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Analytical Study on Automobile Engine Line Work Stations and Analyze Their Working

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ABSTRACT

In an automobile assembly line, a series of stations are arranged along a conveyor belt and an automated guided vehicle performs on tasks at each station. Parallel assembly lines can provide improving line balance, productivity and so on. Combining robotic and parallel assembly lines ensure increasing flexibility of system, capacity and decreasing breakdown sensitivity. Although afore mentioned benefits, balancing of robotic parallel assembly lines is lacking – to the best knowledge of the authors- in the literature. Therefore, an observed study is proposed to define/solve the problem of automobile assembly line. The automobile assembly line also tested on the generated benchmark problems for automated guided vehicle/robotic parallel assembly line balancing problem. The superior performances of the proposed algorithms are verified by using a statistical test. The results show that the algorithms are very competitive and promising tool for further researches in the literature.

Keywords: assembly line balancing, automobile parallel, beam search, CNC

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INTRODUCTION

The engine assembly line directly affects production performance and provides to gain economic advantage in a competitive manufacturing sector life. Engine line assembly can be automated, manual operated or of mixed design. In recent years, robots or automated guided vehicles have been widely begun to use in assembly systems instead of human labors and the systems are called robotic assembly lines (RAL). In especially automotive sector, more than 1 million industrial robots may be established until 2018. An assembly robot can work for the 24 hour/7 days without fatigue. Certain advantages of using robots are improvement on productivity, quality of a product, manufacturing flexibility, safety, and to be less demand for skilled labor [1–5]. These advantages make robots a vital component of the Industry.

The robotic assembly operations are commonly performed on an engine assembly line that consists of a number of serial stations. Therefore, the efficiently designed and balanced robotic assembly lines (RAL) have a remarkable importance in production environment. The objective is to make the work content at each station most balanced. On the other hand, a robot could be programmed to execute a wide variety of tasks. However, different robot types may exist at the assembly facility, and they usually have different capabilities and efficiencies for the various elements of assembly tasks. Therefore, allocation of a suitable robot for each station is vital for the performance of robotic assembly lines (Figure 1) [6, 7].

Fig. 1. *Automobile automatic engine assembly line.*

Robotic assembly lines blockage (RALB) problem contains two main works which are assigning tasks to stations and allocation robots in stations due to fact that different robots perform different performance on same task. In summary, the basic differences of between robotic and non-robotic engine assembly line problems are: (i) in robotic engine assembly line problem, robot must be considering while tasks are assign to stations, (ii) task time can be different based on robot type and it causes problem to be difficult, (iii) the objective of the problem is usually preferred as minimization of the cycle time due to capital cost of robots (Figure 2) [8–22].

Fig. 2. *Double line assembly automatic guided vehicle for workers in workshop.*

The design of the line is one of the important classification characteristics in the classical engine assembly line literature, such as straight, U-shaped, two-sided and parallel. This classification can be also used for RAL. The straight line is the conventional layout type and stations are located serially in a line. This layout has some drawbacks, as length of line and less flexible system. U-line is, therefore, developed to eliminate these drawbacks. It is ideal for just-in-time (JIT) and group technology as well as it may provide decreasing cost, cycle time and the number of the stations. Two-sided line has become popular due to fact that it is eligible producing high volume and large size products, like trucks, buses and automobiles. Also, it provides opportunity to be performed on opposite side of the product simultaneously. On the other hand, in parallel assembly line (PAL), more than one line can be established in the parallel layout in order to enhance line flexibility and capacity. PAL has some advantages when compared traditional engine assembly line (AL)s, like shorter line and fewer breakdowns. For example, when a problem emerges at a line, other lines can continue to operate in parallel layout. In the PAL balancing (PALB) problem, more than one assembly line is to be balanced together [23–55].

LITERATURE REVIEW

The Mitsubishi Motors Australia Limited (MMAL) is implemented in many manufacturing industries as one type of assembly line with different models and their variants present at each workstation [56–60].

It is the practice of assembling products without changeovers on the same line. As a component of the Just in Time (JIT) practice, the objectives of MMAL is to deliver the products at a constant rate of part usage, to smooth the overall production and to balance the workload at each workstation [61].
The complex environment of a MMAL requires that thousands of parts for different model variants be assembled on the same line [35].

Golz et al. (2012) addressed five main problems that exist in the automotive industry with the high level of model variants on a MMAL: line balancing, master production scheduling, production sequencing, material flow control and resequencing. The high level of variants also significantly impacts the performance of the assembly line and parts supply [19].

Fisher et al. (1999) and Cheldelin et al. (2004) [9, 15] discussed the most general issues that arise when highly variant parts were placed on the assembly line: omission, incorrect installation, wrong part installation and ‘other’ incorrect operations, such as keying in the wrong serial number and wrong product code. To improve the material flow control and to adapt the JIT parts supply, Toyota Motor Corporation implemented a new system known as the Set Parts Supply (SPS), which has been approved in Toyota [57–60].

The main concept of the system is that the selection and assembly of parts are carried out in different areas and the parts are subsequently supplied in a complete set as a unit load in to the assembly line. The SPS was presented because the assembly operators were projected to assemble a variety of parts for different models while simultaneously they need to remember the correct parts, searching for parts, picking parts and fixing the parts on the car body [42].

This situation causes the assembly operators to forget the information and means they are unable to complete the process within the task time [43].

Robots can perform the tasks continually without worries of fatigue and the assembly lines with robots are called robotic assembly lines [18]. A layout of two-sided robotic assembly line has different assembly lines. In this line, each mated-station is composed with two facing stations, and each station is allocated with a robot to operate different tasks. Two-sided assembly lines have several advantages over the traditional one-sided assembly lines, such as a shorter line length, less material handling, and reduced cost of tools, also considered the RALB-II problem and a genetic algorithm hybridized with local search was utilized to solve it.

To balance this line, two-sided robotic assembly line balancing (TRALB) problems are designed. TRALB problems are divided into two types. Type I TRALB problem deals with diminishing the number of stations with a given cycle time whereas type II TRALB minimizes the cycle time on a set of mated-stations [3].

Kim et al. (2009) and Purnomo et al. (2013) [26, 51] studied Robotic assembly lines have several advantages over manual assembly lines, such as high productivity, manufacturing flexibility, less skilled labor and good quality of products

In a robotic assembly line, the energy consumption is a major expense, and the increase of the energy price makes it nonignorable [33].
Also considered the type II robotic assembly line balancing (RALB-II) problem and they proposed a genetic algorithm.

Fysikopoulos et al. (2012) indicate that the energy cost during a car manufacturing process is about 9e12% of the total manufacturing cost, and 20% reduction in energy consumption * Corresponding author. results in about 2e2.4% reduction in the final manufacturing cost. Reduced usage of energy can also keep the industries competitive and reduce pollution. However, the research on the reduction of energy consumption in the assembly line systems is limited, and they are only related to one-sided or U-type assembly lines.

To the author's best knowledge, there is no research reported where energy consumption in a two-sided robotic assembly line is considered [41]. In addition, the energy consumption and the balance of the assembly line are not positively correlated strictly, and they may be conflicted as proven. Focuses on the two-sided robotic assembly line with the objectives of minimizing the energy consumption and cycle time simultaneously. Three main contributions of this research are:

(1) A new type II two-sided robotic assembly line with the objective of minimizing the energy consumption is defined and new benchmark problems are generated.
(2) A new mixed-integer programming model is developed to minimize the energy consumption and cycle time simultaneously. Also proposed a model to minimize the maximum of the energy consumptions on all stations in a straight robotic assembly line. In this paper, the sum of energy consumption on all stations is minimized. This new objective is more practical when there is no limitation on the peak energy consumption of the stations.
(3) A restarted simulated annealing (SA) algorithm as a metaheuristic method is developed to solve the multi-objective type II two-sided robotic assembly line balancing (TRALBII) problem. New local search and a restart phase are put forward to enhance the performance of the SA algorithm.

€Ozcan et al. (2009b) and €Ozcan (2010) [43, 46, 48] utilized simulated annealing algorithms to solve two-sided balancing problems with different objectives. Faced with diverse customers' demands, the concept of robotic assembly line draws growing attentions in recent days. In this line, robots rather than human beings assemble the products on each station, which was first come.

Rubinovitz et al. (1993) extended a branch-and-bound algorithm based heuristic approach to design and balance the robotic assembly line.

Tsai et.al. (1993) [8] utilized a heuristic approach for series-type robotic assembly line.

Kim et al. (1995) [26] developed a cutting plane algorithm for the robotic assembly line balancing with the objective of minimizing the total number of robot cells.

Yoosefelahi et al. (2012) [60] proposed an evolution strategies algorithm for a multi-objective RALB-II.

Aghajani et al. (2014) [1] balanced the robotic mixed-model two-sided assembly line with robot setup times. paper by dealt with the two-sided robotic assembly line. With regard to the energy consumption in manufacturing systems, the research is limited.

Dai et al., (2013) [11] and the research on energy consumption on an assembly line is very minimal.

Fysikopoulos et al. (2012) [17] presented a study of energy consumption in an automotive assembly and they showed that modeling an assembly by including energy considerations can save energy and cost.

He et al. (2012) [20] provided modeling method of task-oriented energy consumption for machining manufacturing system and they utilized SIMULINK simulation environment to solve this problem.

Nilakantan et al. (2015a) [44] investigated the total energy consumption in straight robotic assembly line systems. They developed two models to minimize the cycle time and energy consumption respectively. Later,

Nilakantan et al. (2015b) [44] considered the energy consumption in U-shaped robotic assembly line with a bio-inspired algorithm, and then they proposed a differential evolution to minimize total energy consumption in U-shaped robotic assembly line.

RESEARCH AND METHODOLOGY

The research and methodology of this project is to study VE COMMERCIAL VECHILES, Pithampur, INDORE (A Volvo group and Eicher motor joint ventures) engine line stations and analyze their working and to record working time and number of workers to do work on each station. To study the assembly of various parts on engine line and to do time study on each station. By observing various station processes, by the guidance of person working there and by finding the solutions of problems.

This study focuses the work performed in the LCV task in 2 valves, 4-cylinder engines. In this task a decision matrix including details about the investigated auxiliaries and the implementation effort has been collected.

The decision matrix shows all the available components and the selected components for implementation. Along with this the individual function of some part with their specification has also describe.

The components of LCV or LD engines of 70kw includes engine parts, fuel injection pump setting, connecting rod tappet setting etc. described.

Introduction to VE Commercial Vehicles

Eicher Motors Limited (BSE: 505200, NSE: EICHERMOT) established in 1982, is an Indian automotive company based in Gurgaon. Eicher Motors Limited (EML) owns Royal Enfield (India). It is one of the leading manufacturers of the commercial vehicle. It has manufacturing facilities located in Madhya Pradesh, Tamil Nadu, Maharashtra, and Haryana.

Eicher Motors is a commercial vehicle manufacturer in the India. The company's origins date back to 1948, when Good Earth Company was established for the distribution and service of imported tractors.

In 1959 the Eicher Tractor Corporation of India Private Ltd was recognized, jointly with the Eicher tractor company, a German tractor manufacturer. Since 1965 Eicher in India has been completely owned by Indian shareholders. The German Eicher tractor was partly owned by Massey-Ferguson from 1970, when they bought 30%. Massey-Ferguson bought out the German company in 1973.

In 2005 Eicher Motors Ltd sold their tractors and engines business to TAFE Tractors (Tractors and Farm Equipment Ltd) of Chennai, the Indian licensee of Massey Ferguson tractors.

In October 1982 a collaboration agreement with Mitsubishi for the manufacture of Light Commercial Vehicles was signed in Tokyo and in the same period the incorporation of Eicher Motors Limited also took place. In February 1990, Eicher Good earth bought 26% stake in Enfield India Ltd and by 1993 Eicher acquired a majority stake (60% equity shareholding) in Royal Enfield India.

In July 2008, EML and Volvo Group's 50:50 joint ventures VE Commercial Vehicles (VECV) designs, manufactures and markets commercial vehicles, engineering components and provides engineering design.

Basic Motto of Company: We care for TSELF
T stands for TIGHETENING & TORQUING
S stands for SETTING
E stands for ELECTRICAL CONNECTIONS
L stands for LEAQUAGE POINT
F stands for FOULING

Group Structure

The Eicher Group has diversified business interests in design and development, manufacturing, and local and international marketing of trucks, buses, motorcycles, automotive gears, and components. Eicher has invested in the potential growth areas of management consultancy services, customized engineering, and maps and travel guides.

Products

Motors – It designs, manufactures and markets reliable, fuel–efficient commercial vehicles of high quality and modern technology, engineering components and provides engineering design solutions. It has technical and financial collaboration with Mitsubishi Motors Corporation of Japan which led to manufacturing of CANTER range of vehicles. It manufactures around 20000 vehicles per annum.

Motorcycles– It manufactures bullet motorcycles Royal Enfield. It manufactures six dissimilar models ranging from 300cc to 600cc. The manufacturing plant has fixed capacity of 39,000 motorcycles per annum.

Engineering Components

The Company manufactures complete range of automotive gears. The range of gears includes Spiral bevels (Crown wheel and pinions), Straight bevels and Transmission gears.

VE Commercial Vehicles (VECV) Limited is a 50:50 joint venture between the Volvo Group (Volvo) and Eicher Motors Limited (EML). VECV is divided into five business units:

Eicher Trucks and Buses – The E Series
Volvo Trucks India – The VE Series
Eicher Engineering Components
Eicher Engineering Solutions
VE Power train
Eicher Goodearth

RESULTS AND DISCUSSIONS

Detail of Various Sections Contain VE Commercial Vehicles, Pithampur, Indore (A Volvo Group and Eicher Motor Joint Ventures)

1. PDD (Product Development & Design)
2. QC (Quality Control)
3. PPC (Product Planning & Control)
4. PMO (Productive manufacturing operations)
5. EDC (engine development center)
6. VDC (vehicle development center)
7. Safety

ME (Manufacturing Engineering) Engine Assembly Line
Transmission Assembly
Machine Shop
CT (Cab Trim)
HD Chassis
LMD Chassis
Cab Weld

8. Paint Shop
9. TS (Technical Services)
10. Inventory

Detail of various station processes, by the guidance of person working there and by finding the solutions of problems.

Standard Operating Procedure (SOP)

A Standard operating procedure is a set of step-by-step instructions compiled by an organization to help workers carry out routine line operations. SOPs aim to attain efficiency, quality output and consistency and performance, while reducing miscommunication and failure to comply with industry regulations.

MODEL – CNG 4V
ENGINE LINES

1. PRB LINE
2. AGV-1 (Automatic guided vehicle- 1)
3. AGV-2 (Automatic guided vehical-2)

Process of Engine Assembly Line

Machine Shop

Drilling, trimming, machining, etc. machine works are being carried out:

(1) PRB line (Power Roller Belt)
(2) AGV-1 (Automatic guided vehicles-1)
(3) AGV-2 (Automatic guided vehical-2)
(4) Pre-Delivery inspection
(5) Testing @ (LD 4v-2750-2850 RPM)
(6) Pre-Delivery inspection
(7) Transmission & coupling (Gear box connect)
(8) Painting
(9) Pre-Delivery inspection
(10) LMD Line (Light Medium Duty Vehicle) where engine drop on the chassis, cabin, etc. are to be assembled.

Types of Models Manufactured

LD4V stands for light duty 4 valve, 4 cylinders
HD4Vstands for heavy duty 4 valve, 4 cylinders
LD2V stands for light duty 2 valve, 4 cylinders
HD2Vstands for heavy duty 2 valve, 4 cylinders

CYLINDER ENGINE

The inline-four engine or straight-four engine is a type of inline internal combustion four-cylinder engine with all four cylinders mounted in a straight line, or plane along the crankcase. The single bank of cylinders may be oriented in either a vertical or an inclined plane with all the pistons driving a common crankshaft. Where it is inclined, it is sometimes called a slant-four. In a specification chart or when an abbreviation is used, an inline-four engine is listed either as I4 or L4 (for longitudinal, to avoid confusion between the digit 1 and the letter I, Figure 3).

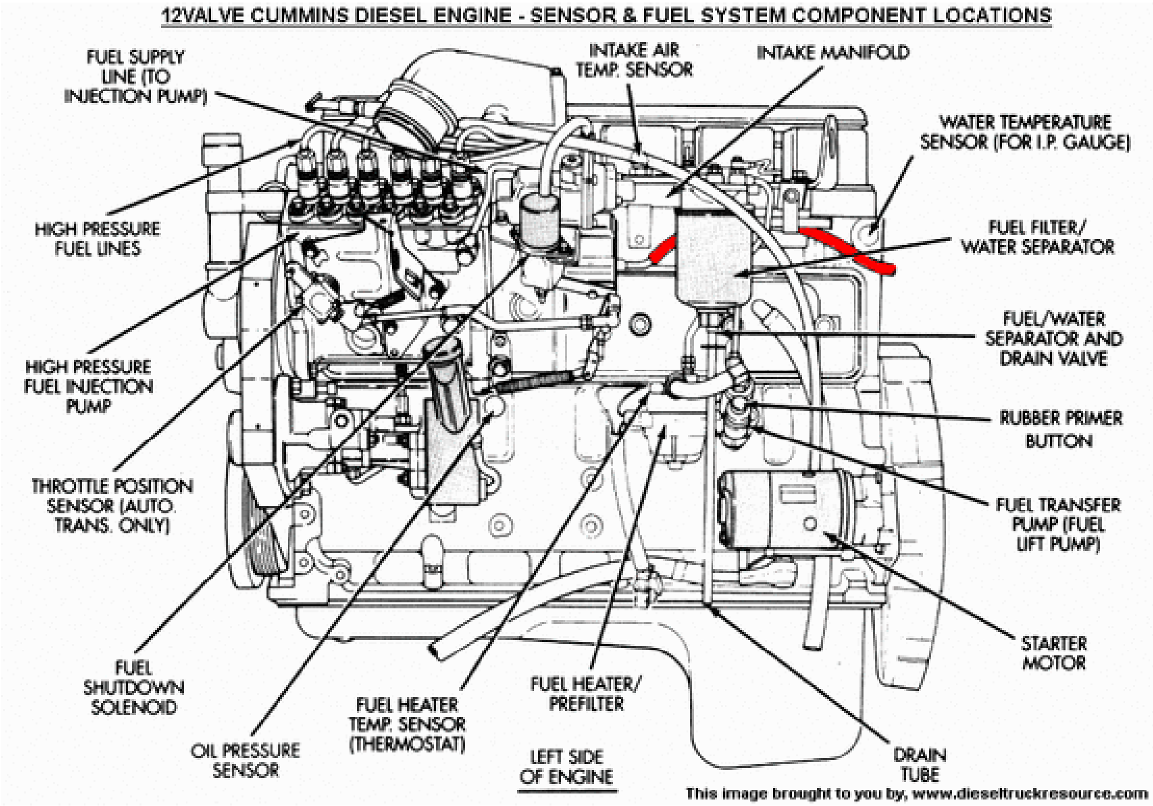

Fig. 3. *Four-cylinder engine.*

The inline-four layout is in perfect primary balance and confers a degree of mechanical simplicity which makes it popular for economy cars. However, despite its simplicity, it suffers from a secondary imbalance which causes minor vibrations in smaller engines. These vibrations become more powerful as engine size and power increase, so the more powerful engines used in larger cars generally are more complex designs with more than four cylinders.

Today almost all manufacturers of four-cylinder engines for automobiles produce the inline-four layout, with Subaru's flat-four engine being a notable exception, and so four-cylinder is synonymous with and a more widely used term than inline-four. The inline-four is the most common engine configuration in modern cars, while the V6 engine is the second most popular. In the late 2000s (decade), due to stringent government regulations mandating reduced vehicle emissions and increased fuel efficiency, the proportion of new vehicles sold in the U.S. with four-cylinder engines (largely of the inline-four type) rose from 30 percent to 47 percent between 2005 and 2008, particularly in mid-size vehicles where a decreasing number of buyers have chosen the V6 performance option.

CONCLUSION AND FUTURE RESEARCH

The robotic assembly line is widely used in developed countries and it can be proposed for flexible production to deal with a great variety of products. Due to the consequence of the serious environmental impacts and the increased cost of energy consumption, reducing the total energy consumption becomes more and more important in two-sided assembly lines. This paper focuses on minimizing the energy consumption and cycle time in two-sided robotic assembly line, and it is the first one to consider the energy consumption in two-sided robotic assembly line. A mathematical model for type II two-sided robotic assembly line balancing (TRALB) is provided. This model considers the line balance and the cost of the energy consumption simultaneously, and multiple constraints are also presented. To deal with the multi-objective type II TRALB problem, a restarted simulated annealing (RSA) algorithm is developed to obtain Pareto-optimal solutions. New encoding and decoding procedures based on robot assignment vector, task assignment to mated-station vector and task sequence vector are implemented to explore the search space. A multinomial probability mass function is utilized to activate one objective to decide the probability of accepting a new dominated solution. And a new restart mechanism is developed based on a modified crowding distance assignment procedure in order to obtain a better spread of the Pareto-optimal set. In order to evaluate the proposed multi-objective model, the RSA is compared with two SA algorithms with only one objective.

The computational results show that the SA with the objective of minimizing the cycle time cannot reduce the energy consumption effectively. The RSA, on the contrary, can obtain solutions with much less energy consumption. These results show that the multi objective model is helpful to reduce the energy consumption and the RSA can obtain a set of diverse high-quality solutions. In order to evaluate the proposed RSA, a set of benchmark problems composed by seven benchmark problems are generated and RSA is compared with the well-known elitist non-dominated sorting genetic algorithm (NSGA-II). The computational results are evaluated with three metrics, including the ratio of non-dominated solutions, the convergence of the Pareto-optimal solution and the spread metric, and comparison results demonstrate the superiority of the modified RSA over NSGA-II in both convergence and spread criteria [62].

This paper addresses only single model and double TRALB problem and multi and mixed model TRALB problems could be addressed in the future. And new metaheuristics, such as co-evolutionary algorithms and scatter search algorithm, can be employed for better performance.

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