.

7. Event driven programming.

When programming in Visual Basic the application developer must decide how the application interacts with the user. The user may click a mouse on various controls, or press a key or key combination on the user interface. These are known as events. The application developer must decide how the application must react to each of the user actions. This is called event driven programming.

8. Microsoft Developer network (MSDN) is used for online help facility.

9. Interactive Help Features like Auto List Members and Auto Quick Info that no longer wait for the user to interact ant interface.

5.2 DATABASE DESIGN:

A database is a repository of collections of related data or facts. It arranges them in a specific structure. Data in a database is most commonly viewed in one or more two-dimensional tables, each consisting of columns and rows. The entire collection of related data in one table is referred to as a file or **Table**. Each row in a table represents a **Record**, which is a set of data for each database entry. Each table column represents a **Field**, which groups each piece or item of data among the records into specific categories or types of data.

The data are stored in the back end i.e., MS Access 97. MS Access is very easy to use. It costs less because it is coming along with windows.

Three tables were created namely,

(i) Component header table,

(ii) Component table and

(iii) Machine table.

The component number is a nine-digit number. So, it is not advisable to specify as it is in all the places. Hence a component identification code is given for the components for easy accessing. This is stored in component header table.

In components table, for each component according the operation sequence the components are listed along with their operation time, process description and the machine number.

In machine table, the machine numbers are listed along with their capacity and the machine description.

5.2.1 DATABASE STRUCTURE:

Based on the conceptual structures, the databases can be classified as follows:

1. Flat – File database.
2. **Relational database.**
3. Hierarchical database.
4. Network database.
5. Object-Oriented database.

The relational database structure is the most prevalent database. A relational structure represents a database made up of a set of related tables. In this project work, relational type of database is used. In a relational database, one or more common fields existing in two or more tables create a relationship between these tables. The common field or fields are called the keys.

Various fields are created in each of the tables along with their data type. This is helpful in fetching all the details of the process. Database structure of the tables is shown in the Tables 7, 8 and 9.

Table No: 7 DATABASE STRUCTURE – COMPONENT HEADER TABLE

S.No	Field Name	Data Type	Description
1	Comp_icode	Number	To identify and access the component easily
2	Comp_no	Text	Component number is in Alphanumerical form

Table No: 8 DATABASE STRUCTURE – COMPONENTS TABLE

S.No	Field Name	Data Type	Description
1	Comp_icode (Primary key)	AutoNumber	Component number from table 7 is linked with this table through this field.
2	Comp_mac_icode (Foreign Key)	Number	This field is used to link with the machine details in table 9.
3	Comp_hicode	Number	Operation sequence of components.
4	Comp_time	Number	Processing time of each operation.
5	Comp_proc_desc	Memo	Name and details of the process.

A primary key is a key that uniquely identifies a record in a database table. In relational databases, a primary key can consist of one or more fields. For instance, in table 8, Comp_icode is a primary key, since it uniquely identifies the component number.

Table No: 9 DATABASE STRUCTURE – MACHINE TABLE

S.No	Field Name	Data Type	Description
1	Mac_icode	AutoNumber	Machine Number is accessed through this field.
2	Mac_no	Number	Machine Number is stored in this field.
3	Mac_capacity	Number	Capacities of the machines are stored.
4	Mac_desc	Memo	Name and Details of the machines.

5.3 MODE OF ACCESSION:

The details about all the processes of the components have to be displayed when required. They are stored in three different tables, which are linked to retrieve for further processing. The method of linking is shown in figure 11.

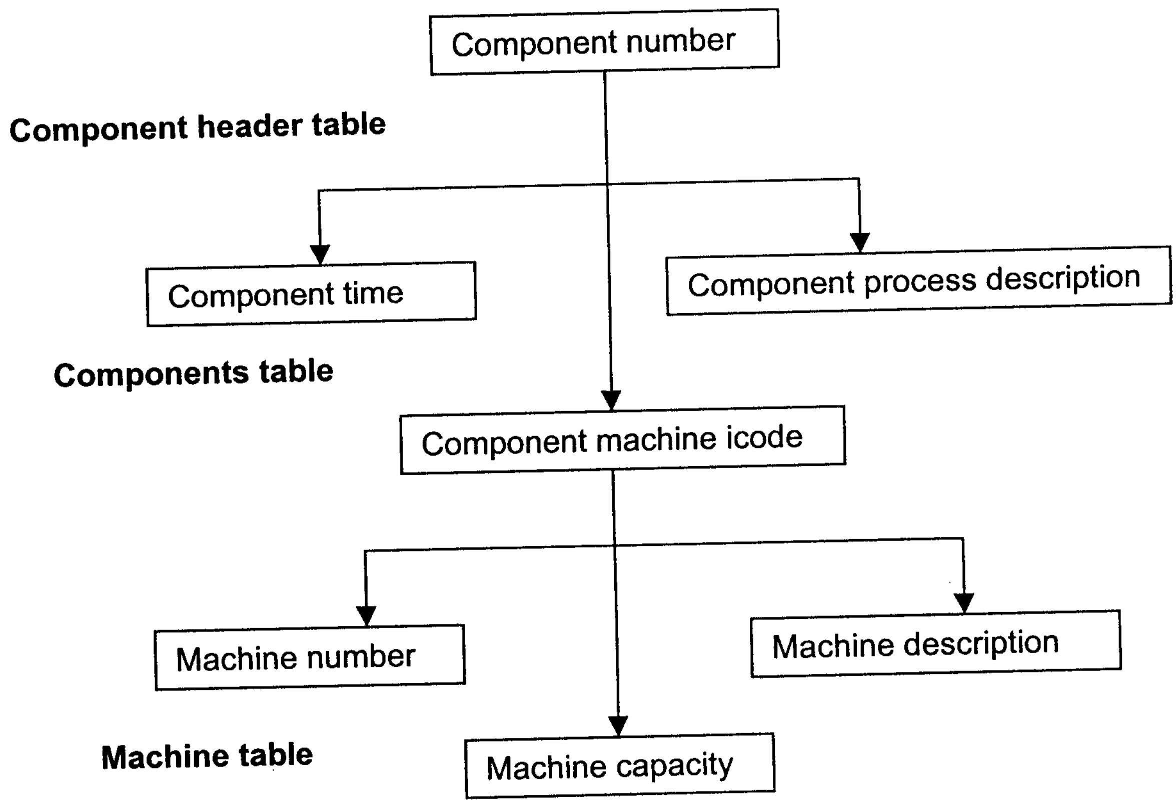

Fig 11. **METHOD OF DISPLAYING THE DATA FROM THE DATABASE**

The Comp_icode field from the components table get the component number from the component header table. This acts as a primary key and fetches the component time and the process details. The Comp_mac_icode acts as a foreign key in the components table. This is used to track the required details such as machine number, machine capacity and machine description from the machine table.

The load chart i.e., the final output is displayed in the Visual Basic by interfacing with the Microsoft Excel. This enables us to visualise the sequence of components that are passing through each machine.

The developed software package will display the load chart for the cubical cell machines. The process details of all the components are accessed from the records of MS Access and displayed in order, which enables the user to know the process sequence of all the components. This can be seen at the front end i.e., Visual Basic.

The load chart is displayed for all the 44 machines shown in Appendix B - figure 1and the same is displayed for all the groups such as Radial drilling, Jig boring, Surface grinding, Machining center and Milling separately shown in Appendix B - figures 2, 3, 4, 5 and 6.

The shop supervisor is aided now with the utilisation and the idle time of all the machines. In the analysis it is found that the trial orders and spare orders can be carried out in the idle time available in the load chart.

The software package is developed keeping in mind the scheduler's day-to-day problems in the textile machinery manufacturing industry. This software package is of immense benefit to the end user to track jobs in the system and to visualise the scheduling problem in a better way. This software generates the charts, which provides information about the idle time or the utilised capacity of the machineries. This aspect enables the scheduler to engage the trial orders and the fluctuation of demand.

The software has been prepared after thorough analysis of existing manual scheduling process. The heuristic procedure has been made on certain assumptions, which were listed based on the interaction with the employees of the cubical cell. The output of the software algorithm is a machine-loading chart for the various categories of the machines of the cubical cell. The machine-loading chart enables the end user to better visualise the scheduling of jobs and make proper use of unutilised machining resources.

The databases are designed by using MS Access database software. The data items themselves act as pointers to get the final chart form from the software. However, the final chart of machine loading and scheduling of machines could be optimised if we establish an objective function using processing times.

Scope for further research:

The optimized scheduling meeting the fluctuation of demand can be taken as a further improvement on the work done in this thesis work. The company does not find any difficulty in accompanying the trial orders and the fluctuating demand of the products. However, the future requirements may be different in the company where the trial orders may not be simply accommodated. Further research can be done in this direction and the company plans for optimised scheduling. The final form of the output can be very well designed as the output is now interfaced with MS Excel software. The software may be made for multi user so that every one associated with scheduling could access the information.

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1.David Randhir Rao, D.R.Yadav and I.K.Kaul, *Computer aided Jobshop scheduling*, Proceedings of *The Second National Conference on CAD/CAM*, PSG College of Technology, Coimbatore, 1994.

MANUAL SCHEDULING

23609	COMP-LEFT	504799961/3	511190060/3	511190080/3
	125	6.75	1.22	1.22
	125	131.75	132.97	134.19

23611

24001	COMP-LEFT	503095520/2	COMP-LEFT	511190152/3	511190154/3
	16	1.62	3	2.64	3.36
	16	17.62	20.62	23.26	26.62

24002	COMP-LEFT	504472020/2	COMP-LEFT	504741461/3
	48	9.2	3.25	2.5
	48	57.2	60.45	62.95

24006	COMP-LEFT	502180320/2	502180340/2	COMP-LEFT	502197360/2	503095520/3	COMP-LEFT	504243741/2	504243761/2	COMP-LEFT	542193060/4
	5.7	3.78	3.78	1.45	6.12	2.16	17.85	3.04	3.04	185.35	27.7
	5.7	9.48	13.26	14.71	20.83	22.99	40.84	43.88	46.92	232.27	259.97

26002	503095283/1	503095284/1	503095285/1	504290923/1	504290943/1	504490989/1	504491483/1	504491523/1	503094840/2	505199380/1	505199720/1
	6.12	6.12	6.12	9.2	9.2	13.12	6.56	6.56	6.84	39.36	39.36
	6.12	12.24	18.36	27.56	36.76	49.88	56.44	63	69.84	109.2	148.56

5E0390080/1
22.95
171.51

26009	COMP-LEFT	502197060/6
	107	14.54
	107	121.54

26101	COMP-LEFT	504791260/2	504791340/2	505199380/2
	25	101.75	61.75	40.56
	25	126.75	188.5	229.06

26102	COMP-LEFT	504290923/2	504290943/2	503094580/4	503095440/2	504491483/2	504491523/2	503095283/3	503095284/3	503095285/3	COMP-LEFT
	30	10.8	11.04	30.15	16.02	10.8	10.56	9.18	10.44	9.18	42.75
	30	40.8	51.84	81.99	98.01	108.81	119.37	128.55	138.99	148.17	190.92

5E0390080/3	505199720/3
35.1	27.6
226.02	253.62

26103	502196841/1	503094680/2	COMP-LEFT	5E0390120/2	505199720/2
	51.46	28.08	47	40.8	46.8
	51.46	79.54	126.54	167.34	214.14

26301	503094840/1	503094740/1	504499960/1	504499981/1	COMP-LEFT	502198080/2	COMP-LEFT	503094740/3	503094840/3	COMP-LEFT	504491125/2
	6.57	4.86	11.28	23.84	22.85	5.67	2.25	4.86	6.48	21.15	1.68
	6.57	11.43	22.71	46.55	69.4	75.07	77.32	82.18	88.66	109.81	111.49

COMP-LEFT	505199320/2
15.28	4.56
126.77	131.33

26302	511190152/1	511190154/1	COMP-LEFT	503094580/2	COMP-LEFT	502197921/2	COMP-LEFT	502197663/2	COMP-LEFT	504499981/4	505199740/2
	1.72	1.72	11.1	12.24	14.65	10.8	3	12.6	16	19.04	56.4
	1.72	3.44	14.54	26.78	41.43	52.23	55.23	67.83	83.83	102.87	159.27

COMP-LEFT	542191560/2	COMP-LEFT	542191580/2
11	43.37	13.75	39.2
170.27	213.64	227.39	266.59

26402	502196820/1	511190153/1	511190155/1	511190152/2	511190154/2	COMP-LEFT	503094580/3	504499960/2	COMP-LEFT	504499981/2	COMP-LEFT
	13.51	2	2	1.18	1.18	9	16.47	2.72	0.5	4.72	5.5
	13.51	15.51	17.51	18.69	19.87	28.87	45.34	48.06	48.56	53.28	58.78

502197921/3	502196820/4	502197663/3	502198080/3	505187760/3	503094740/4	503094780/4	503094840/4	COMP-LEFT	5E0390080/2	COMP-LEFT
3.15	13.51	3.15	5.22	5.28	3.42	4.14	4.32	72.5	15.45	26.75
61.93	75.44	78.59	83.81	89.09	92.51	96.65	100.97	173.47	188.92	215.67

542191560/3 COMP-LEFT 542191580/3
9.5 41.5 9.6
225.17 266.67 276.27

26403 503094780/1 COMP-LEFT 504491622/2 502197980/2 COMP-LEFT 502197060/2 504292140/2 504292220/3 504492140/2 504299980/2 505187760/2
5.67 11 2.64 7.11 1.55 11.93 2.8 2.56 2.8 8 6.48
5.67 16.67 19.31 26.42 27.97 39.9 42.7 45.26 48.06 56.06 62.54

COMP-LEFT 503094780/3
21.5 4.86
84.04 88.9

26404 504491622/1 COMP-LEFT 502197940/2
14.24 47.5 4.14
14.24 61.74 65.88

26406 505187760/1 504292140/1 504492140/1 503095283/2 503095284/2 503095285/2 504491622/3 502197060/3 COMP-LEFT 502197940/3
15.36 3.6 3.6 3.96 3.96 3.96 8.16 6.45 18.85 5.49
15.36 18.96 22.56 26.52 30.48 34.44 42.6 49.05 67.9 73.39

26407 504791260/1 502196820/2 COMP-LEFT 504490989/2 504499960/3 504499981/3 COMP-LEFT 505199740/3 5E0390120/3
22.25 8.22 21.5 10 6.4 13.52 79.5 25.92 14.1
22.25 30.47 51.97 61.97 68.37 81.89 161.39 187.31 201.41

26409 502197060/1 504292220/2 502197980/3 504292240/2 COMP-LEFT 502197060/4 505191480/2
25.97 4 8.01 4 9.1 22.89 8.64
25.97 29.97 37.98 41.98 51.08 73.97 82.61

26501 COMP-LEFT 504290923/3 504292140/3 504290943/3 504292240/3 504299980/3 504471382/2 504491622/4 504492140/3 505191480/3 COMP-LEFT
43 7.92 2.88 5.52 15.52 5.12 1.68 3.6 2.72 1.2 3
43 50.92 53.8 59.32 74.84 79.96 81.64 85.24 87.96 89.16 92.16

504292220/4 502197940/4 502197980/4 502197060/7 COMP-LEFT 504791340/3 505199220/3 542192720/3 542190080/4
19.68 15.75 7.92 13.13 42 88.25 187.2 51.8 52.51
111.84 127.59 135.51 148.64 190.64 278.89 466.09 517.89 570.4

26503	COMP-LEFT	504791320/2	505188040/2	511190153/2	511190155/2	COMP-LEFT	505199320/3	5E0390240/2		
	55	26.75	6.72	1.94	2.32	40.6	44.4	19.2		
	55	81.75	88.47	90.41	92.73	133.33	177.73	196.93		
26504	COMP-LEFT	503095440/3	COMP-LEFT	505199380/3	5E0390080/4	505199720/4				
	100	14.49	116.6	14.16	45.75	83.28				
	100	114.49	231.09	245.25	291	374.28				
26505	COMP-LEFT	502196820/3	COMP-LEFT	502197663/4	503094680/3	504490989/3	502197921/4	COMP-LEFT	504491483/3	504491523/3	504491125/3
	32.5	24.13	24.9	4.05	4.23	7.36	8.82	5	9.28	7.76	5.68
	32.5	56.63	81.53	85.58	89.81	97.17	105.99	110.99	120.27	128.03	133.71
	504791260/3	505187760/4	504499981/5	503094740/5	503094780/5	503094840/5	505199740/4	COMP-LEFT	542192620/2	COMP-LEFT	542192640/2
	10.5	7.68	32.48	5.22	5.22	5.22	78	6.6	30.8	29.6	30.8
	144.21	151.89	184.37	189.59	194.81	200.03	278.03	284.63	315.43	345.03	375.83
26705	505199220/1	503095440/1	504791340/1	504491125/1	5E0390120/1					
	65.28	13.86	25	3.68	16.5					
	65.28	79.14	104.14	107.82	124.32					
26711	502195321/1	502197921/1	502197663/1	502197940/1	502198080/1	504290969/1	504290989/1	505199360/1	542191560/1	542191580/1
	27.44	11.7	13.86	6.66	7.74	9.92	9.92	19.2	61.73	57.2
	27.44	39.14	53	59.66	67.4	77.32	87.24	106.44	168.17	225.37
26712	503094580/1	503094680/1	504791320/1	505199740/1	505199320/1	5E0390240/1				
	12.51	12.51	27.75	39.36	32.64	19.5				
	12.51	25.02	52.77	92.13	124.77	144.27				
26806	COMP-LEFT	502197060/5								
	75.5	29.19								
	75.5	104.69								
26807	503094620/1	502197980/1	504292220/1	504292240/1	504299980/1	504471382/1	504741461/1	504741442/1	505188040/1	505191480/1	511190140/1
	13.77	3.6	6.4	6.4	12.8	4.88	0.5	1	11.04	7.44	1.98
	13.77	17.37	23.77	30.17	42.97	47.85	48.35	49.35	60.39	67.83	69.81

	503094740/2	503094780/2	542190660/1	542190680/1
	5.49	6.75	33.04	33.04
	75.3	82.05	115.09	148.13

26810

37102	502197840/1	590090261/1	502195385/2	502197467/2	502196760/2	502196780/2	503073141/2	503094620/2	503094721/2	503095261/2	504741620/2
	28.64	0.5	10.8	6.03	6.57	6.57	2.34	12.69	4.59	3.6	19.75
	28.64	29.14	39.94	45.97	52.54	59.11	61.45	74.14	78.73	82.33	102.08
	504799961/2	505199360/2	505199660/2	COMP-LEFT	542190680/3	COMP-LEFT	542192740/2	5S0661273/2	COMP-LEFT	5S0817481/2	
	20.25	21.84	12.48	23.75	90.51	42	32.7	5.6	2	22.2	
	122.33	144.17	156.65	180.4	270.91	312.91	345.61	351.21	353.21	375.41	

37105	542190740/1	COMP-LEFT	505157120/2	COMP-LEFT	511190060/2	511190080/2	COMP-LEFT	5S0820753/2	5S0820763/2	5S0820773/2	5S0820783/2
	25.3	32	13.65	30	1.18	1.22	13	17	18.8	14.6	14.6
	25.3	57.3	70.95	100.95	102.13	103.35	116.35	133.35	152.15	166.75	181.35
	5S0820803/2	5S0820812/2	COMP-LEFT	5S0826702/3							
	25.8	45.8	52	17.9							
	207.15	252.95	304.95	322.85							

37110	COMP-LEFT	502195321/2	502196760/3	502196780/3	COMP-LEFT	511190182/3	COMP-LEFT	542190660/3	542190060/2	542190080/2	542192720/2
	30	42.15	2.34	2.34	4.3	3.94	75.25	90.51	47.72	47.72	38.1
	30	72.15	74.49	76.83	81.13	85.07	160.32	250.83	298.55	346.27	384.37

37201	504491720/1	504491721/1	502180740/2	COMP-LEFT	502197341/2	502873460/2	502873360/2	502198020/4	504491822/2	542190740/2	542193060/2
	7.28	5.36	5.4	10	6.21	5.49	6.57	8.37	6.88	100.5	55.3
	7.28	12.64	18.04	28.04	34.25	39.74	46.31	54.68	61.56	162.06	217.36
	590090240/2	5S0826702/2	5S1591671/2	542193040/1							
	48.86	36.65	38	71.05							
	266.22	302.87	340.87	411.92							

37202	542190160/1	502180760/2	502198240/2	502199720/2	COMP-LEFT	503095560/2	503095561/2	COMP-LEFT	505199680/2	511190182/2	511190760/2
	11.34	4.95	5.85	4.95	11.3	2.07	2.07	15.35	14.4	6.76	4.7
	11.34	16.29	22.14	27.09	38.39	40.46	42.53	57.88	72.28	79.04	83.74

	511190360/2	511190780/2	511190380/2	511190740/2	511190121/5	COMP-LEFT	542192780/2	COMP-LEFT	5S1581270/2
	2.18	4.7	2.18	3.72	5.62	38.2	37	18	31.4
	85.92	90.62	92.8	96.52	102.14	140.34	177.34	195.34	226.74

37203	COMP-LEFT	502197820/2	COMP-LEFT	542192820/2
	37.05	27.45	86.25	37
	37.05	64.5	150.75	187.75

37301	COMP-LEFT	503093084/2	503093085/2	503093125/2	503093126/2	505199220/2	502198080/4	504290969/2	504290989/2
	14.75	13.14	13.14	13.14	13.14	161.76	18	34.08	34.08
	14.75	27.89	41.03	54.17	67.31	229.07	247.07	281.15	315.23

37401	COMP-LEFT	511190740/3
	100	1.88
	100	101.88

37602	COMP-LEFT	502198240/3	511190121/2	542190160/2	511190121/3	COMP-LEFT	504491822/3	502197820/3	COMP-LEFT	503094580/5	511190121/6
	24.2	0.81	2.88	1.53	1.14	33	4.4	7.31	8.75	33.84	0.52
	24.2	25.01	27.89	29.42	30.56	63.56	67.96	75.27	84.02	117.86	118.38

COMP-LEFT	542191560/4	542191580/4	542192740/3
110	51	71.2	33.1
228.38	279.38	350.58	383.68

37603	COMP-LEFT	504491720/2	504491721/2	502180740/3	502198020/2	502199941/2	504243741/3	504243761/3	502197360/4	COMP-LEFT	503093084/4
	15	9.52	1.44	1.89	5.22	6.12	0.4	0.48	2.34	91	3.06
	15	24.52	25.96	27.85	33.07	39.19	39.59	40.07	42.41	133.41	136.47

COMP-LEFT	5S0820773/3	COMP-LEFT	5S0820783/3	542192780/3	542192820/3	5S0820763/4	502198020/5	503093085/4	503093125/4	503093126/4
41	1	5	1.2	27.2	27.2	0.8	2.97	1.98	2.7	1.98
177.47	178.47	183.47	184.67	211.87	239.07	239.87	242.84	244.82	247.52	249.5

502198080/5	511190760/5	511190780/5	5S0820803/3	542190740/3	COMP-LEFT	504290969/3	504290989/3	COMP-LEFT	542190060/3
8.19	1.16	1.44	4.8	5.5	20	16.96	15.36	11	41.11
257.69	258.85	260.29	265.09	270.59	290.59	307.55	322.91	333.91	375.02

37604	COMP-LEFT	502180320/3	COMP-LEFT	502180340/4	503095520/4	COMP-LEFT	503095261/1	504741620/1	504799961/1	504472020/3	505199680/3
	11.5	2.07	11	2.16	1.98	17.35	15.75	4.5	15.75	1.2	12.72
	11.5	13.57	24.57	26.73	28.71	46.06	61.81	66.31	82.06	83.26	95.98
	COMP-LEFT	504741461/4	511190152/4	511190154/4	511190140/2	511190760/3	511190360/3	511190182/4	511190780/3	511190380/3	COMP-LEFT
	1.75	3.1	4.78	4.4	1.5	0.74	1.28	3.2	0.74	1.28	100.6
	97.73	100.83	105.61	110.01	111.51	112.25	113.53	116.73	117.47	118.75	219.35
	542193060/3	5E0390120/4	5S1581270/3	COMP-LEFT	590090240/4						
	10.9	33	12	15	80.26						
	230.25	263.25	275.25	290.25	370.51						
38811	502195385/1	502196760/1	502196780/1	502197467/1	503073141/1	503094721/1	503093126/1	511190121/1	502197820/1	505199660/1	511190060/1
	10.17	4.32	4.32	8.55	2.07	4.5	2.88	3.22	12.3	27.12	1.06
	10.17	14.49	18.81	27.36	29.43	33.93	36.81	40.03	52.33	79.45	80.51
	511190080/1	542192820/1	542190060/1	542190080/1	542192740/1	542192720/1	5S0661273/1	COMP-LEFT	542190080/3	5S0661273/4	COMP-LEFT
	1.06	67.2	76.55	57.29	28.1	28.1	4	18	19.26	2.4	3.25
	81.57	148.77	225.32	282.61	310.71	338.81	342.81	360.81	380.07	382.47	385.72
	5S0817481/4										
	1.8										
	387.52										
38812	502180760/1	502198240/1	502199720/1	503093084/1	503093085/1	503093125/1	502199941/1	502873460/1	502873360/1	503095560/1	503095561/1
	2.52	2.97	2.52	2.88	2.88	2.88	4.14	1.08	3.78	1.35	1.35
	2.52	5.49	8.01	10.89	13.77	16.65	20.79	21.87	25.65	27	28.35
	505199680/1	511190182/1	511190360/1	511190380/1	511190740/1	511190760/1	511190780/1	511190121/4	542192780/1	542190660/2	542190680/2
	27.12	2.32	0.6	0.6	2	3.22	3.22	3.68	67.2	20.02	20.02
	55.47	57.79	58.39	58.99	60.99	64.21	67.43	71.11	138.31	158.33	178.35
	5S1581270/1	511190780/4	511190760/4	542192620/1	542192640/1	5S0817481/1					
	14.8	3.64	1.84	84	60.4	8.2					
	193.15	196.79	198.63	282.63	343.03	351.23					

38814	502180320/1	502180340/1	502180740/1	502197360/1	502197341/1	502198020/1	502198020/3	COMP-LEFT	504741461/2	504243741/1	504243761/1
	3.6	3.6	2.88	2.61	11.25	1.62	1.71	13.5	7.9	3.6	3.6
	3.6	7.2	10.08	12.69	23.94	25.56	27.27	40.77	48.67	52.27	55.87
	504472020/1	504491822/1	505157120/1	542193060/1	590090240/1	5S0820753/1	5S0820763/1	5S0820783/1	5S0820803/1	5S0820812/1	5S0826702/1
	3.76	4.88	4.62	15	20.94	9.2	9.4	9.2	9.2	6.6	11.75
	59.63	64.51	69.13	84.13	105.07	114.27	123.67	132.87	142.07	148.67	160.42
	5S1591671/1	511190140/3	505157120/3	503093084/3	503093085/3	503093125/3	503093126/3	502197360/5	5S0820753/3	5S0820763/3	5S0820773/4
	7	2.64	4.93	2.07	2.07	2.07	2.07	2.43	5.2	5.2	5.2
	167.42	170.06	174.99	177.06	179.13	181.2	183.27	185.7	190.9	196.1	201.3
	5S0820783/4	COMP-LEFT	590090240/3	5S0820803/4							
	5.2	61.75	20.01	1.8							
	206.5	268.25	288.26	290.06							
38815	5S0820773/1	503095520/1	COMP-LEFT	502180340/3	502197360/3	COMP-LEFT	504741620/3	502196760/4	502196780/4		
	9.2	3.87	8.3	1.44	2.43	79	20.5	4.41	4.41		
	9.2	13.07	21.37	22.81	25.24	104.24	137.32	141.73	146.14		
38822	COMP-LEFT	502195385/3	590090261/2	COMP-LEFT	502197467/3	COMP-LEFT	505199360/3	COMP-LEFT	505199660/3	COMP-LEFT	542190660/4
	42	4.41	0.42	2	5.49	62.5	3.6	9	3.84	119.65	53.97
	42	46.41	46.83	48.83	54.32	116.82	120.42	129.42	133.26	252.91	306.88
	542190680/4	5S0661273/3	COMP-LEFT	5S0817481/3							
	46.86	3.8	20	6.2							
	353.74	357.54	377.54	383.74							

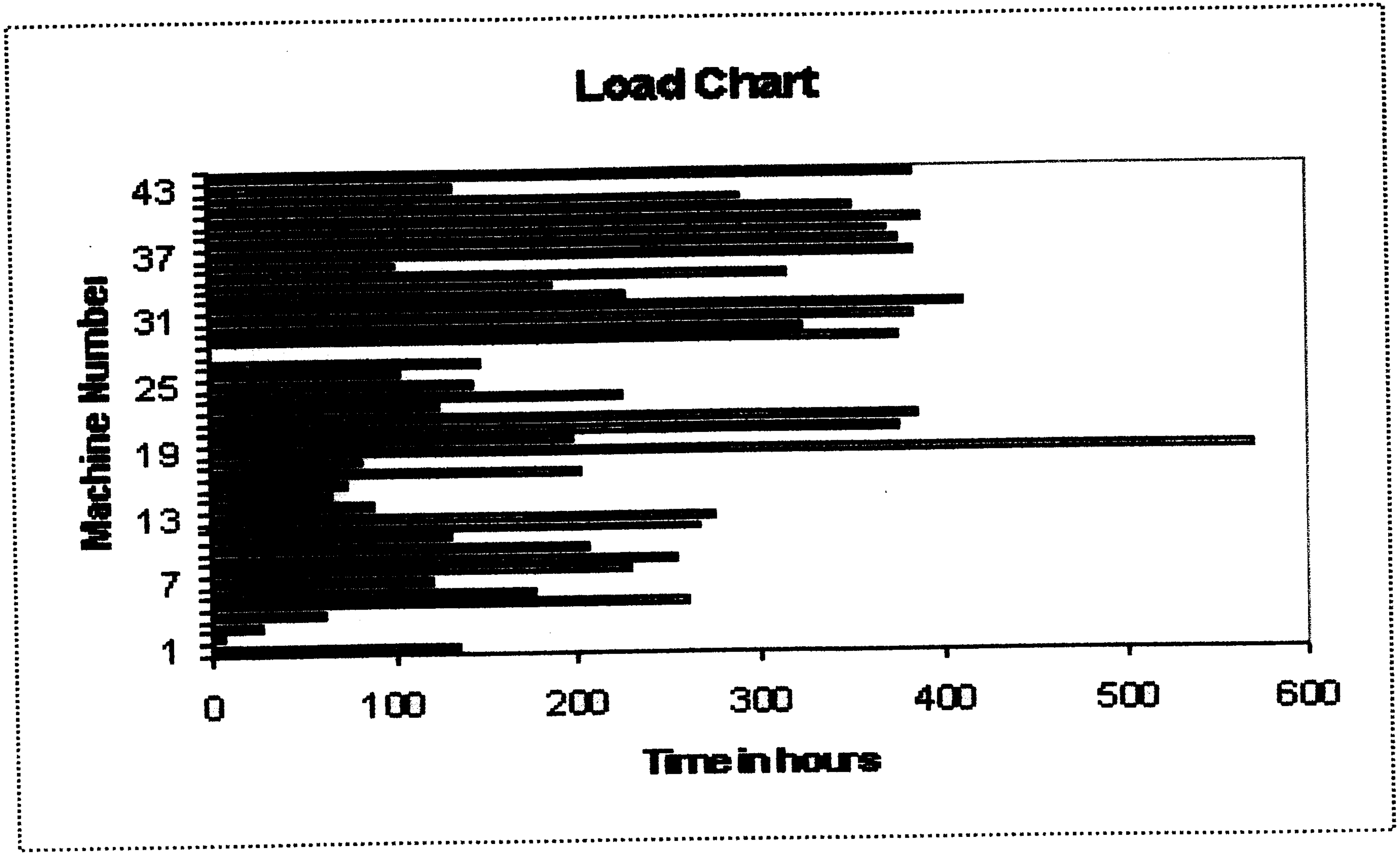

Fig 1. LOAD CHART OF CUBICAL CELL MACHINES

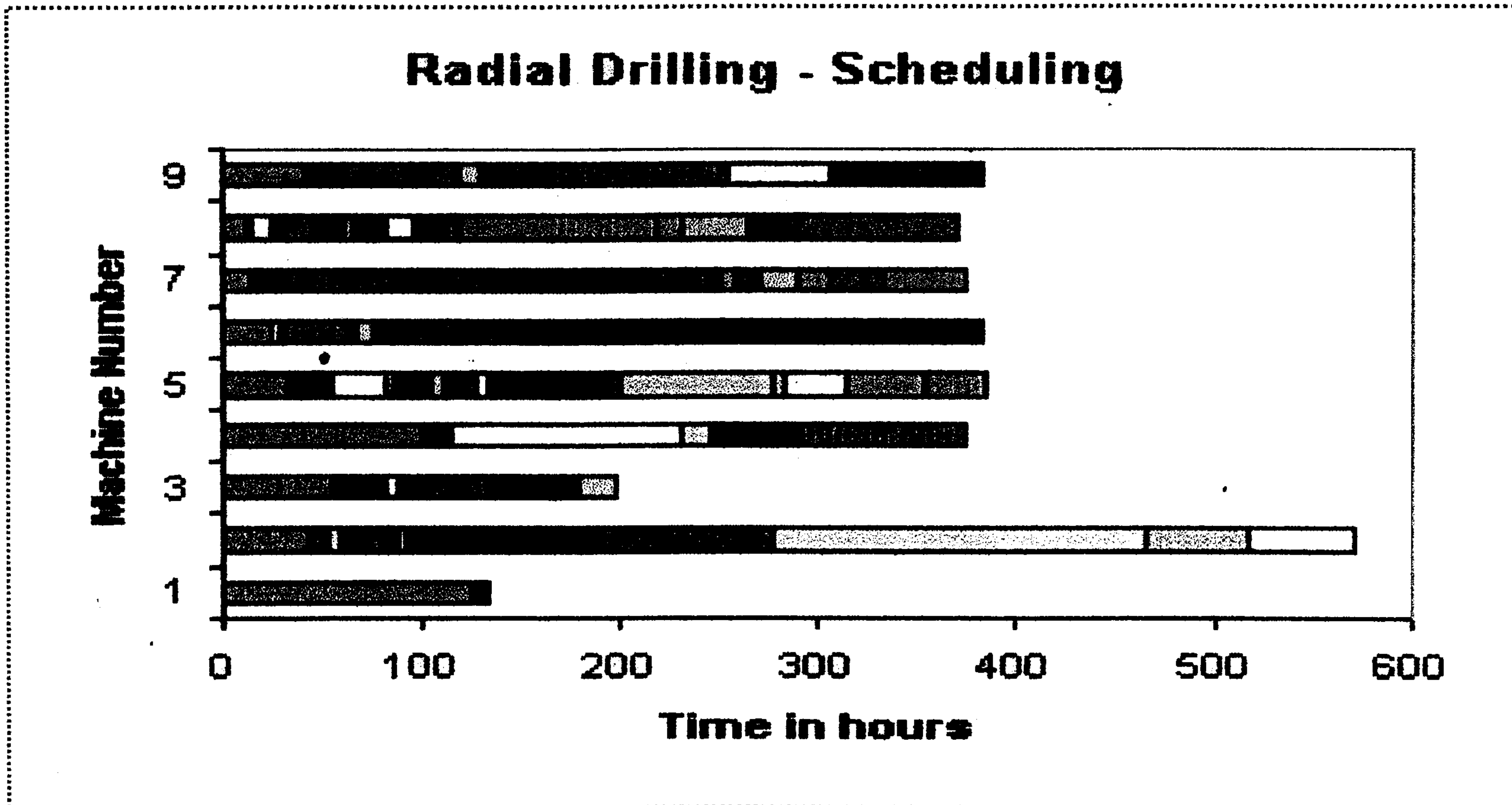

Fig 2. LOAD CHART OF RADIAL DRILLING GROUP

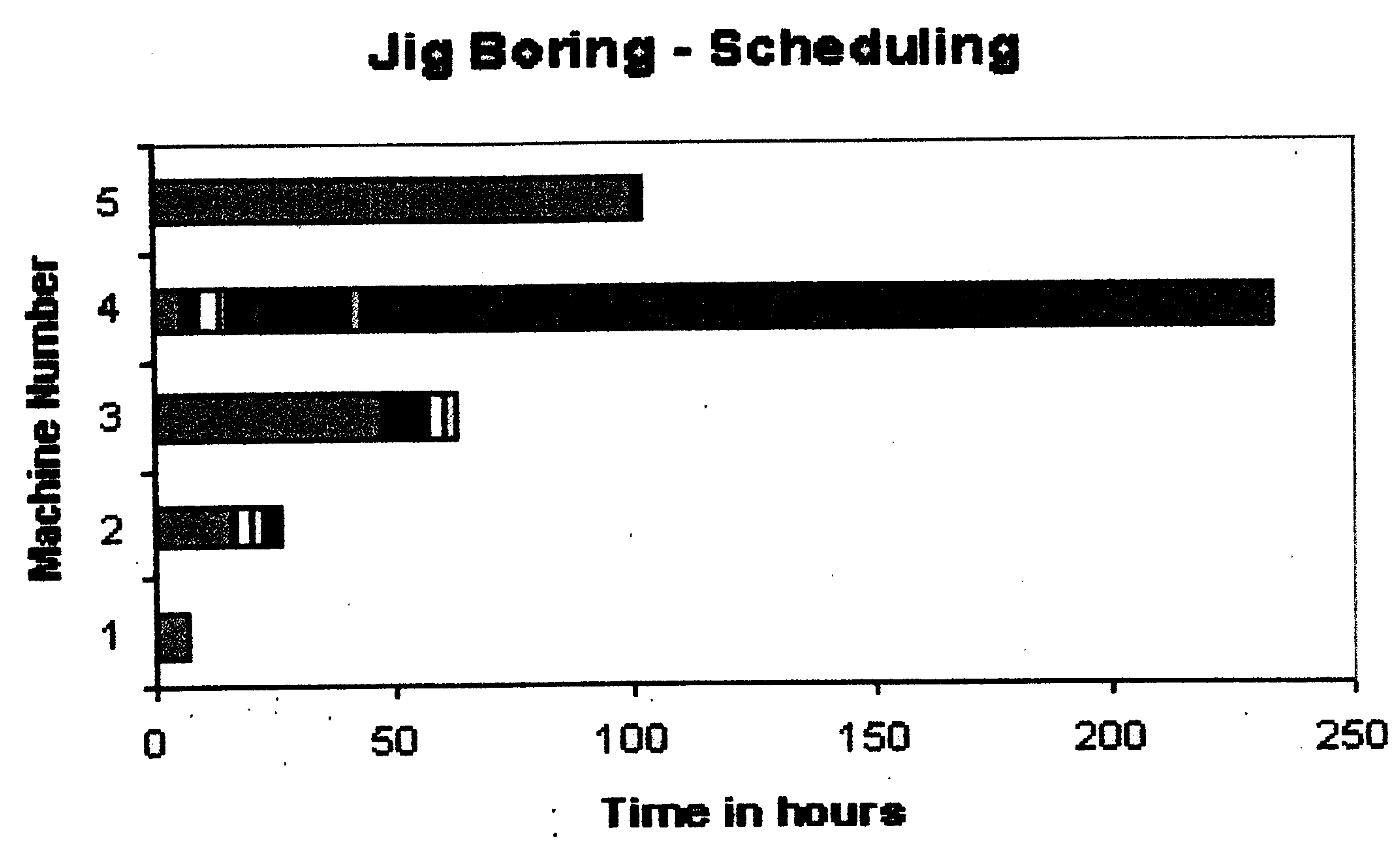

Fig 3. LOAD CHART OF JIG BORING GROUP

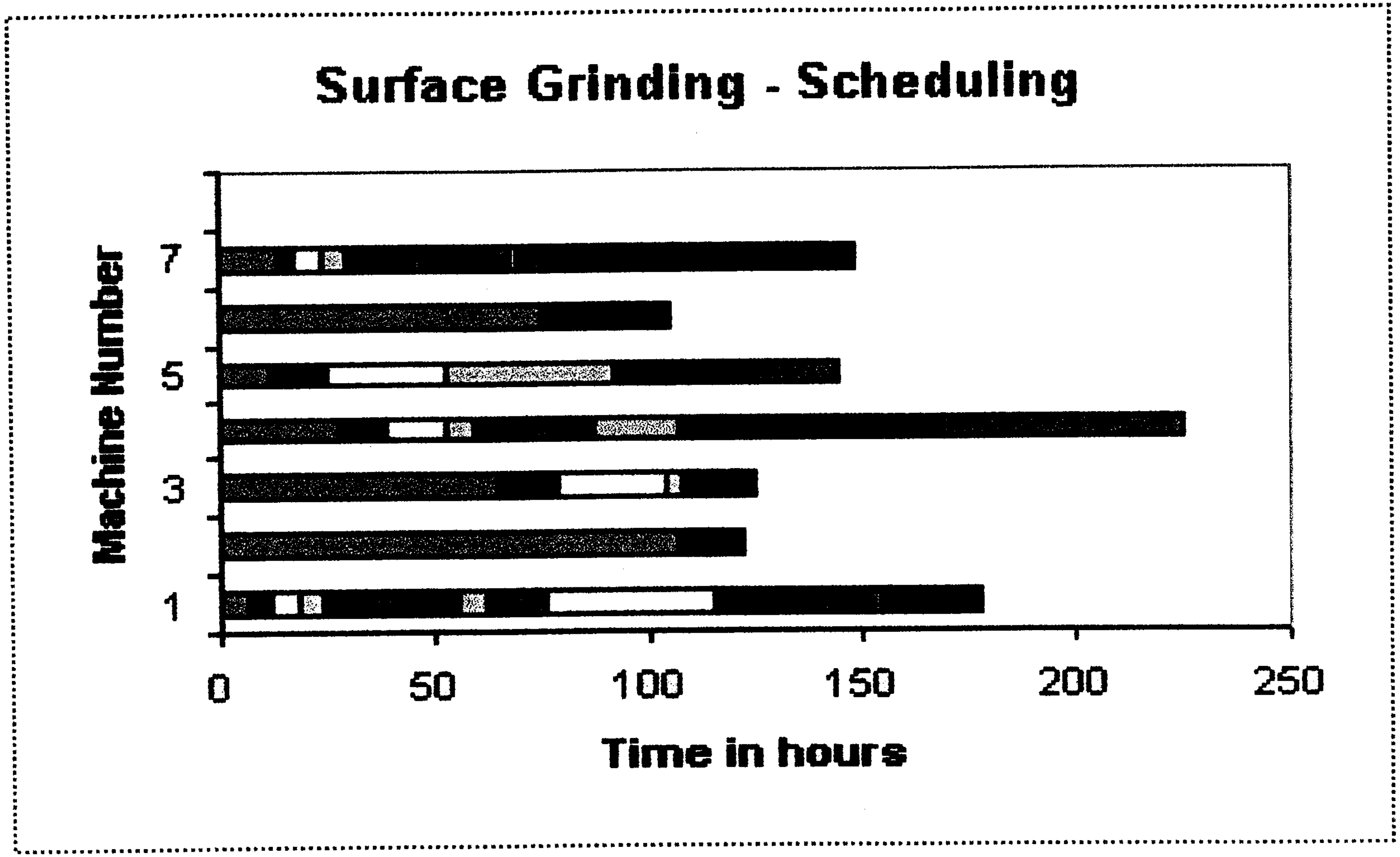

Fig 4. LOAD CHART OF SURFACE GRINDING GROUP

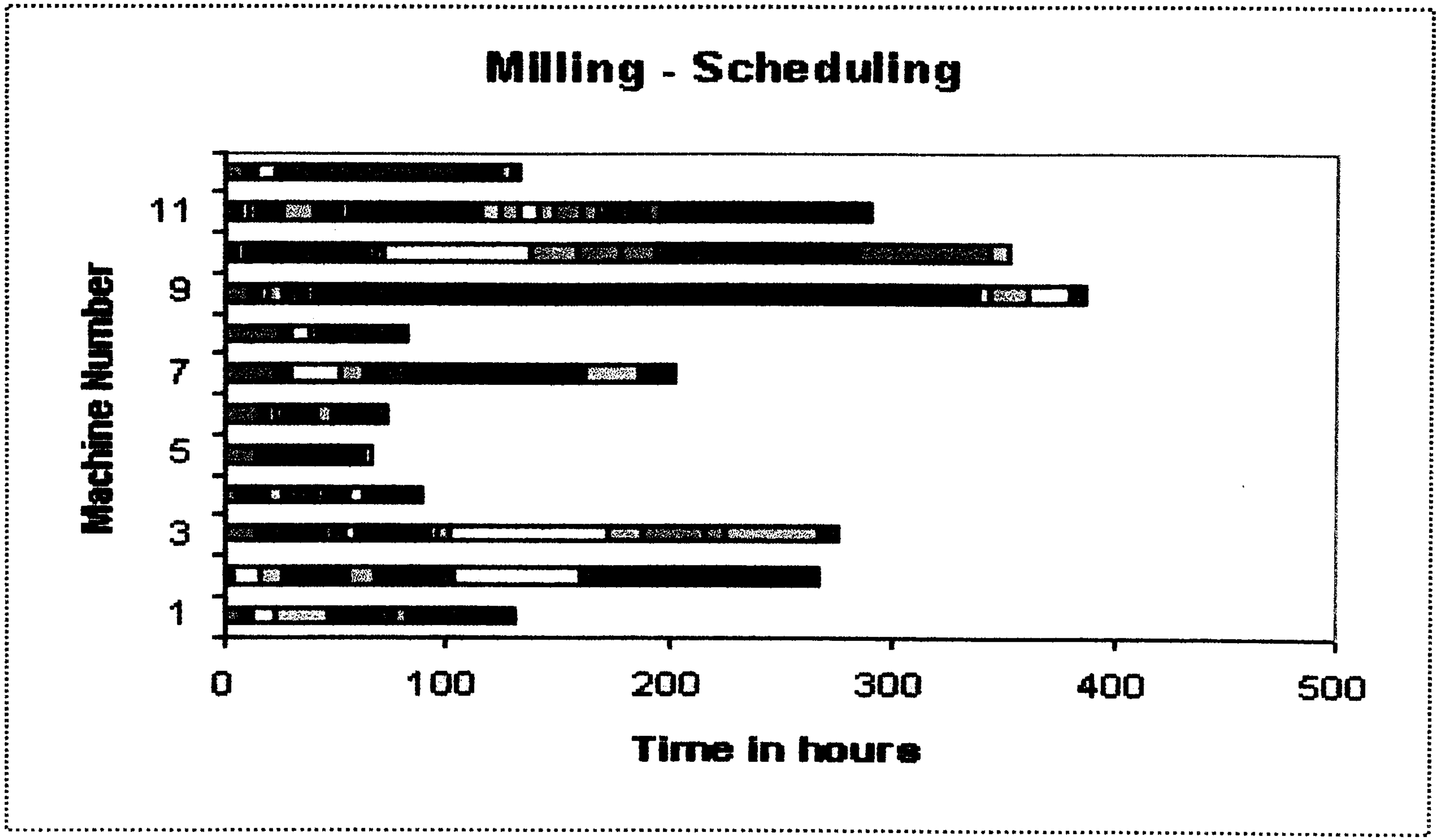

Fig 6. **LOAD CHART OF MILLING GROUP**

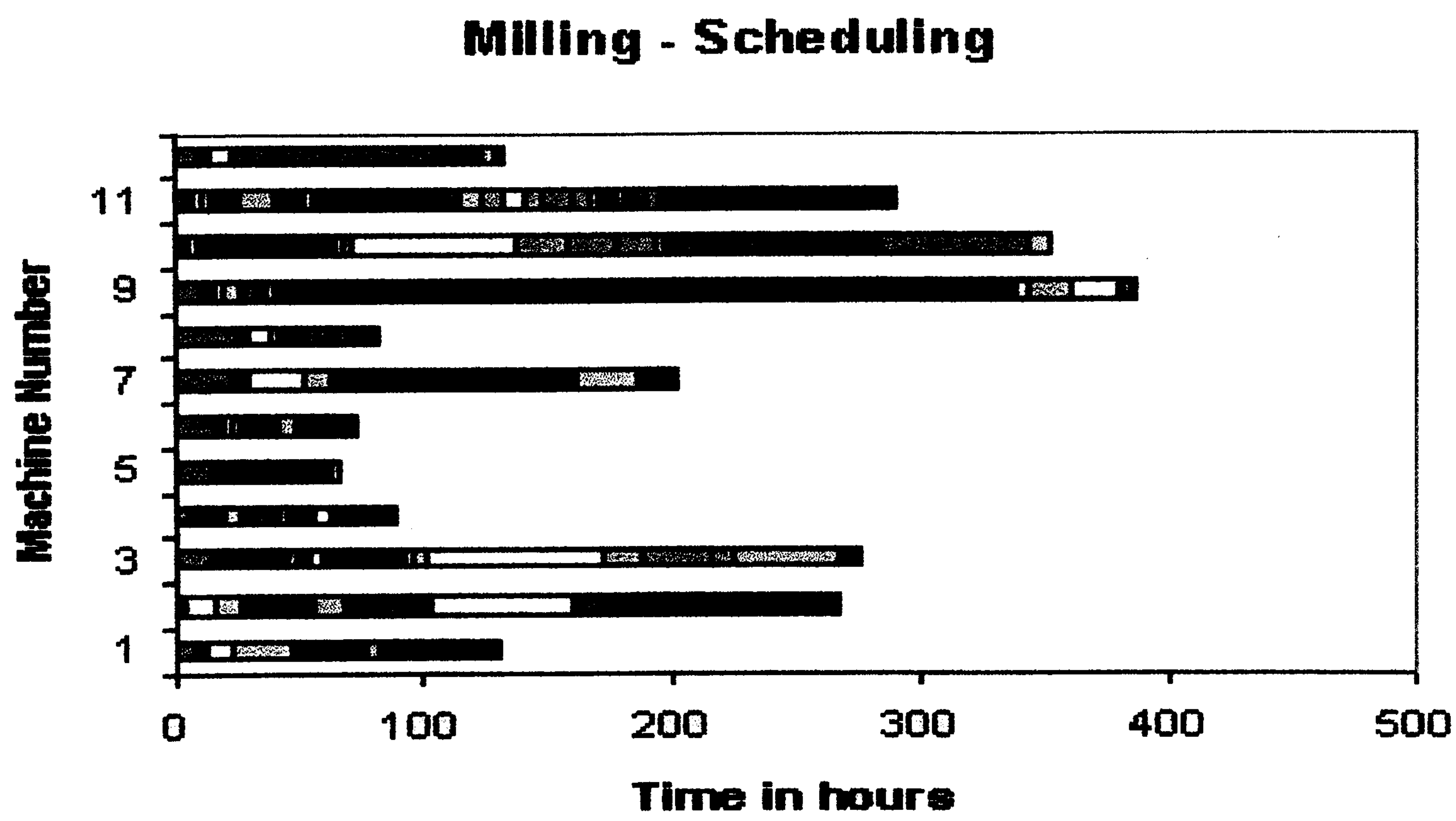

Fig 6. LOAD CHART OF MILLING GROUP

```
Option Explicit
Dim gcn As New ADODB.Connection
Dim gcn1 As New ADODB.Connection
Dim gcn2 As New ADODB.Connection
Dim rs As New ADODB.Recordset
Dim rs1 As New ADODB.Recordset
Dim rs2 As New ADODB.Recordset
Dim qry1 As String
Dim qry2 As String

Private Sub Chart1_GotFocus()
 Chart1.Height = 2000
 Chart1.Name = "Load chart"
 Chart1.HelpContextID = "Load Chart"
 Chart1.Width = 2000
 Chart1.ToolTipText
 Chart1.Top
End Sub

Private Sub Chart2_GotFocus()
 Chart2.Height = 2000
 Chart2.Name = "Radial Drilling chart"
 Chart2.HelpContextID = "Radial Drilling Chart"
 Chart2.Width = 2000
 Chart2.ToolTipText
 Chart2.Top
End Sub

Private Sub Chart3_GotFocus()
Chart3.Height = 2000
 Chart3.Name = "Jig Boring chart"
 Chart3.HelpContextID = "Jig Boring Chart"
 Chart3.Width = 2000
```

```
 Chart3.ToolTipText
 Chart3.Top
End Sub

Private Sub Chart4_GotFocus()
Chart4.Height = 2000
 Chart4.Name = "Surface Grinding chart"
 Chart4.HelpContextID = "Surface Grinding Chart"
 Chart4.Width = 2000
 Chart4.ToolTipText
 Chart4.Top
End Sub

Private Sub Chart5_GotFocus()
Chart5.Height = 2000
 Chart5.Name = "Machining Center chart"
 Chart5.HelpContextID = "Machining Center Chart"
 Chart5.Width = 2000
 Chart5.ToolTipText
 Chart5.Top
End Sub

Private Sub Chart6_GotFocus()
Chart6.Height = 2000
 Chart6.Name = "Milling chart"
 Chart6.HelpContextID = "Milling Chart"
 Chart6.Width = 2000
 Chart6.ToolTipText
 Chart6.Top
End Sub
```

```
Private Sub Command1_Click()
Dim icode As Long
Dim sArray() As String
Dim samac() As String
Dim i As Integer
Dim j As Integer
Dim result As String
   While Not rs.EOF
      ReDim Preserve sArray(i)
      ReDim Preserve samac(i)
       sArray(i) = rs!comp_process_desc
      icode = rs!comp_mac_icode
      qry1 = "select * from machine where mac_icode=" & icode
      rs1.Open qry1, gcn1
       samac(i) = rs1!mac_desc
     ' MsgBox rs1!mac_no, vbInformation
      'MsgBox rs1!mac_capacity, vbInformation
         qry2 = "select * from comp_header where comph_icode=" &
rs!comph_icode
      rs2.Open qry2, gcn2
      result = "COMPONENT NUMBER   : " & rs2!comp_no & ";                " & "
OPERATION TIME             : " & rs!comp_time & " hours;                " & "
PROCESS DESCRIPTION  : " & sArray(j) & ";          " & "
 MACHINE NUMBER           : " & rs1!mac_no & ";                        " & "
MACHINE CAPACITY         : " & rs1!mac_capacity & ";                  " & "
MACHINE DESCRIPTION   : " & samac(j)

       MsgBox result, vbInformation, "Process Details"
       'MsgBox rs!comp_time & " hours", vbInformation, "Operation Time"
       'MsgBox sArray(j), vbInformation, "Component Process Description"
       'MsgBox rs1!mac_no, vbInformation, "Machine Number"
       'MsgBox rs1!mac_capacity & " hours", vbInformation, "Machine Capacity"
       'MsgBox samac(j), vbInformation, "Machine Description"
```

```
rs1.Close
   rs2.Close
   i = i + 1
   rs.MoveNext
  Wend
 ' For j = 0 To i - 1
  '  MsgBox sArray(j), vbInformation
  '  MsgBox samac(j), vbInformation
 '  Next j
End Sub

Private Sub Form_Load()
  Dim sconn As String
  Dim ssql As String
  sconn = "Provider=Microsoft.Jet.OLEDB.3.51;Persist Security Info=False;Data
Source= DB1.mdb"
  gcn.Open sconn
  gcn1.Open sconn
  gcn2.Open sconn
  Set rs = New ADODB.Recordset
  Set rs1 = New ADODB.Recordset
  Set rs2 = New ADODB.Recordset
  ssql = "select * from components"
  rs.Open ssql, gcn
End Sub
```