AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

# BALANCING OF LARGE ASSEMBLY LINES

*BY*

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*Thesis submitted for*
*The Degree of Doctor of Philosophy*

*IN*

**Mechanical Engineering**

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**1991**

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# STATMENT

This dissertation is submitted to Faculty of Engineering, Ain Shams University for the *Degree of Doctor of Philosophy in Mechanical Engineering*.

The work included in this thesis was carried out by the author in the Department of Design and Production Engineering, Ain Shams University, from *April 1986* to *september 1991*.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

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# ACKNOWLEDGEMENTS

The author wishes to express his sincere gratitude and deepest thanks to *Dr. Amin M.K EL-Kharbotly*, Associate Professor of Production Engineering, Faculty of Engineering, Ain Shams University, for his valuable supervision throughout this work.

The author wishes also to extend his sincere thanks to *the Lecturer* **Dr. Ahmed sayed shaban** for his great help during this work and his contineous encouragment.

# SUMMARY

The assembly line balancing is a combinatorial problem. It is very difficult to construct and evaluate all possible combinations. The available algorithms used in balancing of assembly lines still need more development especially for solving large size problems.

The aim of the present research is to develop a model to solve efficiently the assembly line balancing problems. Special emphasis is made to solve large size problems on PC-computers.

A heuristic algorithm was developed to construct all possible combinations in structured form. Certain boundaries are built to confine the local optimal solutions of each work station in considerably short time. The heuristic algorithm succeeded in achieving fast and precise solutions on pc-computer. Several developed heuristics are incorporated in the model whose main features are summarized in the following:

1- Determination of the candidated work elements to each work station by applying the earliest and latest work station heuristic rule.

2- Structuring all possible combinations specified within each work station in form of a set of matrices. These matrices are arranged in routes and levels according to their dimensions in the form of a tree named in this work "the combinations tree".

3- Bounding the area where a feasible solution can be found on the combinations tree. The bounding heuristics always confine local optimal solutions at each work station.

4- Due to the structured form of combinations, infeasible routes are excluded from search by applying a developed heuristic.

5- Determination of the search direction across the routes of the combinations tree in order to follow the shortest route to the local optimal.

6- Application of the developed modified zero level matrix MZLM heuristic rule which leads to the same local optimal solution at each work station. The MZLM heuristic rule was proved to be efficient in solving larger size assembly line problem in considerably short time on PC-AT computer.

7- Plantation of work elements was developed as a heuristic and proved its applicability and efficiency in solving Assembly Line Balancing Problem ALBP. This heuristic when applied with the modified zero level matrix (MZLM) heuristic enables solving considerably large size problems in a relatively short time on PC-AT computer. Although, local optimal solution at each work station can not be achieved, very competitive results were obtained and compared with others well known heuristic algorithms.

In the present work, different algorithms were developed each is composed of different heuristics to solve different assembly line balancing problem sizes having different characteristics. The first to solve small to medium size problems applying mainly the MZLM heuristic. The second to solve large assembly lines and the third to solve small size lines. Actually, there is no definite values of line work elements that can be used to classify the size of the line (small, medium and large). However, in the present work, a line that contains less than 50 work elements will be considered as small line. A line that incorporate from 50-90 work elements will be considered as medium. The line that consists of more than 90 work elements will be considered as large lines.

The developed heuristic algorithms were tested with different case studies with variable characteristics and gave better results in most of the cases. Slight increase in both cycle time and balance delay was noticed in large size problems due to the plantation heuristic. However, the increase is negligible and did not exceeded 2.8%

The discussions of the results of the developed heuristic algorithms have led to the following main conclusions:

1- Structuring the combinations specified within each work station in form of a set of matrices, facilitates the construction of all possible combinations. The matrices representing all combinations are specified by routes and levels in a representation tree . When work elements are sorted in ascending order according to their times, the tree has then a meaningful pattern. The combination tree proved to be efficient in representing the different combinations. Its application has also gave a chance to confine the area where a solution may exist in a very limited number of combinations. The developed search procedure has proved to yield always a local optimal.

2- The developed algorithm, was capable to exclude all infeasible routes at start instead of making check about the feasibility of each combination, by applying certain rules.

3- Structuring the possible combinations specified within each work station in combinations tree, makes the problem more complicated. The number of candidated work elements increases and consequently both the matrices, routes and levels required are as well.

4- In large assembly lines, the problem will be more complicated when both the comutability and work element to work station WEST ratios increase. Increasing both these ratios, will increase the number of candidated work elements for each work station. The complexity represented in the problems of larger work elements at higher comutability and WEST ratios.

5- Planting work elements with its predecessors, according to specified rules, make the problem more easier to be solved in shorter time. The number of combinations required to be constructed in this case is reduced. However, the local optimal solution for each work station can not be obtained. Naturally, the final solution obtained is different from the other solutions applying other heuristics.

6- Planting work elements, has proved to be efficient as it can solve the problems which cover a wide range of WEST ratios.

7- The application of different heuristics enables the use of pc-computers with large lines. Other algorithms use main frame computers and solve less numbers of work elements.

8- The developed heuristic algorithm in this work is very competitive to other known algorithms. It reaches the same or even better results in most of the cases.

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