A hybrid approach to Cellular Manufacturing

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***Abstract*: The most significant contribution of this research is the use of taboo search techniques to the solving of the CMS job scheduling problem. In this research, an attempt has been made to alter the work sequence in order to get the best possible job sequence. The goal of this research is to interrupt sequences in order to get better results. The larger the number of sequences, the higher the degree of objective optimization (COF). Using this technique, you may investigate the amount and ability of work sequences that are generated from the supplied task sequence. The main aim is to maximize the usage of the equipment while keeping the expense of the penalty to a bare minimum. A schedule approach is intended to maintain the flexibility of a specific FMS while still achieving the performance metrics that are required for that FMS. The mechanism operates on a taboo basis and simultaneously maximizes two objectives that are diametrically opposed. The Tabu search hybrid and the genetic algorithm may be used to solve the problem, which includes determining the cross-over rate, mutation rate, and so on. This hybrid approach aids in the resolution of the issue in a shorter amount of time. It is unlikely, however, that the answers generated by the hybrid algorithm would be as precise as those obtained by the enumeration technique. Thus, standard optimization theory methods may also be utilized to determine the solution to the algorithm in this case. Through the use of the tabu search method, it is possible to optimize the scheduling problem to a greater degree. The issue of scheduling in flexible manufacturing sectors is one that is often encountered; thus, there has been a significant amount of further research into it. The following are some of the most important topics that may be investigated over the course of the present research. The problem in this research is that each work step has a certain processing time, which is taken into consideration. It is possible that, in the future, fixed timings of machines and intercellular motion times will be taken into consideration while addressing the planning problem.**

***Keywords*: Cell production, Complex Manufacturing, Manufacturing, CMS job scheduling problem, Hybrid Approach**

I. INTRODUCTION

Cell production is a modern Technology application in which machines or processes have been aggregated into cells, each of which is dedicated to the manufacturing of a component or family of products, or a limited set of goods, according to the needs of the customer. It is then determined which parts have similar processing requirements and organized into logical groups called part families, after which the equipment requirements for each component family are specified. A family of components is a collection of components that are similar in their geometrical shape and size, as well as the processing procedures that are required during their manufacturing. A production cell is made up of a number of functionally distinct machines that are located close to one another and are all dedicated to the manufacture of a single component family. A division and conquest strategy is used to divide a complex manufacturing facility into multiple groups of machinery (cells), each dedicated to the processing of a certain component family, and then to conquer those cells. Thus, each component type is produced in a separate cell, where it may be optimized. This streamlines the flow of materials and makes planning easier as a result of this.

ROLE OF CMS

In order for us to be more competitive, we must improve the quality and value of the goods and services we offer while being flexible enough so that we can respond quickly to market needs. On the other hand, we must embrace new technological advancements. This is particularly essential when the project involves hazardous labour and high-value capital investments. Many technical problems may prevent CMSs and FMSs from being widely used. Some of these issues, such as the machine device specifications, spindle rpm, the type of material that can be cut, and the adaptability and power required by the control system, could present challenges that would make the CMS technology more difficult to implement and thus prevent its widespread adoption. However, there are additional non-technical issues which need a management viewpoint to evaluate the situation. Therefore, besides the technical specifics of the system, the decision makers have a comprehensive knowledge of the organizational and human factors relating to the purchase and deployment of FMS. These difficulties help to highlight the different obstacles faced by Indian management while adopting modern manufacturing. These include financial, corporate and personal problems. Financial problems may usually relate to an organization's economic well-being and performance. Organizational problems relate to and influence on organizational culture, value systems and tactics. Personnel difficulties address the challenges emerging from the human system in an organization because of the choice of new systems. The benefits in terms of system performance obtained from cellular production compared to conventional production methods may be stated as follows:

1. Configuration time is decreased. A production cell has been developed to handle components of comparable forms and sizes. Many of the components may thus use the same or comparable holding devices (fixtures). Generic devices for the component family may be created so that the time needed for changing devices and instruments is reduced.

2. The size of the lots is decreased. Small batches are feasible and affordable if setup times in CM are significantly reduced. Small quantities also produce smoothly.

3. Inventories of work-in-process (WIP) and completed products are decreased.

WIP may be decreased via lower batch sizes and reduced set-up periods. Askin and Stand ridge have shown that when the setup time is halved, the WIP may be decreased by 50%. In addition to decreased installation times and a WIP inventory, the inventory of completed products is lowered. The components may be manufactured either just-in-time (JIT) or at set, short intervals instead of Make-to-Stock systems which are either running at lengthy, fixed intervals or at random intervals.

4. Costs and time for material handling are decreased. Each component of CM is fully digested in a single cell (where possible). The time and distance between cells is thus low.

5. A flow time decrease is achieved. Reduced handling time and reduced setup time significantly reduce flow time.

6. Requirements for tools are decreased. The cell components are identical in form, size and content. They thus frequently have comparable needs for tools.

7. Space reduction needed. WIP reductions, stocks of completed products and lot sizes have led to less space.

8. Due time is shortened. 8. In a workshop, components are moved in batches between machines. In CM, however, each component is instantly transported to the next machine after processing. Thus, the waiting time is significantly decreased.

9. Improved product quality. Since components move as a single unit from one station to another, they are fully processed in a compact space. Feedback is quick and if things go wrong, it can be halted.

Design of cellular manufacturing systems

The CMS design is known as cell formation (CF), part family/machine cell formation (PF/MC) and production cell design. Given a number of parts, processing needs, component type requirements, and resources (machinery, machinery, etc.), CMSs are designed in three main steps: The following:

1. Part families are established on the basis of their needs for processing.
2. Machines are organized into cells of production.
3. The cells are allocated to part families.

These three stages are not always carried out in or consecutively in the above sequence. Part families and production cells may be created at the same time as part families are transferred to the cells. Once the design processes are finished, a cell configuration (or short cell configuration) will be obtained. It is called a CMS system consisting of a series of manufacturing cells, each cell consists of a group of machines and is devoted to the production of a family of components.

The three solutions are as follows:
1. Family grouping technique: the grouping of components into families and subsequently the assignment of machines to the production of family parts.
2. Machine grouping method: this technique first uses similiarity in component routings to construct manufacturing cells, then the parts are assigned to the cells.
3. Machine-part grouping technology: Parts families and manufacturing cells are created concurrently with this method. This is the simultaneous solution grouping method for machines. It is sometimes called group analysis of machine components and is based on PFA.

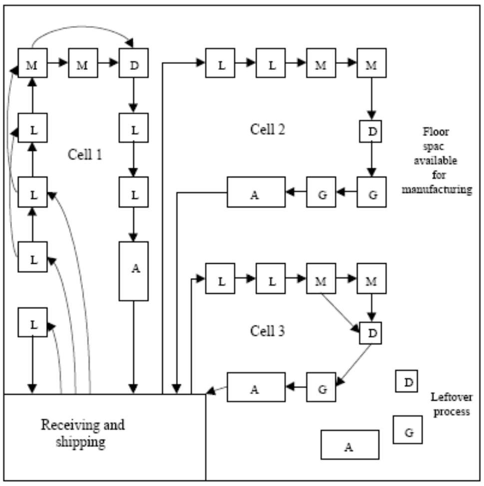

Fig. 1: Cellular Manufacturing

Cell formation

Shahrukh A. Irani's Handbook on Cellular Manufacturing Systems [1999] is the collection of works by various scholars in the area of CM. The different methods used for cell generation problems are defined by Narendran and Srinivasan [1999]. Eric Molleman et al. [2002] pointed out that in the choice to modify the system two linked variables played a significant role: the market and production technologies and it is necessary for a cellular system that they reflect market characteristics. Therefore, market trends, new production technologies and contemporary production control systems are factors that need to be considered in cell creation.

Cellular shops/layouts

The queuing theory used by Vijay R. Kannan and Susan W. Palocsay (1999) illustrates the connection between cellular and job stores processing time and flow time performance. Models are created that enable the learning rate to be estimated in a mobile phone store to provide a performance similar to the workshop performance. Results show that a mobile phone store needs just a slightly greater degree of learning than a workshop to operate at a similar level. Results indicate that a mobile phone store may work well in comparison with a working shop without fundamental modifications in the way a cell phone shop is implemented. However, this does not comply with most previous research which has shown that certain changes are necessary rather than continual improvement or in addition to them.

The Modified Multi Task Chart was developed by Shahrukh A. Irani et al. [1999] and replaces all previous representations of multi-product material flow networks used for facility planning. A mixture of string clustering, matching and alignment techniques is used in PF AST. This novel product routing representation allows the design for layouts that are intermediate between the conventional process, cellular and flow lines for any bespoke manufacturing plant for multi-products.

One of the drawbacks of CMS is that it limits the flexibility of routing. Most current data indicates that cellular companies perform worse than jobs when the environment requires a flexible strategy to deal with changing market circumstances. Nevertheless, Vijay R. Kannan et al. [1995] enhances cellular system flexibility by introducing the "Virtual Cells" idea, dynamically generated cells, i.e., virtual cells, are transitory and logical, unlike conventional cells which are permanent and physical. In a conventional sense, cells do not exist; they are instead flexible routing systems. The distinction is that the machines are not physically adjacent. This results in a shop structure that incorporates both the benefits of workshops and cellular production while overcoming their respective limitations. This is called virtual cell production (VCM). The VCM production control system here shows the illusion that manufacturing cells use production without altering a process architecture physically, but yet achieving the advantages of cellular production. The article written by Vijay R. Kannan et al. [1995] uses a simulation model to make the idea practical and specifies the circumstances under which VCM is a more suitable form of small batch manufacturing than conventional processes and cell layout procedures.

In recent years, two new paradigms have been created that inherit the cellular manufacturing idea. These new paradigms are the use of the potential of a virtual cellular organization and a dynamic mobile organization. The virtual cellular production idea and the dynamic notion of cellular production allow both performance and flexibility to be improved. Jocelyn Drolet et al. [1996] explain the several conditions during which cellular production is necessary. They also provide an understanding of the cellular dynamic production system.

The agreement is developing that already existing layout configurations do not satisfy the requirements of the multi-products company and there is a need for a more flexible, modular and easier reconfigurable new generation of factory layouts. Saifallah Benjafaar et al. 2000 works on the creation of alternative layouts and solutions for the "next generation" of industrial layouts. They also use the VCM idea and create flexible and changeable designs. The ultimate aim is to investigate alternate configuration and performance measures to build flexible and changeable factories.

CMS ISSUES

Companies transitioning to cellular production (CM) frequently struggle to execute and get less than expected outcomes. With significant focus on technical elements, the current corpus of CM research does not offer practitioners with the support they require for effective implementation. Because the culture of organisation is a major obstacle to change, Charlene A. Yauch and Harold J. Steudel [2002] study was conducted to uncover the effect of culture on the conversion process for CM. Two case studies were performed in small manufacturing businesses to identify eight important cultural variables affecting CM conversion. The ultimate objective of the study is to concentrate on why businesses have achieved success or failure via the implementation of CM initiatives.

Various empirical studies have looked at the impact of cellular manufacturing (CM) on employee attitudes, job satisfaction, morale, and the overall quality of the work performed. In addition to enabling practitioners to identify the unwanted consequences that may be avoided during CM implementation, there is no study that has been conducted that has had a major impact on the success of CM implementation when it comes to desirable socio-technical tasks. The Festus Olorunniwoa and Godwin Udob research [2001] utilizes the concepts of sociotechnical systems (STS) to establish three main categories of factors likely to affect the implementation of CM including high-level management, operator-based job design and cross-training. In the empirical research, 19 socio-technical factors have been discovered, which may have an effect on CM implementation. There were three distinct exploratory regression models to find sub-sets of factors that have the greatest effect on CM performance. Among other things, the findings suggest that the CM implementation seems to be more effective when senior management starts the CM project and when staff are cross-trained in running different machines and reading blue imprints.
Nine case studies (theory building) were performed in the autumn of 1996 to identify actions needed to change small businesses. A cross-case study of those case studies showed that the whole company may be changed when cellular production is applied using cultural and technological methods. Dr. Rayan et al. [1999] discusses CM as a transformation tool for enterprises and concludes that CM problems are specific to small enterprises.

A.Sobhanallahi and E. Shayan [1998] carried out an extensive research to develop a model for an Iranian manufacturing firm to enhance their efficiency. The report describes the behavioral system that prevails and is in turn influenced by the cultural and environmental circumstances, historical effect, geographical location, the technological state and the attitude of the people.
G. Chand and B. Shirvani [2000] connect CMS to TPM and TQM and thus present CMS as one of the world's finest production methods. In cooperation with a top tier automotive component provider, a study was carried out to estimate the total efficiency of a semi-automated assembly cell (GEE). It has been determined that implementing TPM is simpler for the business (which uses CMS).

II. DEVELOPMENT OF SCHEDULING MODEL FOR CMS

The setup of the CMS examined in this study is given in Figure 4.1 by S.G.Ponnambalam & S. Saravana Sankar,[2002];
• There are 5 machining cells (MC) each with two to six computer numerical control machine numbers (CNCs). For intracell transportation of materials between processes, each cell is supported by one to three specialized Robot/s.
• A loading station is available from where the components are discharged in batches.
• There is an unloading station that collects the completed components.
• One Automatic Storage and Recovery Systems (AS/RS) is available.
• MCs are linked with identical Automated Guided Vehicle numbers (AGVs). These AGVs conduct intercell moves between MCs, transfer the loading station to any of the MCs, transport the completed goods from any MC to the unloading station and move semi-finished products between AS/RS and the MCs. These AGVs are also used in the intercellular movement.

FORMULATION OF THE PROBLEM

There are two functions in the combined objective function. These routines address the issue of programming work in a flexible workshop in order to minimize complete machine idleness and maximize machine use. To maximize the usage of the machine, we utilize a minimum of the entire machine idle time. Thus, the combined objective (COF) function minimizes the machine idle time while maintaining zero penalty costs. In order to achieve our goal of reducing overall costs and increasing the use of machines.

COMBINED OBJECTIVE FUNCTION (COF):

Minimize
$$COF = (W1) * [(Xp * C) \div MPP] + (W2)*(Xq \div TE)$$

Where W1 = Customer satisfaction weight age factor.
TE = Total Elapsed time (make span)

Xp= Cost of penalty imposed

W2= Machine use weight age factor

C = Penalty cost function If CTi raises DDi's work deadline, C becomes unity which indicates that there is a penalty cost that is not an acceptable condition. If Tabu searches movements, the neighborhood network will be searched to obtain the necessary conclusion that the value of idleness and COF is equal to zero penalty costs.

III. RESULTS AND DISCUSSION

The performance is evaluated by means of an objective function that maximizes the machine use by keeping penalty cost nil. In the prior study, no additional sequences were examined by disturbing fixed sequences. The power of Tabu search resides in random and high numbers creation. Many sequences are necessary to remove the local minima. We created a huge number of sequences in this study, so that we can find an optimum global solution.

Some of the remarkable characteristics of the schedule algorithm:

1. Various work sequence combinations should be assessed by disturbing sequences from the set task sequence.

2. In accordance with every work sequence, the machine allocation is carried out in order to accomplish the combined goal function of reducing the overall delay and optimizing the machine use by fulfilling the system restrictions (Available machining time at different machine for each job and penalty after due date).

To find the best solution to the issue in Example we have ran the program and compared the results with other planning guidelines. The results are shown in the table:

Special Cases

Case Name	Seq.	Penalty	Idleness	COF
Highest Pro Time	21;14;8;30;32;13;12;19;43;3;33;27;42;39;15;37;35;6;29;17;28;	0.2074205	0.7207892	0.4641049
Shortest Pro Time	20;23;38;1;9;26;22;10;34;18;36;11;25;5;16;2;40;4;31;41;7;24;2	0.1683454	0.6090647	0.388705
Highest Batch Size	12;14;30;28;35;8;21;3;31;32;41;16;4;6;13;15;29;36;17;43;33;3	0.1729306	0.7219588	0.4474447
Shortest Batch Size	20;23;38;9;1;5;10;2;22;24;7;11;18;37;40;34;25;27;42;19;26;33	0.2014075	0.60933	0.4053687
Earliest Due Date	9;11;31;28;19;24;29;40;38;35;39;5;20;34;3;23;15;32;43;6;21;1	0.1909506	0.6657351	0.4283428
Highest Due Date	16;26;33;4;7;8;13;18;22;25;14;27;37;41;10;17;36;12;42;30;1;2	0.1857098	0.7003389	0.4430244

TABLE 1: Comparison of Results

Case Name	Sequence of parts	Penalty	Idleness	COF
Tabu Search	23; 38; 35; 36; 31; 26; 42; 40; 16; 3; 11; 1; 7; 34; 25; 24; 15; 41; 19; 28; 37; 12; 18;32; 39; 5; 14; 17; 29; 9; 2; 43;33 21; 30; 4; 20; 13; 22; 27; 6; 10; 8	0.0000	0.3986	0.3587

The findings indicate the value of the penalty in Tabu search techniques is the lowest to maximize machine use. In the case of a Tabu search technique, our combined goal function is likewise minimal. Therefore, it can be stated that there is a minimization of the penalty and a maximization of the use of machines of work sequences. This confirms that this method performs better than other algorithms.

IV. CONCLUSION AND FUTURE SCOPE

The major contribution of this study is to use taboo search methods for the solution of the CMS task scheduling. In this study, an effort has been made to modify the task sequence such that optimum job sequence may be obtained. The aim behind this study is to disrupt sequences for better outcomes. The more sequences the greater the degree of objective optimization (COF). This method is appropriate for exploring the quantity and ability of work sequences from the given job sequence. The primary goal is to combine the maximum use of the machine in order to keep the cost of penalty zero. A timetable method is designed to preserve its flexibility and therefore the desired performance metrics for a particular FMS. The mechanism works on a taboo basis and concurrently optimizes two contradictory goals. The Tabu search hybrid and the genetic algorithm may be used for the issue, such as cross-over rate, mutation rate etc. This hybrid method helps to solve the problem in a quicker period. It is doubtful, however, that the hybrid algorithm-produced answers would be as exact as the enumeration method. This implies that conventional optimization theory techniques may also be used to find the solution to the algorithm. This allows to optimize the scheduling issue to a larger extent by using the tabu search technique. As the issue of scheduling in flexible manufacturing sectors is a very frequent problem, there is a great deal of additional study in this area. Some of the key points which may be examined in the course of the current study are provided. The issue in this study is seen as each work step has a particular processing time. In future, set timings of machines and intercellular motion times may be taken into account while resolving the planning issue.

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