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   HYPOTHESES

   RESEARCH METHODOLOGY

   RESULTS & DISCUSSION

   FINDINGS

   RECOMMENDATIONS/SUGGESTIONS

   CONCLUSIONS

   SCOPE FOR FURTHER RESEARCH

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CONTRIBUTIONS TO BOOKS

- Sharma T., Kwatra, G. (2008) Effectiveness of Social Advertising: A Study of Selected Campaigns, Corporate Social Responsibility, Edited by David Crowther & Nicholas Capaldi, Ashgate Research Companion to Corporate Social Responsibility, Chapter 15, pp 287-303.

JOURNAL AND OTHER ARTICLES

- Schemenner, R.W., Huber, J.C. and Cook, R.L. (1987), "Geographic Differences and the Location of New Manufacturing Facilities," Journal of Urban Economics, Vol. 21, No. 1, pp. 83-104.

CONFERENCE PAPERS

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- Kumar S. (2011): "Customer Value: A Comparative Study of Rural and Urban Customers," Thesis, Kurukshetra University, Kurukshetra.

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- Garg, Bhavet (2011): Towards a New Natural Gas Policy, Political Weekly, Viewed on January 01, 2012 http://epw.in/user/viewabstract.jsp

MACHINE USAGE BASED ON PRODUCT MIX IN MANUFACTURING CLASSIFICATIONS

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ABSTRACT
This research elucidates an algorithm for the calculation of optimal product mix and machine utilization for a manufacturing process employing trainee engineers. A study of the important parameters influencing the system performance has also been conducted.

KEYWORDS
Product Mix, Capacity, Time reduction.

INTRODUCTION
The product and process for mass production are characterized by high non-productive time, unavoidable delays and occasional inspections as stated by Hitomi(n.d). Application of group technology consist [trainee engineers] along with process experts environment has been known to offer the advantages of mass production and result into cost reduction. In order to derive maximum benefit of group manufacture it is essential to allocate the technical team based part facilities, to different machines in an optimal manner. Each part family may visit a number of machines but not necessarily all the machines in the system. However, for this situation the amount of effort needed to work out an optimal schedule, for a real life problem, would be quite large. By adopting simpler manufacturing business strategy would comprise of a number of cells with each cell being provided with different number of machines of varied types. One cell would process a particular group of part. A system of this type is shown in Fig. 1:

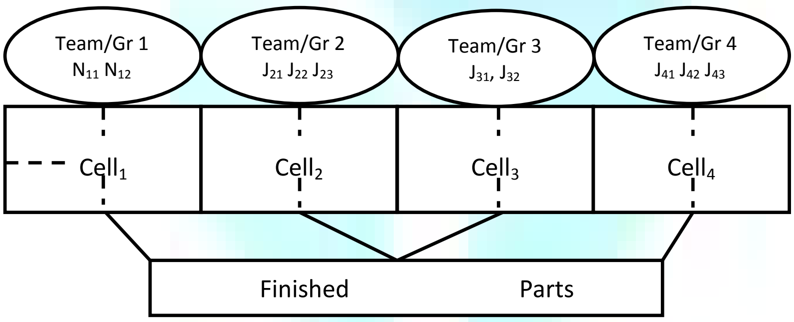


Fig. 1

For the manufacturing system in Fig. 1, the machine loading and product mix decisions are major problems. These problems have been investigated analytically with mathematical programming techniques by Hanssman (1999). From trainee engineer stand point, the production scheduling problem has been investigated by Hitomi and Ham (1978) whereas, Petrov (1977) has dealt with flow type group production planning. PERA (1950) has considered the loading and scheduling of work in a trainee engineers cell. Hitomi (n.d) and Ham (1978) have also developed optimizing algorithm for machine capacity planning and product mix in a single machine and multi stage production systems.
In this paper the authors have presented an efficient computer algorithm for the determination of optimum product-mix and machine-load, in a manufacturing system of the type shown a manufacturing system of the type shown in Fig. 1. for three different conditions.

MODEL FORMULATION
The cells in Fig. 1 comprise of a number of machines of varied types grouped in accordance with the operations necessary for a part family. Each group consists of two or more parts and is processed fully in a single cell. The present work is based on the model of Hitomi et al. (1982) however, the solution methodology and the computer algorithm developed by the authors are more accurate and less tedious to use.

MACHINE LOADING AND PRODUCT-MIX ANALYSIS
The assumptions:
1. The case of a single machine is treated and the total time available on the machine is'd'.
2. Parts to be processed are classified into M groups. The group index is denoted by I (= 1, 2, …… M). In group G_i, N_i parts are included where the part index denoted by J (= 1, 2, … N_i).
3. The group production time consists of group set up time, and sum of job production times for each group.
4. Job-production time is equal to job set-up time, and unit production time multiplied by lot size.
5. All the parts are cylindrical in shape and produced by turning.

It is required to determine the optimal numbers of the kinds of parts to be produced within a limited time available as well as to decide the optimum machining speed for all products so as to maximize the production rate.

(A) Part Manufacturing Time :

The manufacturing time of jth part is ith group is given by eqn.1. The part is machined in a single pass at a constant feed and cost factor, tool life, set time etc. are all deterministic. It is assumed that the Taylors tool life relationship ($VT^n = C$) holds true.

$$Pij(vij) = aij + \frac{\lambda ij}{Vij} + \frac{\lambda ij\ bij}{(Cij)1/nij} Vij\ (\frac{1}{nij} - 1)$$

(for j = 1, 2 … N_1 and i = 1, 2, … M)

Unit production time from above equation when plotted against the cutting speed provides a typical bell shaped curve for which optimal cutting speed is obtained as:

$$Vij\ (t) = \frac{Cij}{\left[\left(\frac{1}{nij} - 1\right) pij\right] nij}$$

When processing J_{ij} in a lot of size J_{ij} the total manufacturing time is given by :

$$Pij = Sij + LijPij(Vij)$$

(for j = 1, 2, … N_i and I = 1, 2, … M)

(B) Manufacturing Cost

The cost of a part can be expressed as a function of machining speed $(V_{ij})^{(c)}$. This cost is given by below equations :

$$qij(Vij) = \alpha aij + \frac{(\alpha + \beta ij)\lambda ij}{Vij} + (\alpha bij) + rij)\frac{Vij\lambda ij}{Cij} 1/nij$$

For j=1,2….Nij and i=1,2…M

Optimal product mix decision is to be based on the fact that optimal amount of part has to be produced within the prescribed delivery period.

ANALYSIS FOR SOLUTION

The solution of eqns. 6-8 has been attempted for three cases

Case I : (Q = d)

For this case all X_{ij}'s are 1 and the objective function assumes the form

$$Z\ max = \sum_{i=1}^{M} \sum_{j=1}^{Ni} \text{lij}$$

The optimal solution is:

$$X\ ij = l\ v\ ij = vij\ (t0$$

(For j=1,2….Ni and j=1,2….M)

Case II : When Q > d

The problem is now replaced by the following 0-1 type linear program. The machining speed is initially set corresponding to maximum production rate. The objective function of CASE 1 i.e. maximized subject to $P_{ij} = P_{ij}^{(t)}$. A heuristic takes into account the selection and rejection criterion. The part with maximum production time including the set up has been considered as a candidate for rejection.

Case III : When Q < d

The unique feasible speed values for machining all the parts are based on the minimization of the total cost with the slack time. Based on this criterion the problem assumes a non-linear nature as below:

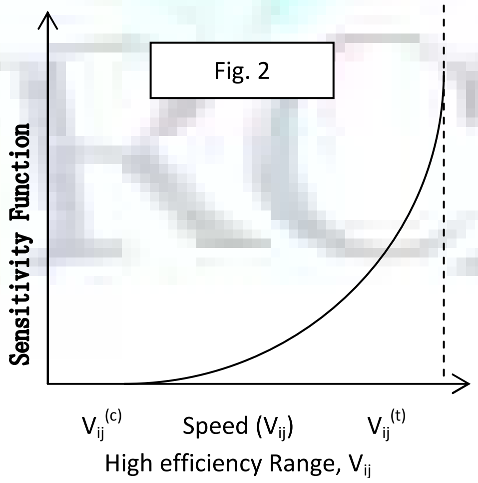
Minimize,

$$Y = \sum_{i=1}^{M} [(\alpha Si + \sum_{j=1}^{Ni} \alpha\zeta Sij + LijQij(Vij)\zeta]$$

The optimal solution, V_{ij}, to this non-linear problem is solved using KUHN-TUCKER conditions . This function is termed 'Efficiency sensitive function'. Properties of this function can be derived with following consideration. At the minimal points, the machining speed for minimum production cost is derived from the conditions.

$$\frac{dpij}{dvij}\left(\text{Vij(t)} = 0 \text{ and } \frac{\text{dvij}}{\text{dvi}}\Big|\ \right) = 0$$

Exponent, n_{ij} varies between O<n_{ij} < 1 due to which ($1/n_{ij}^{\ -1}$) > 0. Also, since ($V_{ij}^{(c)} < V_{ij}^{(t)}$ therefore, from r_{ij} – bij, ij $>^{0}$ and in the speed range E_{ij} obtained as :



The relationship between sensitivity function and speed is shown in Fig. 2.

RESULTS

The programme has been tested for the data of Hitomi & Ham and the following conclusions have been derived :

1. Proposed procedure is computationally simpler than the branch and bound algorithm of Hitomi & Ham (1978).
2. It is noted (Table 1) that for a_{ji} remaining constant, as b_{ij} increases the rejection increases slowly. The percentage utilization is almost same, nearly 100%.

3. Effect of variation of ratio of tool replacement time and preparation time is given in Table 2.
4. For Q<d, the sensitivity function drops faster with marginal increase in allowable time (Table 3).

CONCLUSIONS

The approach developed to compute the optimal product mix in a GT manufacturing cell is efficient, simpler and takes less computational time. This also offers high machine utilization. It has been observed that the preparation time has maximum influence on the production rate. There is a significant relationship between the optimum value of sensitivity function and allowable time.

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NOMENCLATURE

A_{ij}	Preparation time for part j of group i, min/pc
B_{ij}	Tool-replacement time for part j of group i.
C_{ij}	1 min tool life machining speed for part j of group i.
N_{ij}	Slope constant of the Taylor's tool life equation for part j of group i
P_{ij}	Maximum production rate per unit production time for part j of group i.
S_{ij}	Job set up time for part j of group I, min/lot.
β_{ij}	Machining over head for part j of group i.
λ_{ij}	Machining over head for part j of group i.
1_{ij}	No. of pieces in the lot J_{ij}
G_{ij}	Speed dependent unit production cost (Rs./min)
S_i	Group set up time for the group G_1 (min/group0
V_{ij}	Machining speed for the lot J_{ij} (m/min)
X_{ij}	0-1 variable for G_1
$\propto$	Direct Labour cost and overhead (Rs./min)

TABLE 1 : EFFECT OF a_{ij}:b_{ij} OVER PERCENTAGE UTILIZATION AND REJECTION

Ratio a_{ij}:b_{ij}	Rejected PCS	Rejection, %	Allowable time utilization %
1:1	252	41.70	99.89
1:2	270	44.26	99.80
1:3	283	46.39	99.78
1:4	292	47.86	99.62

TABLE 2 : EFFECT OF a_{ij}:b_{ij} OVER PERCENTAGE UTILIZATION AND REJECTION

Ratio a_{ij}:b_{ij}	Rejected PCS	Rejection, %	Allowable time utilization %
1:1	224	36.7	99.78
1:3	348	57.18	99.78
1:5	408	66.88	99.83

TABLE 3: ALLOWABLE TIME VS SENSITIVITY FUNCTIONS

Allowable Time (min)	Optimum Sensitivity function
6,200	66.0
6,300	97.0
6,400	33.5

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