OPTIMIZING MACHINE SHOP SCHEDULING TO MEET ASSEMBLY REQUIREMENTS BY APPLYING JUST IN TIME PRODUCTION CONCEPTS

Thesis submitted in partial fulfillment of the requirements
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2001-2002

CERTIFICATES

CERTIFICATE

This is to certify that this thesis work entitled "**OPTIMIZING MACHINE SHOP SCHEDULING TO MEET ASSEMBLY REQUIREMENTS BY APPLYING JUST IN TIME PRODUCTION CONCEPTS**" being submitted by **T.ARAVIND KRISHNA** (REG. No. 0137H0001) for the award of degree of MASTER OF ENGINEERING IN MECHANICAL ENGINEERING (INDUSTRIAL ENGINEERING) is a bonafide work carried under my guidance. The results embodied in this thesis have not been submitted to any other university or institute for the award of any Degree or Diploma.

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LMW

LAKSHMI MACHINE WORKS LIMITED

HRD/2002
12.11.2002

TO WHOMSOEVER IT MAY CONCERN

CERTIFICATE

This is to certify that Mr.T.Aravind Krishna, Final year ME Industrial Engineering student of Kumaraguru College of Technology, Coimbatore 641 006 had undergone Project work titled as **"OPTIMIZING MACHINE SHOP SCHEDULING TO MEET ASSEMBLY REQUIREMENTS BY APPLYING JUST IN TIME PRODUCTION CONCEPTS"** in our Company from 12.06.2002 to 12.11.2002.

For LAKSHMI MACHINE WORKS LIMITED,

GENERAL MANAGER-HRD

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SYNOPSIS

The ultimate goal of Production is to constantly increase productivity and reduce cost through continuous improvement of operations by eliminating delays and idle hours in the production process. Further production must be streamlined to adapt promptly to fluctuations in the market demand without any slack in due date or completion time. This can be accomplished by resorting to Just in Time practices. In recent years, increased emphasis is given on time factor since delay in any form increases cost and at times results in the loss of customers to competition. JIT can be applied as an effective tool to reduce the lead time and to improve the flow of materials and information.

In this project an attempt has been made to tackle the problem of scheduling operations in a manufacturing facility which produces large assemblies such as machine tool manufacturers, textile machinery manufacturers etc, where manufacturing lead time extends over several weeks.

Here, based on the demand forecast and assembly due dates for end items, the objective is to schedule the operations involved in various subassemblies and their components within the specific period. A Just in time production concept can be adopted in which production is scheduled as late as possible (in order to minimize WIP) at the same time avoiding backlogging of end items.

An effective operation sequence based algorithm has been developed to aid Just in Time scheduling. The software developed with user-friendly front end and back end tools can aid manufacturers to plan the shop floor activities effectively and to meet assembly needs. This helps manufacturers to improve their competitiveness in the market.

CONTENTS

INTRODUCTION

1.1 SCHEDULING

SEQUENCING AND SCHEDULING

Sequencing is the determination of the order of processing of a given set of jobs on the available machines [2]. Scheduling involves the time tabling of various operations and jobs to be performed in the shop floor. Both sequencing and scheduling help the operations manager in effectively carrying out the manufacturing activities in order to meet the desired objectives of the organization.

IMPORTANCE OF SCHEDULING

Scheduling is one of the most important operational decisions to be made in any manufacturing system. In simple terms it consists of allocation of operations to time intervals on the available machines, the objective being minimization of make span [6].

It is a complex phenomenon, which involves routing, sequencing and time phasing of components. This complexity demands additional and special considerations in order to ensure smooth and streamlined flow of in process material and information among the various departments in an organization. This ultimately reflects on the performance of shop floor and the effectiveness of the entire organization as a whole.

SCHEDULING IN HEAVY MACHINERY MANUFACTURING SYSTEMS

Scheduling the production in a heavy machinery (involving several subassemblies) manufacturing environment requires coordinated flow of materials through the different stages of manufacturing which spans over several weeks. This would ensure availability of components for assembly as per requirements.

However in real time situations delays are bound to occur due to nonavailability of resources (or) lack of jobs needed for processing. This will reflect on the utilization of resources, lead-time for manufacturing and performance of the shopfloor. Hence the need for an efficient shop floor scheduling system, which will ensure proper utilization of resources, substantial reduction in lead-time and better shopfloor performance.

1.2 COMPANY PROFILE

Lakshmi Machine Works Limited famously known as LMW was established by Dr.Cavalier G.K.Devarajulu in the year 1962. LMW is one of the three leading manufacturers of textile machinery in the world. A multi product company, LMW represents the actualization 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 Nine units of LMW and all are in Tamil Nadu. 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 fibres and yarns ultimately going into the production of fabrics and ready-made garments. Its production infrastructure has been kept up to date with regular modernization.

The acquisition of ISO 9000 accreditation has helped LMW to test its work practices and also to full 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.

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 lists of products that are manufactured in LMW are shown in the Table below.

TABLE 1: LIST OF PRODUCTS BEING PRODUCED BY LMW

	PRODUCT NAME	MODEL
1	Carding	LC1/3, LC300, LC300A
2	Draw frame	LDO6, RSB851
3	Comber	LK250, LK250/2
	a) Sliver lap	LE2/4A
	b) Ribbon lap	LE4/1A
4	Speed frame	LF1400A, LF1465, LFS1660
	a) Open End Spinning	LM1/2
	b) 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 1000 customers, the premiere 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. Polyspin Pvt Ltd, Ahmedabad.

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 machinery. Bureau Veritas Quality International (BVQI) has given the ISO 9000 certificate for LMW in the year 1994.

AWARDS RECEIVED:

LMW's commitment to quality standards has won laurels and awards. The company standardization in 1995 from the institute of standards engineers recognizes 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 recognizes 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.

LAYOUT:

Product layout is adopted in LMW. It is divided into four groups and two 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 that acts as internal sub contractors namely,

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

2.0 LITERATURE SURVEY

A schedule may be defined as a plan with reference to the sequence of operations and time allowed for each item or operation necessary for its completion [4]. The entire sequence of operations necessary sequential constraints, time estimates for each activity and the required resource capacities for each activity are inputs to the development of a detailed plan or schedule.

Scheduling determines the program for the various operations to be performed for completion of the orders for a specified period. Thus scheduling may also be defined as the fixation of date and time for each and every operation to be performed [6].

In scheduling order of sequence of each operation and their starting and finishing times are decided so that the required materials, machines etc may be kept ready as per requirements [4]. This program is prepared by the planning department, which assigns timing for various operations or processes to be performed in a specified period of time.

TYPES OF SCHEDULES

Schedules are of the following types:

1. Master schedule
2. Shop or manufacturing schedule.

MASTER SCHEDULE

Master schedule shows the date on which important production items are to be completed. It is a weekly or monthly break-up of the production requirements for each product. Whenever any order is received it is accommodated first in the master schedule considering the availability of machines and labour. It helps production manager for advance planning and to have a check over production rate and efficiency.

SHOP OR MANUFACTURING SCHEDULE

After preparing master schedule, shop schedules are prepared. It assigns a definite period of time to a particular shop for manufacturing products in the required quantity. It shows how much products are to be prepared and on what day or week etc.

PERFORMANCE CRITERIA

There are three primary objectives or goals that apply to scheduling problems.

- The first goal is concerned with due dates where one wants to avoid late job completion leading to unsatisfied customers.
- The second goal is concerned with flow times (make span) where one aims to minimise the time that a job spends on the system from creation or opening of a shop order until it is closed.
- The third goal is concerned with work centre utilisation where one wants to fully utilise the capacity of expensive equipment and personnel.

These three objectives are often conflicting in nature. One can do a better job of meeting due dates if more capacity is provided and if the work centre capacities are less intensively utilised. Similarly more capacity will typically reduce flow time but at reduced capacity utilisation. If extra jobs are released to the shop they will tend to have longer flow times but capacity can be better utilised and perhaps due date performance can be improved [4].

BASIC SCHEDULING RESEARCH

There have been two fundamental kinds of scheduling problems namely, static scheduling problems and dynamic scheduling problems.

STATIC SCHEDULING PROBLEMS

Static scheduling problems consist of fixed set of jobs to be run. Typical assumptions are that the entire sets of jobs arrive simultaneously and that all work centres are available at that time. Most of the static scheduling problem researches have been conducted on minimum make span criterion. This is just a flow time criterion and not due date or work centre utilisation criterion.

Static scheduling research has been performed using deterministic processing times (known and non varying) and stochastic processing times(subject to random variations).

Methods for dealing with deterministic times can be divided into those that produce optimum results and that utilising heuristic scheduling procedures. In general optimisation methods are only applicable to relatively small problems.

Large scale problems are usually treated with heuristic procedures called dispatching or sequencing rules. They are logical rules for choosing which available job to select for processing at a particular machining centre. In using dispatching rules scheduling decisions are made sequentially.

DYNAMIC SCHEDULING PROBLEMS

Dynamic Scheduling problems are those in which new jobs are continuously being added over time. The processing time for these jobs can be either deterministic or stochastic.

One approach in dynamic scheduling studies is to use different scheduling rules at work centres. Queuing models can also be applied where randomness in interarrival and service times are considered and steady state results are provided for average flow time and average work in process, work centre utilisation and average waiting time.

DISPATCHING RULES:

A dispatching rule is a rule that prioritises all jobs that are waiting for processing on a machine [1].

Some well known dispatching rules used in research are

1. SIRO - Service In Random Order according to which jobs are selected at random from those waiting for processing.
2. FCFS – First Come First Serve rule schedules incoming jobs in their order of arrival.
3. SPT – Shortest Processing Time rule first, gives priority to waiting jobs whose processing time is shortest.
4. EDD – Earliest Due Date first, according to which job with earliest due date is selected to be processed first.
5. LPT – Longest Processing Time first orders jobs in decreasing order of their processing times.
6. LST – Least Slack Time Rule gives priority to waiting job whose slack time is least. Slack is the difference between length of time remaining until job is due and length of operation time.

EMERGING ISSUES IN SCHEDULING

A major shift in direction has occurred in recent research on scheduling methods [4]. It is very closely related to the major changes that are taking place today in the design of production process at many firms. These changes are motivated by the introduction of new processing technologies such as Computer Integrated Manufacturing (CIM), introduction of Just in Time (JIT) concepts and the intensity of world wide competition exiting in the global market.

While the scheduling methods described earlier have been developed for job shop production process, many new processes being installed today are designed to capture the benefits of flow shop production (repetitive manufacturing and continuous flow of materials).

As a result new scheduling researches are concerned with the development of new concepts and methodologies to schedule repetitive manufacturing operations leading to enhanced competitive position in the market.

3.1 INTRODUCTION

LMW produces all major textile machineries such as carding, drawing, comber and speed frames. They use CELL concepts in machine shop. The two cells namely cylindrical parts cell and cubical parts cell act as internal subcontractors to assembly department in addition to few external subcontractors or vendors for outsourcing of components.

The **cylindrical parts cell** consists of machine tools performing operation on circular components such as rollers, grooved rollers, redirecting rollers, top and bottom doffing rollers, crush rollers etc.

The **cubical parts cell** consists of machine tools for performing operations on non cylindrical components such as skeleton items like frames, spring pieces, gear boxes, ventilator housings, carding base frames, end frames etc.

The cubical parts cell in which this project is carriedout is classified into three cells namely

1. Heavy CNC cell
2. Heavy milling cell and
3. Surface grinding cell.

They consist of various types of CNC machines, surface grinding machines, milling machines and drilling machines

The physical arrangement of machines in the heavy machine shop is as shown in fig. 1.

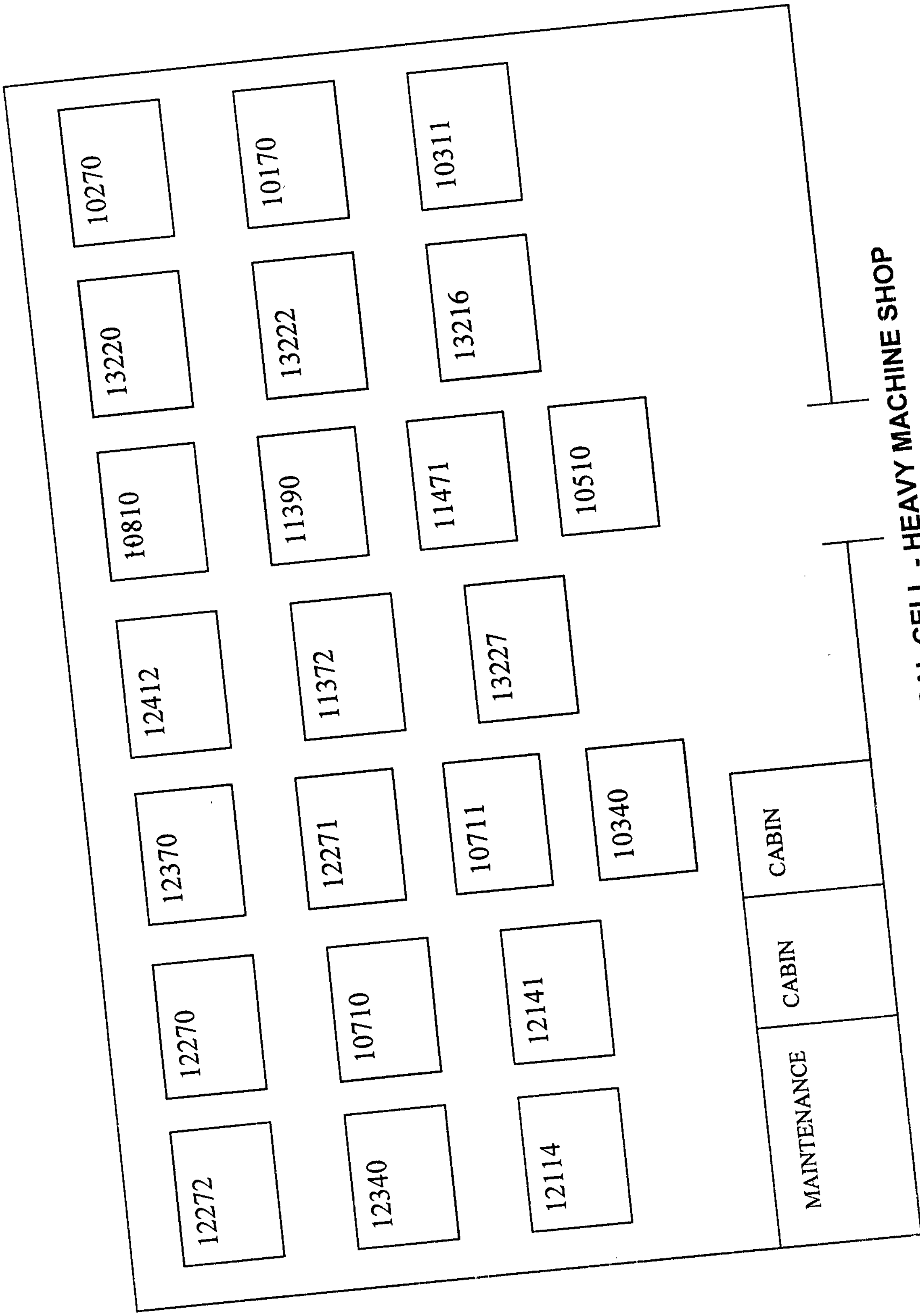


FIG1. LAYOUT OF CUBICAL CELL - HEAVY MACHINE SHOP

TABLE 2: LIST OF MACHINES AVAILABLE IN CUBICAL CELL HEAVY MACHINE SHOP.

S No	Machine number	Machine name
1	11371	CNC ZAYER MACHINING CENTER
2	11372	CNC ZAYER MACHINING CENTER
3	11490	CNC ZAYER MOVING COLUMN MACHINE
4	12271	BLANCHARD SURFACE GRINDING MACHINE
5	12272	REFORM SURFACE GRINDING MACHINE
6	13227	HMT RADIAL DRILLING MACHINE
7	10510	HMT DUPLEX MILLING MACHINE
8	10710	LOUDON PLANO MILLING MACHINE
9	10711	TITAN PLANO MILLING MACHINE
10	10810	ZAYER PROGRAM MILLING MACHINE
11	12370	WMW SURFACE GRINDING MACHINE
12	12270	NAXOS SURFACE GRINDING MACHINE
13	13220	HMT RADIAL DRILLING MACHINE
14	10170	HMT BED TYPE MILLING MACHINE
15	10270	WMW VERTICAL MILLING MACHINE
16	10311	ZAYER 6 BM PROGRAM MILLING MACHINE
17	10340	HELLER PROGRAM MILLING MACHINE
18	12412	ELB SURFACE GRINDING MACHINE
19	12114	DANOBAT SURFACE GRINDING MACHINE
20	12340	MAS SURFACE GRINDING MACHINE
21	12141	DANOBAT SURFACE GRINDING MACHINE
22	13216	HMT RADIAL DRILLING MACHINE
23	13222	HMT RADIAL DRILLING MACHINE

TABLE NO. 3 : LIST OF COMPONENTS BEING PROCESSED IN CUBICAL PARTS CELL .

		504299980	505158740
502197060	503091981	504471382	505187760
502197663	503092042	504491125	505188040
502197921	503099980	504491483	505191480
502197940	503075280	504491523	505199320
502197980	503075420	504491622	505199360
502198080	503093483	504492140	505199380
502894202	503094580	504499960	505199720
542173840	503094620	504499981	505199740
542173860	503094680	504770280	505199020
542190660	503094740	504790580	505199040
542190680	503094780	504790669	505199060
542193220	503094840	504791260	505199080
542193240	503095283	504791320	5F0190020
542144220	503095284	504791340	5F0190040
542191740	503095285	5E0301070	5F0190060
542191780	503095440	5E0390080	5F0250320
542173860	504290082	5E0390120	5F0250340
5C0090020	504290343	5E0390160	5F0250360
5C0170280	504290923	5E0390240	5F0290140
5C0170320	504290943	504791060	5F0290160
503090840	504291380	5E0390520	5F0290180
503091180	504292140	5E0390540	511190560
503091260	504292180		

3.2 EXISTING SYSTEM

The company uses MRP system and the forecasted demand is provided as input to the MRP software. It calculates materials requirements and production plans to satisfy the forecast sales orders as given below.

1. Prepares Bill Of Materials against inventory records.
2. Identifies material required for satisfying the demand requirements based on reorder level and prepares purchase orders, work orders and material plans.
3. The list of items to be manufactured consisting of below reorder level items are sent daily to the progress chasers in each group. The chaser selects items based on its urgency or current requirements. Work orders for such items are generated and distributed to the respective departments for production. Each department allocates the job for production based on machine availability and urgency conditions.

The present system of scheduling is based on the daily requirements and scheduling of jobs takes place on their urgency. Sometimes machines are loaded to avoid them from being idle.

This system is marked by the following disadvantages.

- Queues in front of certain machines.
- Delay in material flow leading to delay in manufacturing.
- Increase in lead-time.
- Components not reaching the assembly stores on time.
- Normal production becomes a problem in cases of breakdown of machines and labour absenteeism.

3.3 ANALYSIS OF THE EXISTING SYSTEM

Load on each machine is calculated as follows.

Load per machine = setup time + operation time per unit(Npmr + 0.3 Npme)

Load per month = load per machine X number of machines.

Npmr denotes number per machine regular i.e. the number of regular components required for a product.

Npme denotes number per machine eventual i.e. the number of optional components required for a specific customer. This is generally found to be 30 %.

Allotted time is the operation time allotted for a particular operation. This is generally expressed as time per hundred numbers.

Setting time is the time for preparing the machine for production. This is generally expressed as time per batch.

Using the above formula load on each machine is calculated.

Utilisation of each group of machines is calculated using the formula

$$\% \text{ Utilisation} = \frac{\text{sum of load of all machines in that group}}{\text{sum of available machine hours for each group.}}$$

TABLE NO. 4 : UTILISATION OF EACH GROUP OF MACHINES.

S No	Machine Group	% Utilisation
1.	Radial drilling machines	78.13
2.	Milling machines	80.08
3.	Surface Grinding machines	82.08
4.	CNC machines	70.15

Load on each machine is depicted in Fig 2, 3, 4,5.

Utilisation of each group is depicted in Fig 6.

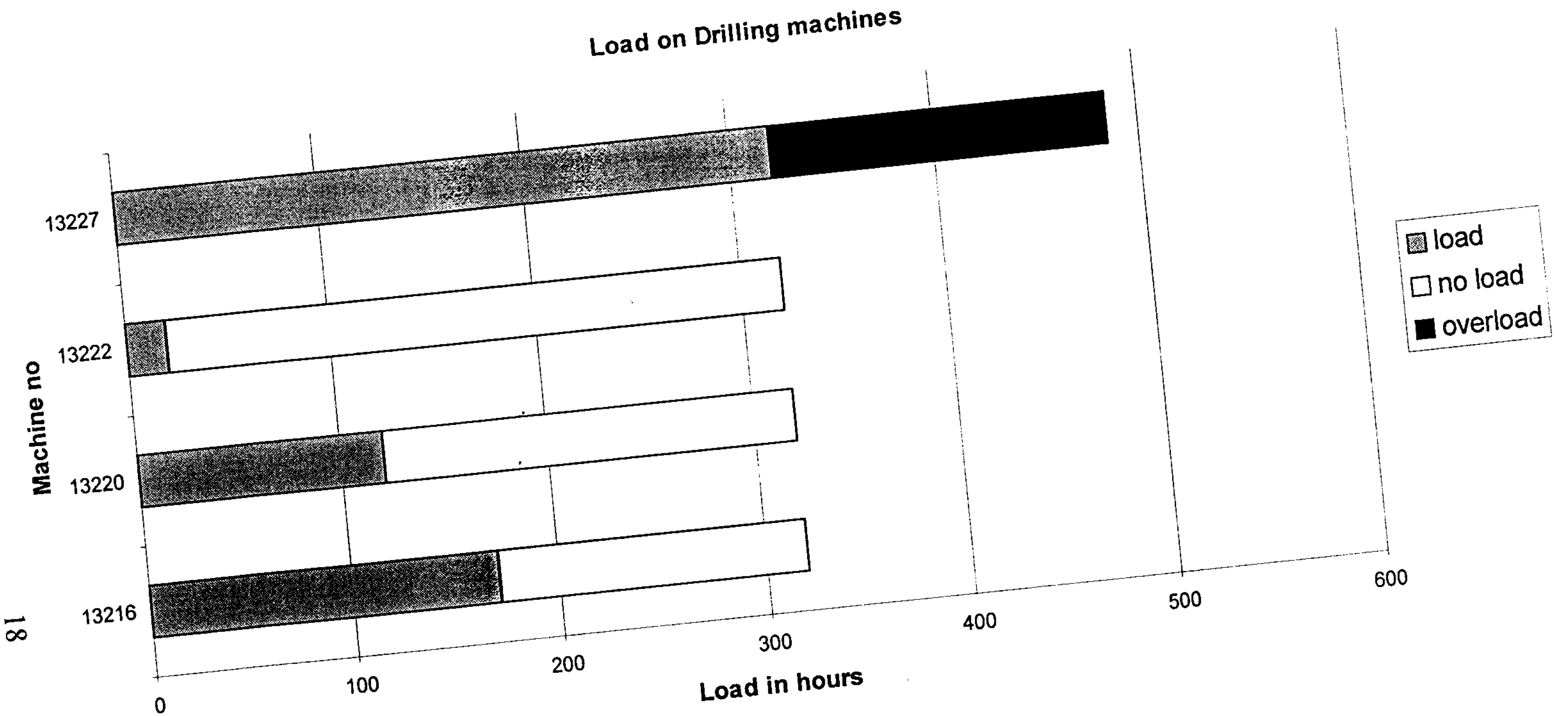


FIG 2. LOAD ON RADIAL DRILLING MACHINES

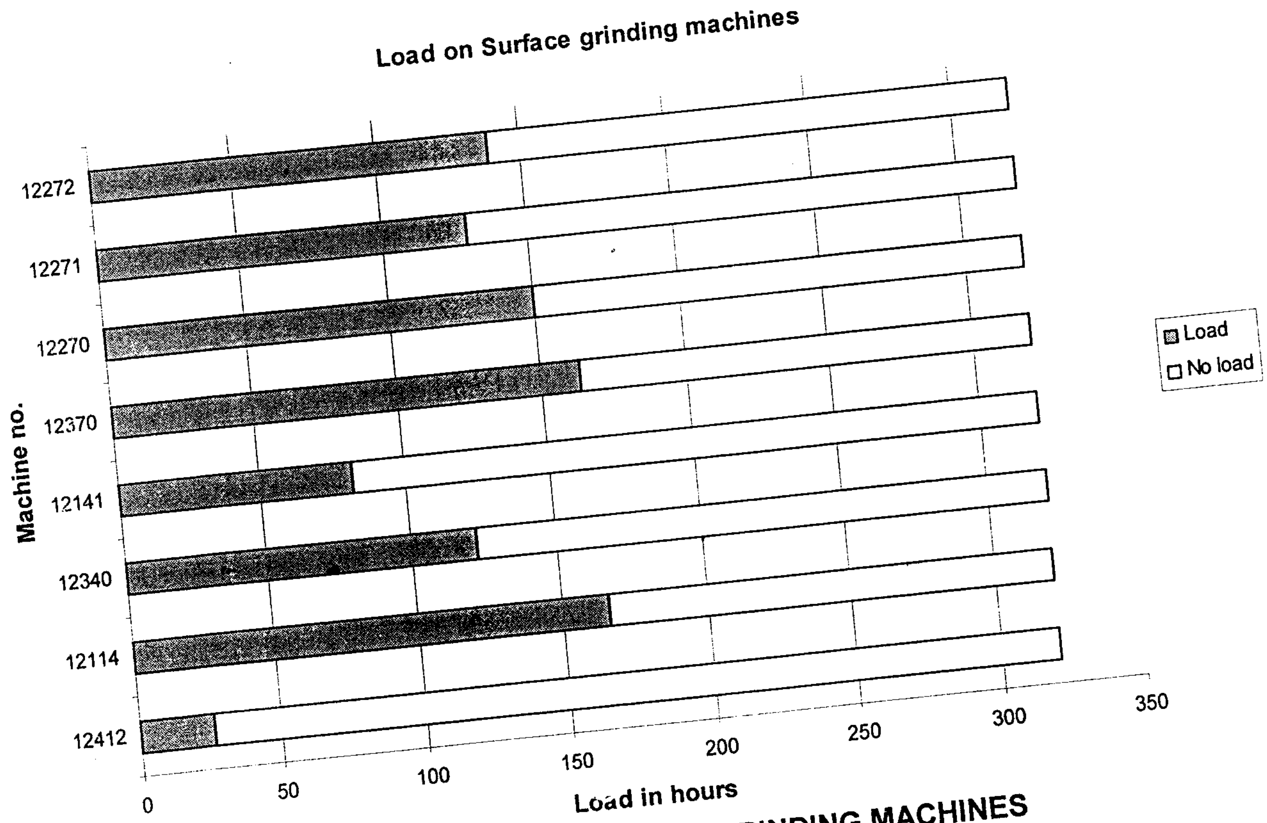


FIG 3. LOAD ON SURFACE GRINDING MACHINES

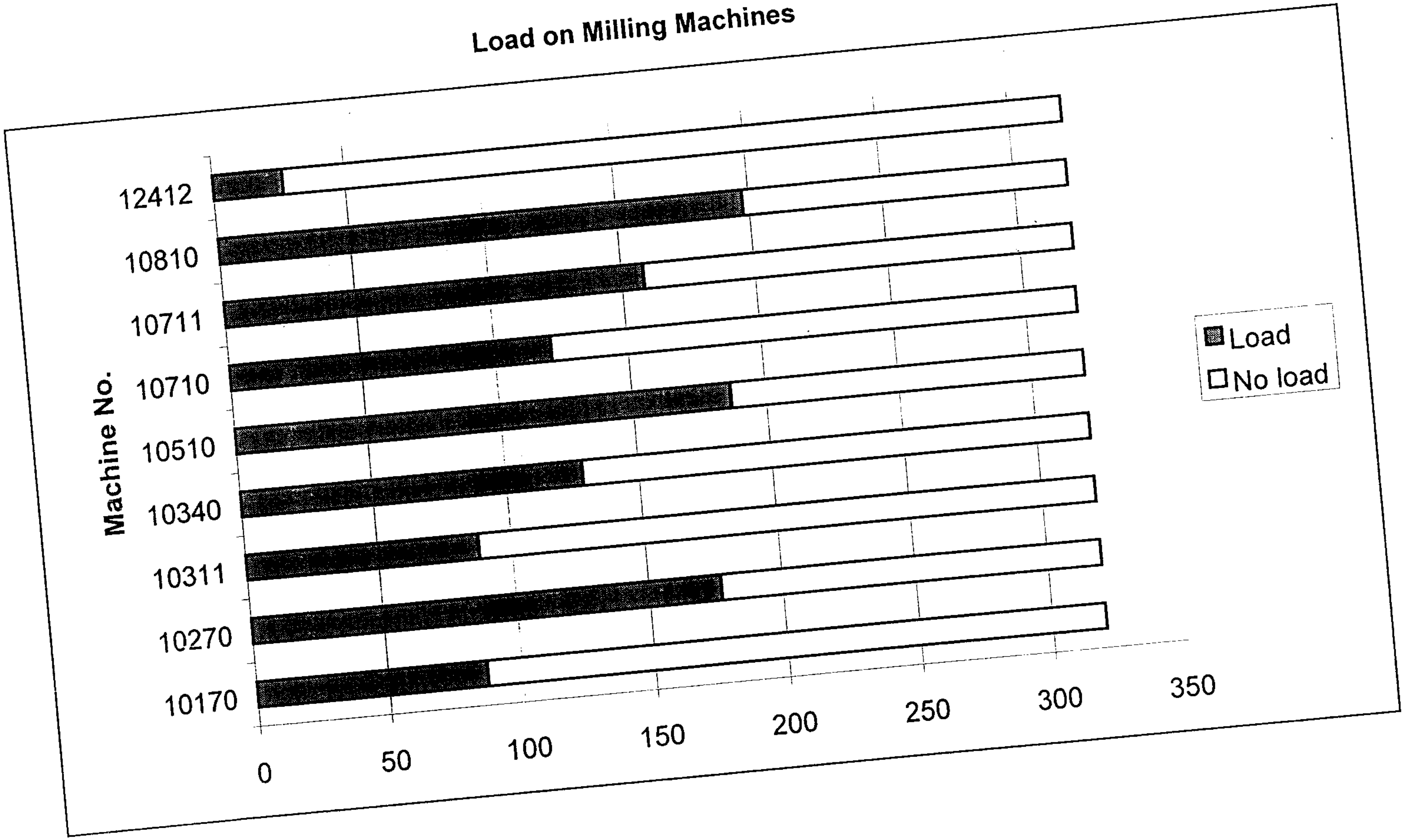


FIG 4. LOAD ON MILLING MACHINES

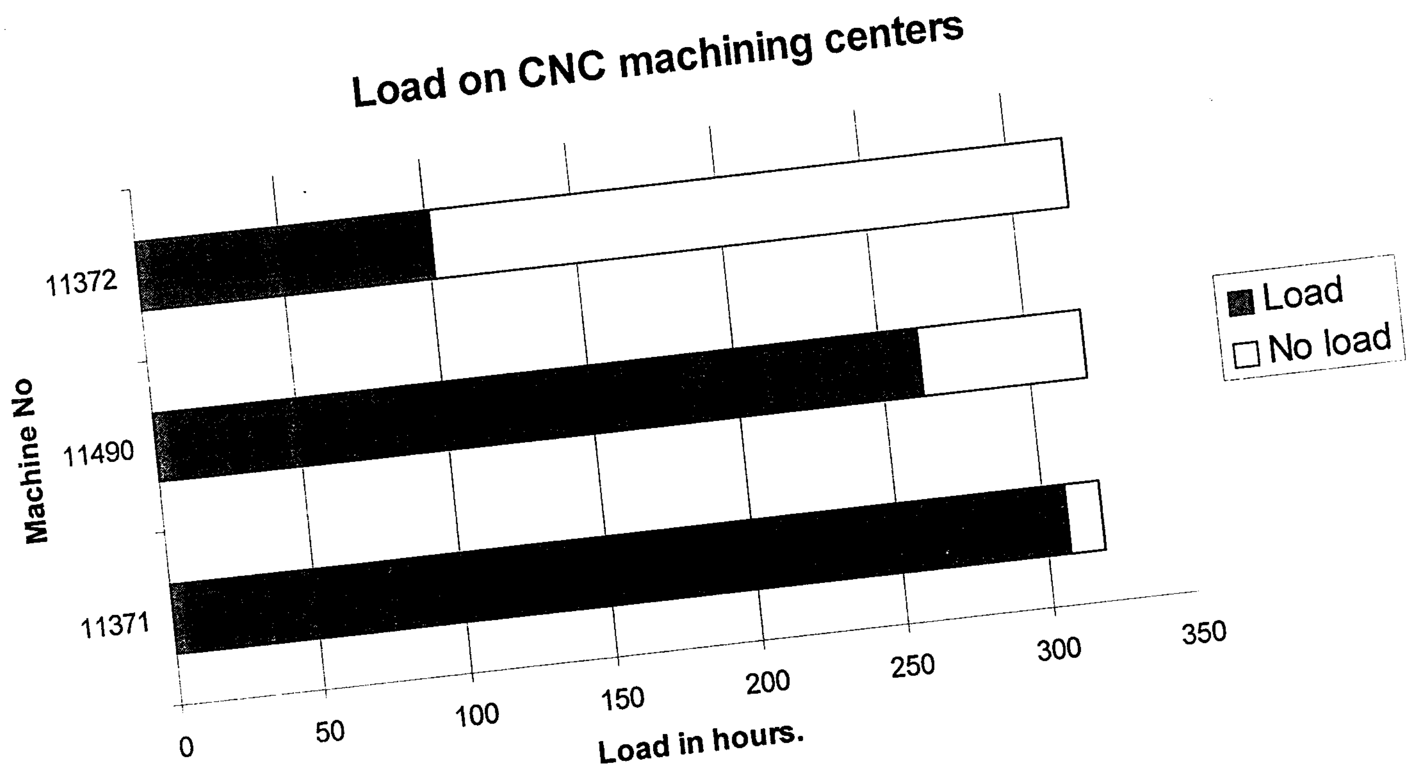


FIG 5. LOAD ON CNC MACHINES

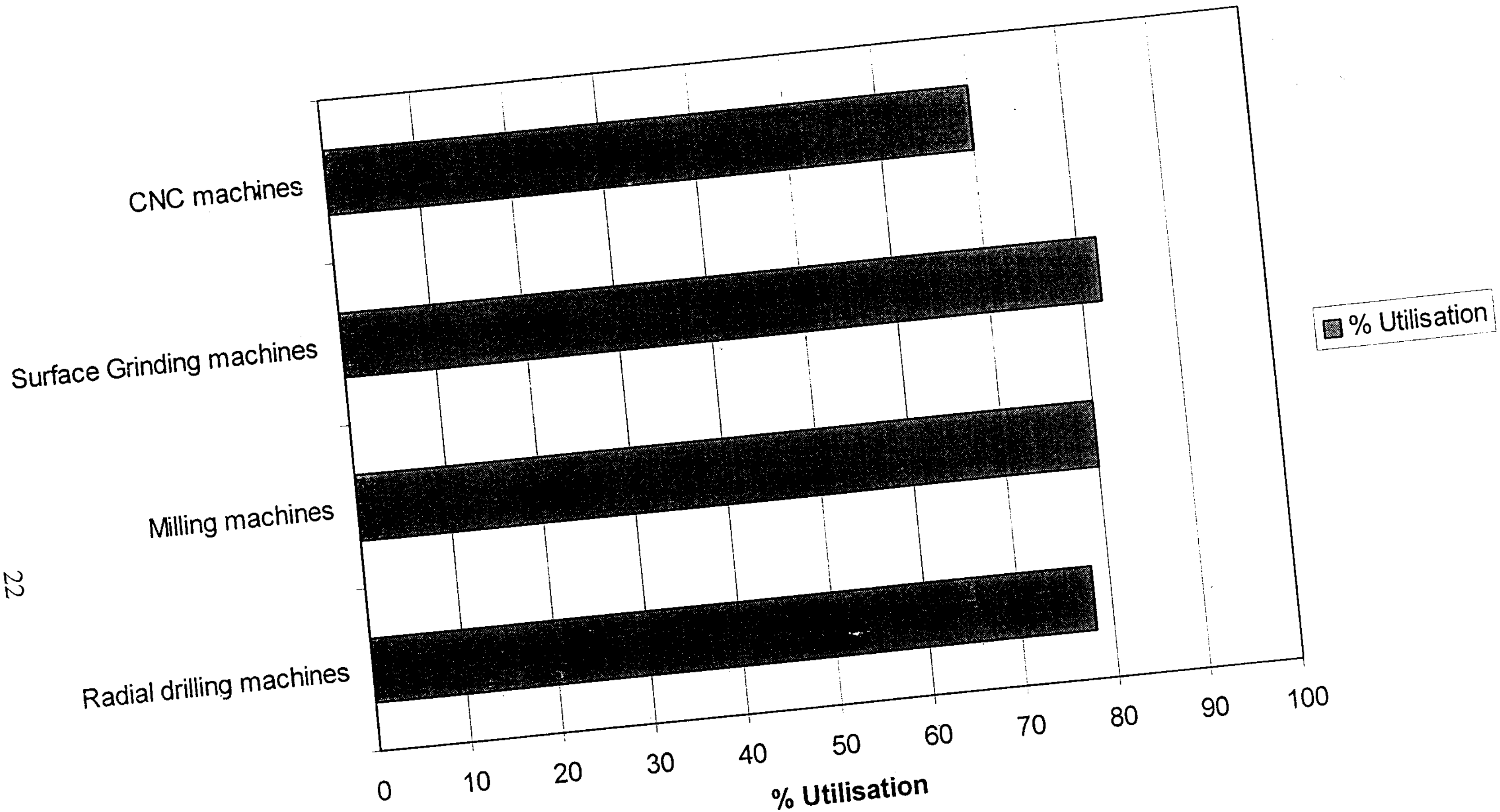


FIG 6. UTILISATION OF EACH MACHINE GROUP

3.4 PROBLEM IDENTIFICATION

The cubical parts cell of heavy machine shop consisting of 23 machines is the focussed area for this project work. The problems identified in the existing system of scheduling are as follows

1. LOW UTILIZATION OF MACHINES.

The utilization of resources is inversely proportional to the time required to complete the tasks for satisfying the requirements. In finite problems the resource utilization can be improved by scheduling the set of tasks so as to reduce the make span.

2. HIGH THROUGHPUT TIME.

Throughput time is defined as the time taken for a job between the beginning of its first operation and time it comes out of the last operation. Throughput time is high for the existing system because of improper scheduling.

3. HIGH INPROCESS INVENTORY.

Non priority jobs are sometimes loaded on machines to avoid machines remaining idle. Hence many jobs are completed earlier well ahead of the required date of completion. This leads to substantial increase in work in process inventory.

4. DELAYED DELIVERY TO ASSEMBLY.

Delays in material supply and queues in front of machines result in increased lead-time for manufacturing. This leads to products remaining unfinished at the required time. Hence timely delivery to assembly becomes difficult resulting in customer requirements not being met in time.

3.5 GOAL OF THE PROJECT

Scheduling helps in effective and advance planning and allocating jobs and their respective operations on specified machines at the planned time periods.

Based on the above, this project on "OPTIMIZING MACHINE SHOP SCHEDULING TO MEET ASSEMBLY REQUIREMENTS BY APPLYING JUST IN TIME PRODUCTION CONCEPTS" has been planned. The main goals of this project are as follows,

To enhance the shop floor capability to meet assembly requirements.

Fulfilling assembly requirements demands that the components required for assembly in the next month are to be made available by the end of this month. This requires advance planning and production of such components within this month. This will help assembly shop to carry out their duties smoothly without delays in any form.

To improve shop floor performance.

Shop floor performance can be measured by its ability to produce the required components and supply them to the next stage on time. This can be achieved by improving utilization of machines.

To improve assembly shop performance.

Assembly shop performance is affected by delays due to timely arrival of components from machines shop, rework in machined components etc.

In this regard proper scheduling methodology has to be developed to achieve the above. It is proposed to develop a software for monthly scheduling to ensure that operations are scheduled well in advance ... planning horizon in order to meet the assembly requirements and ... utilization of machines.

4.1 INCORPORATION OF JUST IN TIME PRODUCTION

JUST IN TIME (JIT) is a manufacturing philosophy, which focuses on simplifying shop floor control systems and purchasing while trying to eliminate waste and improving efficiency, quality, worker attitudes, and vendor relations.

JIT attacks wastes in production process that come from over-production, waiting time, transport, process, inventory, movements and defect goods. The wastes are identified and removed for the purpose of reducing lead-time and reducing costs at the same time maintaining quality of the end products. The crux of JIT is timely supply of materials.

JIT is designed for production environment where production of each part is repetitive. A schedule is set for a week or a month after which it is reformulated to accommodate changes in demand. The fluctuations in demand prove to be a constraint for JIT adaptations. However JIT can function effectively with fluctuations of upto 10%.

Devising a system in which goods and components move by pull mechanism rather than push mechanism can lead to substantial savings on account of a lean inventory situation. This requires initiation of a pull system on the shopfloor where each stage produces only as much as next stage needs. This debuffering of production process will establish a lean supply chain leading to considerable savings.

JIT PRODUCTION SCHEDULING is a system of production scheduling which employs a strategy by which production is scheduled as late as possible in order to minimize Work In Process (WIP) at the same time ensuring against backlogs. Here given the demand and due dates, the objective is to minimize the cumulative lead-time of the production schedule and hence deliver products at the right time.

The basic idea is to simplify shop floor control by reducing WIP and lead times and to aid in better scheduling. Orders will move through so smoothly that there would be no need to track them within the complex shop floor system.

The above just in time production concept can be applied for achieving the goals of this project as follows.

ENHANCING THE SHOP FLOOR CAPABILITY TO MEET ASSEMBLY REQUIREMENTS.

Assembly shop is the immediate customer for the shopfloor. Fulfilling assembly requirements demands availability of components at the time of assembly. In order to ensure this backward scheduling method is adopted.

In **Backward scheduling** given the due date a schedule is prepared by working backward to determine the required start date.

Adopting backward scheduling helps to ensure that the components may not be produced well ahead of their requirements thereby reducing inventory carrying costs.

In backward scheduling production is scheduled as late as possible at the same time avoiding backlogging of end items. This results in just in time production scheduling.

IMPROVING SHOP FLOOR PERFORMANCE.

Proper utilization of machines is a key factor for shopfloor performance. Proper utilization of machines requires the idle time of machines to be used.

Utilization is mainly affected by the delays due to machines waiting for components or components waiting for machines. This can be solved by, segregating functionally identical machines (alternate machines) and using them for production of a particular component when the planned machine is engaged in the specified time period.

This helps in minimizing the delays in production process and reducing make span thereby enhancing utilization of machines and improving shop floor performance.

Achieving the above two objectives ensures improved assembly shop performance as delays in the form of components arrival may be eliminated.

SOFTWARE FOR SCHEDULING:

For achieving the goals, a software has been developed. It is based on an algorithm that has been designed taking into consideration the following,

- Backward scheduling.
- Checking for functionally identical machines incase planned machines are engaged at the specified time periods.

4.2 ASSUMPTIONS

The algorithm and hence the software for scheduling have been developed based on the following assumptions.

1. Machines are reliable.

All machines are ready to work at any point of time provided they have not been scheduled already i.e. they are free from stoppages such as breakdowns.

2. A machine utmost performs one operation at a time.

No machine can perform more than one operation at a time. Only after a particular operation for a specific component has been completed the next operation, even if it can be done on the same machine, can be performed. Simultaneous performing of two operations on the same component in one setting is not permitted.

3. Processing times of all operations and assembly due dates are deterministic and known.

The processing time and due dates are always known and fixed i.e. there is no randomness in the processing times and due dates.

4. Backlogging is not permitted.

All components required have to be scheduled within the planning horizon i.e. dragging the current requirements beyond planning horizon is not permitted.

5. Sufficient buffer space is available at each machine.

Sometimes jobs have to wait in queues in front of machines. In such cases storage space needs to be available by each machine for the pending jobs.

6. Preemption of operations is not permitted.

Jobs once started cannot be interrupted for any reason until entire batch is completed.

7. In process inventory is allowed when components wait for a machine for operation.

Jobs may wait for the next operation incase the machine for the respective operation is engaged.

8. Machines may be idle.

Machines being idle due to want of operations for processing cannot be avoided.

9. No two operations of same job may be processed simultaneously.

Only when a specific operation for a batch of components have been completed the next operation on the same batch can be performed i.e. parallel processing is not allowed.

10. Three hours gap is provided for all jobs between successive operations.

This is to provide time for

- Inspection
- Pad closing and
- Transportation to the next stage.

4.3 ALGORITHM

INTRODUCTION ABOUT THE ALGORITHM

The proposed algorithm proceeds in a backward scheduling manner. Here the operation having the largest value of earliest finish time, obviously last operation for a specific component among the list of components to be manufactured is scheduled first and remaining components and their respective operations are scheduled backwards in subsequent steps giving due respect for precedence and capacity constraints.

The due dates, product structures, routing data and time study data are inputs to the algorithm. Given the inputs a set of feasible operations is defined using which the algorithm generates a schedule in the following four steps.

1. Select an operation from the feasible set of operations
2. Select the specified machine or alternate machine
3. Schedule the selected operation in the selected machine
4. Update the set of feasible operations.

STEP BY STEP PROCEDURE

The step by step procedure is enumerated below.

1. Input Manufacturing System Data
   - Product data
     - Due dates
     - Running time
     - Processing time, Setting time.
     - Routing information

2. Generate operations network from routing data of products.

3. Using forward pass compute earliest start and earliest finish times of all operations.

4. Form a list of all operations (say F)

5. While feasible list of operations is nonempty (i.e. $F \neq \varnothing$)

   5.1 Select operation from list having largest value of earliest finish time
   say O_j

   5.2 Set tentative finish time F_j equal to

   (i) Due date if operation is the last operation for a job (or)

   (ii) Latest starting time of successive operation, if successive operation exists.

5.3 (i) Set tentative latest starting time for operation as $S_j = F_j - t_j$.

(ii) If machine is available during $[S_j, F_j]$, S_j and F_j are the ideal starting and finishing times respectively.

Go to 5.4

Else check for identical machine availability

(i) If identical machine is available during [Sj, Fj]; Sj, Fj are starting and finishing times.

Go to 5.4

(ii) **Else** select machine whose Sj+1 is larger and set Fj =Sj+1 as the latest available finishing time and set Sj = Sj+1 – tj as the starting time, such that the machine is available during [Sj, Fj].

Go to 5.4

5.4 Schedule operation Oj during the time duration of [Sj, Fj] on the corresponding machine.

5.5 Delete respective operation Oj from the list.

6. Display load chart on request

WORKING OF THE ALGORITHM

Initially on receiving the forecasted demand and due dates for assembly a list of feasible operations for the production of required components are generated.

Earliest finish time for all operations in the list are calculated and the scheduling is done starting from the operation having the largest value of earliest finish time.

The operations scheduling process proceeds as follows

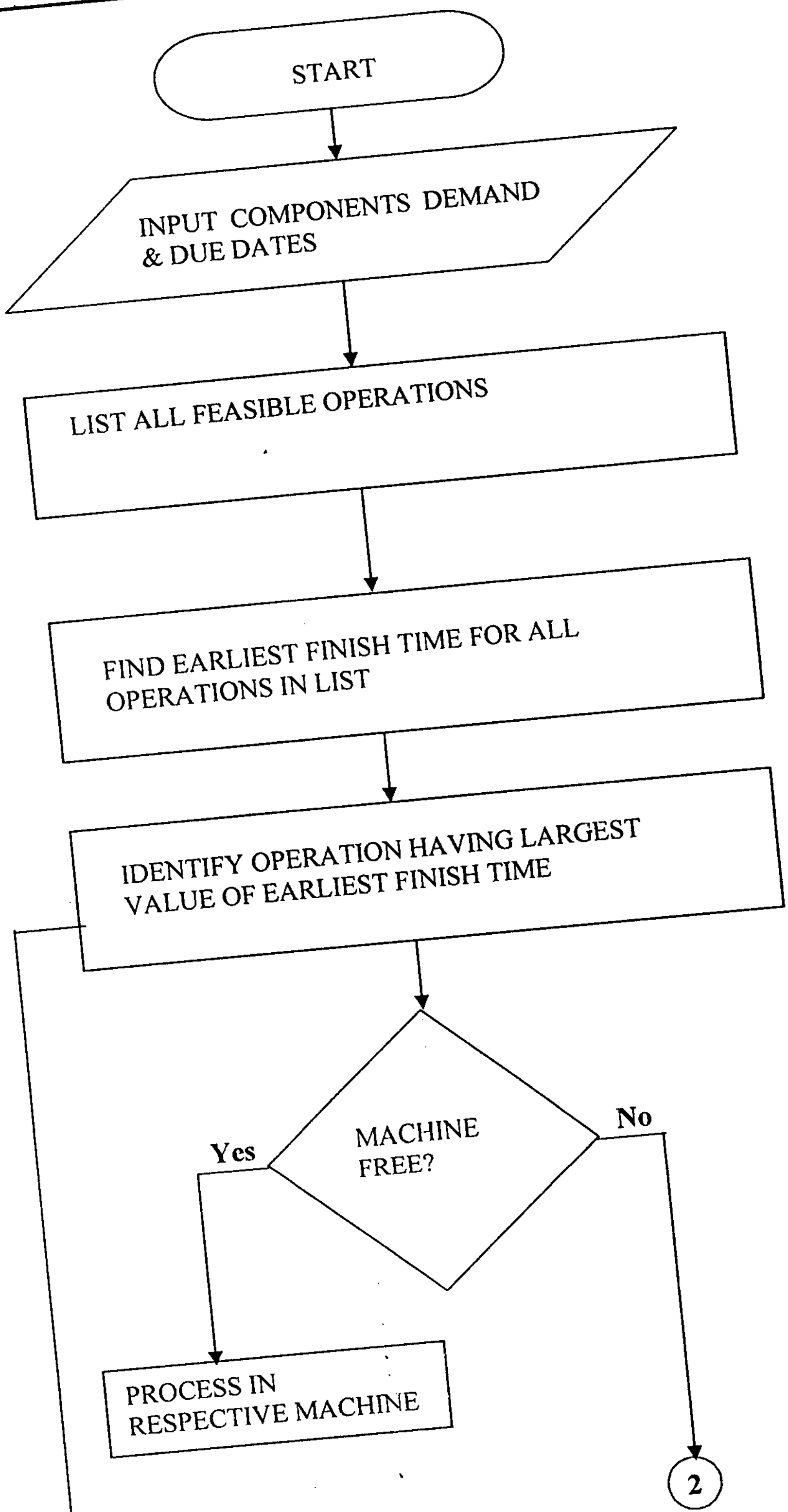
The scheduling process starts from the component and its respective operation having the largest value of earliest finish time. The respective operation is scheduled for the specified machine such that the component may be available at the time of assembly. All other remaining operations and components are scheduled by selecting the components based on the largest value of earliest finish time criterion.

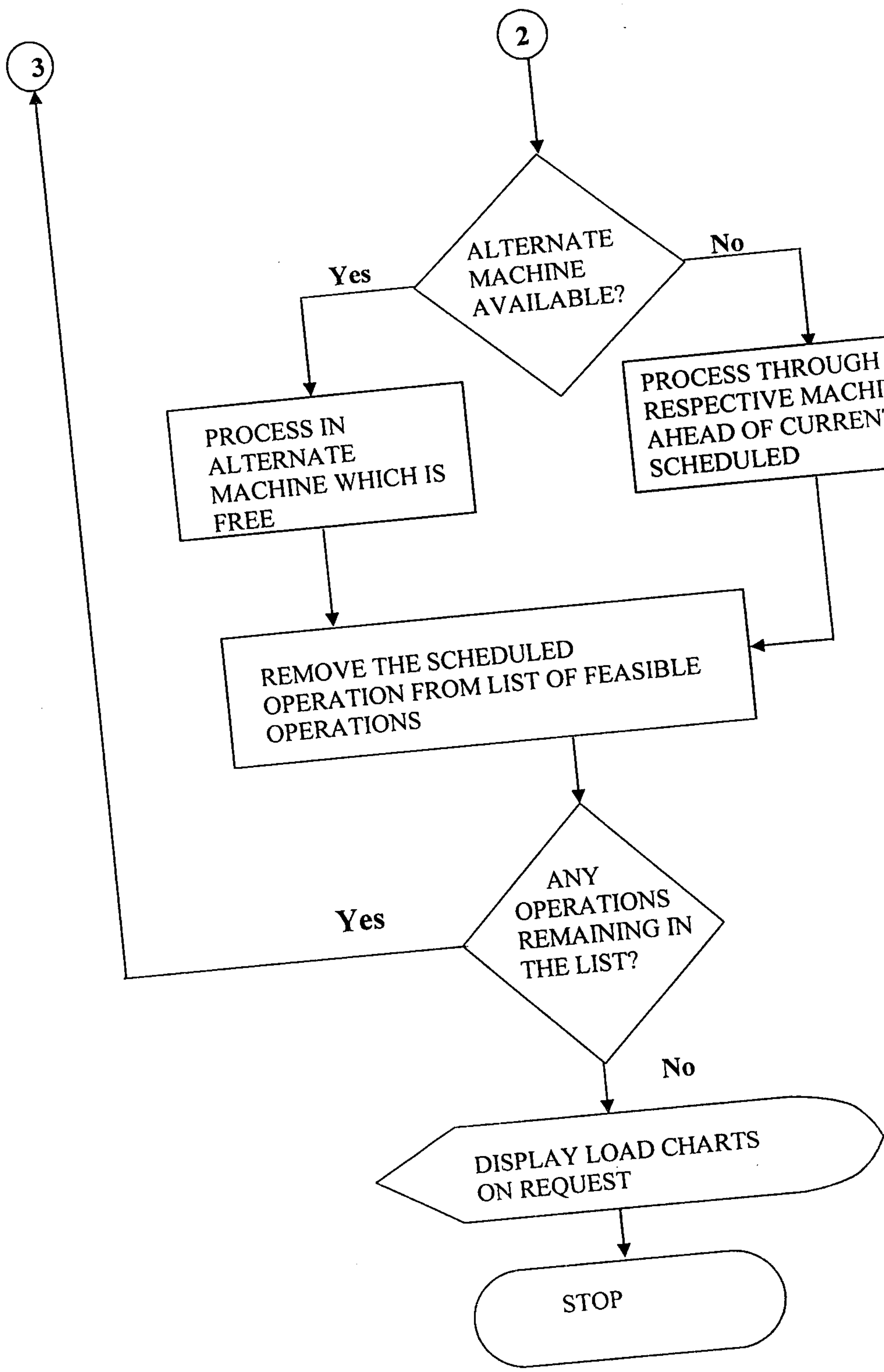
While scheduling the operations, if the specified machine is found to be engaged alternate machines (functionally identical) machines are checked for availability during the specified start and finish time. If it is available during the specified start and finish times then that particular operation is scheduled in the alternate machine during the same time.

If both planned machine and alternate machine are not available during the specified start and finish times then the operation is allotted for the machine, which becomes available at the latest i.e. whose starting time for the subsequent operation is largest. This makes sure that the operation is scheduled ahead of the currently scheduled operation as late as possible.

Scheduled operations are removed then and there as they get scheduled. The algorithm continues until all operations are scheduled in appropriate machines.

FLOW CHART


START
INPUT COMPONENTS DEMAND
& DUE DATES
LIST ALL FEASIBLE OPERATIONS
FIND EARLIEST FINISH TIME FOR ALL
OPERATIONS IN LIST
IDENTIFY OPERATION HAVING LARGEST
VALUE OF EARLIEST FINISH TIME
MACHINE
FREE?
Yes
No
PROCESS IN
RESPECTIVE MACHINE
2



2
3
ALTERNATE MACHINE AVAILABLE?
Yes
No
PROCESS IN ALTERNATE MACHINE WHICH IS FREE
PROCESS THROUGH RESPECTIVE MACHINE AHEAD OF CURRENT SCHEDULED
REMOVE THE SCHEDULED OPERATION FROM LIST OF FEASIBLE OPERATIONS
ANY OPERATIONS REMAINING IN THE LIST?
Yes
No
DISPLAY LOAD CHARTS ON REQUEST
STOP

5.1 SOFTWARE INTRODUCTION

INTRODUCTION

Computerization of any step by step repetitive procedure helps to run the procedure again and again whenever required at the minimum time and utmost accuracy and repeatability.

Hence to execute the algorithm in a simple and effective manner, a software package was developed. The software uses Visual basic as front end and Microsoft Access 97 as backend tools.

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 it to be feasible so far.

The salient features are as follows.

Visual refers to the method used to create graphical user interface. Rather than writing numerous lines of codes to describe the appearance and location of interface elements pre-built objects are simply placed on the location of interest on the screen.

1. **User- friendly GUI (Graphical 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 moves over the icon for about a second or so.

2. Building screen savers.

This consists of creating the display portion declaring module level variables displaying the form in full screen mode, adding a configuration form, adjusting the programs properties and adding a module and a subroutine etc.

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,

(1) Create new forms.
(2) List all the forms in the application.
(3) Delete all the newly created forms.

4. **Easy to connect with MS office application.**

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

5. Easy for coding.

The readily available tools for creating forms helps in limiting the coding to help the software to perform its intended function alone unlike the conventional programming languages like C-programming etc. where coding has to be done for creating forms also.

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 online for help facility**.

9. **Interactive Help Features** like auto list members and auto quick info that no longer wait for the user to interact with an interface.

5.2 DATABASE DESIGN

A database is a collection of data or related facts. It arranges the data in a specific structured format. Databases are generally viewed in the form of tables consisting of rows and columns. The collection of related data in one table is generally referred to as a file or table. Each row in a table represents a record set while each column represents a field.

A record consists of a set of data for each database entry made manually in the table. Similarly a field groups each piece of data among the records into specific category of data.

In this software data are stored in MS Access 97 used as a back end tool. MS Access stores volume of records and query designing is very user friendly. Further it also costs very less as it comes along with MS Office software or along with windows.

Five tables were created namely,

1. Orders table.
2. Machining details table.
3. Intermediate table 1.
4. Intermediate table 2.
5. Intermediate table 3.
6. Machine status table.
7. Final table.

ORDERS TABLE:

In orders table the forecasted quantity with assembly due dates are listed corresponding to the month of schedule.

MACHINING DETAILS TABLE:

Here for each product code, components as per their drawing numbers are listed along with their operation numbers, operation times, machine numbers .

The remaining tables are created for intermediate calculations to be made for scheduling and displaying the final schedule.

INTERMEDIATE TABLE 1:

This table is for storing the product code and component drawing numbers with the processing time and total time calculations for each operation.

INTERMEDIATE TABLE 2:

This table stores the product codes, drawing numbers, operations with the earliest start and earliest finish times for each operation.

INTERMEDIATE TABLE 3:

This table stores the tentative finish and tentative start times for each operation .

MACHINE STATUS TABLE:

This table maintains the status of each machine. It contains the times during which the machine is engaged or free.

FINAL TABLE:

This table stores data regarding the operations and the time during which they are scheduled with the machines to which they are allotted for.

DATABASE STRUCTURE:

The databases are generally classified into five types,

1. Flat file database.
2. Relational database.
3. Hierarchical database.
4. Network database.
5. Object oriented database.

Relational database is mostly used due to its flexibility in accessing related data. The relational structure represents a data made up of set of related tables.

In this project a relational database is used. Various fields are created in the tables along with their data type. This would be helpful in retrieving the details regarding the process.

Database structures of the tables are shown below.

TABLE No: 5 DATABASE STRUCTURE – ORDERS TABLE.

S NO	FIELD NAME	DATA TYPE	DESCRIPTION
1	Pdtcode	Number	Product code
2	Qty	Number	Quantity
3	Date	Date/time	Scheduled date
4	Month	Text	

TABLE No: 6 DATABASE STRUCTURE – MACHINING DETAILS TABLE

S NO	FIELD NAME	DATA TYPE	DESCRIPTION
1	Pdtcode	Number	Product code
2	Drgno	Text	Drawing number
3	Npmr	Number	Number per machine regular
4	Npme	Number	Number per machine eventual
5	Opnno	Number	Operation number
6	Stgtime	Number	Setting time per batch
7	Attdtime	Number	Allotted time per unit
8	Machinecodeno	Number	Machine number

TABLE No:7 DATABASE STRUCTURE – INTERMEDIATE TABLE 1

S NO	FIELD NAME	DATA TYPE	DESCRIPTION
1	Pdtcode	Number	Product code
2	Drgno	Text	Drawing number
3	Opnno	Text	Operation number
4	Ttime	Number	Total time
5	Ptime	Number	Processing time

TABLE No: 8 DATABASE STRUCTURE – INTERMEDIATE TABLE 2

S NO	FIELD NAME	DATA TYPE	DESCRIPTION
1	Pdtcode	Number	Product code
2	Drgno	Text	Drawing number
3	Opnno	Text	Operation number
4	Erlyfhtime	Number	Early finish time
5	Erlysttime	Number	Early start time

TABLE No: 9 DATABASE STRUCTURE – INTERMEDIATE TABLE 3

S NO	FIELD NAME	DATA TYPE	DESCRIPTION
1	Pdtcode	Number	Product code
2	Drgno	Text	Drawing number
3	Opnno	Text	Operation number
4	Erlyfhtime	Number	Early finish time
5	Ttime	Number	Total time
6	Tentfnsh	Number	Tentative finish time
7	Tentstrt	Number	Tentative start time

TABLE No: 10 DATABASE STRUCTURE – MACHINE STATUS TABLE

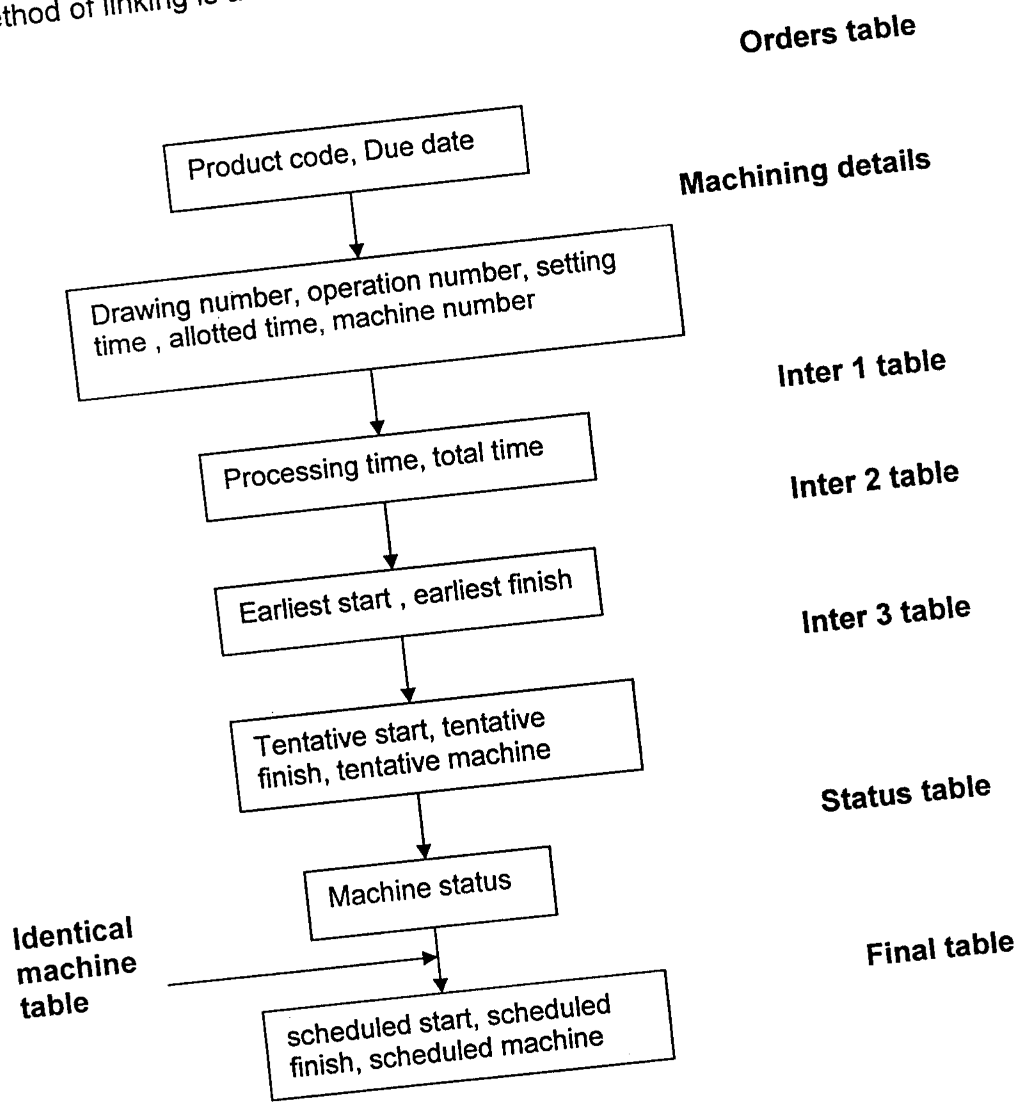
S NO	FIELD NAME	DATA TYPE	DESCRIPTION
1	Pdtcode	Number	Product code
2	Drgno	Text	Drawing number
3	Opnno	Text	Operation number
4	Erlyfhtime	Number	Early finish time
5	Ttime	Number	Total time
6	Tentfnsh	Number	Tentative finish time
7	Tentstrt	Number	Tentative start time

TABLE No: 11 DATABASE STRUCTURE – FINAL TABLE

S NO	FIELD NAME	DATA TYPE	DESCRIPTION
1	Pdtcode	Number	Product code
2	Drgno	Text	Drawing number
3	Opnno	Text	Operation number
4	Tentfin	Text	Tentative finish time
5	Tentstr	Text	Tentative start
6	Tentmachcod	Text	Tentative machine code
7	Tentmachnum	Text	Tentative machine number
8	Schlfin	Text	Scheduled finish
9	Schlsrt	Text	Scheduled start
10	Schlmachcod	Text	Scheduled machine code
11	Schlmachnum	Text	Scheduled machine number

5.3 MODE OF ACCESSION

The method of linking is as shown in figure.



6. RESULTS AND DISCUSSION

By analysis of the existing system it was found that due to improper urgency based scheduling the shop floor activities are not planned effectively.

Ineffective scheduling at the nick of time leads to poor performance in

- Delivery of components and subassemblies not on time to assembly
- Poor utilization of resources.
- Over looking the quality of components at the manufacturing stage resulting in rework at the time of assembly.

The reasons behind the above were identified. To counter the causes an effective operation sequence based algorithm was developed. The algorithm utilizes the just in time production strategy in scheduling operations to prevent the components being produced well in advance at the same time to ensure that backlogging is avoided.

Based on the algorithm a software package has been developed. The package schedules operations as late as possible in order to satisfy assembly requirements at the same time ensuring that delays in the form of queues are minimized thereby achieving reduced make span and improved utilization of resources.

It can be seen from the load charts that the production can be completed within the specified periods thereby satisfying the assembly requirements. In case there is excess load on certain machines then extra shifts may be planned for such machines.

The usage of functionally identical machines ensures that the delays are minimized to the possible extent there by enhancing the machine shop performance.

Incorporation of trial and spares orders can be met in the no load time. The exact time for scheduling trial and spares can be determined by proper examination of free times available in the final schedule table.

ADVANTAGES OF THE SOFTWARE:

1. **Current job status can be identified.**

   The scheduling software helps in identifying the current job status of what jobs are running and where they are located. They can be identified from the final schedule table displayed as MS Access table.

2. **Future operations can be planned.**

   The schedule generated helps in guiding future operations i.e. determining what operations should be processed next and in what work centers.

3. **Ensures availability of materials and capacities for later requirements.**

   The shop supervisor can plan adequacy of materials and availability of machines, tools, jigs and fixtures required for ensuing operations. This helps in preventing delays in the form of waiting for raw materials, toolings etc.

4. **Maximizes operational efficiency.**

   The schedule generated ensures to maximize utilisation of machines and minimize inventory and related costs.

5. **Maintains operational control.**

   Monitoring job status and lead-times, measuring progress at ach and every stage helps the shop to signal corrective action whenever deviations from the planned production arise.

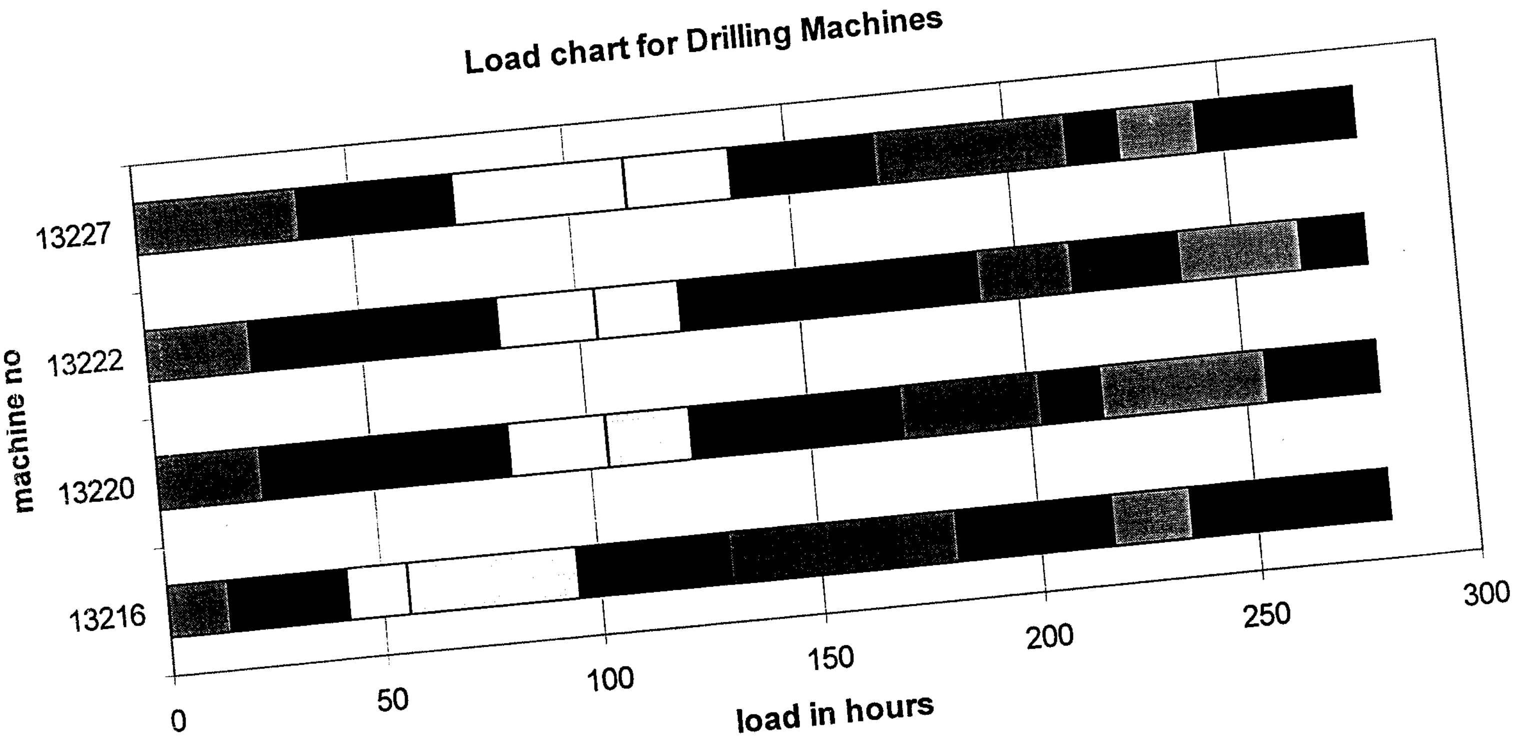


FIG 7. LOAD CHART FOR RADIAL DRILLING MACHINES

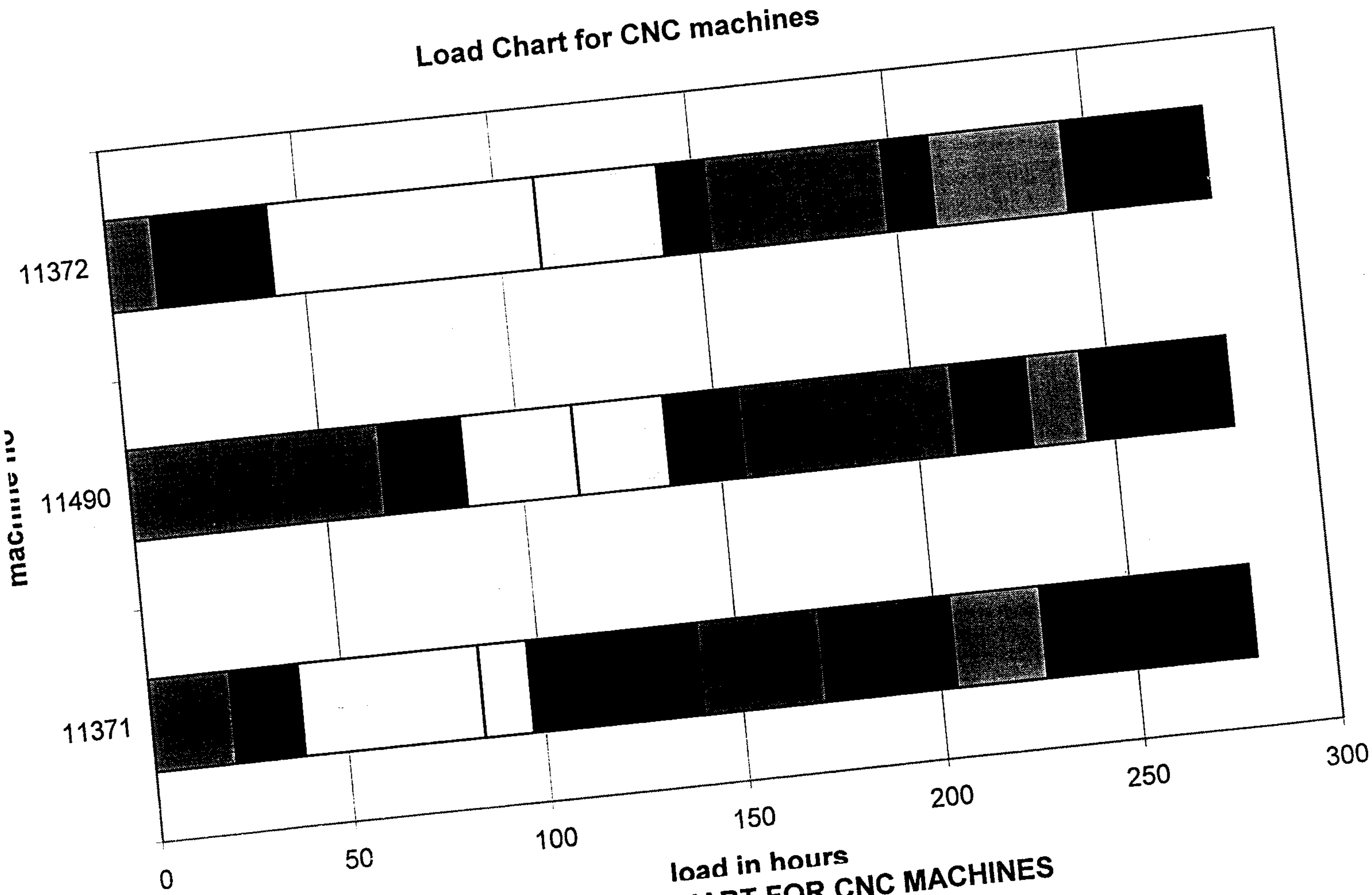


FIG 8. LOAD CHART FOR CNC MACHINES

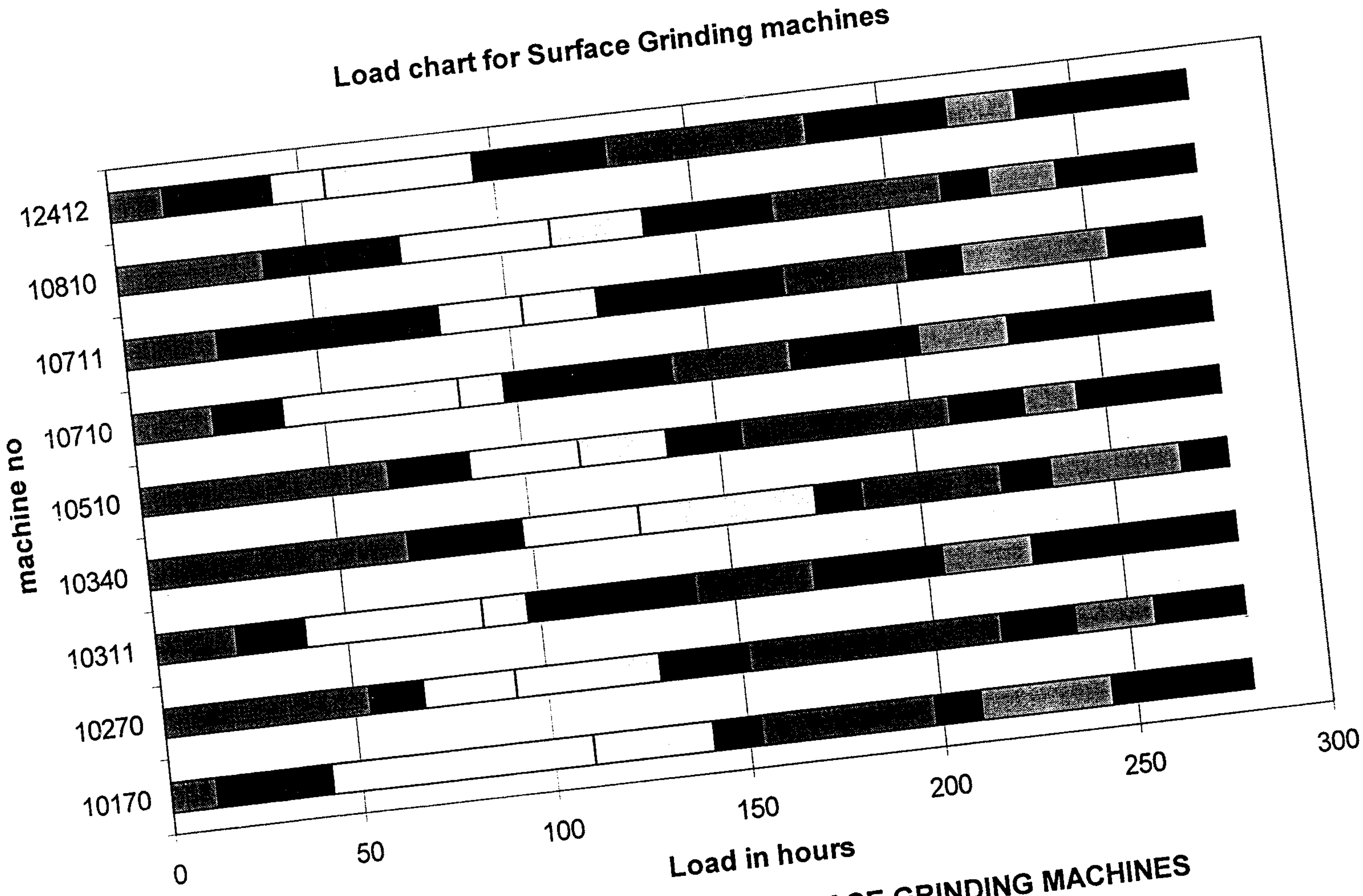


FIG 9. LOAD CHART FOR SURFACE GRINDING MACHINES

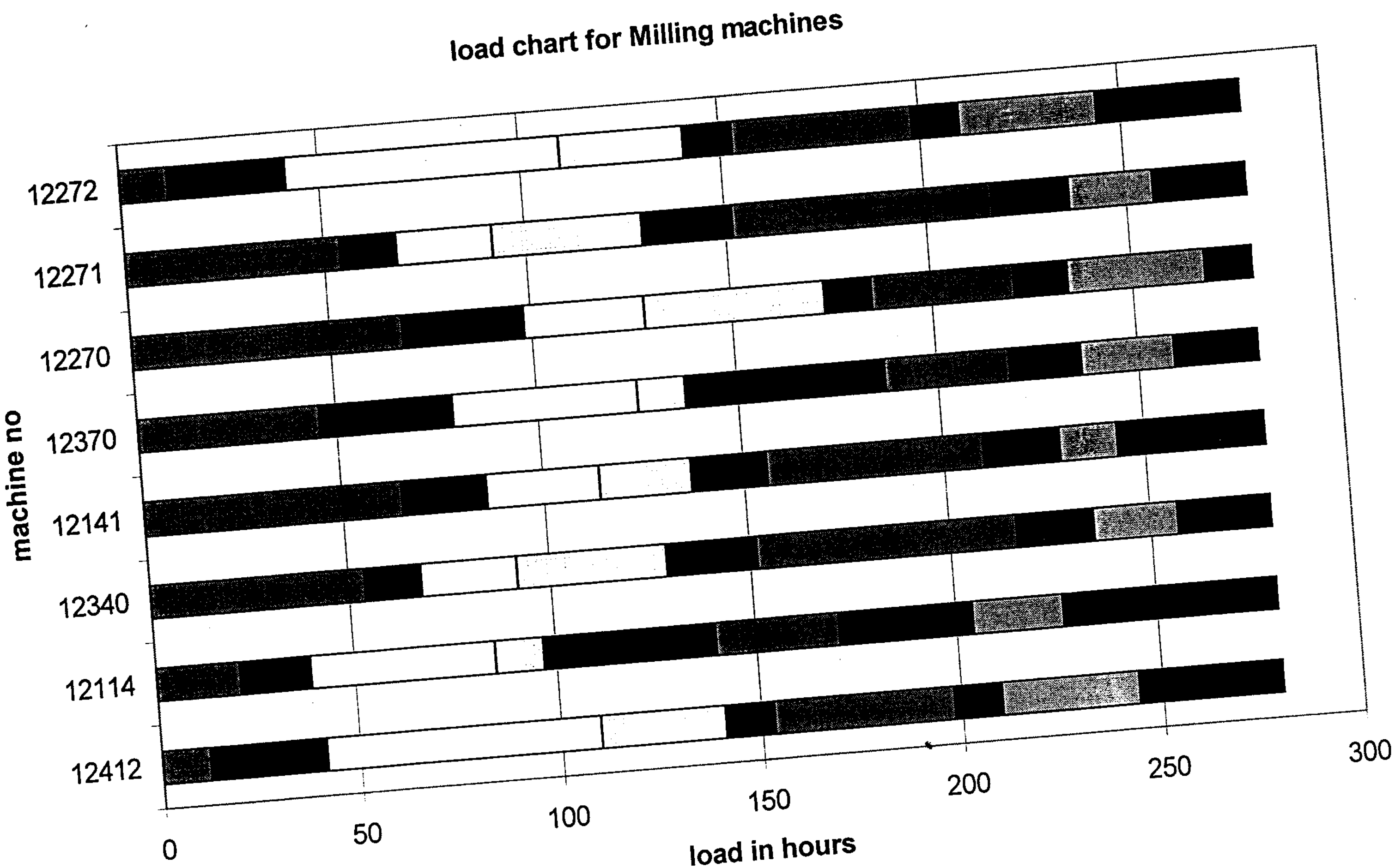


FIG 10. LOAD CHART FOR MILLING MACHINES

7. CONCLUSION

Proper scheduling practices enable the end user to ensure the availability of finished goods on time, track the jobs in the system at any time and make proper utilization of machines.

The software package has been developed keeping in mind the above requirements. The algorithm has been designed giving due considerations to operation sequence, machines availability and assembly shops requirements.

The output of the software is a machine-loading chart for the various machines available and a schedule of operations for the available machines within the planning horizon.

The load chart displayed by interfacing with MS Excel gives the shop floor supervisor an idea of the load available on the individual machines. He can use it effectively for planning trial and spares order production.

DIRECTIONS FOR FUTURE RESEARCH:

Optimization of the schedule in order to achieve minimum make span for a specified set of operations can be carried out. Establishing an objective function using the quantity of each component and processing time of each operation, framing constraints for the machine capacity, alternate machines availability etc. and solving by operations research techniques will help performing optimization.

This will enhance the shop floor's capability to adapt to fluctuations in demand and the production of trial and spares orders effectively.

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WEBSITES:

www.emaraldinsight.com

www.dynamicscheduling .com

```
Dim db As Database
Dim rs As Recordset
Dim rs2 As Recordset
Dim rs3 As Recordset
Dim rs4 As Recordset
Dim rs5 As Recordset
Dim rs6 As Recordset

Private Sub cmdCalculate_Click()
    Dim od As Date
    Dim cdd As Date
    path = App.path + "\db2"
    Set db = OpenDatabase(path)
    rs.Close
    Set rs2 = db.OpenRecordset("orders", dbOpenDynaset, dbReadOnly)
    Set rs3 = db.OpenRecordset("inter1", dbOpenDynaset)
    Set rs4 = db.OpenRecordset("inter2", dbOpenDynaset)
    Set rs5 = db.OpenRecordset("inter3", dbOpenDynaset)
    Set rs6 = db.OpenRecordset("tent", dbOpenDynaset)
    cdd = Day(rs2.Fields("date")) - Day(DATE)
    dd = cdd * 14
    Text4 = dd
    rs3.MoveFirst
    rs4.MoveFirst

    Do While Not rs4.EOF
      rs5.AddNew
      rs5.Fields("pdtcode") = rs4.Fields("pdtcode")
      rs5.Fields("drgno") = rs4.Fields("drgno")
```

```
rs5.Fields("opno") = rs4.Fields("opno")
rs5.Fields("erlyfhtime") = CVar(rs4.Fields("erlyfhtime"))
rs5.Fields("ttime") = CVar(rs3.Fields("ttime"))
rs5.Fields("tentfnsh") = dd
rs5.Fields("tentstrt") = dd - rs3.Fields("ttime")
dd = rs5.Fields("tentstrt")
rs5.Update
rs4.MoveNext
rs3.MoveNext
Loop
rs2.Close
rs3.Close
rs4.Close
rs5.Close
db.Close
End Sub

Private Sub Form_Load()
    Dim path As Variant
    Dim prsstime As Variant
    Dim erlyStTime, erlyFhTime As Variant
    Dim schdlStTime, schdlFhTime As Variant
    Dim pcont, dcont As Variant
    Dim drawno, opno As Variant
    Dim oprdcode As Variant
    Dim Olderlyfhtime
    path = App.path + "\db2"
    Set db = OpenDatabase(path)
    Set rs = db.OpenRecordset("machiningdetails", dbOpenDynaset)
    Set rs2 = db.OpenRecordset("orders", dbOpenDynaset, dbReadOnly)
    Set rs3 = db.OpenRecordset("inter1", dbOpenDynaset)
    Set rs4 = db.OpenRecordset("inter2", dbOpenDynaset)
```

```
Set rs5 = db.OpenRecordset("inter3", dbOpenDynaset)
  rs2.MoveFirst
Do While Not rs2.EOF
 pcont = 0
 prdcode = rs2.Fields("pdtcode")
 rs.MoveFirst
   Do While Not rs.EOF
     If (prdcode = rs.Fields("pdtcode")) Then
         pcont = pcont + 1
         drawno = rs.Fields("drgno")
         opno = rs.Fields("opnno")
         rs3.AddNew
         rs4.AddNew
         rs3.Fields("pdtcode") = prdcode
         rs4.Fields("pdtcode") = prdcode
         rs3.Fields("drgno") = drawno
         rs4.Fields("drgno") = drawno
         rs3.Fields("opno") = opno
         rs4.Fields("opno") = opno
         prsstime = (rs.Fields("attdtime") / 100) * (rs2.Fields("qty")) +
                                                    rs.Fields("stgtime")

           Text1 = prsstime
           Text2 = prsstime + 3
           rs3.Fields("ttime") = Val(Text2)
           rs3.Fields("ptime") = prsstime
            If opno = 10 Then
              erlyStTime = 0
            Else
              erlyStTime = Olderlyfhtime
            End If
           erlyFhTime = erlyStTime + Val(Text2)
             rs4.Fields("erlysttime") = erlyStTime
```

```
      rs4.Fields("erlyfhtime") = erlyFhTime
      Olderlyfhtime = rs4.Fields("erlyfhtime")
      rs4.Update
      rs3.Update
    If rs.EOF Then
        rs.MovePrevious
      End If
   End If
   rs.MoveNext
   Loop
  rs2.MoveNext
  Loop
 Text5 = DATE
 frmModule1.Show
 rs4.Close
 rs3.Close
 db.Close
End Sub
```

TABLE 12: LIST OF ALTERNATE MACHINES

<table>
<tr><th>MACHINE TYPE</th><th colspan="6">MACHINE NUMBERS</th></tr>
<tr><td>RADIAL DRILLING MACHINE</td><td colspan="6">13216
13220
13222
13227</td></tr>
<tr><td>MILLING MACHINE</td><td>10710
10711</td><td>10510</td><td>10170</td><td>10270</td><td>10311
10340</td><td>10810</td></tr>
<tr><td>MACHINING CENTER</td><td colspan="3">11371
11372</td><td colspan="3">11471</td></tr>
<tr><td>SURFACE GRINDING MACHINE</td><td>12141
12114</td><td colspan="2">12270
12271
12272</td><td colspan="2">12370
12340</td><td>12412</td></tr>
</table>