Ain Shams University

Faculty of Engineering

Scheduling of Numerically Controlled Hoist Handling Systems

A Thesis

By

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Submitted in partial fulfillment of the requirements of the degree of M.Sc. in Mechanical Engineering

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Statement

This thesis is submitted in the partial fulfillment of master degree in Mechanical Engineering to Ain Shams University.

The author carried out the work included in this thesis, and no part of this thesis has been submitted for a degree or qualification at any other university.

Signature

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Summary of the M.Sc. Thesis

"Scheduling of Numerically Controlled Hoist Handling Systems"

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Many Industrial processes involve multistage production lines where material handling is performed by a computer controlled hoist or robot.

Production systems such as electroplating lines, printed circuit boards production lines and other chemical processes employ hoists to transport jobs between different stations represented by the processing tanks. The processing times in the different processing stations can be either described by a fixed value or an interval value prescribed between a lower and upper bounds known as a time window.

Such systems are known as no wait systems since the job has a maximum processing time in each station that it must not exceed. Thus the hoist must be ready to transfer the job to its next processing station before exceeding the permissible processing time.

Production stages with long processing times may create severe bottlenecks degrading the system throughput. Therefore, a group of duplicate stations can be added in order to eliminate such bottleneck. This stage is denoted by multi station stage. The problem under consideration accounts for the possibility of having a number of processing stages sharing one physical station in order to reduce facility costs. This type of station is denoted by multi function station.

Efficient scheduling of such hoists can improve production throughput, as well as the utilization of the hoist and the processing stations.

The objective of hoist scheduling problems is to find a sequence of hoist moves that minimizes the cycle time or maximizes the throughput of a production system.

Hoist scheduling problem has been addressed by several researchers. Hoist scheduling problem with fixed processing time and has been solved polynomially. Hoist scheduling problems with time windows have been proven to be NP hard in a very strong sense. Several branch and bound algorithms have been introduced for solving hoist scheduling problems of identical parts with time windows processing times. Other researchers introduced genetic algorithms and artificial intelligence approaches to generate cyclic schedules. Other approaches extend simple cycles towards the generation of higher degree cycles. They proved that higher degree cycles allows more than one part being loaded into the line while performing the cycle and thus increasing the chance of achieving an improved schedule. Hoist scheduling problem with multiple product types has received relatively little attention as only few heuristics approaches are known since the problem with multiple items has been proven to be NP hard.

In the present work a proposed algorithm is developed based on the enumeration of all possible hoist moves before every hoist action. It checks that such moves will not lead to any defective jobs in the remaining processing tanks. A nested priority rule is developed and applied to select the most appropriate hoist action among all enumerated hoist actions. As a conflict occurs either due to the unavailability of a vacant tank or due to the unavailability of the hoist, a backtracking algorithm is applied in order to resolve the conflict. The developed heuristic was computerized through a specially designed simulation program which helps in determining detailed statistical information representing the utilization of line facilities.

The algorithm was tested on three bench mark problems of considerable line size simulating real life case problem. The results showed that the

proposed algorithm leads to comparable results with those obtained by exact mathematical methods with a difference in the cycle time lying between 2.5-14 %. Also the algorithm was applied to a problem of two product types and the same results as that obtained by other heuristic approaches were achieved. The algorithm was applied to different problem configurations to study system performance under the effect of different scheduling parameters such as hoist action times, time window processing times and the usage of parallel processing tanks at the bottleneck stages. Also the performance was tested in case of processing multiple product types, where the sequencing between jobs of different product types was found to have a positive effect on the system throughput under certain conditions.

The proposed algorithm was applied to a practical example of an anodizing production line, the obtained results and conclusions from the above mentioned experiments were applied to the problem to examine their effectiveness.

Mathematical models for a number of special problems are developed. The mathematical models determine the system cycle times in terms of different system parameters as well as the required conditions for the system to perform the ideal sequence of hoist moves.

Scheduling of Numerically Controlled Hoist Handling Systems

Abstract

Many production systems such as electroplating lines and printed circuit boards production lines employ hoists to transport jobs between different stations represented by the processing tanks. The processing times in the different processing stations can be either described by a fixed value or an interval value prescribed between a lower bound and an upper bound known as a time window.

Such systems are known as no wait systems since the job has a maximum soaking time in each tank that it must not exceed, thus the hoist must be ready to transfer the job to its next processing station before exceeding the permissible soaking time.

Efficient scheduling of such hoists can improve production throughput, as well as the utilization of the hoist and the processing tanks.

Hoist scheduling problems with fixed processing time and has been solved polynomial. Hoist scheduling problems with time windows have been proven to be NP hard in a very strong sense. Several approaches such as branch and bound algorithms and artificial intelligence approaches have been introduced for solving hoist scheduling problems of identical parts with time windows processing times. Other researchers considered the case of single product, multiple hoists either on parallel tracks or sharing the same track. Hoist scheduling with multiple product types has received little attention, as only few heuristics approaches are known.

This research addresses hoist scheduling problem for a single hoist, multiple products system, each product type have its own processing sequence and processing time at each stage. A heuristic algorithm is developed for scheduling of hoist moves. The algorithm considers an extended system with multi- function tanks and multi-tank stages.

The results of applying the algorithm showed that the proposed algorithm leads to comparable results with test problems which use exact mathematical methods with a difference in the cycle time lying between 2.5-14 %. The algorithm was capable to solve a problem of multiple product types. Exactly the same results were obtained as that obtained by the other heuristics. The results prove that the proposed heuristic can be used efficiently for single hoist multiple product scheduling problems.

The algorithm was also applied to study the effect of different system parameters such as hoist action times, time window processing times and the usage of parallel processing tanks at the bottleneck stages on the system performance in terms of throughput and facilities utilization. The obtained results were applied to a case study of considerable line size to study the effect of changing scheduling parameters on the performance of the system. Mathematical models to determine the system cycle time and other parameters are developed for a number of special cases.

Keywords: Hoist scheduling, No wait system, Time window, Heuristic, Electroplating

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