CHAPTER 4

INTEGRATED SCHEDULING FRAMEWORK FOR FMS

4.1 INTRODUCTION

One of the most difficult operational problems in FMS is the proper coordination of the production scheduling and control of all the constrained resources, which include CNC machines, AGVs, Robots and so on [110, 111]. Because of this, an optimal job input sequence generated for the FMS, by any heuristic algorithm, in isolation (that is, without taking into account the interdependencies and constraints among the resources of the FMS) when executed, may found to be sub-optimal or at times even infeasible because of the occurrence of situations like deadlocks and machine blockings.

In order to ascertain that the optimal sequence generated through an intelligent search heuristic algorithm is feasible, during the search process, at each of the repetitive iteration, every job sequence must be evaluated for its feasibility and optimality. This requirement is met through an integrated scheduling framework, wherein every job input sequence found in its search path by the heuristic search algorithm is evaluated by using a special purpose discrete event simulator. The structure of the integrated scheduling framework and its working methodology are detailed in this chapter.

4.2 INTEGRATED SCHEDULING FRAMEWORK

The integrated FMS scheduling problem which encompasses the generation of nearer-to-optimal as well as feasible job input sequences, which will result in an optimal integrated schedule for the FMS, ensuring proper co-ordination and control of all the constrained resources, is approximately solved by a two stage iterative procedure that tries to
accommodate the combinatorial nature in finding the solution. The two stage iterative procedure is based on the following three components:

1. Phase I: An intelligent search heuristic algorithm, employed to find an optimal job input sequence, for the FMS operation.

2. Phase II: A Discrete event simulator to simulate the FMS operation for the given job input sequence (found during the search process by the heuristic algorithm) and to evaluate the job input sequence with respect to the desired performance measure of the FMS (that is, the objective criterion of the scheduling problem)

3. An iterative structure (as shown in Figure 4.1) that links the above two phases and facilitates the search to find a good solution.

After a given number of iteration the procedure will terminate with the best job input sequence (generated by the search heuristic algorithm) which will result in an optimal integrated schedule for the FMS.

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**Figure 4.1 Template of the iterative structure of the integrated scheduling framework**
4.2.1 Phase I: Generation of job input sequences

In Phase I, an intelligent search heuristic is deployed to generate job input sequences for the FMS model described in section 3.2. In this work, different search heuristics have been developed based on GA, SA, TS and SS (which are described in Chapters 5 to 8) and are employed separately in Phase I, for the comparative study.

4.2.2 Phase II: Evaluation of Job Input Sequence - Discrete Event Simulation of the FMS operation

In Phase II, the operations of the FMS are modeled as a Discrete Event Simulation Model, incorporating most of the real time events and activities of the FMS, which include

1. AGV and/or CNC machine blocking.
2. AGV dispatch rule.
3. Delay due to non availability of AGV and/or CNC machines.
4. Delay due to deadheading time of AGV.
5. Other conditions such as prescribed routing for each part, non-pre-emptiveness of part machining, limited capacity of input/output buffer, prescribed travelling speed of the AGV, the given FMS layout etc.,

For every solution generated by the Phase I mechanism, the operations of the FMS are simulated and performance measure (combined objective function value, as described in section 3.2.4) is computed satisfying all the stipulated constraints. The objective function value obtained in Phase II, is fed back to the Phase I heuristic mechanism, to further explore its search, under the designed iterative framework. The logical flowchart of the simulation is shown in Figure 4.2.
4.2.3 Assumptions/Parameters used in Simulation

1. Machine dispatching rule: First-In, First-Out. The part that enters first in the IB is selected first for machining.

2. AGV dispatching rule: First-Come (request), First-Served. The AGV is dispatched to the OB to pick up the job, having the earliest completion time.

3. AGV stop rule: AGV stays idle at the earmarked place and waits for the request.

4. A load is always delivered and dropped off to the IB and picked up from the OB, by the AGV.

5. The AGV pick-up/drop-off only one job at a time; the pick-up and drop-off operations at stations are assumed to take one minute.

6. If the CNC machine is preoccupied, the parts wait for the CNC machine to become free in the IB or if the AGV is busy, the parts wait in the OB.

7. The vehicle travelling speed is 0.5 meter per second and is constant (acceleration and deceleration are not considered)

8. Battery recharging for the AGV is done during the off shift hours. The time loss due to breakdown of AGV is negligible.

9. The robots perform the inter-cell movements; pick up and transfer only one job at a time; take 30 seconds for each pick-up and drop-off operations; transfer the jobs at a speed of 0.05 meter per second.

10. The relative distance between the locations in the example FMS layout (shown in Figure 3.1) and the travelling distance for the robot/AGV are shown in Appendix - II

In this thesis, a special purpose discrete event simulation software is developed using C++ language incorporating all the above mentioned features, assumptions and
parameters whose procedural mechanism is outlined through the flow chart shown in Figure 4.2.

![Flow chart for the Discrete Event Simulator](image)

**Figure 4.2 Flow chart for the Discrete Event Simulator**

In the above explained integrated scheduling framework, the FMS model described in section 3.2, is embedded and the different heuristic search procedures developed in this work are separately applied in the Phase I (as the Sequence Generator of the iterative structure) for studying and evaluating their individual effectiveness. Hence, through such integration, every sequence generated during the search process in phase-I, is verified for its validity (that is, whether it rectifies all the constraints stipulated in the operation of the FMS and on every FMC within the FMS by the discrete current simulator of phase – II).
4.3 SUMMARY

As the complicated FMS comprises of many interconnected and interdependent facilities, optimization of job schedule must be done in consonance with that of machines and devices schedule which is done through an integrated scheduling framework, discussed in this chapter. Also, only by an efficient scheduling mechanism, the productivity and the desired performance measures of the capital intensive FMS can be improved.

Hence, the objective of this research work is defined as, to evolve intelligent search heuristic procedures to generate satisfactory, nearer-to-optimal sequence of incoming parts to the FMS with the given configuration and operating environment for maximum system utilization and minimum total penalty for tardy jobs by satisfying all the stipulated constraints among the interdependent facilities of FMS during its integrated operation.

In this research work the following search heuristics are developed:

1. GA based search heuristic, explained in Chapter 5
2. SAA based search heuristic, explained in Chapter 6
3. TS based search heuristic, explained in Chapter 7
4. SS based search heuristic, explained in Chapter 8

All these search heuristics are evaluated by conducting experiments through the integrated scheduling framework, described in this chapter, using the model and problems described in Chapter 3 as the common platform.

All the above mentioned heuristic search techniques are also tested with some benchmark FMS layouts and job dataset found in the literature and the results are discussed in Chapter 9.