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# Flexible Manufacturing System Layout Optimization Using Particle Swarm Optimization (PSO)

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**ABSTRACT:** Layout arrangement is important to achieve high productivity in flexible manufacturing system (FMS). This paper discusses the design of loop layout in FMS. The objective of the loop layout problem is the determination of the ordering of machines around a loop, and to minimize the automated guided vehicle (AGV) movement. Particle Swarm Optimization (PSO) technique is proposed to optimize the flexible manufacturing system (FMS) layout. In this paper also discusses the AGV movement around the loop layout is considered as bidirectional movement. The clearance between the machines is also considered in the FMS loop layout. Finally the FMS layout is optimized and compared**.**

***KEYWORD :*** Flexible manufacturing system, Loop layout, AGV, Particle swarm optimization, Machine clearance.



## 1 INTRODUCTION

*FMS is "an automated manufacturing system consisting of numerically controlled machines capable of performing multiple functions, linked together by a material handling system, all controlled by a computer system". Fig 1 shows the Flexible manufacturing system.*

**Figure 1** AlliedSignal's flexible manufacturing system

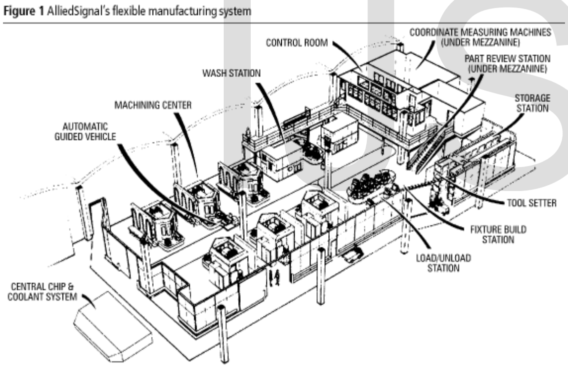


Fig 1.Typical Flexible Manufacturing System

*A flexible manufacturing system is a totally automated manufacturing system that consists of machining centers. with automated loading and unloading of parts an automated guided vehicle system for moving parts between machines, and other automated elements to allow unattended production of parts. In a flexible manufacturing system a comprehensive computer control system is used to run the entire system [1]. The layout of a flexible manufacturing system (FMS) involves distributing different resources for achieving maximum efficiency. It was estimated that 15–70% of the manufacturing costs are due to material handling [2]. With a good arrangement of the devices, it is possible to reduce the manufacturing costs by at least 10–30%. The layout has an impact on the production time and cost. Optimal design of the physical layout is one of the most important issues that must be resolved in the early stage of the FMS [3] [4]. Good solutions to layout problems provide a necessary foundation for effective utilization of the system and leads to drastic reduction of material handling expenses [5].The layout of machines in a FMS is typically determined by the type of material handling devices used such as material handling robots, automated guided vehicles, gantry robots etc., In practice the most commonly used types of machine layouts are the following. 1. Linear single row layout 2. Linear double row layout. 3. Cluster layout based on gantry robot. 4. Semi-circular layout with a single robot. 5. Closed loop layout [6] [7]. Among the above layouts, the loop layout was found to be more attractive due to their relatively low initial costs and high flexibility in material handling. The Typical loop layout is shown in Fig. 2.*

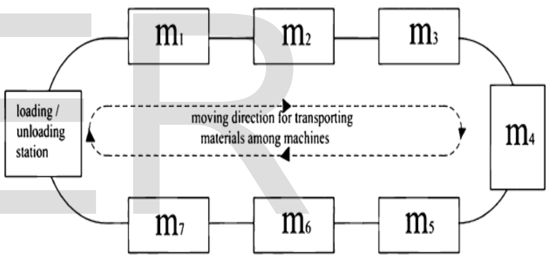


*Fig 2.Typical Loop Layout*

## 2. PROBLEM DESCRIPTION

*A common layout in FMS is the loop layout in which the machines are arranged in a loop network and materials are transported in bidirectional. An important step in designing the bidirectional network is the determination of the ordering of the machines around the loop. Also minimize the total number of backtracking occurs in the loop layout.*

## 3. PARTICLE SWARM OPTIMIZATION

*PSO is an evolutionary computation technique inspired by social behavior of bird flocking or fish schooling. Similar to other non-traditional techniques, PSO is a population based optimization technique. It was developed in 1995 by James Kennedy (social-psychologist) and Russell Eberhart (electrical engineer) [8]9]. Each particle keeps track of its coordinates in the solution space which are associated with the best solution (fitness) that has achieved so far by that particle. This value is called personal best, pbest. Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighborhood of that particle. This value is called gbest. The system initialized with a population of random solutions (particles), searches for optima by updating generations. However, unlike GA, PSO has no evolution operators such as crossover and mutation. In PSO, the potential solutions called particles are flown through the problem space by fol-*

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*lowing the current optimum particlesfig3shows the flow chart of Particle swarm optimization (PSO) algorithm.*

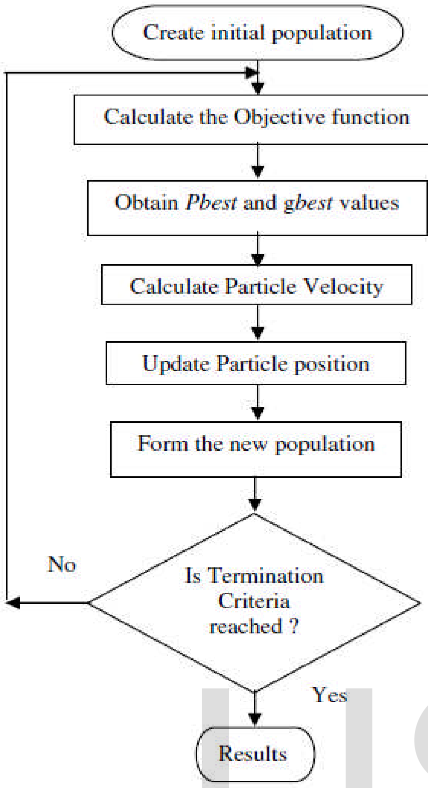



*Fig3Flow chart of PSO Algorithm*

*The PSO has the following advantages: (i) It has roots in artificial life and evolutionary computation. (ii) It is simple in concept, derivative free, computationally efficient. (iii) It only has a few parameters to adjust. (iv) It has no crossover and mutation operators when compared with GA (v) effective on a variety of problems like reactive power and voltage control, structural optimization etc. (vi) It is easy to implement.*

## 4. PSO ALGORITHM

*Step 1.Initialize a population of n particles randomly. Step 2. Calculate fitness value for each particle. If the fitness value is better than the best fitness value (pbest) in history. Set current value as the new pbest.*
*Step 3. Choose particle with the best fitness value of all the particles as the gbest.*
*Step 4. For each particle, calculate particle velocity according to the equation.*

*V [ ] = V [ ] + C1*rand ( ) *( Pbest [ ] – Present [ ] )*
*+ C2 *rand ( ) * ( gbest [ ] – Present [ ] )*
*Where present [ ] = present [ ] + V [ ]*
*V [ ] is the particle velocity,*
*Present [ ] is the current particle (solution),*
*rand ( ) is a random number between (0, 1),*
*C1, C2 are learning factors. (Range between 1 and 4).*

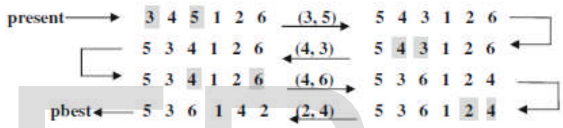
*Step 5. Particle velocities on each dimension are clamped to a maximum velocity Vmax. If the sum of acceleration would cause the velocity on that dimension to exceed Vmax (specified by the user), the velocity on the dimension is limited to Vmax.*
*Step 6. Terminate if maximum number of iterations is reached. Otherwise, go to Step 2.*

## 5.GENERATION OF NEW SEQUENCE

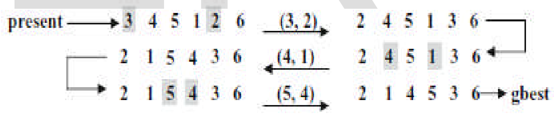
*The initial population is generated randomly and the objective function value (OFV) is calculated. The generation of new sequence for the next iteration from the present sequence is illustrated through the following example.*
*Let us consider the following initial sequences for present, pbest and gbest solutions as follows,*

*Present → 3 4 5 1 2 6*
*Pbest → 5 3 6 1 4 2*
*gbest → 2 1 4 5 3 6*

*V [ ] = V [ ] + C1*rand (1) *( Pbest [ ] – Present [ ] )*
*+ C2 *rand (2) * ( gbest [ ] – Present [ ] )*
*Rand 1 = 0.78 (Generated randomly)*
*Rand 2 = 0.48 (Generated randomly)*
*The difference in the sequence is calculated as the changes need to be made by swapping the individuals of a present sequence to get the pbest sequence. Hence to get pbest sequence from the present sequence the following swapping operation is done.*




Hence [pbest - present] is termed as (3, 5) (4, 3) (4, 6) and (2, 4). Similarly for getting gbest from present sequence, the following swapping is carried out.




*Hence [gbest - present] is termed as (3, 2) (4, 1) and (5, 4).*
*Hence velocity = 1 * 0.78 {(3, 5) (4, 3) (4, 6) (2, 4)} + 1* 0.48{(3, 2) (4, 1) (5, 4)}*
*In the first part of the above equation 78% of the changes have to be considered. So the first three changes (3, 5) (4, 3) (4, 6) are taken.*
*In the second part of the equation 48% of the change in {(3, 2) (4, 1) (5, 4)} has to be considered. It is not possible. So a minimum of 33% of the change is taken i.e., only (3, 2) is considered.*
*Hence the new velocity = (3, 5) (4, 3) (4, 6) (3, 2)*
*New sequence = present + velocity*
*The new sequence is obtained by adding the velocity with the present sequence by swapping.*
*3 4 5 1 2 6 + (3, 5) (4, 3) (4, 6) (3, 2)*

## 6. BASICAL ASSUMPTIONS (INPUTS) FOR LAYOUT OPTIMIZATION

*1. The Machines are not identical.*
*2. The distances between machines are equal.*
*3. No breakdowns for machines or material handling systems.*
*4. All tools are new at the initial stage.*
*5. Each tool and each operation are assigned only to one machine.*
*6. The setup costs differ according to the size and shape of the parts.*

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## 7. Layout Optimization

*The objective function of the loop layout optimization is expressed in terms of the following.*
*Z = X1D + X2B*
*Where,*
*X1, X2 - The normalized weight factors.*
*D – Total distance travelled by AGV for the completion of one cycle.*
*B – Total number of back tracking occurs in one cycle.*

## 8. Industrial Layout

*Ford India (p) Ltd is one of the automated manufacturing automobile industries. In this industry there are various automation sections like Blanking, stamping, painting, engine plant and Trim and chassis final. In this paper optimize the engine plant layout.Fig.4.shows the typical engine plant layout which is existing in the industry.*

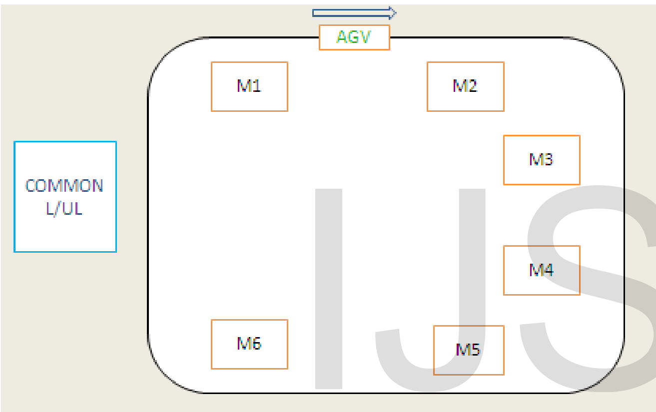


*Fig 4.Engine plant layout*

*The following details are mentioned about the engine plant layout.*

- *Number of machines → 6*
- *Number of parts delivered → 4*
- *Number of AGV used → single (Unidirectional Movement)*
- *Distance between the machines →10 m (It's not common for all the machines)*
- *Total distance travelled by AGV → 300 m*
- *There is no backtracking in AGV.*

## 9. Optimized Engine Plant Layout

*In this optimized layout the AGV movement is shifted over to bidirectional movement from the unidirectional movement and movements are arranged inside the loop layout. The loading stations are also modified and separated from the unloading station. In this optimized layout there is one common unloading station consist of unloading equipments. The every machine slots having separate loading station which is consist of loading equipments. The main advantage of this optimized layout is to reduce the floor space required, productivity improvements, and also minimized the backtracking of the AGV and the total distance travelled by AGV.Fig.5.shows the engine plant modified layout.*

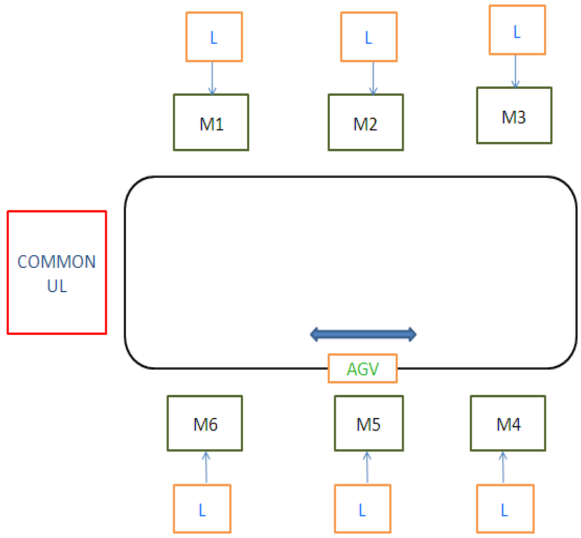


*Fig.5.Engine plant Modified Layout*

*The following details are mentioned about the engine plant modified layout.*

- *Number of AGV → single (Bidirectional movement)*
- *Distance b/w machines → 5m (common)*
- *Total distance travelled by AGV →150m*
- *Optimal machine sequence → 352416*
- *No. Of back Trackings → 3*

*The optimized engine plant layout consist of six machines are arranged in a machine slots as per the optimal sequence (Min value) of the loop layout.fig.6.shows the engine plant optimized layout.*

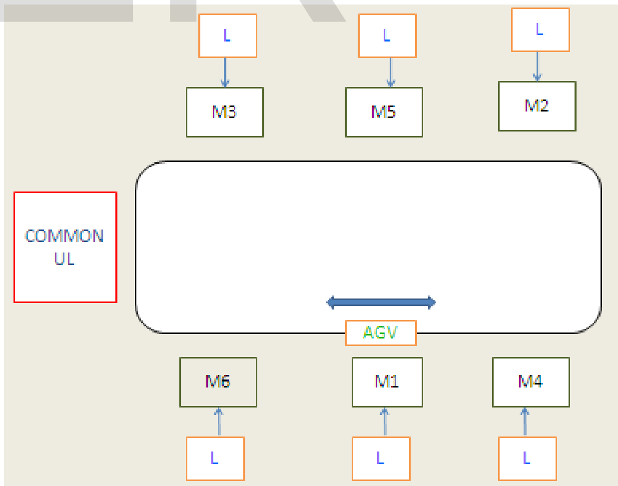


Fig.6.Engine plant optimized layout

## 10. Result And Discussion

*In the optimized engine plant layout the machines are located in the proper allocation and the distance travelled by AGV is minimized so that the AGV idle time is reduced. By applying the Particle swarm optimization (PSO) technique the optimum machine sequence for the FMS layout is 352416, the distance travelled by the AGV is 150m per cycle and the number of backtracking is reduced to 3 per cycle. Here*

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*some of the optimal sequences derived from the calculation are shown below in the table No.1.*

| S.NO | SEQUENCES | OPTIMAL VALUE |
|---|---|---|
| 1 | 354612 | 123.2 |
| 2 | 341652 | 101.4 |
| 3 | 142653 | 103.6 |
| 4 | 231456 | 133.6 |
| 5 | 352416 | 91.2 ► Min Value |
| 6 | 532146 | 97.6 |
| 7 | 246153 | 104 |

Table No.1.Optimal Sequences

## 11. Conclusion

*In this paper, a PSO (Particle swarm optimization) algorithm is proposed for obtaining the optimal solution of bidirectional loop layout problem in which the minimization of total movement of the AGV and the backtracking has been considered as an objective. It is seen that the PSO algorithm is efficient in finding good quality solutions for the layout problems.*

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