The Optimal Design of gas oven assembly line with the Simulation and Evolution Strategy

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시뮬레이션과 진화 전략을 이용한 가스 오븐 조립라인의 최적 설계

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Abstract

The assembly line is one of the typical process hard to analyze with mathematical methods including even stochastic approaches, because it includes many manual operations varying drastically depending on operators' skills. In this paper, we suggest the simulation optimization method to design the optimal assembly line of a gas oven. To achieve the optimal design, firstly, we modeled the real gas oven assembly line with actual data, such as assembly procedures, operation rules, and other input parameters and so on. Secondly, we build some alternatives to enhance the line performance based on business rules and other parameters. The DOE(Design Of Experiment) techniques were used for testing alternatives under various situations. Each alternatives performed optimization process with evolution strategy; one of the GA(Genetic Algorithm) techniques. As a result, we can make about 7% of throughputs up with the same time and cost. By this process, we expect the assembly line can obtain the solution compatible with their own problems.

1. Introduction

Today, many manufacturing companies are changing their assembly line and management system to be more competitive. In order to insure its efficiency on the global competition, manufacturers are interested in techniques for process modeling and simulation that ensures the limited cost and time [1].

In an increasingly competitive world, simulation has become a very powerful tool for the design of production systems. The main purpose of the simulation study described in this paper is to analyse an assembly system for the high production of product and to evaluate the system performance among different design alternatives. Using the simulation approach, it is possible to achieve a feasible design of an assembly line through maximizing throughputs [2].

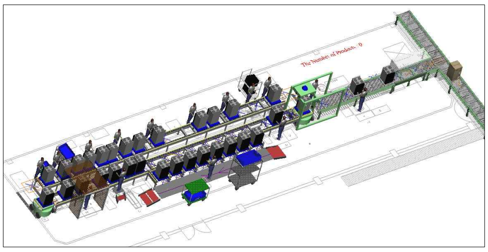
In this condition, we have also studied to design optimal assembly line with simulation. However, only using simulation analysis is good way for optimal design no longer. We add the Evolution Strategy (ES), as optimization theory, to design optimal assembly line. The optimization theory derives each optimal alternative value to achieve objectives. Objective would be explained next paragraph. The Evolution Strategy is explained following paragraph. Alternative can be called independent variable, and objective can be called dependent variable in this paper.

The study reason in this paper is to add optimization case study. It is actually difficult that one standard optimization method exists, because of unspecific factors in various fields, like other manufacturing industries. Therefore, we would announce a new approach procedure for gas oven assembly line optimization.

2. Gas oven Assembly Line

The gas oven assembly line consists of 15 processes. An operator works each process. The processes from #1 to #9 are for gas oven assembly.

The #10 process is for physical inspection, such as a check for some of cracks. The #11 process is the final assembly process. The #12 process is to check whether a gas oven exactly works or not. The # 12 process has the capacity to inspect 8 gas ovens, contemporary. The #12 process is sometimes called Aging process. The #13 process is the last inspection with the naked eye. A gas oven is perfectly manufactured at the # 13 process. In the other processes, #14 and #15, a gas oven is packaged. After these processes, the finished product is shipped.



[Fig. 1] Gas oven assembly line

The gas oven assembly line is circulation line. A gas oven is laid on a pallet when working at # 1 process. A gas oven and pallet move from # #1 process to #12 process. When gas oven arrives at #12 process, there is one rule. The rule is successively to transfer the gas oven and pallet from # 8 to #1 space at #12 process. When the gas oven moves from #13 to #14 process with Load/Unload equipment, the pallet is separated from the gas oven and goes to #1 process with Transfer to travel with new gas oven in #1 process. After separated from pallet, the gas oven is packaged during #14 and #15 process.

3. Simulation Model Building

The simulation assumption and real data of gas oven assembly line are used to build simulation model.

3.1 Assumption for Simulation

There are some assumptions to simulate the gas oven assembly line.

① Simulation running time is 460min per a day.

② The normal distribution is used for process time, not constant value.

③ The MTBR, MTTR and MTTF of Transfer and Loading/ Unloading equipment are not considered.

3.2 Simulation Model

We developed the simulation model of this gas oven assembly line by AutoMod, 3D Simulation tool. The simulation is designed based on the layout and process scenario we explain above.

Based on the simulation model, we would design optimal assembly line by some alternatives, below. The alternatives are not fixed factors and operation scenario. The objective of optimal design is to maximize throughputs.

4. Alternative Design

We create alternatives to improve assembly line. All alternatives are be checked by ANOVA analysis.

4.1 Alternative #1 : Determining the number of pallet on chain conveyor.

There are some pallets on chain conveyor to transfer a gas oven from a process to a process. We cannot confirm how many pallets is optimal to get maximal production. With Simulation, we would determine the best number of pallet on chain conveyor. The range for the number of pallet is the maximum 40 and the minimum 20.

4.2 Alternative #2 : Determining the velocity of conveyor.

The velocity of conveyor is important to determine moving time form a process to a process. Moving time influence cycle time and throughput. We would determine the velocity. The range for the velocity of conveyor is between 10 and 20 m/min. The range is from the conveyor motor specification of assembly line.

4.3 Alternative #3 : Adding buffer space in front of #1 process.

When going to #1 process from #13 process with transfer, a pallet, which can move a gas oven from a process to a process, confirms whether #1 process is occupied or not. If occupied, the pallet cannot move to #1 process, and hold on Transfer. Because of above that, we suggest this alternative.

4.4 Alternative #4 : Determining the operation rule of aging process(#12).

We determine how each space should be occupied. There are 8 spaces in #12 process to inspect gas ovens. For example, a gas oven and a pallet can occupy a space successively from #8th space to # 1 space or from # 1 space to # 8 space. We would search what sequence is the best.

5. Optimization

In this paper, Evolution Strategy is used for optimal design of assembly line. Evolution Strategy can derive optimal point among various alternatives to achieve the objective. AutoStat, plug-in tools in AutoMOD, is used for optimization.

5.1 Evolution Strategy

Evolution Strategy(ES) is optimization heuristic methods based on the principle of natural evolution.

ES was originally developed by a German researcher Rechenberg in 1973 as shown in Ref. [3], to solve resistance problems in the field of various industries. At that time, the ES is rather simple and easy, without the concept of population. It just includes evolution of a single individual, and relies only on the mutation to search a better individual.

ES procedure is shown below.

Step1 : Generate the first simulation run

Step2 : Randomly create the first generation of children

Step3 : Make the runs for each child

Step4 : Select the parents based on the fitness score [fitness function]

Step5 : Combine them

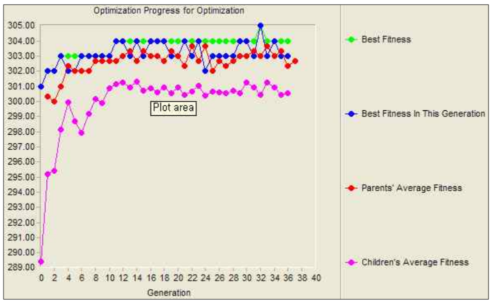
Step6 : Mutate the factor value

Step7 : Repeat step 3-6 until the termination criteria are met

5.2 Optimization Result

We would develop optimal design with 4 alternatives, as independent value, based on evolution strategy to achieve its objective, maximal throughput. For optimal design, we need the optimal set of alternatives.

Below graph is to show the procedure that the optimal set of 4 alternatives is found. Independent values are 4 alternatives and dependent value is throughput.



[Fig. 2] Optimization graph of throughput

We can have the optimal set of alternatives by above procedure. The optimal set is shown at table 1.

[Table 1] Optimal set of alternatives

Alternatives	Value
The Number of Pallet	31
The Velocity of Conveyor	19.197
Additional Buffer (#1 Process)	Use
Operation Rule (#12 Process)	From 1# to #8

If above data would be input, the maximal throughput can be obtain, as 305. In comparison with minimal throughput, difference with maximum is about 20 throughputs.

6. Conclusion

In this study, we optimize the assembly line with simulation and evolution strategy.

The procedure is that : First, simulation model, by which we can confirm how much various alternatives and factors influence assembly line in limited time and cost, is developed. The simulation model helps to progress evolution strategy because various alternatives and factors are tested for optimization. Evolution strategy is meta-heuristic method. The alternatives consist of changing business rule and parameter values.

By the procedure, the assembly line we explain above is improved and optimized. Moreover, We are convinced that the procedure and methods can make other assembly line be better and optimized.

References

[1] Yasmina Hani, Lionel Amodeo, Farouk Yalaoui, Haoxun Chen, "Simulation based optimization of a train maintenance facility", J Intell Manuf 19 pp. 293 - 300 , 2008.
[2] J Y H Fuh, Y S Wong, C Y Yee, L Zhuang and K S Neo, "A Modeling, analysis and simulation for the design of a robotic assembly", Computer lntegrated Manufactring Systems Vol.9 No.1 pp.19-31, 1996.
[3] Rechenberg I. Evolutions strategies: optimierung technisher systeme nach prinzipien der biologischen evolution. Stuttgart: Frommann-Holzboog Verlag, 1973.
[4] Moriarty, D. E., Schultz, A. C. and Grefenstette, J. J. "Evolutionary Algorithms for Reinforcement Learning", Journal of Artificial Intelligence Research, Vol. 11, pp.241-276., 1999
[5] Averill M.Law, W. David Kelton, SIMULATION MODELING AND ANALYSIS 3rd Edition, McGraw-Hill, pp. 118, 2007