CHAPTER 1

1.0 INTRODUCTION
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The global competition in liberalised markets has forced all economies to learn an important lesson that the manufacturing can be a potent competitive weapon. Towards meeting this end, Manufacturing Management should improve to make full use of all resources. At the same time it must be able to quickly introduce new concepts and improve productivity levels with full utilisation of resources for maximum throughput.

This doctoral thesis deals with the analysis of dynamic behaviour of manufacturing systems to meet the demands of fluctuating markets effectively and to ensure optimal performance. In carrying out this work, systems concepts and modeling, industrial dynamics, dynamic scheduling, and system simulation (Event based approach) are used.

Batch processing industries are more important for any industrialised country as they contribute a major percentage of wealth and thus play a vital role in the National Economy. In batch manufacturing, products are manufactured in small lots (batches) at intervals which vary according to demands. Batches are repeated for processing at certain intervals of time. This kind of manufacturing systems poses considerable problems to management in maintaining performance efficiency at changing demand patterns. Manufacturing systems deployed in the above environment are inherently complex and a large number of factors influence inter-relationship between components/batches, machines and personnel.

Managers of batch manufacturing industries, often complain about fluctuating manufacturing lead time for different batches, frequent bottlenecks in manufacturing, high WIP and difficulties in tracking down the progress of individual orders. Priorities assigned to various components or batches

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change dynamically and the components waiting for processing are kept aside to meet the changes in priorities. This increases queue lengths, piles up WIP, hampers space utilisation and leads variation in manufacturing lead time. Increased manufacturing lead time implies that the forecast has to be made more accurately in fixing proper priorities to the components waiting for processing.

Thus, all the problems mentioned above are direct consequences of fluctuating market conditions and the manufacturing lead times. It has been confirmed by numerous studies [28] that in the conventional batch manufacturing of engineering products, only 5% of total flow time for a component is spent on a machine tool. Remaining 95% is spent in transportation and waiting. Of this 5% also, less than 30% (1.5% of total flow time) is the time during which actual machining is taking place. The remaining 70% (3.5% of total flow time) is required for loading, unloading, positioning and gauging and other causes of non-processing time. Figure 1.1 shows the graphical presentation of time spent by a component in batch manufacturing system.

Fig. 1.1 DISTRIBUTION OF TIME SPENT BY A COMPONENT IN A BATCH MANUFACTURING SYSTEM
To counter these problems in batch manufacturing, some solutions are conceived for a standard manufacturing distribution system as suggested by Coyle[3]. This system was used by Mohapatra and Sharma [9] to illustrate the use of feedback control theory in the design of industrial system. A new model consisting of different functions related to a manufacturing system has been developed based on the above configuration in this thesis work using industrial dynamics and discrete event simulation technique to measure the optimal performance of manufacturing systems. Any industrial system has two important functions such as marketing and manufacturing. Marketing holds stock to meet the sales and the stock is replenished by manufacturing. While carrying out the manufacturing activities, the backlog of unfilled orders and market fluctuations influence the manufacturing rate and the customers receive goods through a distribution system after a delay. The two rates, firstly the MWF (demand) and secondly the actual rate of manufacturing (capacity) control the flow of materials to the manufacturing system.

It is against this background a critical review of literature available in this field are made in Chapter two. On the basis of this review, it is found that there exists a need to establish a generalised model for analysing the manufacturing systems under dynamic conditions.

Chapter three deals with the manufacturing system design and dynamic analysis through a mathematical model developed using Industrial Dynamics approach. The analysis is carried out by running the program with input of forecast demands, various delays in processing orders, required rates of filling and dispatching orders. When ordering rates are high, the inventory levels go down rapidly. This situation affects the manufacturing inventory system in meeting orders at the desired rate. The required manufacturing rates are predicted using this analysis and fitted to standard statistical distributions. The performance of manufacturing system is measured at varying market conditions.
Chapter four deals with design and development of a computer program for Stabilised Sequence Planning System (SSPS) of batch manufacturing. The main characteristic features of this SSPS are the sequence planning which includes the ability to provide logical basis for determining the average level of Work-In-Process (WIP) and stabilisation of manufacturing lead time. The logical loading strategy adapted by SSPS enables to monitor the WIP in batch manufacturing. Using dynamic queue records of components/products, the capacity utilisation of work-centers is measured.

Chapter five covers a method of capacity assessment of manufacturing systems with program input such as the number of components to be manufactured (MWF), machine time available in hours, standard process plans and backlog of orders through dynamic simulation. A generalised model developed for such dynamic simulation of batch manufacturing systems is dealt in detail in this chapter.

Chapter six deals with the dynamic scheduling and computer simulation of batch manufacturing systems. Eight popular scheduling rules chosen for the study of behaviour of dynamic scheduling system model are presented in this chapter.

Chapter seven presents with the dynamic scheduling problems and solutions of job shop comprising six work centers and 'n' components. This study is about the behavior of the system, with the arrival of urgent orders and normal orders. Urgent orders are scheduled for processing based on their urgency and given priority over normal orders. The system is analysed in processing the urgent orders on the basis of non preemptive priority and preemptive resume priority over normal orders. The system performances had been analysed for the two mostly popular scheduling rules such as, FIRST IN FIRST OUT (FIFO) and SHORTEST PROCESSING TIME (SPT) using a system simulation computer program. The system performances for any scheduling rules can be studied using this simulation program.
Chapter eight brings out the development of a new simulation software with features of visual interactive computer graphics for analysing the dynamic scheduling of Flexible Manufacturing Systems (FMS) to cater to the needs of fluctuating markets. The arrival pattern of components to the shop floor is fitted to a suitable statistical distribution based on work order position. The effects of rules such as, SIO, LIO, SPT, LPT, LRO, HRO, and FIFO on scheduling can be analysed using the simulator to emulate real life operation of FMS. The performance of an FMS has been examined for the scheduling rules of FIFO, SIO, and EDD and found that the SIO rule for scheduling the FMS to yield better result over other rules for the chosen conditions. The visual interactive computer graphics enables to find out machine utilisation levels, queue length of the components, throughput and comparison between the application of various dispatching rules. Since dynamic queue records are maintained, it is possible to establish the various components waiting at the respective work centers and their attributes, such as lateness, slackness, remaining operations, etc. This software is very useful to select the appropriate scheduling rules based on the performance.

Chapter nine deals with scheduling of a Flexible Manufacturing Cell (FMC) with automatic set-up features consisting of a machining center, an industrial robot, a loading/unloading station, an index pallet changer and finite intermediate buffers. This FMC model is considered as a two machine (machining center and robot) flow shop problem with finite buffers. An algorithm has been developed based on Enumeration Method for finding the best possible scheduling with minimum throughput time in accordance with the arrival pattern of components based on fluctuating market and the optimal number of clamping stands required on the index-pallet changer.
The analyses have led to find optimal solutions for scheduling problems of batch manufacturing systems under varying market conditions. The schedules developed through computer simulation runs are dynamic in nature with enhanced utilisation of facilities and considerable amount of reduction of waiting time leading to maximum throughput. The specific conclusions drawn out of these analyses are about MWF at fluctuating market conditions, sequence planning, capacity planning, and effects of scheduling rules on batch manufacturing systems. There are presented at the end of each chapter 3-9 and general conclusions arrived at are given in chapter 10.