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Modelling and Simulation of Crankcase Cover Manufacturing in the Automobile Industry

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The simulation creates the virtual production model which is exactly like the real environment, and it provides future insights before laying down the actual production plant layout. With the help of simulation, we can simulate the complex and costly manufacturing system without investing money physically and check the system's real-life behavior. In this study, for the first time, the modelling and simulation of two-wheeler crankcase cover manufacturing are done with the help of Flexsim. This study deals with the development of a simulation model for crankcase cover manufacturing systems in the automobile industry. Flexsim simulation tool is used as an optimization tool for analyzing the effect of varying the number of operators and process stations on system performance using various scenarios. The results indicate that scenario 2 is best for crankcase cover manufacturing which reduces the overall idle time of all process stations and optimizes the number of Die-Casting Machines (DCM) and Vertical Milling Center (VMC). These results are useful for all industries for simulating their process or product layout.

Keywords: Flexsim, Optimization, Plant layout, Production model, System performance

Introduction

Simulation helps in the analysis of the various manufacturing system. It solved the problems related to resource allocation, scheduling, shop floor, material handling, storage, and manufacturing. Nowadays the different company provides different simulation software. This software reduces production costs and provides effective resource allocation.[1]

The various simulation software available in the market are Flexsim, Arena, Simul8, Anylogic, Witness, and Promodel. Flexsim is discrete event simulation software used for complex optimization problems. Flexsim is a very powerful tool used for modelling and simulation. This tool can be effectively used for appointment booking analysis and manufacturing problems. It also helps the management in hiring employees for future projects and changing the work schedules. The simulation also highlights any inefficiency or bottleneck occurring in the system.[2]

The simulation approach can be effectively used in design, production planning, and scheduling problems. These approaches help in decision-making problems and in finding more realistic results based on the actual dynamic conditions.[3] Flexsim consists of the experimenter tab of the design of experiments used for optimizing the set of solutions and performance of the production plant.[4] Flexsim tool can solve multi-objective optimization problems and develop the hybrid simulation model which optimizes the various parameters such as makespan, due date, tardiness, work in process inventory and machine utilization, etc.[5] This tool provides a complete output report which can be analyzed for measuring the performance of the system.[6]

The study of simulation-based papers consisting of the problem type, parameter optimized, and types of simulation is represented in Table 1. Bjorklund *et al.*[1] solved the real-time forecasting problem with the help of Flexsim simulation software. Badri *et al.*[7] utilized the simulation modelling concept for effective operations in hospital emergency cells by minimizing the waiting time, and cost and increasing the throughput, resource utilization, and efficiency of the system. Cheng *et al.*[8] developed a simulation model for machined component manufacturing in a flexible manufacturing system. They optimized the routing sequence of operations. Peng *et al.*[9] applied the Flexsim simulation method for improving

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Table 1 — Study of simulation-based papers

Problem Type	Factors/Parameters	Type of Simulation
Real-time forecasting problem[1]	Machine failure times	Flexsim
FMS Scheduling problem[2]	Makespan	Flexsim
Warehouse logistic system problem[3]	Space utilization, use of equipment and tools, work safety	Flexsim, Arena, and Promodel
Parallel machine scheduling problem[4]	Makespan	Flexsim
Jobshop Scheduling[5]	Makespan and machine utilization	Agent-based simulation
Gantry crane scheduling problem[6]	Operator efficiency and waiting time	Flexsim
Health services scheduling problem[7]	Waiting time, cost, throughput, resource utilization, and efficiency	SLAMSYSTEM
FMS Scheduling problem[8]	Routing sequence of operations	Flexsim, OptQuest
Assembly line problem[9]	Productivity and reducing the cycle time	Flexsim
Assembly line problem[10]	Machine utilization rate, efficiency, and blockage rate	Flexsim
Micropump design problem[11]	Fabrication cost	INTELLISUITE
Pull system problem[12]	Work-in-process inventory	SIMAN
Appointment scheduling and resource allocation[13]	Resource overtime, patient waiting time, and waiting area congestion	Simulation-based heuristic algorithm
Trucks appointment scheduling problem[14]	Waiting time and productivity of container terminals	Flexsim
Trucks appointment scheduling problem[15]	Truck turn time and resource utilization	Flexsim
Machine shop operations scheduling problem[16]	Productivity and energy cost	Anylogic
Job shop scheduling problems[17]	Total processing time, machine utilization, and allocation of jobs	Flexsim
Production planning problem[18]	Uncertainty and robustness of production planning	GeneSim
Logistics system problem[19]	Production efficiency	Flexsim and Petri net

productivity and reducing the cycle time in the assembly line problem. Gong *et al.*[10] developed a simulation model for an automobile mixed assembly line. They increased the machine utilization rate and efficiency and reduced the blockage rate in the assembly line.

Chandika *et al.*[11] designed and simulated the micropump in the automobile industry using the INTELLISUITE software and optimized the fabrication cost. Kesan *et al.*[12] utilized the SIMAN simulation software for the analysis of the pull system to optimize the work-in-process inventory. Lin *et al.*[13] developed a simulation-based heuristic algorithm for appointment scheduling and resource allocation. Azab *et al*.[14] utilized the simulation approach for minimizing waiting-time and emissions of trucks and enhanced the productivity of container terminals. Krishna *et al.*[2] used the Flexsim simulation-based approach for analyzing the effect of buffers on a Flexible Manufacturing System (FMS) performance. Nathan Huynh[15] analyzed the effects of varying scheduling rules on truck turn time and resource utilization. Kim *et al.*[16] developed a simulation-based scheduling system for machine shop operations of the manufacturing industry of the USA to optimize productivity and energy cost. Jarernram *et al.*[4] solved the parallel machine scheduling problem using Flexsim simulation software and optimized the makespan. Rodrigues *et al.*[5] developed the hybrid simulation model and solved the multi-objective problems to optimize the makespan and machine utilization.

Nie *et al.*[6] optimized the operator efficiency and waiting time of the gantry crane using the simulation approach of Flexsim and find out the best operating scheduling mode for the gantry crane. Kumar *et al.*[17] optimized the total processing time, machine utilization, and allocation of jobs in job shop scheduling problems using the simulation approach based on Flexsim. Steinhauer *et al.*[18] presented a simulation approach for reducing the uncertainty for optimizing the quality and robustness of production planning in shipbuilding. Wang *et al.*[19] utilized the Flexsim and Petri net simulation model for optimizing the production efficiency of the logistics system of the automobile industry. Zhang *et al.*[20] developed the simulation truck–shovel system model using Flexsim. Marek Climent *et al.*[21] utilized the Flexsim tool for digital engineering elements application in innovation and optimization of production flows. Past studies show that most of the researchers have successfully utilized the Flexsim tool for modelling and simulation problems. It is also found from the literature review that the modelling and simulation of crankcase cover manufacturing in the automobile industry is an untouched area of research. This study initially aims

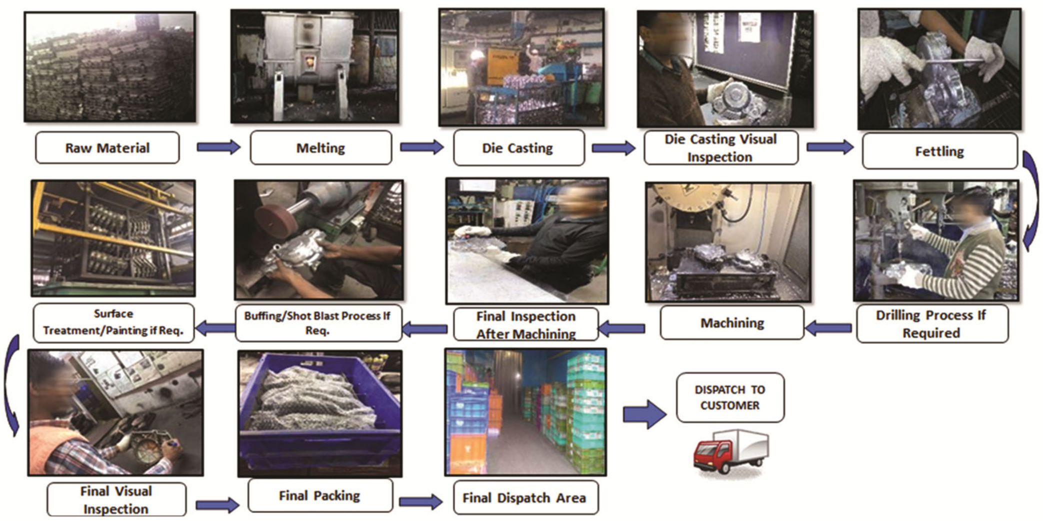

Fig. 1 — General process model for crankcase cover manufacturing

to develop the 3D simulation model based on the generic process model. Later, the experimenter function is utilized for selecting the best scenario for crankcase cover manufacturing and optimizing the number of process stations.

Materials and Methods

For simulating the layout of any industry, the first step is to analyze the process model. The next step is to convert this process model into a simulation model. Flexsim is a powerful tool for converting any chimerical process model into a realistic 3d simulation model.

Process Model

The crankcase cover manufacturing process consists of the processes such as the melting of raw material in the furnace, die casting process, fettling process, drilling process, machining process, buffing process, surface treatment, or painting process. The general process model for the crankcase cover manufacturing process is shown in Fig. 1. Our main aim of the study is to find out how the system performance varies with changes in the number of operators and the number of working process stations.

Flexsim Simulation Approach

Flexsim simulation software tool is used for developing a simulation model of the crankcase cover manufacturing process. Additionally, this tool generates models that are freely expandable, resulting in infinite space.[21] This tool provides a 3-D model that can be analyzed without establishing it in its physical form.[22]

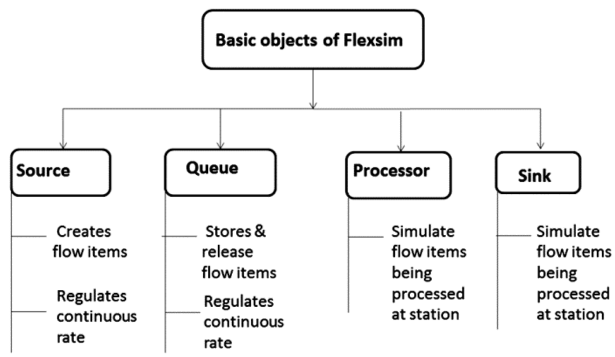

Fig. 2 — Basics objects of flexsim

Assumptions

The following assumptions are considered while developing a simulation model.

(i) There is no bottleneck present in the system.

(ii) All machines have enough capacity to operate.

(iii) The arrival rate of raw materials is assumed to be an exponential distribution with a location value of zero and a scale value of 4 minutes.

(iv) The setup time is assumed to be a triangular distribution with a min time of 0.05 minutes, a max time of 0.15 minutes but most commonly a time of 0.01 minutes.

(v) The processing time is also assumed to be triangular distribution.

Flexsim contains the four basic objects as shown in Fig. 2. These objects are a source, sink, processor, and queues.[22]

Simulation Model

There are generally 3 inputs of the simulation model which are arrival rate, processing time, and the number of resources. The model output is generally measured in terms of throughput, utilization, and states. The flow items of this simulation model are crankcase covers. The fixed resources used in this simulation model are the source, queue, processor, and sink. Operators are also used for loading and unloading flow items. A dispatcher is used to coordinate the operators. Updating the virtual model is necessary using the company's real database system from time to time. The 3D simulation model of crankcase cover manufacturing is represented in Fig. 3. There is a need of defining the model parameters for running this simulation model. These model parameters are defined in Table 2 with their statistical distributions and values.

During the simulation, the reset and the run option are used in Flexsim for running the model, and the dashboard option provides all analysis of the manufacturing system in terms of various charts. Analysis of the virtual model eliminates any uncertainty present in the production system. The scheduling of all tasks on the processing stations is represented by the state Gantt chart in Fig. 4. This chart gives a visual representation of all the tasks scheduled on the various stations with object and state information.

Optimization

The scenarios option of Flexsim provides the option of adding variables for optimization. The two types of variables considered in this study are the operator group (dispatcher 1) and the processor group (processor group DCM & VMC). The three scenarios of simulation experiment control consisting of the various variable groups are shown in Fig. 5. Scenarios 1 include only one dispatcher, one DCM processor

Table 2 — Simulation model parameters

Model parameters	Distribution	Values (mins)
Arrival rate of raw materials	Exponential	4.00
Setup time	Triangular	0.01
Die casting machine (DCM)	Triangular	1.50
Manual fettling (MF)	Triangular	0.18
Drilling machine (DM)	Triangular	0.35
Vertical milling center (VMC)	Triangular	4.00
Buffing machine (BM)	Triangular	0.22
Painting Shop (PS)	Triangular	21.3

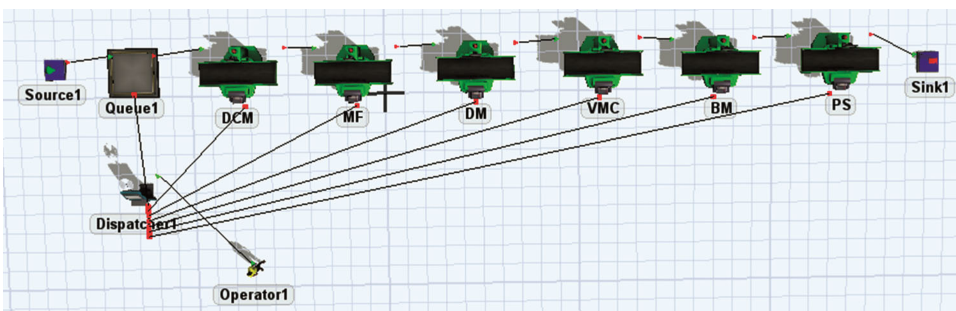

Fig. 3 — Simulation model of crankcase cover manufacturing

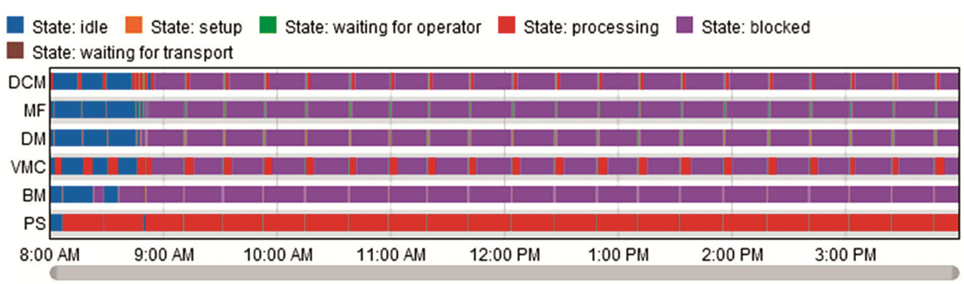

Fig. 4 — State gantt chart with the object and states information

	Variable	Scenario 1	Scenario 2	Scenario 3
Variable 1	Nr TEs in Team /Dispatcher1	1	2	3
Variable 2	Nr Objects in Processor group DCM	1	2	3
Variable 3	Nr Objects in Processor Group VMC	1	2	3

Fig. 5 — Various scenarios of simulation experiment control

group, and one VMC processor group, whereas scenario 2 and scenario 3 includes more than one dispatcher and processor groups.

Results and Discussion

In this study, we have taken processor groups of die-casting machines and vertical milling centers only. Because these machines are costly, industries can't afford many of these types of machines. So, there is a need of identifying the optimal number of these machines. A similar study had conducted by Marek Krynke[23] for optimizing the number of employees so that the production time for a single batch is the shortest. After adding all the variable groups with their numbers in this study, the experiment run tab is used for optimization. The statistical distribution of all the model parameters is identified from the expert Fit function of the Flexsim. The replications per scenario are 30 and this experiment is run for 3 days. The experimental conditions and running status are depicted in Fig. 6.

After running the simulation for 3 days, the processor and operator's state pie chart is obtained. The processor state pie chart represented in Fig. 7 shows the performance of all the processing stations in percentage terms of processing time, setup time, idle time, blocked time, operator waiting time, and transport waiting time. The results indicate the idle time for the painting shop and buffing machine is lowest for scenario 2, the idle time for the die casting machine is lowest for scenario 1, and the idle time for the drilling machine is lowest for scenario 2 and scenario 3. The idle time for the vertical milling center is the lowest for scenario 1.

The operator's state pie chart represented in Fig. 8 shows the effect of increasing the number of operators on the system performance in percentage terms of the

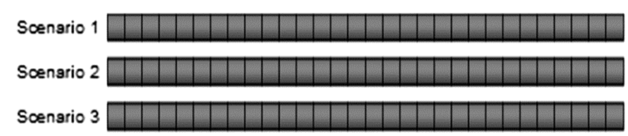

Fig. 6 — Experiment run window of simulation experiment control

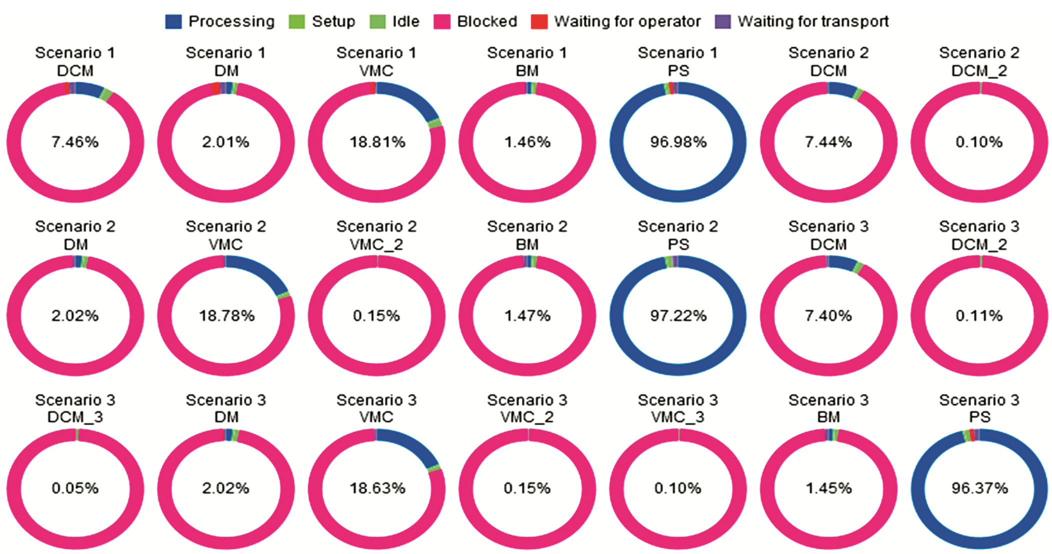

Fig. 7 — Processor state pie chart

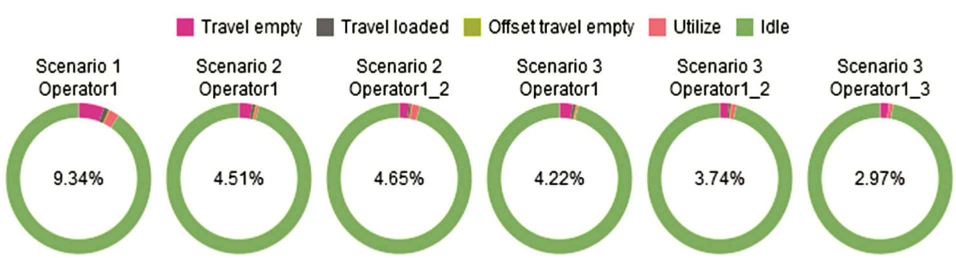

Fig. 8 — Operators state pie chart

parameters such as travel empty, travel loaded, offset travel empty, utilize time, and idle time. The operator's state pie chart shows that as the number of operators increased, overall idle time also get decreased.

Conclusions

With the rapid development in the automobile industry, effective operations and effective machines are the need of the hour. Simulation and modelling have changed the way of establishing new industries and always provide us the optimal results. This study deals with the simulation and modelling of crankcase cover manufacturing in the automobile industry to find out the optimal scenario with the Flexsim tool. The objective of this research was to analyze the effect of changing the number of operators and process stations on the system performance. The results show the percentage time of processing, blocked, idle, setup, waiting for the operator, and waiting for the transport. It is concluded from all the results that scenario 2 is best for crankcase cover manufacturing which reduces the overall ideal time and provides the optimal number of DCM and VMC required for crankcase cover manufacturing. These results are beneficial for all types of manufacturing industries. This developed simulation model is also helpful for the construction of new efficient production facilities for various industries.

Further study can also be extended by automatic updating of the database with company databases and using a global table with different part sets. The effects of adding the buffers on system performance within the layout of the processing stations can also be analyzed as a future study.

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