CONTROL OF INVENTORY AND RESOURCES USING SIMULATION BASED SCHEDULING

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Summary

This article illustrates how a control engineering approach has been adapted to provide a novel form of inventory and resource control centred on simulation based scheduling.

Introduction

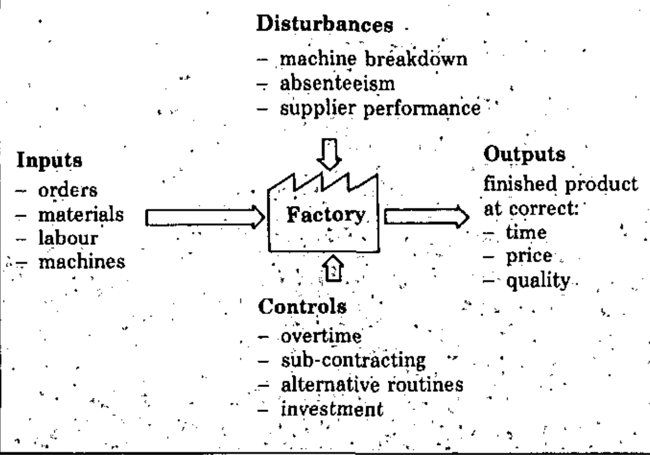
Practitioners in Production Planning and Control might be forgiven for thinking that the problem they face, the control of inventory and other resources, the execution of a Production Plan and meeting the demands of the market, is a uniquely difficult one. However, there are other areas of human activity in which we face the same generic problem and in examining the solutions offered we should be able to improve our own approach to controlling manufacture.

Current methods, whether manual or computer-based, for creating and executing a schedule appear in practice to have a number of deficiencies, not so much at the administrative or accounting level but at the detailed control level. In fact it could be argued that they do not truly control but rather plan and then provide a series of contingency measures to cope with the inevitable deviations. Excessive stock-holding or leadtimes hide the deficiencies in control procedures but at a cost to flexibility and competitiveness. A typical example in a machining and assembly environment is early marshalling to compile shortage sheets. Not only does this result in large amounts of marshalled stock but the machine shop is driven by shortages rather than 'true' priorities which are dynamic in nature. Existing computer systems tend to treat the *question of detailed scheduling rather informally* by giving the planner a whole host of reports leaving the final scheduling decision to their experience and 'gut feel'.

Why are we unable to provide a more sound and formal approach to this problem? The answer to this lies in the way we perceive production. Any manufacturing unit has all the characteristics of a SYSTEM; because it has inputs, processes and outputs. A more important facet, however, is its vulnerability to disturbances and any method which makes claims to control this process must include the ability to compensate dynamically. Disturbances in manufacturing are many and varied but generally we might say there are those which exist external to the manufacturing unit such as changing market requirements and supplier performance, and those which exist within the unit, such as machine reliability, absenteeism, inaccurate stock records and highly variable process times.

In response to disturbances the planner is not unarmed but has a number of "control" or correction tools, such as the ability to increase or reduce overtime, subcontract work and select alternative routings. On the longer horizon he may also consider changing the product design to suit manufacturing methods or investing in new technology. The 'control' to use in the face of disturbances is not a question with a single answer but rather a series of options and the final selection may involve corporate policy and financial considerations. It may involve corporate policy and financial considerations. It is not possible to construct these options without understanding in detail the dynamic nature of the process, the interactions of machine and manpower constraints, and in the case of batch manufacture, the relationship between machining and assembly. (Fig. 1 shows the elements of the production system and the scope of the problem). This is the main requirement of any method or system which attempts to control and we should not be satisfied by claims of 'feedback control' or 'closed-loops', if these do not incorporate a real understanding of the process and its dynamic nature.

Fig. 1 The Production System



Having defined the 'requirement' the remainder of this article will discuss the solution offered by a control engineering approach and how simulation can and is being used in the control of manufacturing with particular reference to inventory control.

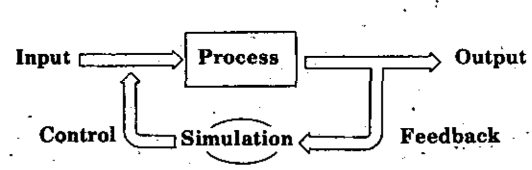
Control Engineering Approach

In order to control any dynamic process adequately it is necessary to monitor the outputs and, if possible, the disturbances directly and to compute and apply the control actions required in a closed loop. In the field of process control these techniques have been developed and successfully applied over many years. Many practical examples exist where simulations and models have been included in the dynamic control loops to ensure that the correct control action is taken under all operating conditions. This technique is responsible for significant performance improvements in several applications.

In the production of flat aluminium and steel sheet advanced thickness control systems employing this technique have been implemented. These systems respond to disturbances 2-3 times faster than conventional systems, resulting in significant reduction of out of tolerance material, reduced scrap and a better quality product.

Whilst the analogy to production and inventory control

Fig. 2 Feedback Control Using Simulation



should not be extended too far the use of a model or simulation within the feedback loop is founded on good principles. In practice the very building of these models has given those involved a far better understanding of the real constraints and dynamics of production systems and therefore could be seen as an end in itself.

Fig. 2 illustrates how the output from the process is fed back through a simulation model and the results used to control the process.

Simulation Software

Computer simulation or modelling is not a new tool and already many software packages claim some sort of simulation at various stages in the planning and control of manufacturing. Most often these are simplistic (for example, they assume infinite capacity) or they load to finite capacity on machines only and do not consider the flexibility and constraints of the labour force or the effect of true queue times which can be a serious cause of errors. More recently simulation has been employed as a tool for design of FMS and 'green-field' sites, but these are not usually capable of controlling the day to day activities of the entire plant or interface to existing databases, because they are designed primarily to provide an attractive user interface (mainly for marketing reasons, one suspects), and are usually limited to micro-computers which offer greater flexibility in this area. A simulation designed for on-line control, must satisfy at least one major criterion and that is performance. Repeated simulations to obtain the best results will not be practical unless the run times can be measured in minutes especially over the shorter planning horizons. Additionally it must be able to consider the large amounts of data required to describe even a small-to-medium sized factory.

There are now a number of reasons as to why simulation used in this manner is a more practical proposition.

- Improved cost/performance of computer hardware enables the simulation to run in a realistic time at affordable cost.
- Supporting database software is available to manage and give access to the required input data. Most companies already have access to all the data required.
- A well constructed simulation can take advantage of the similar nature of most scheduling and control problems reducing software development cost.
- Shop floor data collection methods maintain the data more accurately and ensure the simulation starts and proceeds as closely as possible to actual conditions.
- Current report-writers and business graphics software facilitate an effective interface for management.

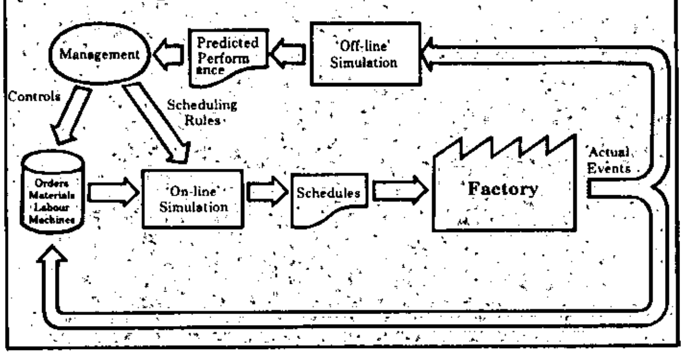
The writing of a simulation demands a trade-off between functionality and performance and whilst in theory it might be possible to consider all influences and events, a typical batch machining and assembly environment will only require the scheduling of operators, machines, tools, and stock. In addition scheduling rules need to be specified, and in order to evaluate the 'fit' of the model they should initially mimic the formal and informal rules that currently exist in the factory. In order to achieve a close fit a good deal of analysis and understanding of the production processes is required, but once the rules are ascertained, a flexibly built simulation will allow them to be simply 'plugged' in. The initialisation, or reading in of the data will be unique to each particular company database and consequently is a separate module, as is the module producing output, which must be geared to specific user requirements.

The Simulation in Practice

The simulation is employed in parallel with other planning tools such as Master Production Scheduling and an MRP calculation which are used to generate a file of Works Orders. Additional software will be required to plan and maintain the availability times of machines and operators, reflecting shift patterns, planned maintenance, holidays and other disturbances. The skills of operators must also be defined meaning the machines they are capable of operating and setting. Management can then define objectives in terms of acceptable cost levels and customer service which are translated into scheduling rules and parameters, and the run iteratively to obtain the best results.

Two modes of operation can be distinguished and described suitably as 'on-line' and 'off-line', not reflecting the computer processing method, but rather the use to which the results are put. Figure 3 shows the difference in function between these two modes of the simulation. In the on-line mode the simulation is used to provide a detailed and feasible schedule, as it loads to finite capacity, for labour, machines, tools and material. This schedule is issued to the factory floor and personnel encouraged to follow it as closely as possible; this has the benefit that deviation is minimised and the model becomes more

Fig. 3 Simulation Based Scheduling



accurate by definition. Inevitably a factory cannot be entirely faithful to the schedule and this is catered for by monitoring and reporting the deviation and at a defined point rapidly regenerating the schedules. In practice this will occur regularly, such as every shift change, or whenever there is a major disturbance such as machine breakdown or supply failure. The schedule can also be used to make very accurate customer promises and supply requests.

In 'off-line' mode the model can be used to evaluate different scenarios and view the results before actually committing any decisions in the factory itself. All the inputs to the simulation, the resources, the schedule and the scheduling rules, can be varied, and the results in terms of delivery performance, work-in-progress value, utilisation of men and machinery, predicted cash-flow, (Cash is a resource as well), and all the effects on P & L and balance sheet can be reported.

Techniques for Inventory Control

Without a forward view in detail, of what is going to happen on the factory floor, Inventory Controllers can only base action on what has happened or is happening, and simply log the excess or shortage. In fact most computer software for Inventory Control amounts to no more than an extravagant method for counting and maintaining the data. It may include some sophisticated statistical method for safety stock and reorder point calculations, but invariably this is based on what would be required if past conditions and events repeat themselves. In practice we require a view of not only where we have been and where we are, but also where we are going, and whilst MRP will set out a plan for material, it does not consider the true dynamics and contraints of the process (i.e. it usually assumes infinite capacity).

A simulation can help in two respects. The creation of the 'on-line' schedule uses a number of scheduling rules and parameters which can be tuned to consider company wide objectives, (informal methods will be incapable of this), and the results reviewed before committal. The 'off-line' mode of running can be used to evaluate outcomes on the longer horizons and the parameters and rules necessary to meet Inventory Policy. These scenarios are easily expressed in financial terms for management decision making.

Using the simulation as an on-line control tool there are a number of steps that can be taken immediately to improve the level of stockholding, both under-stocks and over-stocks. Firstly identification of those machines which have a high changeover time will allow introduction of scheduling rules which will sequence together batches of the same part, or similar parts (belonging to the same family group), and reduce total set-up costs. This will not only avoid the large batch sizes, (necessary to make set-up worthwhile on an economic order basis), and reduce the leadtimes and stock-holding, but also avoid splitting batches in the later stages of manufacture. The effect of bringing these batches together is to create dynamic batch sizing controlled by a parameter and the current loading held against a machine or machine group.

In general the use of the simulation as a detailed finite scheduler opens up the possibility of utilising any (or all) of the scheduling priority rules which are available. For example we may consider the stock at 'downstream' operations such that the job going to the smallest queue can be processed and excess queues avoided.

The simulation also affords improved control of assembly by considering stock availability. Management are able to decide on the rules to be used in case of shortage (i.e. delay, start with a smaller quantity, start and report the shortage, or simply advise the earliest make date). The shortage can then be fed back via the simulation and used for prioritisation of component manufacture in the machine shop.

Similarly the delay can be extrapolated forward and the effect on Customer Order lateness evaluated. This calculation can be made for various levels of stockholding controlled by the MRP basis and inventory levels can be fixed on a cost benefit basis. In practice this required firstly pegging of Works Orders and secondly some sort of Customer Order visibility; both are generated by the MRP calculation.

Having decided the final schedule, a material schedule can be generated. This defines quantity, location and the delivery date for materials required for each job. A prioritized chase list can be passed to purchasing showing bought-out components and raw materials likely to delay production and in return the latest promise dates can be supplied and included in subsequent simulation runs.

Applications

Simulation is still emerging as a technique for production and inventory control and currently the number of suppliers and installations is small. This is largely a question of management attitude and it is not surprising that most interest has been shown in the United States rather than the UK. Results so far have been good, in application areas as diverse as small batch manufacturing plants and large process orientated manufacturing. Significant reductions in leadtimes and batch sizes, and 40% reduction in Work-In-Progress has been recorded. In terms of computer processing time, typically, we would expect run times of less than 1 minute per day on a mini-computer, for a single-shift comprising 100 men and machines, and scheduling 400-500 jobs. Run times will be extended if more complex scheduling rules are introduced.

Improved performance has been achieved by preparing the data at the earlier planning stages, and not presenting the simulation with overloads. This is achieved by using a load-smoothing program, applied after the MRP calculation, which re-computes the optimal start dates of orders based on known capacity constraints. Using this method, followed by simulation based on scheduling, delivery performance (measured as % of Orders completed at or before the due-date), has been improved in practice, from 40% to 98%. This calculation is tuned to achieve a desired level of delivery performance for a given inventory carrying cost.

Conclusion

Whilst existing methods may not give control in the sense that a control engineer would understand, techniques such as MRP and philosophies such as JIT do achieve benefits, and therefore simulation should be looked upon as complimentary to existing approaches rather than a replacement. One exciting aspect of simulation is the enormous possibility for evaluating the financial outcomes of various decisions or strategies. Current developments include an advisory or monitor function which in response to a problem such as a due-date which cannot be met, will not only advise the earliest attainable date but also suggest jobs to reschedule in order to meet this due-date. Similarly whenever the simulation recognises that operator availability does not match the schedule requirements the advisor will recommend overtime levels to resolve the difference.

In the longer term, faster and cheaper processing will allow development of more complex scheduling algorithms which attempt not only to control but to optimise resource and manpower utilisation, minimise cost and maximise service levels.

Systems simulations of this type are being developed and installed, and the advantages discussed have been proved in real industrial situations.

About the Author

Gary King is a Manufacturing Systems Consultant and Project Leader within the Software Development Group of Fyne Management Systems Limited.

After graduating in 1981 with a First Class Honours degree in Industrial Technology, he joined SKF (UK) Limited and worked in Decision Support System Development for varied manufacturing and commercial applications.

Currently he is engaged in developing Manufacturing Models and Control Software for major US manufacturing companies.