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INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

# ENHANCEMENT OF ASSEMBLY LINE EFFICIENCY WITH OPTIMIZATION OF PRODUCTIVITY

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**DOI**: 10.5281/zenodo.1320902

## ABSTRACT

Manufacturing process is a process of producing and creating a product with the use of technologies and machinery resources. In manufacturing process there are three dimensions, which are important in improving the production system. These are cost, quality, and speed that can be considered as basics of every process. In this thesis speed of the manufacturing process is enhanced, which leads to acquire the production orders in given time and also reduces the number of dropped orders.

Assembly lines are the part of manufacturing process to convert raw materials into finished products. Considering optimization problems in assembly lines, applying PSO algorithms to the established model could lead to efficient manufacturing. PSO algorithm is a programming search technique for maximizing productivity, maximizing line efficiency and reducing production time.

This research work presents an approach for developing assembly line simulation models used for optimization of assembly lines. This model is designed in MATLAB 2015(a) with the help of inbuilt Production Toolbox. The simulation of the assembly line is created to assess cycle times and utilization of workstations using MATLAB Simulink. The optimization, in the context of presented work, is the process of locating and scheduling the products in the line achieving best timing to fulfill production orders. The workstations can be first balanced for better performance and then products are scheduled based on reduction of the production time.

**Keywords:** Assembly Lines; PSO Algorithms; Simulation Model; Production Toolbox; Cycle times; Workstations; Matlab Simulink

## I. INTRODUCTION

An assembly line (AL) is a production process which is composed of different operations. Workpieces are successively combined on a product at each station to manufacture a final product. ALs are the mostly used technique in mass production, as they enable the assembly of complicated products by workers with restricted training and devoted robots and/or machines. Assembly lines consist of workstations arranged by a conveyor belt or a similar material handling system. The parts are flowed towards end of the line and transferred among the workstations, Gocken, et al.[1]. At every station, specific operations are performed continually in connection with cycle time. When tasks are completed at each station, finished product is obtained.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

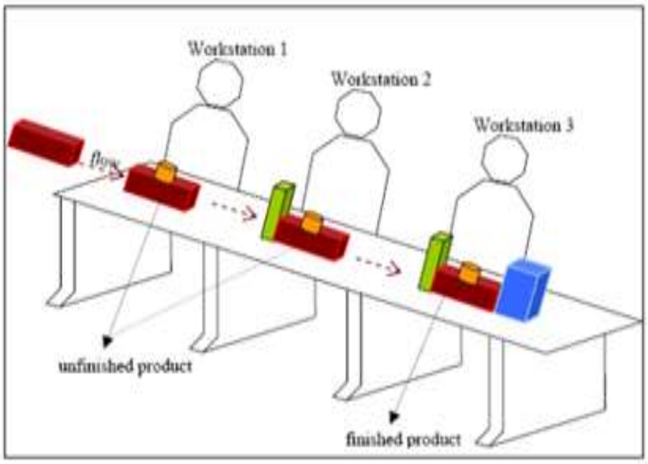


***Fig 1.A Concept of assembly line (Ozmehmet T., 2007) [4]***

Assembly lines are flow-oriented production systems where the units of production performing the operations are aligned in a serial manner, referred to as *stations*. Workers and/or robots perform certain operations on the product at the stations in order to exploit a high specialization of labour and the associated learning effects, Manavizadeh et al. [5]. The smallest individual and indivisible operations are called *tasks*. The necessary time for a task to be performed is called the *task time* or *the processing time*. Every product follows the stations along the assembly line until the raw materials turn into a final product. The operations assigned to stations are carried out on the product at each station within a specified time. This time, which is equal to the maximum of sums of processing times of the tasks in all stations, is called the *cycle time*. Production rate of the assembly line, which is the amount of final goods produced in a period of time, is directly determined by the cycle time. Assembly line balancing (ALB) problem is an assignment problem aiming to assign the tasks to the stations in order to minimize the cycle time, i.e. maximize the production rate, or minimize the line length, i.e. the workforce required.

Assembly lines can be divided into two different groups based on product characteristics and some technical requirements: (i) one-sided assembly lines, and (ii) two-sided assembly lines. While only one restricted side (either left (L) or right (R) side) is used in one sided assembly lines, both left and right sides are used in two-sided assembly lines. Two-sided assembly lines are usually constructed to produce large-sized high volume products such as buses, trucks, automobiles, and some domestic products. Two directly facing workstations called *mated station* are allocated at each working position, Chutima et al. [6]

In terms of the various numbers of product models assembled on the line, assembly lines can also be classified as single-model assembly lines and mixed-model assembly lines, Kara et al.[7] The production lines in which more than one product model is assembled on the same line without any setup requirement between models and/or tasks are called as mixed model assembly line, Battini et al. [8]. Mixed model assembly lines offer several advantages over single-model assembly lines, including avoidance of constructing several lines, satisfied different customer demands, and minimized workforce need. Constructing parallel assembly lines is another type of line configuration which was proposed by Gokcen et al. [9] to increase the efficiency when demand is high enough. Parallel assembly lines have some advantages like minimised idle times, reduced operator requirements, enhanced communication between operators, and improved resource utilization, Ozcan et al. [10]

Through analysis of operations at the pre-assembly line and processes at the corresponding workstations, the objectives of this study are,

- To investigate the balance losses in the current pre-assembly line and maximise line efficiency,
- To minimize the number of work stations for a given cycle time.
- To minimize the cycle time for a given number of workstations.
- To minimize the number of incomplete jobs or dropped orders.
- To minimize the expected total costs.
- To maximize the productivity.

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# II. METHODOLOGY

Methodology used in this research is optimization of thirty days production data of Force India Limited (Indore) using PSO technique and this optimized result is used in designing the model of balanced assembly line in MATLAB Simulink. Kanban system is also used for withdrawing and releasing the stored material.

## *A. Particle Swarm Optimization*

PSO is a **swarm intelligence** meta-heuristic inspired by the group behavior of animals, for example bird flocks or fish schools. Similarly to genetic algorithms (GAs), it is a population-based method, that is, it represents the state of the algorithm by a population, which is iteratively modified until a termination criterion is satisfied. In PSO algorithms, the population $P=\{p_1,\ldots,p_n\}$ of the feasible solutions is often called a **swarm**. The feasible solutions $p_1,\ldots,p_n$ are called **particles**. The PSO method views the set $R^d$ of feasible solutions as a "space" where the particles "move". For solving practical problems, the number of particles is usually chosen between 10 and 50.B.Santosa[31].

Characteristics of particle i at iteration t:

- $x_i^{(t)}$ … the position(a d-dimensional vector)
- $p_i^{(t)}$ … the "historically" best position
- $l_i^{(t)}$ … the historicaly best position of the neighboring particles; for the fully connected topology it is the historically best known position of the entire swarm.
- $v_i^{(t)}$ … the speed; it is the step size between $x_i^{(t)}$ and $x_i^{(t+1)}$

At the beginning of the algorithm, the particle positions are randomly initialized, and the velocities are set to 0, or to small random values. A.Chatterjee et al.[32]
Parameters of the algorithm:

- w(t) … inertia weight; a damping factor, usually decreasing from around 0.9 to around 0.4 during the computation
- φ1, φ2 … acceleration coefficients; usually between 0 and 4.

Many versions of the particle speed update exist, for example:
$v_i^{(t+1)}= w^{(t)}v_i^{(t)}+ \varphi_1 u_1(p_i^{(t)}-x_i^{(t)})+ \varphi_2 u_2(l_i^{(t)} - x_i^{(t)})$

The symbols u1 and u2 represent random variables with the U(0,1) distribution. The first part of the velocity formula is called "inertia", the second one "the cognitive(personal) component", the third one is "the social(neighborhood) component". Position of particle i changes according to
$x_i^{(t+1)} = x_i^{(t)} + v_i^{(t+1)}$

The algorithm is terminated after a given number of iterations, or once the fitness values of the particles (or the particles themselves) are close enough in some sense.

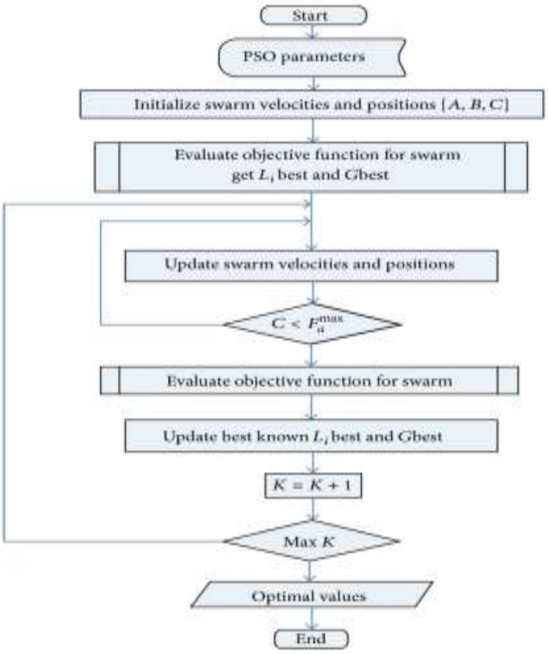


***Fig 2. Flowchart of PSO Algorithm***

*B. Kanban Method*

Inventory costs a lot of money and companies try to solve this problem. First, there are the raw materials and operating expense it costs to produce it. Next, a company must handle it, which means that they need more people and machines like forklifts. Usually moving the material around, more than once before it gets to its desired location. This in turn requires space and transportation and neither are free. Next, we must keep track of it, which means people, computer programs, and reports galore, almost all of which are filled with errors. The company should try to fix these errors. The way it should be fix the errors is to use things like cycle counts which then take more people, more time, more computers, and worst of all more reports and more meetings. Salem et al.[33]. In addition, we must care for this inventory to make sure it does not get damaged. And finally, we must ship it before it becomes absolete. All of these liabilities of inventory are obvious bottom line opportunities, and yet the greatest advantage of reduced inventory is not even mentioned here. In fact, it is often not even recognized. In just a minute, the company will get to that crucial advantage which so few see and even fewer appreciate. Kanban means sign board. A Kanban can be a variety of things, most commonly it is a card, but sometimes it is a cart, while other times it is just a marked space. In all cases, its purpose is to facilitate flow, bring about pull, and limit inventory. It is one of the key tools in the battle to reduce overproduction. Wemmerlov et al. [34].

Kanban provides two major services to the Lean facility. Kanban provides two types of communication. In both cases, it gives the source, destination, part number, and quantity needed. The Kanban system is very flexible, and many types of Kanban can be used. Likewise, as long as they follow the basic rules of Kanban, they can be used in a large variety of ways. However, the majority of Kanban follow a standard pattern. Process improvement in a Kanban system is accomplished by the reduction of inventory, which can be achieved by:

- reducing any of the four replenishment times or reducing the pickup volume by the customer, this is usually achieved by increasing the pickup frequency;
- reductions in any of these items will reduce cycle stock inventory;
- reducing the variation in the production rate, which allows safety stock reductions;
- reducing the variation in the customer demand, which allows buffer stock reductions.

Below is presented a formula witch is using in production to show how kanbans could flow between a customer cell and a supplier cell.

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Step 1:
Kanban quantity =
$$\frac{Designed\ daily\ production\ rate \times replenishment\ time}{Available\ time}$$

Step 2:
Number of cards = $$\frac{Kanban\ quantity}{Lot\ size}$$

The determination of Kanban is an important step in the cell design process because Kanban are the limiting factor for inventory levels (raw material, WIP, finished goods) and are the control elementon lead-times. These operational aspects(inventory and lead-time) have a major influence on continuous improvement within a cellular operation. Harrison et al. [35]

## III. RESULTS AND DISCUSSION

The results of this research presents modelling and simulation of PSO algorithm by using MATLAB Simulink after optimizing the thirty days data of production plant of FORCE INDIA LTD. PITAMPURA, INDORE. This data is given in APPENDIX A. Fundamental simulation defines assembly line efficiency and product completion order with respect to time period i.e. one year. Simulink model consists of three production criteria that is Material Supplier, Production system and Distributor Block with variable assembly parameter. Simulink model is designed with the help of PSO algorithm and inbuilt Kanban withdrawal method.

### A. Material supplier

Product A and Product B are two different products which will undergo through assembly line. Material A and Material B are supplied by supplier in required quantity. Time taken in producing material A is 0.1 minute and material A is delivered to production system in 1 minute. Similarly, time taken in producing material B is 0.08 minute and material B is delivered to production system in 0.5 minute.

### B. Production system

When Material A and Material B are supplied to production system, it is first stored and then by Kanban withdrawl method, materials are withdrawn from the storage. Product A is withdrawn from the storage using Kanban withdrawl method in which 10 count of part A are withdrawn from the storage and transported to assembly line. And 20 count of part A is in working process. Similarly, using Kanban withdrawl method, part B is withdrawn from the storage. 5 count of part B is withdrawn from the storage and transported to assembly line, and 12 count of part B is in working process. And for final assembly 10 counts is in working process.

Time taken to produce part A from storage is 2 minute and time taken in transporting it to assembly line is 1 minute. Similarly, time taken to produce part B from storage is 1.5 minute and time taken to transport it to assembly line is 0.5 minute. For final assembly of A and B, assembling time is 0.6 minute.

### C. Distributor

From assembly line we get final finished product, this final finished product is again with the help of Kanban release method, is released for the distribution. Here we get total number of completed order and economical cost of the completed order. This result can be used to analyse the number of completed order and the number of dropped order with respect to per day of one year. When number of completed order becomes constant according to product demand then we get balanced assembly line.

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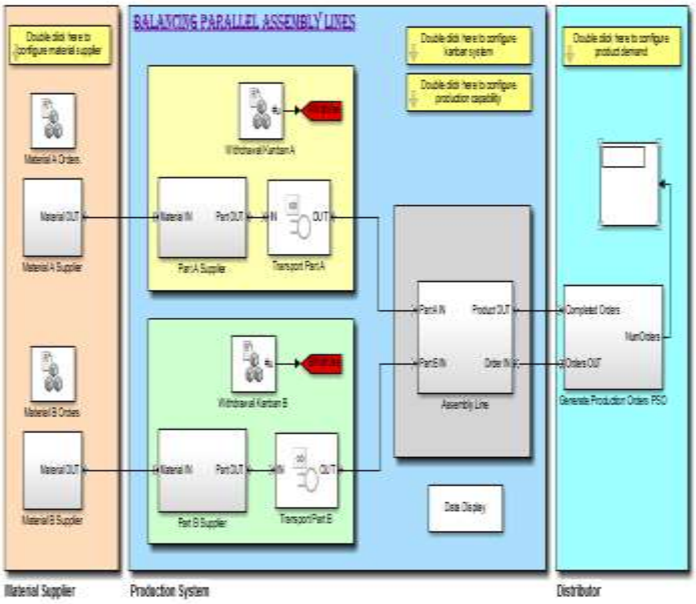


*Fig 3. Assembly line simulation production system*

This model contains three regions which are material supplier, production system and distributor. Additionally, we can face different conditions in real world such as symmetric tasks, synchronous tasks, task separation, station layout, parallel stations, setup times, multi or mixed model, capacity of machines in stations (local cycle times) and ergonomic constraints.

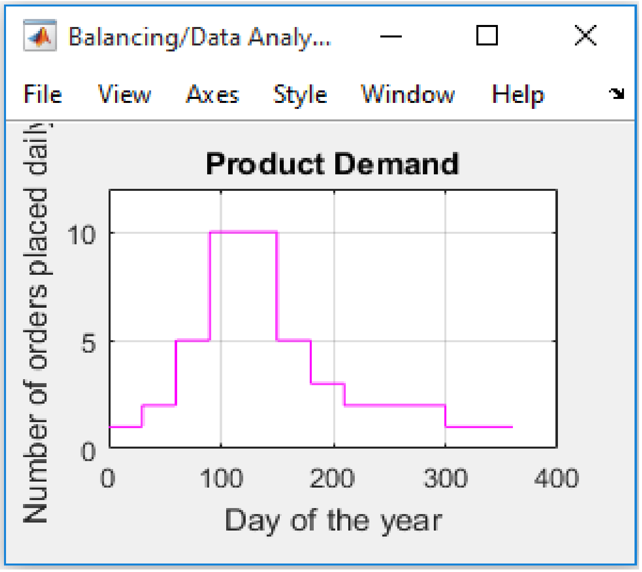


*Fig 4. Variations of Product demand*

This figure shows the variations of product demand with respect to day of the year.

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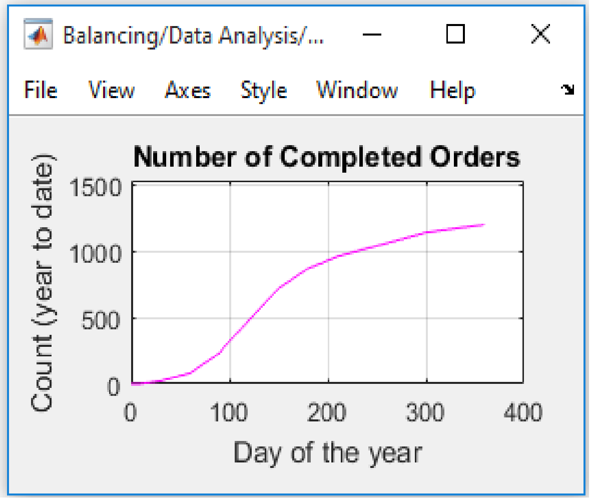


***Fig 5. Variation of completed order***

This figure shows the variation of completed order with respect to day of the year. As we get number of completed order constant at the end of the year which denote that product is getting completed in given time and our assembly line is balanced.

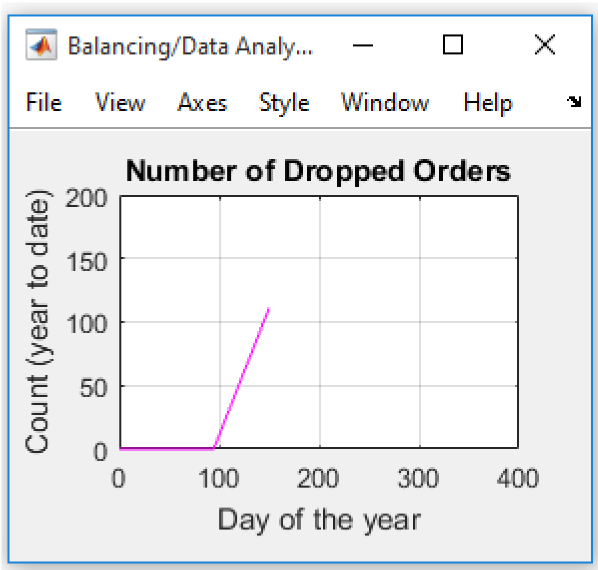


***Fig 6. Variations of dropped order***

This figure shows the variations of dropped order with respect to day of the year. When completed order becomes constant then the number of dropped orders reduces. This condition also fulfils the requirement of balanced assembly line.

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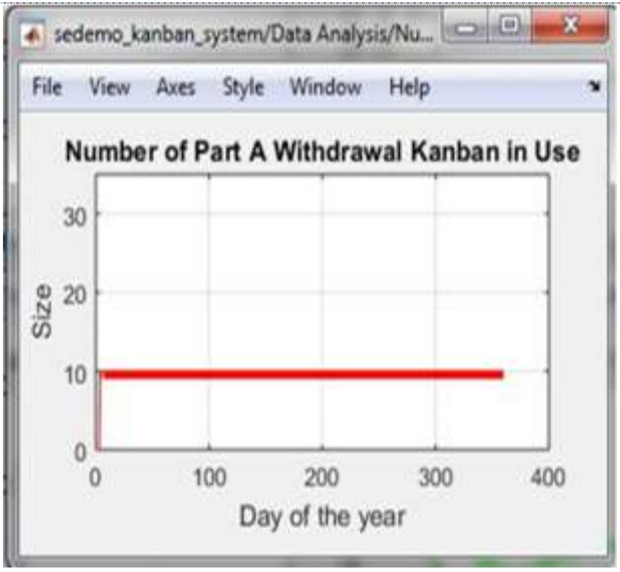


*Fig 7. Product A withdrawl Kanban*

If the Kanban is in storage part A attached to the item, that means there is no call to action for the production process When Kanban are on a Kanban board or in a Kanban Post that means downstream processes have removed and consumed the item from storage and replenishment is needed.

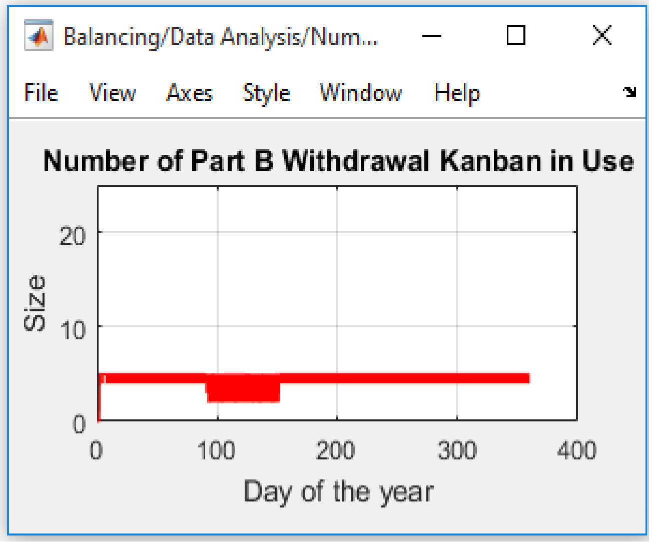


*Fig 8. Product B withdrawl Kanban*

A supplier Kanban communicates with your external material or component suppliers. This is often the last to be implemented because it requires your suppliers to be Kanban capable; internally you will need both smooth operations and a well-established Kanban system, before taking your ideas further upstream.

**D. Optimization result**

- Collect the bus data, line data and cost coefficients and their limits. These data are taken from production plant of FORCE INDIA LIMITED, Pitampura, Indore. And given in APPENDIX A.
- Convert the constrained optimization problem as an unconstrained problem by penalty function method.
- The file .opf2.m is a function file which returns the maximum productivity, assembly line flow, economical dispatching cost, and total load.
- Change your default folder as psoopf. Just run thirty days data to simulate the opf. The results will be displayed on the command window. This is the simulation result of 30 bus system.

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CODEN: IJESS7

- We get a graph between gbest which represent productivity of assembly line and epoch which represents number of sample as shown in figure 9.
- These are the optimized result from our thirty days data.
- P1 (Maximum productivity) = 80, 50, 35, 30, 40
- F1 (Assembly Line Flow i.e. Product per month) = 1.8894e+06
- P (Economical dispatch costing ) = 200, 80, 50, 35, 30, 40
- TL (Total load i.e. demand of production) = 151.6000

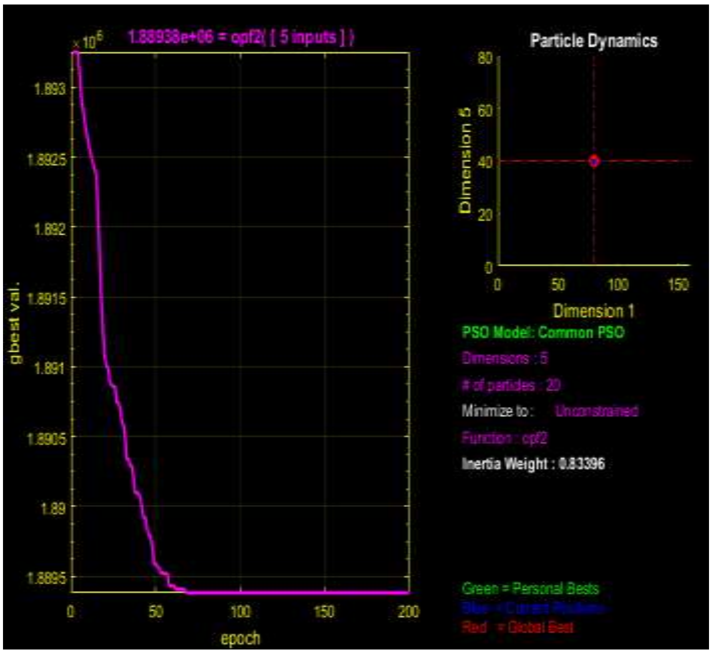


***Fig 9. Optimization graph***

## IV. CONCLUSIONS

Simulation and optimization in manufacturing process are the part of automating the factory floor. Simulation of the production line in this thesis work is done with MATLAB, for data acquisition, such as, cycle time, and utilization of each workstation. MATLAB makes the simulation and programming of the line faster and easier. Optimizing the data and studying them, leads to implementation of balanced assembly line model. In this thesis balanced assembly line model has been represented, with improvements in completion times for the products. The model with two different products A and B for one workstation has the best results, and we get constant result of number of completed orders after applying this optimization technique thus reducing the number of dropped orders. Variation in the number of completed orders in assembly line is the reason for choosing the model for optimization.

Implementing an optimization system on simulated manufacturing line is the intention of engineers, since it can decrease product delivery time and thus increases line efficiency. In this work PSO algorithms are implemented on the non-linear model for optimizing the productivity and economical costing products. PSO algorithm has been chosen for this work, because this algorithm is a method for searching the best solution among the solutions provided by the line.

Although the primary objective of this study is assembly line balancing, as the balance losses at the current system are investigated it is figured out that the problems were originated from various dynamics of the production process, which required consideration of assembly concepts. However, it is not possible to eliminate all problems at such a complex assembly system in such a short time with such a small budget and would also not be a reasonable objective. What this study aimed, though, was highlighting the problems observed during the assembly line balancing process so that it develops a guide for future studies.

- Operations that are object to be inappropriate for the pre-assembly line and readdressed to the sub-assembly stations should be removed from the pre-assembly line,

- the line should be balanced for the minimum number of required operators at stations and on-demand work force should be provided by joker operators,
- Sub-assembly stations should be relocated in order to meet the requirements of the new line layout,
- Factory logistics should be informed about supplying the required parts in the desired sequence

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## CITE AN ARTICLE

Sunil, & Anu, A. K. (2018). ENHANCEMENT OF ASSEMBLY LINE EFFICIENCY WITH OPTIMIZATION OF PRODUCTIVITY. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, *7*(7), 260-269.