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# Effect of Part Selection Decision on the Performance of Additive Manufacturing

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***Abstract:*** *In this paper input data has been collected from the real existing system and proposed AMS simulation models are developed using C programming. The flow of job through the system managed with multi-level scheduling rules related to launching of job in to a system. The proposed simulation models are modeled for the existing system and optimum part selection rule is determined for the performance parameters such as Make Span, mean flow time, average part waiting time.*

***Keywords*** *– Part launching, Scheduling, and Simulation model.*

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## I. Introduction

Additive manufacturing(AM) also recognized as 3D printing is the process of construction materials to make objects from 3d model data, usually layer upon layer, as opposed to subtractive manufacturing approaches, such as traditional machining [1].Additive manufacturing processes carry several important advantages, such as material efficiency, production flexibility, part flexibility and direct kitting. These leads empower additive manufacturing as distinctive competitor in manufacture of intricate products and fast changing designs. A growing number of companies from numerous industries are trying to accept additive manufacturing /3D printing technologies in the manufacture of their products as such, a series of problems are evolving due to the exclusive nature of this manufacture process [2]. AM process is job is based and one or more parts with altered heights can be made simultaneously in one part. Primarily a sequence of operations are required to setup a new part, such as data preparation, filling of powder materials, adjustment of additive manufacturing machine, and filling up shielding atmosphere, subsequently the part can be started. Tiny powder layer with a usual thickness of between 20um to 60 um are produced on metallic base plate. The cross section of a sliced cad (computer aided design) file are consequently scanned using a high power layering and laser melting, will substitute until all jobs are made [3]. Floudas developed a mathematical model is planned to determine each short horizon and the products to be encompassed, then an innovative continuous-time creation for short term scheduling of batch processes with numerous intermediate due dates is applied to each time horizon nominated, leading to a large-scale MILP (mixed-integer linear programming) problem. Unusual structures of the problem are further exploited to increase the computational performance. A combined graphical user interface executing the planned optimization framework is presented. The efficiency of the proposed method is demonstrated with industrial case study that structures the manufacture of thirty five dissimilar jobs according to a basic 3-stage recipe and its disparities by sharing ten pieces of equipment [4]. Shah examined different procedures for optimizing production schedules at distinct sites, with an emphasis on formal mathematical approaches, and then absorbed on growth in the general planning of manufacture and distribution in multi-site d FMS flexible manufacturing systems [5]. Pekny and Reklaitis discussed the nature and features of the scheduling in chemical processing industries and keen out the key effects for the solution procedure for these complications. Utmost of the work in this range has dealt with either the long term planning or the short-term scheduling problem. Long-term planning or capacity expansion problems contain recognizing the timing, location of additional facilities over a relatively long time horizon [6]. Short-term scheduling techniques address detailed sequencing of numerous operational tasks over short time periods. All of the mathematical techniques in the literature are created on the time representations. Initial attempts rely on the discretization of the time horizon into a number of intervals of equal interval. This method is a discrete approximation of the time horizon and outcomes in an unnecessary increase of the overall size of the mathematical model [7, 8]. Mishra developed recipe method it covers two models recipes first the standard recipe approach (SRA) and the complete optimization method (OOA). In the SRA, main the recipes are standardized either empirically or via single batch optimization (SBO) and then the scheduling problem is framed on the basis of these standardized recipes. However, the standardization of recipes eliminates degrees of freedom from the system and because of this, the solutions attained with this method can be suboptimal, whereas in the OOA, the process dynamics are directly comprised in the production scheduling problem design instead of the standardized recipes. This restores the extra degrees of freedom of the system, and therefore this method can yield a better solution. However, direct addition of the process dynamics in the production scheduling problem design results in a mixed-integer dynamic optimization (MIDO) problem, the solution of which can be a formidable task. The benefits and drawbacks of the SRA and OOA for short-term scheduling of batch chemical processes with the help of illustrative examples. It is revealed that the results critically depend on the cost structure of the specific application as well as on the objective function employed, batch type short term and long term production on planning problems [9].

From the literature it is evident that previous authors are focused on design, batch type short term and long term production on planning problems in AMS. Though, not much consideration has been given on job shop scheduling, multi objective system performance measures. The proposed simulation models concentrates on the result of various combination methods of part launching rules in the AMS chosen.

## II. Physical Configuration Of The Proposed Additive Manufacturing System

For the purpose of the simulation based study, a regular Additive Manufacturing System physical configuration is chosen. The AMS physical structure of the simulation based model mentioned in Table 1. is illustrated in Figure 1.

**Table 1**.Physical configuration of AMS

| S.No. | Existing System | Quantity | Proposal System | Quantity |
|---|---|---|---|---|
| 1 | No. of parts to be | 10 | No. of parts to be | 10 |
| 2 | 3d printing machine | 1 | 3d printing machine | 1 |
| 3 | AGV | ------ | AGV | 1 |
| 4 | Unload Station | ----- | Unload Station | 1 |

So the physical configuration of proposed simulation model contains one unload station one 3D printing machine and AGV provides to transfer the jobs3d printing machine to unload station.

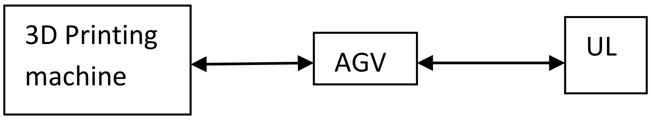

**Fig 1.** AMS Layout

### 2.1. Detailed description of part types.

Table 2. Is illustrated detailed description of job types are taken from Boppana rapid proto typing Industries, Vijayawada, and Andhra Pradesh, India. The company manufactures and supplies different types of job types throughout south India.

**Table 2.**Deatalied description of part types

| S.NO | Volume of the parts ($cm^3$) | Processing Time (min) |
|---|---|---|
| 1 | 137.1 | 758 |
| 2 | 35.62 | 327 |
| 3 | 32.24 | 221 |
| 4 | 6.57 | 74 |
| 5 | 16.66 | 113 |
| 6 | 140.0 | 789 |
| 7 | 14.96 | 107 |
| 8 | 34.09 | 274 |
| 9 | 37.59 | 306 |
| 10 | 19.86 | 187 |

Physical configuration of simulation based model contains one UL (Unload) station, one 3-Dprinter (work station) One automated guided vehicle (AGV) provides job-handling services between unload station and workstation. An automated guided vehicle can travel in between work system and unload station and it can take only single part at a time. In this model there are ten different jobs which can observe in the Table 2. Exponential distribution by a mean of 65 minutes was followed at Inter arrival time of order for processing in the simulation system. An order can be for anyone of the 10 different parts with equivalent possibility. The order of processing for every job is determined.

### 2.2. Operational configuration of simulation model

The primary situation in the simulation is assumed to be unfilled and idle with the initial order arrival event scheduled to happen at time zero. The order may fit in to any one of the 10 different job types. Subsequently, the part associated with the order arrived and part features are identified, i.e. the part order, processing times of the jobs, according to part selection rules jobs are processed. After completion of every required job, the processed job will be transported to UL station wherever completed job is unloaded from Automated Guided Vehicle and then the performance measure is calculated.

### 2.3. Assumptions of a proposed Additive manufacturing system simulation model

I. 3-D printer in the simulation model is initially idle.
ii. AGV is assumed to be available at UL station at simulation time zero.
iii. Design time is included in the processing time of a job.
iv. At a time, work station can handle only single job.
v. Without any failure AGV and workstation are assumed to be operational.

## III.IMPROVEMENT OF PROPOSED AMS SIMULATION BASED MODEL

Discrete event simulation based model is developed in the current approach, for the process of the proposed Additive Manufacturing System. This simulation based model is developed by using C and is used on the personal computer system through Intel I5 processor. C was used because it seems to have a superior programming flexibility than certain other simulation packages. A simulation model is shown below based on the Algorithm of logic.

1. Starts the simulation based system by executing simulation logic.
2. Read the necessary input data from input file.
3. Initialize the input variables part order.
4. Determines the subsequent event from event list.
5. Call the routine event to carry out the present assigned event.
6. Perform the allocated event, update the event, and generate the upcoming activities.
7. Repeat the steps 3 and 6 until event list is empty.
8. If (event list = empty/no event requests to execute), prints performance measures of simulation Model values in to the output files.
9. Exit.

### 3.1 Part selection (launching) rules

3.1.1. First come first served (FCFS)

In this scheduling rule, parts are launched into simulation system based on sequence of their arrival.

3.1.2. Shortest processing time (SPT)

In this scheduling rule, parts are launched into simulation system based on the order of their processing times.

3.1.3. Earliest due date (EDD)

In this scheduling rule, parts are lunched into simulation system based on the order of their EDD.

3.1.4. Largest processing time (LPT)

In this scheduling rule, parts are lunched into simulation system based on the order of their largest processing time.

### 3.2. Simulation model output

The compiling and combining the simulation based model output to present result is shown in this module such as make span, mean flow time, mean machine utilization,. Performance measures are defined as follows:

3.2.1. Make span

Make span is the finish time of all parts.

3.2.2. Mean flow time

Mean flow time (MFT) is defined as the usual time a part spends in the simulation system.

3.2.3. Average parts waiting time.

Average parts waiting time is average difference between turnaround time and burst time.

### 3.3. The Verification and validation for proposed AMS simulation based model

The following steps are used to validate the exactness of a proposed AMS [10].

Step 1: Debugging of programs.
Step 2: Checking of the internal logic.
Step 3: Comparing the simulation model output with manual simulation data.
Step 4: Running the simulation model.

## IV. EXPERIMENTATION

The discrete event simulation model developed for the selected AMS experiments was used. The four scheduling rules used for part launching decision. Hundred replications were made for each experiment. The initial stage in simulation experimentation was the identification of steady state, the moving average method suggested by Law and Kelton [10] was used for this purpose. The moving average plots for the performance measure indicate when the system reaches steady state at the completion of 1000 parts. Hence, in the simulation experiments, the simulation is continued till the completion of 1500 parts. While evaluating the performance measures, the results for the first 1000 parts are not considered and the performance measures are calculated using the results for the remaining 500 parts.

## V. RESULTS AND DISCUSSION

The problem identified in the present investigation involves the analysis of part launching rules. The simulation results are shown in Tables 3 exhibit variations. These variations could have been caused by waiting time.

**Table. 3**. Results

| S.No. | Part selection Rules | Make Span | Mean Flow Time | Average Waiting Time |
|---|---|---|---|---|
| 1 | FCFS | 1498 | 1189.4 | 890.79 |
| 2 | SPT | 1493 | 564.1 | 265.79 |
| 3 | LPT | 2458 | 1753.8 | 1263 |
| 4 | EDD | 2454 | 1450.8 | 960 |

## IV. CONCLUSION

In the present approach, input data has been collected from the real existing system. An attempt has been made to conduct simulation study and investigated the impact of part launching rules on the performance of a proposed simulated AMS. The simulation based models are conceded through multilevel verification tests. The part launching rules influence the system performance. A basic scheduling problem has been remodeled for optimum performance of a proposed AMS found to be good. The priority rules were better analyzed in a proposed AMS scheduling process. Finally, shortest processing time rule was adopted for every performance measures gave better results for the scheduling problem.

More number of simulation tests can be carried out for an Additive manufacturing system scheduling for different part launching rules and this can be extended for large size problems.

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