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A SURVEY ON BOTTELNECK ANALYSIS FOR INDUSTRIAL PRODUCTION

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Abstract: Manufacturing systems have evolved rapidly since their inception and this transformation is expected to continue in a pursuit of optimum utility. A fixed sequence of machine tools connected by an automated material handling system for mass production of a small family of complex parts (several million parts per year). Bottelnecks have several benefits. They require less manpower and space. They ensure low work in progress and lower lead time. Bottelnecks are employed for mass production of a fixed product or a very narrow range of product variants. This paper discuss about different bottleneck balancing problem, process planning and line configuration. For optimize bottleneck is must to be design features of the product are grouped and machining operations are sequenced in an optimal manner. The objective is to find out problem and possible solution on the handling time fraction of the cycle time consisting mainly of orientation change time and tool change time in different bottleneck sequencing, which is used by industrial production.

Key words: Bottleneck, Tool Life Limit, target time, cycle time, Man power, Sequencing.

I. INTRODUCTION

1.1.BOTTELNECK

Manufacturing systems have evolved rapidly since their inception and this transformation is expected to continue in a pursuit of optimum utility. A flow line may be synchronous or asynchronous. In synchronous lines, all parts move thorough the line at the same speed. In asynchronous lines, some parts have to wait before processing at the next station resulting in a buffer. The workstations are also not governed by cycle time [target time] limit. However, synchronous lines respect target time limit at each workstation. The workstations are connected by an automated material handling system, which causes the line to function as a single unit. The layout may be either straight or circular.

Bottelnecks have several benefits. They require less manpower and space. They ensure low work in progress and lower lead time. As a result, they are widely used in the automotive industry [1]. A huge investment is involved in setting up the bottelneck for a particular product. This cost in turn affects the cost of the finished product coming out of the line. Therefore, profitability depends on the investment cost and production efficiency. Hence, it is required that line design be done in an optimal manner because cost and efficiency can be optimized at this stage by solving the line balancing problem [2]. Line design encompasses analysis of the product, process planning, line configuration, dynamic flow analysis and transport system design and detailed design and line implementation. This thesis will consider line configuration and some activities of process planning. Line configuration and process planning are inter-dependent aspects of line design.

The process planning problem involves preparation of plan for performing machining operations in an optimal manner. Several technological constraints like inclusion and exclusion constraints are respected while solving this problem [1].

Operation sequencing and cutting tool allocation problems are part of process planning. The operation sequence generated ought to be feasible with respect to constraints and also serve as the optimal solution with respect to the objective [3]. Figure 1 presents a flowchart depicting activities involved in process planning.

Line configuration determines the allocation of machining operations and required equipment to workstations to maximize utility. Target time limit and precedence constraints are respected in this problem [1]. It aims to distribute the operations to the workstations for the total processing time at each workstation to be less than or equal to the target time. The optimum number of machine tools required by each workstation is determined. Precedence constraints ensure that the operations are performed in the required order [4]. A classification of Line balancing problems is presented in Figure 1.

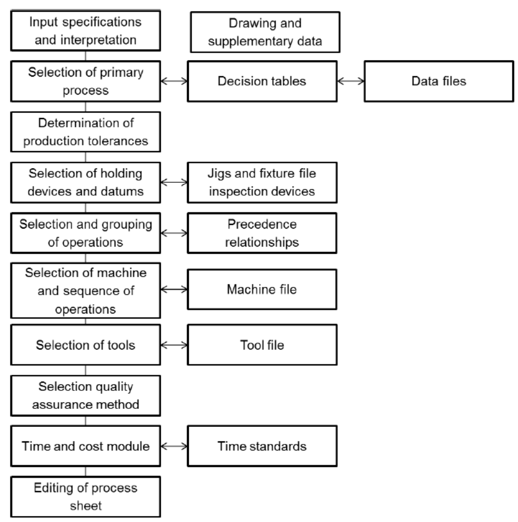

Figure 1: Flow Diagram of Process planning

1.2.LINE BALANCING

Both manual assembly line and bottelneck classify as flow line production systems. A line balancing problem performs assignment of operations to workstations in order to optimize a criterion while respecting precedence and target time constraints. When the number of workstations is minimized while respecting a given cycle time, the problem is called time-oriented simple assembly line balancing problem [SALBP]. If skills of workers are differentiated and the total cost of the product is optimized, the problem is called

cost-oriented assembly line balancing problem [COALBP] [2]. Depending upon the variety of products manufactured, the line may be classified as single-model, mixed-model [different units in arbitrary sequence] and multi-model [sequential batches of different units] [6]. When mixed-model production, equipment selection, cost objectives and parallel stations are considered in ALBP, the problem is called generalized assembly line balancing problem [GALBP] [7]. The assembly line design problem
[ALDP] relates equipment selection to the operations assigned to a station and their execution. When ALBP is extended to apply to bottelnecks, the problem is called bottelneck balancing problem [TLBP]. In TLBP, operations are grouped together to form blocks and these blocks are allocated to workstations. The blocks on different workstations are executed simultaneously and the longest execution time among the blocks determines the pace of the line [8]. The problem considered here is analogous to the simple assembly line balancing problem and hence it is called a simple bottelneck balancing problem.

II. REVIEW OF LITERATURE

Soumitra Bhale, M. Fazle Baki and Ahmed Azab et al. [1] tackle the problem of process planning and system design for bottelnecks. In order to utilize the machinery to the maximum, the design features are grouped together and the operations are sequenced in an optimal manner. A balanced bottelneck ensures a maximum utilization of the machine tools and higher productivity. A new mixed integer linear programming model is developed to solve the problem in a hierarchical manner. At the higher level, feature grouping and allocation problems are solved. The output of this problem is provided to the lower level to solve the operation sequencing and tool allocation problems. Linearization of the model has been carried out to solve it for optimality. The objective of the problem is to minimize the handling time portion of the cycle time. Several technological constraints are respected while solving the problem. A new tool magazine capacity constraint is adopted for an accurate representation. In the case study conducted to test the functionality of the model, a number of automated machines are utilized to manufacture an engine cylinder head in large quantities. The proposed method provides optimal results within a very short period of time. This performance with respect to optimality and computation time is far better than that of the similar methods considered in the literature. Future work is to expand the approach and utilize meta-heuristic methods to solve large instances of the problem.

LIU Xuemei, LI Aiping, and CHEN Zurui et al. [2] proposed Feature group strategy and the polychromatic sets theory are used to establish constraint model. According to the characteristics of boxy part, all the features are grouped into datum feature group, special feature group, basic feature group and oblique feature group. The “feature-operation” constraint matrix and the “feature group-station” constraint matrix are used to describe constrains.

The heuristic algorithm is developed for the FMLBP, which consists of two steps:

sequence operations in each feature group, assign operations to workstation for each feature group.

The proposed approach is validated through a real industrial case. Experimental results show that the proposed approach can address the problem effectively and efficiently. It helps designers to explore different scenarios and possibilities.

Setup plan has significant effect on line configuration and balancing. In order to improve performance of a line economically and competitively, further research can concentrate on the integration of setup planning and line balancing.

Hany Osman and M.F. Baki et al. [3] introduce a new mathematical formulation and solution algorithms to solve the TLB problem. The bottelneck under study is designed to manufacture automotive parts, for example, engine cylinder head, cylinder block, etc. The objective of the study is to find the configuration of the line that minimizes the NPT composed of the transfer time between stations, the tool change time and the face orientation change time. Inclusion, exclusion and preceding constraints among design features and manufacturing operations are considered. The problem is represented by an integer programming model where the design features and tools allocation to stations, the number of machines required for production and the production sequence are considered as decision variables. Proposed approach decomposes the TLB problem into an assignment sub-problem and a sequencing sub problem. The assignment sub-problem is solved first to assign design features and machining tools to the stations. Then, the sequencing problem is solved to find the sequence of production in each station and to specify the number of machines required for performing the machining operations. Given this approach, we devised three solution algorithms.

The first one is a Benders decomposition algorithm that solves iteratively the assignment sub-problem as the BMP and the linearised sequencing sub-problem as the Benders sub-problem. Benders decomposition algorithm finds the optimal solutions for small problem instances, but due to the complexity of the sequencing sub-problem the algorithm could not solve medium and large instances in reasonable time. The second algorithm is a hybrid Benders-ACO algorithm. The algorithm keeps the same formulation as the BMP to solve the assignment sub-problem, but solves the sequencing sub-problem using an ACO technique. The algorithm provides very good results with an optimality gap that does not exceed 4.04%, but the algorithm could not deal with large problem instances in a reasonable time.

Alexandre Dolgui , Nikolai Guschinsky and Genrikh Levin et al. [4] proposed an interesting MIP model for a new line design and balancing problem which dealt with modular machining lines with multi-spindle stations. Unfortunately, this model was somewhat limited to a small scale instances. For medium size and large scale instances the calculation time was prohibitive. The importance of this problem to industry encouraged us to work to streamline this model. Indeed, several original and powerful techniques were proposed decreasing radically the calculation time. An existing algorithm for calculating lower bounds on potential workstation numbers for operations and blocks has been modified. The coupling of this algorithm with the suggested procedure of refinement of m0 leads to decreasing the MIP model size appreciably. The final result is an improved MIP model which finds optimal design decisions in a shorter time. This model has been tested on randomly generated problems. The results proved its extreme efficacy because average total running times were decreased up to 1745 times.

Mohamed Essafi, Xavier Delorme, Alexandre Dolgui and Olga Guschinskaya et al. [5] A MIP resolution approach was proposed. The lines considered are equipped with identical standard CNC machines. Parallel machines are authorized on workstations, accessibility constraints as well as setup times between operations are considered. As stated in the paper, a great number of technological constraints were taken into account. Considering the increase in complexity of the problem, a great deal of time and effort were required to completely comprehend this sophisticated problem and to model it as a mixed-integer program. A pre-processing procedure to reduce the number of variables was also developed. The model is implemented and tested. Experimental results are reported. Our model seems to be able to solve instances up to 18 operations in an acceptable time, especially when the density of the precedence graph is high enough. Indeed, the impact of the reduction procedure appears nearly negligible when the precedence graph has a very low density. This is logical since it mainly uses the precedence constraints. Since industrial problems can involve more than 100 operations, their resolution is not yet possible with this approach and more work is needed.

Xavier Delorme, Alexandre Dolgui and Mikhail Y. Kovalyov et al. [6] studied of optimal equipment selection for bottelnecks This problem is novel and motivated by practical industrial needs for which the use of methods from Operations Research is significantly rewarding. Two new combinatorial approaches for solving this industrial problem have been suggested. First, we showed how to combinatorial enumerate all feasible solutions. Then, we reduced the problem to the well known maximum weight clique problem. A key element of these two approaches is the new concept of locally feasible stations. Instead of searching for an overall optimal assignment of tasks and pieces of equipment to stations, we proposed to enumerate all locally feasible stations and then, to search for a subset of these stations and their order minimizing the line cost. This leads to simpler and more transparent models.

B.M.T. Lin, T.C.E. Cheng and A.S.C. Chou et al. [7] addressed the three-machine assembly-type flow shop scheduling problem with batching considerations to minimize the make span. We first showed that the problem remains NP-hard in the strong sense even when all the jobs have the same processing time on the second-stage machine. We developed an O (n2) algorithm for optimally grouping jobs in a fixed sequence into batches. A lower bound was established through the use of a data transformation scheme and the above algorithm. To find approximate solutions to the general problem, we presented four heuristics that determine the job sequences for use in the optimal batch composition process. The computational results demonstrate the effectiveness of the heuristic algorithms and the lower bound.

A.Dolgui and I.Ihnatsenka et al. [8] investigated a bottelneck balancing problem with blocks of parallel operations. The set of available blocks is given. The blocks of the same workstation are executed sequentially. As compared to the standard assembly line balancing problem, the investigated problem has many additional constraints and properties. The economic benefit which can be achieved, justices the search for an optimal solution, even though it is time-consuming. To solve the problem exactly, an original lower bound based on the set partitioning problem has been developed. The branch-and-bound algorithm has been implemented. As the computational results show, the proposed lower bound is efficient enough and the bottelneck balancing problem with the number of operations smaller than 70 can be solved in three hours on average. The considered problem takes into account a given cycle time. But often, it is interesting to see how the line cost changes when the line cycle time is modified. The proposed algorithms can be used for different possible values of the line cycle time. For each, the optimal solution can be found. These solutions have their investment cost and productivity (line cycle time). Then, the entire cost, which is function on in- vestment cost and productivity, should be optimized while considering the marketing forecast and other managerial factors.

Alexandre Dolgui, Nikolai Guschinsky and Genrikh Levin et al. [9] these lines are used for mass production, for example in the automotive industry, and require a huge investment cost (about 50 million h) and have a long exploitation period (7 years and more). Thus, the search for efficient optimization methods for the lines design is profitable and a scientific challenge. In these lines, the operations are grouped in blocks and each block is executed by one spindle head. Thus, the crucial step of the line design is the choice of the spindle heads and their assignment to workstations minimizing the line cost. We are clearly confronted by a new line balancing problem that is more complex than similar line balancing problems known in the literature. Proposed two exact methods for this problem based on the graph and MIP approaches. This paper concludes by giving a comprehensive analysis based on improvement of these exact models, their experimental tests and development heuristic approaches. As a result, efficient exact and heuristic algorithms have been presented to find an optimal or a ‘‘good’’ solution. In particular, an algorithm for calculating lower bounds on potential workstation numbers for operations and blocks has been enhanced in order to reduce the MIP model size and improve the graph approach. An estimate for the maximum required number of stations has been proposed that leads to a significant improvement of the MIP approach. This results in models capable of solving the problems with at least 80 operations in about 2 h in general. For large-scale problems, we suggested and tested 14 heuristics. These heuristic algorithms use two different techniques: random selection and depth-first search. They are relatively efficient and promising. This conclusion is based on their experimental comparison with the exact models for problems with 50, 60, 70 and 80 operations and on larger tests with the number of operations up to 150. The multi-start depth-first random search (MDFRS) algorithm outperforms all other heuristics on the quality of obtained solutions. In comparison with exact methods, this algorithm gives results within 5% from the optimum on average. An interesting offshoot of this study could be the development of an algorithm to reduce the interval of stations indices taking into account the exclusion constraints and the maximal number of blocks in stations. Another promising way might be the coupling of the MIP approach with constraint programming techniques.

A. Dolgui , N. Guschinsky, G. Levin and J.M. Proth et al. [10] approach for a problem of optimal designing bottlenecks in the mechanical industry is proposed. This problem is combinatorial very complicated. In comparison with the well known problem of assembly lines balancing, the studied problem has a lot of additional constraints and properties. The proposed graph approach describes the manufacturing and design constraints and verifies their compatibility. The graph model with the special technique of weights assignment makes possible the use of the constrained shortest path approach. This approach is more effective when the initial problem has a lot of manufacturing and design constraints, which restrict the digraph size. In industry, the preliminary design stage of bottelnecks often takes several months (from 12 to 18 months). Since these lines are very expensive, an exact solution is preferable and more beneficial than a heuristic solution, even if the former demands considerable more time resources.

Bottelneck balancing problem with an objective of minimizing number of machines is presented in **Essafi et al.** [11]. A Mixed Integer Program (MIP) is presented along with an algorithm. Precedence, inclusion and exclusion constraints are respected and sequence dependent set-up times are specified. Solution time is long even for a small problem. Moreover, the scope is limited to line configuration. No process planning in terms of feature grouping or tool allocation is considered.

Tolio and Urgo et al. [12] present a mixed integer linear program to consider design of flexible bottelnecks. The equipment cost for a multi-model rotary bottelneck is minimized while respecting design constraints.

Zhang et al. [13] provide a hierarchical process planning approach for flexible bottelneck schematic design. The method includes the selection of manufacturing feature machining operation, part set-up planning, feature sequencing, operation sequencing and process plan generation.

An investigation on bottelneck balancing is carried out by **Masood** [14]. A case study is considered to improve cycle time performance and machine utilization. Re-sequencing of operations and tools is carried out to improve the throughput. The results are validated by simulation.

Das et al. [15] follow a hierarchical approach in their machine loading and tool allocation problem. Design features are grouped together at higher level assuming an operation sequence and the operation sequence is improved at lower level to repeat iteration. Long time is required to solve the small problem considered. Transportation time is not considered.

Osman and Baki et al. [16] consider a bottelneck balancing problem to minimize non-productive time. A linearization and decomposition approach is adopted to sequence operations after grouping the features. In the sequel,

Osman and Baki et al. [17] develop a Bender's Decomposition approach and some Ant colony meta-heuristics to solve larger problems and obtain better results than their previous work [16]. However, solution time for large problems is long.

III. CONCLUSION

This is paper, we discuss about different bottelneck sequencing problems and its possible solutions to improve the productivity of production line. In this study we find out some factors of bottelneck, which are affect the sequencing and time of bottelneck. Following factors are important for bottelneck balancing in industrial production.

- Tool Changing Time
- Tool Sequencing Time
- Transportation Time
- Process Planning
- Feature grouping or Tool Allocation
- Operation Time

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