SCHEDULING ALGORITHMS FOR FLOW SHOP SYSTEMS WITH FREQUENT CHANGEOVERS: APPLICATION IN PROTON EXCHANGE MEMBRANE FUEL CELL MANUFACTURING

By

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An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Decision Sciences and Engineering Sciences

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

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June 21, 2007
(For Graduation August 2007)

ABSTRACT

Membrane electrode assemblies (MEA) are the primary component of proton exchange membrane (PEM) fuel cells used in applications such as compact batteries and automotive. The future demand for this technology is highly uncertain. In order for fuel cells to achieve commercial viability, efficient systems for high volume automated mass production are necessary.

The focus of the research is the configuration of fabrication facilities as a function of forecast demand levels over a multi-year period. The decision problem is to determine the number of parallel fabrication lines, the aggregate production schedule and the distribution of tooling. The problem can be classified as a flow shop scheduling problem with frequent product changeovers. A cost model of the process is developed and validated to capture setup, backorder and inventory carrying costs. The model enables decision makers to evaluate the cost performance of alternative production plans and system configurations in order to approximate the overall production costs and facility requirements associated with alternative demand scenarios.

The general flow shop problem with n $>$ 2 machines has been shown to be NP-complete in the strong sense (the hardest set of NP problems) and NP-hard. Therefore, only a near-optimal solution can be obtained by heuristic methods. In addition to model formulation, this work explores the development of a robust Simulated Annealing algorithm for the flow shop scheduling problem with frequent product changeovers. A factorial study permits algorithm tuning. Non-parametric methods must be used to evaluate the robustness of the algorithm over a broad range of test problems and parameter combinations as the underlying distributions are not normal. It is shown that several robust parameter combinations exist that produce good results when compared against alternate algorithms. Lastly, a Two-Stage Simulated Annealing (TSSA) approach is investigated to enhance the search of the solution space, resulting in a secondary algorithm which is shown to improve one of the algorithm's evaluation criteria as opposed to the proposed one stage approach.

This work produces several managerial insights. The study of a variety of problems reveals that the downtime of the line to switch products quickly overwhelms other costs. It is shown that ramping up production under current cycle times has a relatively low upper bound unless infinite production lines are available. Based on demand levels, implementation of the algorithm is seen to result in savings of 10-40% in cases with a random starting schedule of products by full demand, and 5-10% in cases with a random scheduling of products by smaller order amounts.