Development and Evaluation of Dynamic Scheduling System for Flexible Manufacturing Environment

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Abstract- Static and dynamic scheduling methods have attracted a lot of attention in recent years. The development of comprehensive dynamic scheduling system is necessary to deal with dynamic environment of flexible manufacturing system (FMS) and also to achieve highest flexibility and efficiency of the system. This paper presents a simulation study aimed at evaluating the performances of a flexible manufacturing system (FMS) in terms of makespan and number of tardy jobs using developed dynamic scheduling system. The simulation results are compared with performance of static scheduling system in same case study presented. It is observed that in presence of real time events dynamic scheduling approach perform better over static scheduling approach for the objectives considered.

Keywords – Automated Guided Vehicle (AGV), Flexible manufacturing system (FMS), Mean Time Between Recovery(MTBR), Mean Time Between Failure (MTBF)

I. INTRODUCTION

In the present days, most manufacturing companies are confronted with increasing customer demands for a wider variety of products, faster production rates and shorter delivery times. In such cases, flexible manufacturing systems (FMS) are often introduced to manage and control production. Combining the flexibility of job shops and the productivity of flow lines (Wang et al., 2007); FMS is a system equipped with the several computer-controlled machines, having the facility of automatic changing of tools and parts. The machines are interconnected by automatic guided vehicles (AGV), pallets and several storage buffers. These components are connected and governed by computer control using the local area networks (LAN) (Prakash et al., 2011). FMS possesses some potential advantages, such as flexibility, quicker response, reduction in work-in-process inventory, better productivity as compared to job shop production systems and ability to recover gracefully from system stoppages. Also a job can be completed by following several alternate routes though the machines or resources in a FMS (Sarin and Salgame, 1990). Scheduling systems allocate available resources to the jobs by considering their priorities.

Yang and Wu (2003) explained about two different approaches of scheduling which can be followed in different type of environments. One approach is static scheduling approach and second one is dynamic scheduling approach. Static scheduling arranges all jobs in the batch to the available resources within the production horizon. This means if all jobs that are to be scheduled are available and there processing time is also known beforehand, then static scheduling is used to accomplish the target of the system. On the other hand if the jobs input is randomized and job sequences for different resources is not specific then dynamic scheduling is suitable to improve response of the system under uncertain resource availability. Revision of the schedule under changed condition is called as dynamic schedule.

FMS has eight different types of flexibilities (Brown et al., 1984), which are machine flexibility, product flexibility, process flexibility, routing flexibility, volume flexibility, expansion flexibility, operation flexibility and production flexibility. Also ability of FMS to recover from the any malfunction in the system makes FMS a dynamic system. Various uncertainties such as machine breakdowns, cancellation of an order and change of due date can occur at any instance, which makes any acceptable static schedule infeasible. In response to this, it is necessary to revise the existing schedule to improve the efficiency of the disturbed FMS (Yang and Wu, 2003).

Flexible manufacturing system have high initial investment hence under utilization of the system could be very costly. Disturbance due to unexpected events reduces efficiency of the FMS. Hence when unexpected event occurs, present static schedule must be modified and reformed to ensure effectiveness of the FMS under new condition.

1.1 Flexible manufacturing system and scheduling for FMS

According to Brown et al. (1984), FMS has eight different types of flexibilities, which are machine flexibility, product flexibility, process flexibility, routing flexibility, volume flexibility, expansion flexibility, operation flexibility and production flexibility. Also ability of FMS to recover from the any malfunction in the system makes FMS a dynamic system. Various uncertainties such as machine breakdowns, cancellation of an order and change of due date can occur at any instance, which makes any acceptable static schedule infeasible. In response to this, it is necessary to revise the existing schedule to improve the efficiency of the disturbed FMS (Yang and Wu, 2003).

FMS have high initial investment hence under utilization of the system could be very costly. Disturbance due to unexpected events reduces efficiency of the FMS. Meeting deadlines and achieving high resource utilization under varying market demands are the two main goals of task scheduling in real-time systems. For making the scheduling system more effective under dynamic conditions requires more scheduling overheads. So developing a dynamic scheduling system for taking real time decisions is very essential. Critical factor in developing dynamic scheduling system is computation time. If the computation time is more than the component deadlines then it may result in missing task deadlines due to delayed scheduling decisions.

1.2 Dynamic scheduling for FMS environment

Yang and Wu (2003) explained about two different approaches of scheduling which can be followed in different type of environments. One approach is static scheduling approach and second one is dynamic scheduling approach. Static scheduling arranges all jobs in the batch to the available resources within the production horizon. This means if all jobs that are to be scheduled are available and there processing time is also known beforehand, then static scheduling is used to accomplish the target of the system. On the other hand if the jobs input is randomized and job sequences for different resources is not specific then dynamic scheduling is suitable to improve response of the system under uncertain resource availability. Revision of the schedule under changed condition is called as dynamic schedule.

As we know idle time of machines or employees in FMS system will result in inefficient and expensive manufacturing system. Hence integrated production scheduling and controlling system is essential for reducing the wastage’s and for making manufacturing system efficient. FMS can combine the benefits of highly productive, but inflexible transfer line and the flexible job shop type of production only if it utilizes a dynamic scheduling system. The schedule is the order of activities; in FMS, in the order in which parts are manufactured, tools are delivered to processing stations, parts mounted on pallets, and so on. It defines for a particular period of time which operations will be performed, on which components, by which FMS cell.

The scheduling algorithm used in job shop systems is off-line. Since it applies for a fixed period, throughout which it is valid in its unchanged form. The dynamic workplace scheduling system causes decisions concerning which component will be manufactured on which cell to be made when the operation currently being performed by particular FMS cell is almost finished. The order of the process to be performed on each components one of the per-programmed variants. Variable route FMS programming is one of the way to achieve the same.

II. LITERATURE REVIEW

There are two types of problem that need to be addressed in a FMS, namely design problems and operational problems. The design problems deals with selection of FMS components while the operational problems concerns the utilization aspects of FMS (Chan and Chan, 2004). Scheduling is the major aspect in operational procedures of FMS.

The scheduling algorithm used in job shop systems is off-line (static) because it is applied at the beginning of the scheduling period and the results are valid for the entire shift, or longer. If an unexpected event happens, such as tool or equipment failure, production is disrupted because of the deterministic scheduling methods used. On the other hand FMS needs to perform operations under control of dynamic scheduling system. This means that decision concerning what work piece is manufactured next on which cell, are made close to the end of the operation currently being performed by particular cell. In other words FMS schedule is not made in advance because it must be capable of responding to real time decisions (Ranky, 1983).

2.1 Scheduling in presence of real time events

Ouelhadj and Petrovic (2009) have specified limitation of static design of scheduling and reviewed dynamic scheduling in manufacturing systems; also defined dynamic scheduling as scheduling problem in the presence of real time events. The classification of real-time events into two categories, first is resource-related events and second is job related events. Resource related events are machine breakdown, operator illness, unavailability or tool failures, loading limits, delay in the arrival or shortage of materials, defective material (material with wrong specification), etc. and job related events are rush jobs, job cancellation, due date changes, early or late arrival of jobs, change in job priority, changes in job processing time, etc.

In the presence of real time events two major issues are required to address namely rescheduling strategies and problem of when to reschedule; in other words, how and when to react to real time events. While addressing when to schedule problem three policies are proposed in the literature (Ouelhadj and Petrovic, 2009); periodic, event driven and hybrid. In periodic policy schedules are generated at after specific time intervals and not changed during specified time interval. Here dynamic scheduling problem is converted into series of static problems and solved by classical scheduling algorithm.

Suwa (2007) focused on a “when-to-schedule policy” in online scheduling and proposed a cumulative delay-based rescheduling policy. The cumulative task delay can be viewed as aggregated information of unexpected events derived from the differences between the predictive schedule and the actual schedule. That is re-scheduling will occur on the basis of cumulative task delays. Under this policy, schedule inspection is performed to detect its delays at planned times and make a judgment whether or not schedule revision should be conducted at each individual planned inspection time on the basis of the cumulative size of delays.

Decision on frequency of the rescheduling is critical as flexible dynamic system requires adoption to the change in the situation; On the other hand to avoid over reacting to the situation, and reducing frequent rescheduling. Also selection of rescheduling strategy is critical considering factors like utility, stability, robustness, effectiveness and flexibility to achieve better performance of the system. Frequency of real time events occurrences and implications of the events on manufacturing system performance must be studied; Based on one of these, selection of suitable strategy from, completely reactive approach, predictive-reactive approaches and robust scheduling /rescheduling approach should be selected.

2.2 Methodologies used in solving dynamic scheduling problem

Jawahar et al. (1996)have used genetic algorithm (GA) to generate near optimal schedule with minimum makespan criterion. The author addresses capability of an evolutionary program for purpose of scheduling jobs with alternate jobs in FMS. The proposed method is random search process which belongs to class of evolutionary program. Every alternate route is evaluated randomly and schedule is generated for each route; best solution is selected for objective of makespan. Instead of random search of route and evaluation of every route some more quick methodology can considered so that dynamic scheduling system can be used in real time production environment.

Prakash et al. (2011) used the meta-heuristics is used for combinatorial decision-making problem in FMS environment by developing a knowledge based genetic algorithm to improve the performance of the system. The genetic algorithm enables searching the optima simultaneously, the author have considered two objectives in article. In real time systems static designs of schedule leads to high cost and inflexibility as these schedules are prepared based on initial information in hand. Schedules for real time systems should be dynamic and flexible in the nature.

Maniraman et al. (2000) have developed new algorithms for scheduling and resource reclaiming with dynamic fault tolerant system. The authors have created two versions of schedules every time; primary version and backup version. These two versions of every task are executed on different processors. In order to re-allocate the backup version in case the primary version succeeds, the two versions do not overlap in time (time exclusion) in the schedule. Backup version of schedule becomes idle once primary schedule executed successfully. This tool provides an environment to study various dynamic scheduling algorithms and their performances. This kind of exercise is useful for developing better dynamic scheduling algorithm.

Wang et al. (2007) have proposed a heuristic algorithm based on filtered beam search approach to solve dynamic scheduling problem with realistic disturbances in the system. The author have compared filtered beam search algorithm performance with adaptive genetic algorithm performance and shown out-performance of filtered beam search algorithm in terms of computational efficiency and solution quality. Dynamic rescheduling is a critical function for the real-life control and operation of any FMS. The dynamic rescheduling in FMS has not been studied thoroughly compared with the static scheduling. Therefore, there is still a great need to develop effective approaches for this complex problem.

Wang et al. (2008) have proposed a multi-agent approach integrated with a filtered beam search based heuristic algorithm to study the dynamic scheduling problem in a FMS consisting of multiple manufacturing cells. The approach is based on a hybrid architecture which is composed of a set of distributed agents each using local information to generate real-time schedules. The scheduling have been carried out for cell level and for achieving system level integrated objectives agents are introduced between the cells and which achieve shop floor level optimized schedule after negotiations in between cells, where agents are modular and can be used for different purposes. Finally through the comparison outperform of the proposed agent based filtered beam search approach is shown with respect to different combinations of decision making rules and suggested approach new ways of optimizing the solution but still this approach needs to be tested with some more cases and as well as along with real time events.

Using genetic algorithm Chen et al. (2012) have developed a scheduling algorithm for job shop scheduling problem with parallel machines setup which can be used for machine selection and operation scheduling tasks. Comparison of current scheduling practices and simulated results shows that developed genetic algorithm outperforms as compared to current scheduling methods used. The studies can be extended to material handling equipment like pallets, AGV etc selection.

In real time systems static designs of schedule leads to high cost and inflexibility as these schedules are prepared based on initial information in hand. Schedules for real time systems should be dynamic and flexible in the nature, based on real time information. Many algorithms available in the literature, capable of delivering near optimal solutions, are reported to be time consuming and hence are less suited for real time production system. Thus faster algorithms need to be developed for real time scheduling.

III. METHODOLOGY

3.1 Design the structure of dynamic scheduling system

Structure of dynamic scheduling system will be consisting of different subsystems and data flow between these subsystems. The architecture of the dynamic scheduling system is shown in the figure 1.

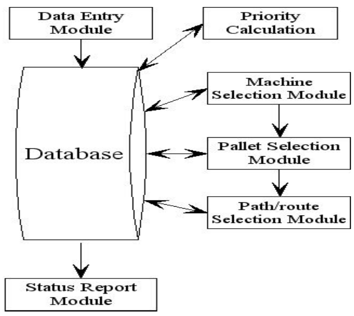


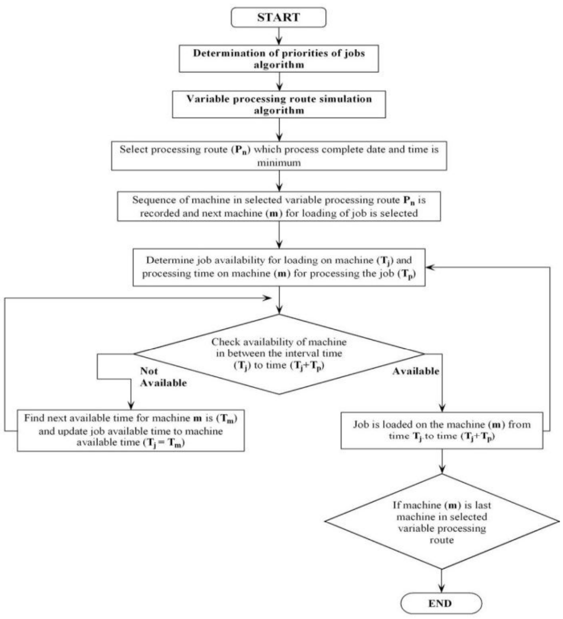
Figure 1: Structure of dynamic scheduling system

3.2 Selection or development of algorithms for each module

Different algorithms and procedures are selected/developed during development of dynamic scheduling system. These procedures deal with following aspects of the scheduling.

3.2.1 Determination of priority for every job order

This is the first step in scheduling activity, where priority of every job order which processing is incomplete is determined. For every order, by following critical ratio criteria, the priority will be calculated in this module. The priority values assigned to the job orders are in a scale of 0 to 5. The 0 priority signifies urgent job and priority 5 is most non urgent job. In case of rescheduling, first priority for all incomplete and in-process job orders are calculated by considering revised remaining processing time and adjustments in schedule are made as per revised priority.



Algorithm 1: Loading of job orders on machines

3.2.2 Loading of job orders on machines

In the typical scheduling problem, every job is fighting for available resources. The example of resources in case of FMS environment can be available machine processing time. Every job order is required to be loaded on machine required for processing respective job. The required machines for processing the jobs are identified by processing route selected, which is in a scope of module for selection of variable path. The job orders are loaded on the machines in order to their priority, highest to lowest. Due to this loading strategy, higher priority jobs will be getting maximum possible available resources (machine time). The detailed algorithm for loading of jobs on machines is shown in algorithm 1.

3.2.3 Selection of pallet for each component

Every component which is required to process is required to be loaded on the pallet. Each component is loaded on separate pallet and once the processing is over the component is unloaded from the pallet. After unloading of the component from the pallet, the same

pallet becomes free to load another component. In this typical selected FMS configuration numbers of pallets of two types are considered. Any number of pallet types and pallets can be added or removed from the configuration.
The selection of a pallet is depends upon compatibility of pallet with machine. Based on processing path selected compatibility of pallets with machines in a processing path will be analyzed and suitable pallet will be selected.

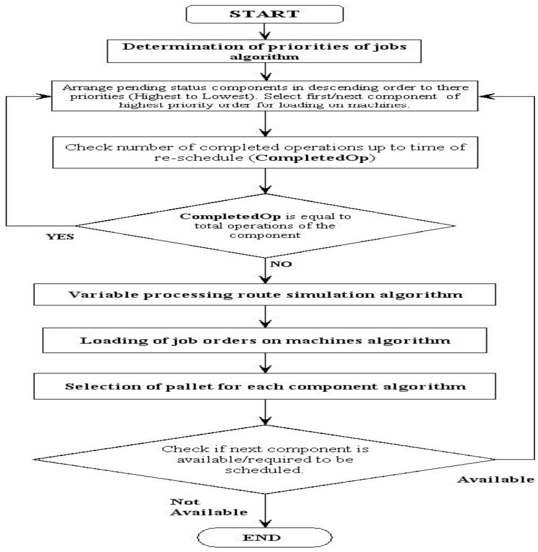
3.2.4 Static schedule preparation

The static schedule is schedule prepared based on available information in hand. In this based on priorities of the jobs, resources such as machines, pallets are assigned to the jobs in order to high priority jobs to low priority jobs.
The job orders are placed by marketing department. Every job order has internal due date for manufacturing department. This due date is considered to determine priority of the job orders. The job orders are consist of combination of particular component and quantity to be produced for that particular component. Steps involved in schedule preparation are as below:

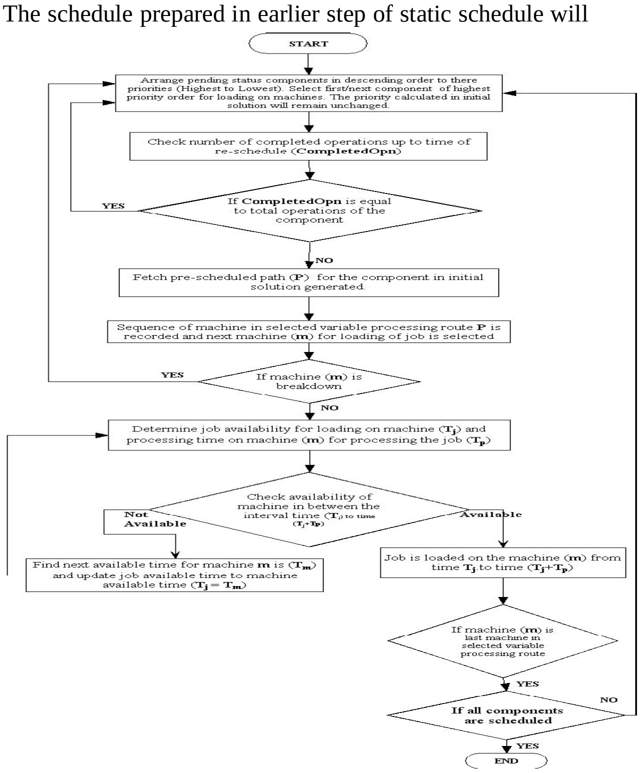
1. Priority of every incomplete job order is determined. The priority will be given to job order which will be assigned to multiple quantities of components in respective job order.
2. The job order with highest priority will be analyzed for number of incomplete operations, number quantities to be produced, operation sequence, parallel routes for processing and pallet compatibility; then first order quantity of current job order will be chose for assignment of machines.
3. The path for processing the component is selected.
4. For processing path selected in earlier step, compatible pallet is selected which is suitable for all machines in selected processing path.
5. The jobs are loaded on the machines as per procedure mentioned in algorithm 1. If machines are not available then next available time for particular machine is searched. Once free time interval is found then job is loaded on the machine in particular time interval.

3.2.5 Revision of current schedule on occurrence of real time event

The schedule prepared in earlier step of static schedule will be modified in case of real time events/disturbances like machine state change to breakdown or up. The revision of the schedule on occurrence of above events will be done using algorithm 2 and algorithm 3. The algorithm 2 is used to simulate dynamic re-scheduling scenario in which schedule revision will be prepared with revised priorities and processing path of the jobs. On the other hand the algorithm 3 is used to simulate static re-scheduling scenario, in which priorities and processing sequence will not be changed.



Algorithm 2: Revision of schedule on occurrence of real time event using dynamic scheduling approach



Algorithm 3: Revision of schedule on occurrence of real time event using static scheduling approach

IV. RESULTS AND DISCUSSIONS

Based on results obtained during executions of dynamic scheduling system under different scenarios, conclusions will be drawn by comparison with existing systems.

The performance of dynamic scheduling system is evaluated by considering three test cases as detailed below. Every case described in this section is consisting of details of job orders, schedule start time and machine hours data. The data regarding machine status such as breakdown or available which is based on mean time between failure (MTBF) and mean time between recoveries (MTBR) is generated using data regarding the machine working time excluding idle time. The results of the test cases, consisting of values for objectives considered are tabulated. At the end of each test case, comparison between static scheduling approach and dynamic scheduling approach is tabulated with respect to objectives considered.

In the case study presented , two machine breakdowns occurred and subsequently recovery of the machines from the breakdown status occurred (four number of events). The initial solution and comparison between two approaches based on two evaluation criteria, makespan of the order and number of tardy jobs are tabulated for the case study.

4.1 Assumptions:

In this simulation system discrete event methodology is applied. There are total 11 number of machines of five types are considered. Same type of machines are parallel machines and five different types can be called as non-parallel machine groups. Multiple machines with alternative processing routes are possible due to versatile machines used in FMS configuration. Preemption is not allowed. Setup time on machine is ignored. Three types of jobs are processed in different batch sizes varying from one to ten jobs per batch. Four job loading and unloading stations (station number 21, 22, 23, 24) are considered in the case study presented. The evaluation is done for two criterions makespan of the job and number of tardy jobs.

V. CASE STUDY

5.1 Details of job orders

The orders considered for case study is tabulated in table 1. The order data tabulated below is arbitrarily generated. Total seven orders are required to be scheduled; in which total number of components to be scheduled are 19 with overall 126 operations. Order date column is time of placing orders, and order due dates are internal due dates assumed to be given by marketing department.

Order no.	**Job arrival time**	**Order due date**	**Compo-nent no**	**Quan tity**
1001	18-07-2014 6:00:00 AM	19-07-2014 7:00:00 AM	103	2
1002	17-07-2014 7:00:00 AM	18-07-2014 7:00:00 AM	101	3
1003	17-07-2014 6:00:00 PM	18-07-2014 3:00:00 PM	102	2
1004	18-07-2014 4:00:00 AM	18-07-2014 4:00:00 PM	102	2
1005	18-07-2014 6:30:00 AM	18-07-2014 7:00:00 PM	101	4
1006	18-07-2014 6:55:00 AM	19-07-2014 9:00:00 AM	103	5
1007	18-07-2014 5:00:00 AM	18-07-2014 1:00:00 PM	101	1

Table 1: Details of job orders for case study

5.2 Expected schedule summary

The schedule is generated for orders mentioned in table 1.

Schedule start date and time : 18-Jul-2014 7.00 AM   Schedule duration : 1 shift - 8 hours

Overall operations to be scheduled are : 126   Number of operations actually scheduled : 126

Since the number of operations required to be scheduled is same as number of operations actually scheduled, it can be inferred that the schedule generated is valid.

5.3 Results and evaluation

5.3.1 Order-wise makespan

The time required completing the order which includes one or many components are shown in the table 2. The order processing start date and time column shows first components first operation start time and order processing end date and time column shows time at which last components last operation ends. If the particular order has only one component to schedule, in this case the time of first and last operation is recorded in these columns. The total makespan is the time between order processing end time and start time in minutes.

Order-wise make span from the static schedule (without any disturbances in the initial conditions)			
Order no.	**Order processing start date and time**	**Order processing end date and time**	**Total make span of the order (min)**
1001	18-jul-2014 08:17:00	18-jul-2014 16:23:00	486
1002	18-jul-2014 07:00:00	18-jul-2014 13:25:00	385
1003	18-jul-2014 07:11:00	18-jul-2014 11:32:00	261
1004	18-jul-2014 07:11:00	18-jul-2014 11:51:00	280
1005	18-jul-2014 07:00:00	18-jul-2014 14:55:00	475
1006	18-jul-2014 07:00:00	18-jul-2014 15:39:00	519
1007	18-jul-2014 07:22:00	18-jul-2014 10:24:00	182

Table 2: Order-wise make span for case study

5.3.3 Number of tardy jobs

The tardy jobs are jobs delayed beyond the due date and time. Total number of jobs to be processed are seven and total tardy jobs are zero. According to initial schedule obtained, all jobs can be completed before the internal due date of the respective jobs.

5.4 Real time events

The real time events are generated with the random data of MTBR and MTBF of the machines in the FMS configuration. According to the random data of MTBR and MTBF, two machines under breakdown and also recovered from the malfunctions during the span of schedule. The details of events due to breakdown and recovery are shown in the table 3. All four events are triggered and results are simulated. The comparison between two approached, static and dynamic schedule approaches are tabulated in next sections. The results compared in these sections are after triggering all real time events in the test case and modification made in response to the events.

5.4.1 Order-wise makespan

The comparative details between static and dynamic scheduling approaches for time required completing the order which includes one or many components are shown in the table 6. The order processing start date and time column shows first components first operation start time and order processing end date and time column shows time at which last components last operation ends. If the particular order has only one component to schedule, in this case the time of first and last operation is recorded in these columns. The total makespan is the time between order processing end time and start time in minutes.

Event	**Time of occurrence**	**Description of the event**
1	18-JUL-2014 8:21:00 AM	Machine number 1 under breakdown
2	18-JUL-2014 10:46:00 AM	Machine number 8 under breakdown
3	18-JUL-2014 2:30:00 PM	Machine Number 8 is recovered from the breakdown condition
4	18-JUL-2014 2:58:00 PM	Machine Number 1 is recovered from the breakdown condition

Table 3: Real time events in case study

From the comparison shown in table 4, make spans of the order number 1001, 1002, 1004 are reduced significantly and makespans of order numbers 1003, 1005, 1006, 1007 is increased marginally. Although the make spans of the four orders have been increased, all these orders can be completed within the due date of respective orders following dynamic approach of rescheduling.

Comparison between static and dynamic approach with disturbances							
Static scheduling approach				**Dynamic scheduling approach**			
Order no	**Order processing start date and time**	**Order processing end date and time**	**Total make span**	**Order no**	**Order processing start date and time**	**Order processing end date and time**	**Total make span**
1001	18-jul-2014 08:17:00	18-jul-2014 19:57:00	700	1001	18-jul-2014 08:17:00	18-jul-2014 16:38:00	501
1002	18-jul-2014 07:00:00	18-jul-2014 19:18:00	738	1002	18-jul-2014 07:00:00	18-jul-2014 14:12:00	432
1003	18-jul-2014 07:11:00	18-jul-2014 11:32:00	261	1003	18-jul-2014 07:11:00	18-jul-2014 14:46:00	455
1004	18-jul-2014 07:11:00	18-jul-2014 17:11:00	600	1004	18-jul-2014 07:11:00	18-jul-2014 10:44:00	213
1005	18-jul-2014 07:00:00	18-jul-2014 15:42:00	522	1005	18-jul-2014 07:00:00	18-jul-2014 15:54:00	534
1006	18-jul-2014 07:00:00	18-jul-2014 16:13:00	553	1006	18-jul-2014 07:00:00	18-jul-2014 17:22:00	622
1007	18-jul-2014 07:22:00	18-jul-2014 10:24:00	182	1007	18-jul-2014 07:22:00	18-jul-2014 12:17:00	295

Table 4: Comparative study of order-wise make span for case study

5.4.3 Number of tardy jobs

The tardy jobs are jobs delayed beyond the due date and time. The numbers of tardy jobs along with the comparative details between the static and dynamic approaches are mentioned in the table provided. Total two jobs are delayed as per simulated in static scheduling approach, where as there is no delayed job in case of dynamic scheduling approach.

The table 5 shows order-wise details of tardy jobs in case of simulating static scheduling approach and dynamic scheduling approach.

Comparison between static and dynamic approach with disturbances							
Orde r no	**Due date**	**Static scheduling approach**			**Dynamic scheduling approach**		
		Order processing end date and time	**Dela y-min**	**Earl y/ Late**	**Order processing end date and time**	**Dela y - min**	**Early/ Late**
1001	19-07-2014 7:00:00 AM	18-jul-2014 19:57:00	Nil	Early	18-jul-2014 16:38:00	Nil	Early
1002	18-07-2014 7:00:00 PM	18-jul-2014 19:18:00	18	Late	18-jul-2014 14:12:00	Nil	Early
1003	18-07-2014 3:00:00 PM	18-jul-2014 11:32:00	Nil	Early	18-jul-2014 14:46:00	Nil	Early
1004	18-07-2014 4:00:00 PM	18-jul-2014 17:11:00	71	Late	18-jul-2014 10:44:00	Nil	Early
1005	18-07-2014 7:00:00 PM	18-jul-2014 15:42:00	Nil	Early	18-jul-2014 15:54:00	Nil	Early
1006	19-07-2014 9:00:00 AM	18-jul-2014 16:13:00	Nil	Early	18-jul-2014 17:22:00	Nil	Early
1007	18-07-2014 1:00:00 PM	18-jul-2014 10:24:00	Nil	Early	18-jul-2014 12:17:00	Nil	Early

Table 5: Comparative study of number of tardy jobs: case study

5.5 Result and discussions

The efficient schedule has been generated as a initial solution, this solution is not efficient for entire schedule span due to occurrences of real time events. Two machines have been under breakdown or stopped working and recovered from such state in the same span of schedule. The observations between two approaches, static and dynamic revision of the schedule are tabulated above subsections. The makespans of critical orders are significantly less in case of dynamic approach as compared to static schedule where order numbers 1002 and 1004 have become tardy. No order is exceeded the due date in case of dynamic approach. Comparison of make spans in two tardy jobs 1002 and 1004 can state this difference; in case of order 1002 can be completed in 738 minutes whereas the same can be completed in 432 minutes in dynamic approach. Similarly order number 1004, can be completed in 600 minutes and can be completed in minutes in 213 minutes by dynamic approach of revision of schedule. Make spans of order numbers 1001, 1002 and 1004 are reduced significantly at the cost of slight increase in make spans of rest 5 orders.

VI. CONCLUSION

It can be observed that from the case study presented, as per static approach of scheduling, make span of the job is minimum possible with relative priority at the time of schedule preparation. The processing route with minimum makespan is selected among variable processing routes available. Hence in absence of real time events generated schedule satisfies all the objectives in maximum possible extent. In case of reschedule, majority of makespans as per static scheduling approach and dynamic scheduling approach are different. This is result of revised priority of the jobs which is depending upon total remaining processing time and job due date. Lower priority jobs as per initial solution gets higher priorities as higher priority jobs are already in-process and time required to process previous low priority jobs will be more than that of higher priority jobs. During rescheduling all available machine resources are allocated to the jobs with revised high priority. This has resulted in to significant reduction in makes-pans of the urgent jobs as per revised priority and all other job's makespans are increased, but this increments makespan of other relatively less priority jobs.

Many factors are impacting tardy jobs objective, such as mainly total number of jobs, relative priority of the jobs and impractical due dates. In such cases the attempt should be aimed at minimizing tardiness of the jobs. As per static scheduling approach, in case of breakdown of any machine, the job waits for machine recovery and this leads to tardy jobs as observed in the case study presented.

Development of dynamic scheduling systems makes manufacturing facility more competitive, the response of the manufacturing systems to the market improves significantly. In dynamic environment dynamic scheduling systems perform better than that of static scheduling approaches to meet due date and makespan related objectives. The automation of scheduling activities saves lots of scheduling efforts and makes the manufacturing system more efficient.

The published literature for finding near optimal static schedules is extensive and several methods have been developed for generating near optimal static schedule, hence there are lots of opportunities for researchers in extending static scheduling methods for solving dynamic scheduling problems. Future researchers can work in regards to selection of best re-scheduling strategy by considering different factors like configuration of flexible manufacturing system, computation time, solution quality and decision on when to schedule in dynamic environment. Also no generalized procedures have reported in the literature referred which can suggest use of particular dispatching rule for the specific condition. Work related to development of integrated dynamic scheduling system by considering detailed factors which influence the performance of FMS like priorities of the jobs, material handling, buffer sizes, setup times and setup dependent factors like pallet selection, machine capabilities for multiple objectives of scheduling can be done and the work can be tested for different sizes of dynamic scheduling problems.

REFERENCES

[1] Brown et al. 1984J Brown and D Duboise and K Rathmill and P Sethi and K E Steke, "Classification of flexible manufacturing systems" (1984), 114-117.

[2] Chan and Chan 2004Felix Chan and H K Chan, "Analysis of dynamic control strategies of an FMS under different scenarios", *Robotics and Computer-Integrated Manufacturing* 20 (2004), pp. 423-437.

[3] Chen et al. 2012J Chen and C Wub and C Chen and K Chen, "Flexible job shop scheduling with parallel machines using Genetic Algorithm and Grouping Genetic Algorithm", *Expert Systems with Applications* 39 (2012), pp. 10016-10021.

[4] Jawahar et al. 1996N Jawahar and P Aravindan and S G Ponnambalam, "Generic algorithm for dynamic scheduling of random flexible manufacturing system" (1996).

[5] Maniraman et al. 2000G Maniraman and A Manikutti and C Murthy, "DHARMA: A tool for evaluating dynamic scheduling algorithms for real-time multiprocessor systems", *The Journal of Systems and Software* 50 (2000), pp. 131-149.

[6] Ouelhadj and Petrovic 2009D Ouelhadj and S Petrovic, "A survey of dynamic scheduling in manufacturing systems", *J Sched* 12 (2009), pp. 417-431.

[7] Prakash et al. 2011A Prakash and F Chan and S G Deshmukh, "FMS scheduling with knowledge based genetic algorithm approach", *Expert Systems with Applications* 38 (2011), pp. 3161-3171.

[8] Ranky 1983Dr Paul Ranky, *The design and operation of FMS* (IFS (Publications) Ltd, UK, 1983).

[9] Sarin and Salgame 1990S Sarin and R Salgame, "Developement of knowledge based system for dynamic scheduling", *Int. J. Production Research* 28 (1990), pp. 1499-1512.

[10] Suwa 2007H Suwa, "A new when-to-schedule policy in online scheduling based on cumulative task delays", *Int J Production Economics* 110 (2007), pp. 175-186.

[11] Wang et al. 2007S Wang and L Xi and B Zhou, "Filtered-beam-search-based algorithm for dynamic rescheduling in FMS", *Robotics and Computer-Integrated Manufacturing* 23 (2007), pp. 457-468.

[12] Wang et al. 2008S Wang and L Xi and B Zhou, "FBS-enhanced agent-based dynamic scheduling in FMS", *Engineering Applications of Artificial Intelligence* 21 (2008), pp. 644-657.

[13] Yang and Wu 2003H Yang and Z Wu, "The application of adaptive generic algorithms in FMS dynamic rescheduling", *International Journal of Computer Integrated Manufacturing* 16 (2003), pp. 382-397.