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Analysing the Bottleneck in Crankcase Cover Manufacturing using Simulation and Modelling

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Before constructing the actual production plant architecture, the simulation builds a virtual production model that is identical to the real environment and offers insights into the future. By using simulation, we can test the behaviour of the expensive and sophisticated manufacturing system without physically putting any money in it. In this study, Flexsim is used for the first time to model and simulate the production of two-wheeler crankcase covers. In this work, a simulation model for crankcase cover production processes in the automotive sector is developed. Flexsim simulation tool is used as an optimization tool for analysing the bottleneck or performing the line balancing. The results indicate that by eliminating the bottleneck in the production line, it increases the line efficiency as well as the production throughput. Initially production line efficiency is just 51.8% when bottleneck is present. After bottleneck is removed, it increases not only throughput but also line efficiency to 97.29%. All manufacturing sectors will profit from these findings.

Keywords: Bottleneck, Line balancing, Optimization, Plant layout, Production model

Introduction

Simulation is a tool for modelling and analysing complex systems. By creating a virtual representation of a real system, simulations allow researchers, engineers, and analysts to study the behaviour of the system and make predictions about how it will perform under different conditions. The use of computer simulation can help to reduce the cost and time required to develop, test, and improve real-world systems, and can also provide valuable insights into the underlying processes and mechanisms of the system being studied.[1]

Analysis of the various production systems is aided by simulation. It resolved issues with resource management, planning, shop floor operations, material handling, storage, and manufacturing. Different companies now provide various simulation software. This software lowers the cost of manufacturing and offers efficient resource management.[2] The development of computer simulations can be traced back to the 1950s when early computer systems were used to simulate complex systems and processes. The creation of programming languages in the following decade made it easier to implement these simulations. Over time, ready-made simulation software emerged, allowing for more complex and accurate simulations to be created, including those that utilized 3D modelling. These advancements have played a crucial role in shaping the fields of science, engineering, and technology, as well as numerous other industries. With the increasing demand for efficient and cost-effective solutions, many companies have started developing advanced simulation software. These programs allow for the creation of virtual models of various processes, providing valuable insights and enabling informed decision-making. The advancements in this technology have made it easier for businesses to optimize their operations, reduce costs, and make more informed decisions. This, in turn, has led to the growing popularity of simulation software across various industries.[3]

Flexsim is a software tool for modelling, simulating, and optimizing complex systems and processes. It is used in various industries such as manufacturing, healthcare, supply chain, and transportation. Flexsim provides a 3D environment for building virtual models and simulating real-world situations, allowing users to experiment with different scenarios and optimize their systems. It can be used for various purposes such as capacity planning, process improvement, resource optimization, and risk analysis. Flexsim offers a range

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of features such as process visualization, data analysis, and reporting, making it a valuable tool for organizations looking to improve efficiency and reduce costs. Flexsim, Arena, Simul8, Anylogic, Witness, and Promodel are some of the simulation software available in the marketplace. Software for discrete event simulation called Flexsim is employed for challenging optimization issues. Flexsim is an extremely potent modelling and simulation tool. This tool may be used to analyse appointment scheduling issues and manufacturing issues. Additionally, it aids management in adjusting work schedules and hiring staff for upcoming projects. The simulation also reveals any system bottlenecks or inefficiencies.[4]

Scheduling, production planning, and design issues may all be successfully solved using the simulation technique. These methods aid in solving decision-making issues and producing more accurate outcomes based on actual dynamic circumstances.[5] The experimenter tab in Flexsim is used to construct experiments that are used to optimise the performance of the manufacturing plant and the set of solutions.[6] The Flexsim tool can construct a hybrid simulation model that optimises a variety of parameters, including makespan, due date, tardiness, work-in-progress inventory, machine utilisation, etc.[7] This tool offers a comprehensive output report that may be examined to gauge the system's performance.[8]

Yaser *et al.*[9] discussed the use of modelling and simulation as a tool for making decisions in the context of improving the performance of a production cell in a manufacturing plant. The use of the Flexsim simulation tool is mentioned as a way to analyse different scenarios and make recommendations for improvement. The results of the simulation indicate that an improved scenario resulted in an increase in production level and the elimination of the need for overtime labour costs. Wang *et al.*[10] established a thorough framework for the logistics distribution centre layout design problem. A small logistics distribution center's structure and operational procedures were examined and planned using logistics simulation software to create the simulation model and the distribution centre model of logistics is optimised using Flexsim simulation software.

Hassan *et al.*[11] used Flexsim to analyse the behaviour of a 500 Kg capacity shea nut processing plant and found that the initial plant design had bottlenecks and low efficiency (35.7%). After improving the layout, the plant efficiency increased to 83.3% with shorter lead times, improved machine utilization, and increased throughput capacity. The results showed that effective layout design and simulation can improve traditional shea nut processing practices. Ljaskovska *et al.*[12] presented the results of analysing and applying the study of mechanical systems in various industries, such as electronics, processing, and food. The importance of simulating and visualizing the processes of creating technological systems and analysing their relationships is highlighted to improve the efficiency of resource and time use in production processes. Luscinski *et al.*[13] focused on the development of a simulation model of a flexible manufacturing system using Flexsim 3D software. The aim is to achieve and maintain both strategic and operational goals in a global competitive market. The model is designed to match both production and market requirements in the face of variable demand for products made in many variants and short lead times.

Watnakornbuncha *et al.*[14] reduced production costs of Eureka lemon shampoo products by using Flexsim software simulations. Data was collected from Pasutara Farm in Thailand. Results showed a 39.58% reduction in time cost by implementing three stages of production improvement on the nine-workstation production line. The research suggests improvements to the production processes based on the results. Rao *et al.*[15] improved the productivity of the spool casing assembly process in the horn armature core. The study uses method study, time study and Value Stream Mapping (VSM) to identify the value-added and non-value-added activities and transportation wastes in the current state process. The future state VSM is developed to reduce these wastes and the results of both current and future state time study are simulated using Flexsim simulation software.

Flexsim is a simulation software that can also be used to model and analyse queues in public healthcare systems to reduce waiting times. The software can be used to create a virtual representation of a healthcare system and simulate the flow of patients through various stages of the process. By analysing the data generated through simulation, healthcare managers can identify bottlenecks and areas for improvement, and test different strategies for reducing waiting times before implementing them in real-life settings.[16] Flexsim is also used to simulate a production line and visualize it in real-time, allowing you to test different scenarios, analyse results, and make informed decisions about optimizing the production process. Flexsim graphical user interface makes it easy to build and modify simulation models, and its advanced simulation engine provides fast and accurate results. The software can also be used to analyse data and present results in customizable reports and charts.[1] Flexsim simulation environment can also be used for personnel management on the production line by creating a virtual simulation of the production process. This can help to analyse and optimize various aspects of personnel management such as staffing levels, work scheduling, training, and motivation. Flexsim can also help to identify bottlenecks in the production process, evaluate the impact of changes in personnel management policies, and estimate the costs and benefits of different personnel management strategies.[17]

Modern techniques, such as Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) software, can help improve machine shop layout design by providing faster and more efficient methods of modelling and simulation. These tools allow designers to create virtual models of the shop floor, test different layout configurations, and optimize the use of space and resources. By using these modern techniques, machine shops can reduce the time it takes to design layouts, minimize the risk of design errors, and improve overall efficiency and productivity.[18] According to previous study, most researchers have used the Flexsim tool to solve modelling and simulation issues. The literature analysis also reveals that there is little research in the domain of modelling and simulation of crankcase cover manufacture in the automotive sector. The primary goal of this work is to create a 3D simulation model based on a general process model. Later, bottleneck will be identified, and removed for increasing the production line efficiency and production throughput.

Materials and Methods

Analysing the process model is the initial stage in simulating any industry's layout. The next step is to turn this simulation model into a process model. Flexsim is an effective tool for turning any theoretical process model into a realistic three-dimensional simulation model.

Process Model

A crankcase cover is made by going through a number of processes, including melting raw materials in a furnace, die casting, fettling, drilling, machining, polishing, surface treatment, and painting. In Fig. 1, the overall process model for the crankcase cover manufacturing process is displayed. Our main aim of the study is to find out the bottleneck present in the production line and to eliminate this bottleneck to increase the line efficiency.

Flexsim Simulation Approach

A simulation model of the crankcase cover manufacturing process is created using the Flexsim

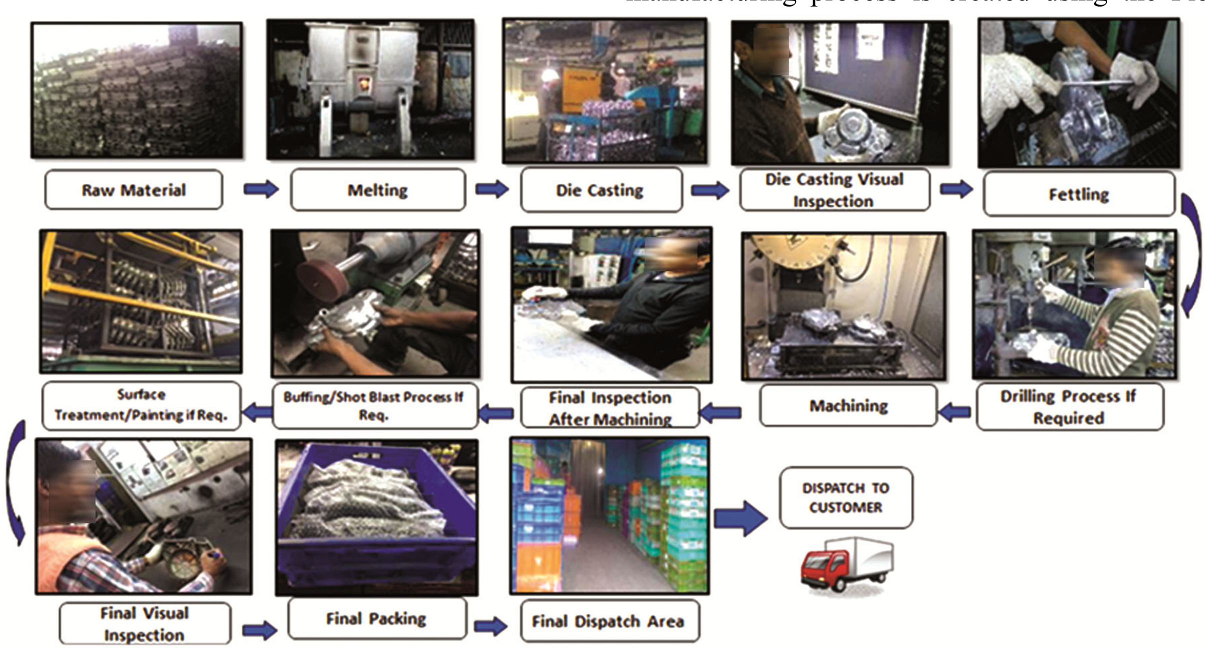

Fig. 1 — General process model for crankcase cover manufacturing

simulation tool. Additionally, this programme creates infinitely extensible models that may be freely expanded.[19] With the use of this instrument, a 3-D model that cannot be established in its actual form may be examined.[20]

Assumptions

When creating a simulation model, the following assumptions are taken into account.

(a) Every machine has sufficient capability to function.

(b) It is expected that the raw material arrival rate will follow an exponential distribution with a location value of zero and a scale value of 4 minutes.

(c) A triangular distribution with a minimum setup time of 0.05 minutes, a maximum setup time of 0.15 minutes, and a typical setup time of 0.01 minutes is considered.

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

The four fundamental elements are present in Flexsim. A source, sink, processor, and queues are among these elements.[20]

Simulation Model

The arrival rate, processing time, and resource number are the usual three inputs of the simulation model. Throughput, line efficiency, and states are typically used to gauge the model output. Crankcase covers are the flow components in this simulation model. The source, queue, processor, and sink are the fixed resources employed in this simulation model. Additionally, loading and unloading flow items are done by operators. The operators are coordinated by a dispatcher. The real database system of the organisation must occasionally be used to update the virtual model. The crankcase cover manufacturing 3D simulation model is shown in Fig. 2. To execute this simulation model, the model's parameters must be defined. The various operations performed for the manufacturing of crankcase cover are assumed to be triangular distribution. Initially raw material (aluminium bricks of 5 kg) is melted in the furnace. Then, molten metal is carried to die casting machine with the help of a ladle. The time taken by cold chamber Die Casting Machine (DCM) is approximately 1.5 minutes. After that, Manual Fettling (MF) is done for 0.18 minutes for cleaning some extra material. Then drilling machine is done for 0.35 minutes if required some holes for particular places in the part. Then, main finishing operation is done on Vertical Milling Centre (VMC) for 4 minutes. After that, Buffing Machine (BM) is used to remove dirt and polish the part. Last, part is processed in Painting Shop (PS) for various coatings on the part for 21.3 minutes for removing any surface defect. Data used in this study is collected from the Super Auto Limited company, Faridabad, India.

Flexsim reset and run options are used to run the model during simulations, and the dashboard option presents all system analysis in the form of numerous charts. Any uncertainty that was present in the production system is eliminated through analysis of the virtual model.

Elimination of Bottleneck in Production Line

The run speed during simulation is taken as 2401 sec. On running the simulation model for 8-hour (28800 sec) shift, it has been observed that the bottleneck is created on the queue 4 as shown in Fig. 2. The production line efficiency of this model is calculated as 51.8%. The throughput during an 8-hour shift is shown in Fig. 3. It can also be seen from this diagram that bottleneck is present after drilling machine due to which throughput value of VMC is 115 as compared to 218 value of drilling machine. Since the bottleneck is created before VMC machine, So, add one more VMC machine in production line as shown in Fig. 4. After removing this bottleneck, the production line efficiency becomes 97.29%. The increase in throughput value after eliminating bottleneck is also shown in Fig. 5.

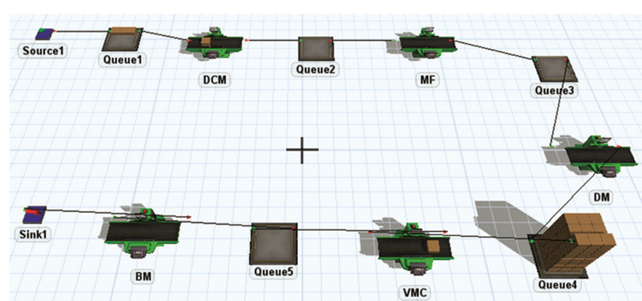

Fig. 2 — Simulation model of crankcase cover manufacturing

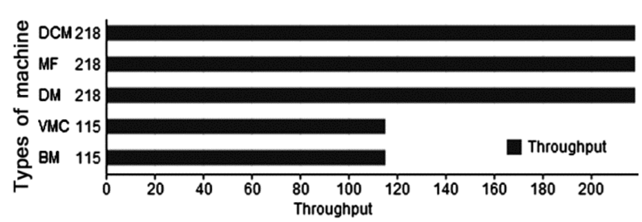

Fig. 3 — Throughput during 8-hour shift

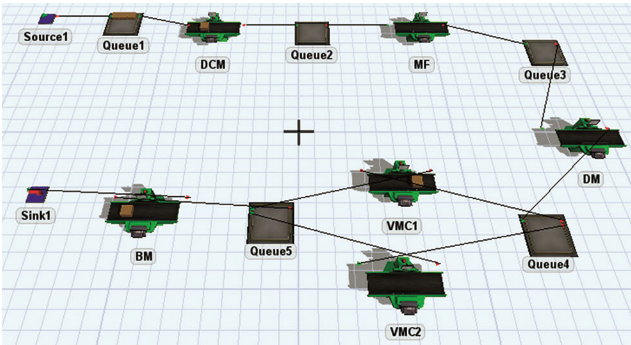

Fig. 4 — Simulation model after removing bottleneck

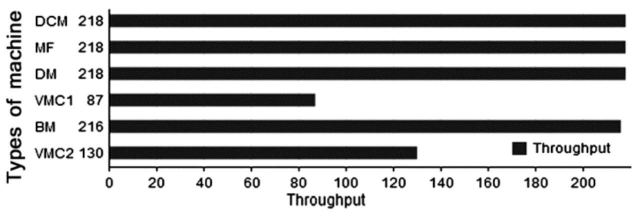

Fig. 5 — Throughput after removing bottleneck

Results and Discussion

There are various line balancing methods to eliminate bottlenecks in a production line discussed as follows:[21]

a) Increase capacity: This can be done by adding more resources, such as employees, machines, or raw materials, to the production process.
b) Reallocate resources: Moving resources from low-demand areas to high-demand areas can help balance production and eliminate bottlenecks.
c) Improve efficiency: Streamlining processes, reducing waste, and increasing productivity can help reduce bottlenecks.
d) Prioritize tasks: Focusing on the most important tasks first can help ensure that resources are used efficiently, and bottlenecks are minimized.
e) Automation: Automating certain tasks can help increase productivity and reduce the likelihood of bottlenecks occurring.
f) Improved scheduling: Scheduling production in a way that considers potential bottlenecks can help prevent them from occurring.
g) Collaboration and communication: Encouraging collaboration and communication among different departments can help identify and resolve bottlenecks more effectively.

There are some specific ways to eliminate bottleneck in any simulation model such as increasing the inter-arrival time of source1, decreasing the setup time/processing time or adding some more machines in production line. The most preferable method for line balancing is to increase the capacity i.e. adding more machines in production lines. Since the bottleneck is created before VMC machine, so, add one more VMC machine in production line as shown in Fig. 4. After removing this bottleneck, the production line efficiency becomes 97.29%. The increase in throughput value after eliminating bottleneck is also shown in Fig. 5.

By simulating the behaviour of the production system, it can determine whether the production targets can be met within the specified time and evaluate the performance of each machine in the production line. The simulation results can provide valuable information about the capacity, efficiency, and bottlenecks in the production process, which can be used to identify areas for improvement and optimize the production line for maximum performance.

Effective operations and machinery are crucial for the automotive industry to sustain its growth and meet the demands of the market. Efficient and reliable processes and equipment help improve production capacity and product quality, leading to increased customer satisfaction and competitiveness in the market.

Modelling and simulation have certainly had a significant impact on the process of launching new businesses. They provide a powerful tool for evaluating and testing new ideas, concepts, and designs in a virtual environment before they are implemented in the real world. This allows entrepreneurs to identify and address potential challenges and make informed decisions, leading to more effective and efficient launch processes. The results indicate that by eliminating the bottleneck in the production line, it increases the line efficiency as well as the production throughput.

Conclusions

By creating a virtual model of the manufacturing process, it's possible to evaluate various scenarios and test different solutions to identify the root cause of any bottlenecks and determine the most effective way to remove them. Initially production line efficiency is 51.8% when bottleneck is present at queue 4. By adding one more vertical milling centre in the production line, queue 4 bottleneck is removed, and it increases not only throughput but also line efficiency to 97.29%. All manufacturing sectors will profit from these findings. The development of new, effective manufacturing facilities for a variety of sectors can also benefit from the use of this simulation model. By employing a global table with various part sets and automatically updating the database with corporate databases, further research may also be expanded. Future research might also examine how adding buffers affects system performance within the design of the processing stations.

References

1 Ishak A, Zubair F & Cendani A S, Production line simulation in vise using the Flexsim application, in *IOP Conf Series: Mater Sci Eng* (IOP Publishing) **1003(1)** (2020) 1–6, doi: 10.1088/1757-899X/1003/1/012103.

2 Bjorklund S, Yamani N & Lloyd T, Simulation software for real time forecasting as an operational support, *Proc of the Second World Conf POM 15th Annual POM Conf* (Cancun, Mexico) 2004, 1–30.

3 Kliment M, Trojan J, Pekarcikova M & Kronova J, Creation of simulation models using the Flexsim software module, *Advanced Logistic Systems - Theory and Practice*, **16(1)** (2022) 41–50, doi: 10.32971/als.2022.004.

4 Krishna L S R, Saketh T S S & Kumar M V S, A simulation based approach for studying the effect of buffers on the performance of an FMS, *Int J Eng Sci Invent*, **4(1)** (2015) 5–9.

5 Fauadi M, Azimi N Z, Anuar N I, Ali M M, Sued M K & Ramlan S, Simulation approach for logistical planning in a warehouse : A review, *Orient J Comput Sci Technol*, **11(4)** (2018) 201–208.

6 Jarernram J & Samattapapong N, Parallel machine scheduling using simulation software, *Proc* of the *ICMEIT* (Pattaya, Thailand) 2018, 150–155.

7 Rodrigues R P, Pinho A F D & Sena D C, Application of hybrid simulation in production scheduling in job shop systems, *Simul Trans of the Soc Model Simul Int*, **96(3)** (2019) 1–16, doi: 10.1177/0037549719861724.

8 Nie X & Wang L, Simulation process design for scheduling mode of railway container terminals based on Flexsim, *Proc J Phys : Conf Ser*, **1176(5)** (2019) 1–6, doi: 10.1088/1742-6596/1176/5/052012.

9 Yaser S, Abdelatif N, Fahim I, Emad Y, Saleh A, & Kassem S S, FlexSim simulation to enhance productivity of a production cell: A case study, *Proc* of the *3rd NILES* (Giza, Egypt) 2021, 312–317. doi: 10.1109/NILES53778.2021.9600545.

10 Wang S, Wang S M & Zhang N, Flexsim-based simulation and optimization of green logistics distribution center, *Proc of the 14th ICCMS* (Chongqing, China) 2022, 76–82, doi: 10.1145/3547578.3547590.

11 Hassan N A, Arogundade A I, Iyenagbe U B & Musa D I, Simulation and analyses of shea nuts (vitallaria paradoxa) processing plant using FlexSim, *J Fut Sustain*, **3(2)** (2023) 67–74, doi: 10.5267/j.jfs.2022.11.006.

12 Ljaskovska S, Martyn Y, Malets I & Velyka O, Optimization of parameters of technological processes means of the flexsim simulation simulation program, *Proc of the IEEE 3rd ICDSMP* (Lviv, Ukraine) 2020, 391–397, doi: 10.1109/DSMP47368.2020.9204029.

13 Luscinski S & Ivanov V, A simulation study of industry 4.0 factories based on the ontology on flexibility with using flexsim software, *Manag Prod Eng Rev*, **11(3)** (2020) 74–83, doi: 10.24425/mper.2020.134934.

14 Watnakornbuncha D, Muangwai A, Wichitphongsa W, Amdee N & Inthawongse C, Processing cost reduction of lemon products in community enterprises using Flexsim simulation, *Proc of the IEEM* (Kuala Lumpur, Malaysia) 2022, 670–674, doi: 10.1109/IEEM55944.2022.9989661.

15 Rao G V P, Nallusamy S & Raman P, Enhancement of production in subassembly line of a medium scale industry using different lean tools and FlexSim simulation software, *Int J Eng Res Africa*, **44** (2019) 229–239, doi: 10.4028/www.scientific.net/jera.44.229.

16 Amalia P & Cahyati N, Queue analysis of public healthcare system to reduce waiting time using flexsim 6.0 software, *Int J Ind Optim*, **1(2)** (2020) 101–110, doi: 10.12928/ijio.v1i2.2428.

17 Krynke M, Personnel management on the production line using the Flexsim simulation environment, *Manuf Technol*, **21(5)** (2021) 657–667, doi: 10.21062/mft.2021.073.

18 Patil R J, Kubade P R & Kulkarni H B, Optimization of machine shop layout by using Flexsim software, *Proc of the AIP Conf* (AIP Publishing) **2200(1)** 2019, doi: 10.1063/1.5141203.

19 Kliment M, Trojan J, Pekarcíková M & Kronova J, Creation of simulation models using the Flexsim software module, *ALS-Theory and Practice*, **16(1)** (2022) 41–50, doi: 10.32971/als.2022.004.

20 Kessel D, Jeon J, Jung J, Oh E & Kim C, Logistical simulation modeling for planning a soil remediation process, *Sci Technol Nucl Install*, **2019** (2019) 1–13, doi: 10.1155/2019/6789506.

21 Kikolski M, Identification of production bottlenecks with the use of plant simulation software, *Eng Manag Prod Serv*, **8(4)** (2016) 103–112, doi: 10.1515/emj-2016-0038.