Optimization and Analysis For Manufacturing Time of Automated Guided Vehicles in FMS

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Abstract—In the present paper, optimization of manufacturing time for Flexible Manufacturing System is done by analyzing AGVs, further AGVs (Automated Guided Vehicles) have been optimized according to constraints as number of AGVs and the speed of AGVs. Various designs of experiments have been taken into account for the AGVs and its effect on various parameters such as layout, batch size and manufacturing time. It is seen that various parameters are found most suitable and speed of AGVs is the deciding factor for the optimization of manufacturing time for a FMS.

Keywords- AGVs, FMS, Design of Experiments, Interaction Factors, layout,manufacturing time.

1. INTRODUCTION

A flexible manufacturing system (FMS) is a manufacturing system in which there is some amount of flexibility that allows the system to react in the case of changes, whether predicted or unpredicted. This flexibility is generally considered to fall into two categories, which both contain numerous subcategories.

The first category, machine flexibility, covers the system’s ability to be changed to produce new product types, and ability to change the order of operations executed on a part. The second category is called routing flexibility, which consists of the ability to use multiple machines to perform the same operation on a part, as well as the system’s ability to absorb large scale changes, such as in volume, capacity or compatibility.

2. DESIGN OF EXPERIMENTS APPLIED TO FLEXIBLE MANUFACTURING SYSTEMS:

DOE as applied for AGVs

The most important elements of a flexible manufacturing system are flexible machining centers, an automated and flexible material handling system, storage and retrieval system where parts, tools and fixtures can be stored. Most of today's flexible manufacturing systems have multipurpose, flexible machining centers which are capable of processing, a number of different part types. The FMS, thus, have the flexibility of alternate part routings which leads to limited work-in-process inventories in these systems**.** The workstations in FMS are connected by a material handling system which transfers parts, tools etc. between workstations. The automated guided vehicle (AGV) system is an important element in most of the present days in FMS**.** The essential capability of an AGV system is the ability to transfer loads (often heavy loads) to distant locations and through complex paths. The AGV technology is now being increasingly used in flexible manufacturing systems Factorial design is used in the work throughput rate of the system is design with help of factor like layout, batch size, operation time, number of AGVs, speed of AGVs and work load. For manufacturing time calculation these factors are most important and useful.

T_{ijklmn} = $A_i+B_j+C_k+D_l+E_m+F_n+\{(AB)_{ij}+(BC)_{jk}$+------+2factor interaction}+{$(ABC)_{ijk}+(BCD)_{jkl}$+-----+3factor interaction}+{$(ABCD)_{ijkl}$+------+4factor

interaction} +$\{(ABCDE)_{ijklm}$+--------+5factor interaction}+$(ABCDEF)_{ijklmn}$ Here,
A_i= effect of batch size
B_j=effect of operation time
C_k=effect of number of AGVs
D_l=effect of speed of AGVs
E_m=effect of work load
F_n=effect of number of jobs in the system etc.
So to find out the effect and influence of these factors design of experiments and factorial design helps. A force factor comes and regression model gets the effect of these factors that how much these low or high and two or more factor influence is considered.

Degrees of flexibility

The traditional flexible manufacturing system (FMS) is based on numerically controlled machines in addition to other value-added, automatic, material handling facilities. A degree of flexibility within FMS serves to satisfy demands for a relatively diverse range of products with a small to medium batch size production. Compared with FMS, more part varieties are produced in a mass-customized production environment, and manufacturing requirements are often dynamically changed.

3. EFFECT OF SPEED OF AGVS AND NUMBER OF AGV ON MANUFACTURING TIME IN FMS

The most important task in FMS is manufacturing time, so it is a biggest requirement to know the influence of all parameters which involve in the manufacturing time calculation. To evaluate and to analysis manufacturing time it is most difficult that collection or arrangement of data related with total manufacturing time. So this task is with help of individual calculation of travel time, loading/unloading time and job processing time on each machine. considering a problem of FMS and sequences and the associated processing time for a selected work parts are summarized

Table 1. Processing Time and Number of Jobs Produced

M → P↓	1	2	3	4	5	Product Produced
1	116.4	306	604.7	793.8	180x2	11
2		255.6	510		180	11
3	386.4					40
4	291.6					41
5		666.6				18
6		605.4				17
7			791.4	853.2	180x2	10
8			796.2		180	10
9				864	180	12

This particular problem loading/unloading time for each job on each machine is given below

Table.2. Loading-Unloading Time matrix

	Loading	Unloading	Jobs	TLT	TUT
M_1	0.5	0.5	92	46	46
M_2	0.5	0.5	57	28.5	28.5
M_3	0.5	0.5	42	21	21
M_4	0.5	0.5	33	16.5	16.5
M_5	0.5	0.5	54	27	27

Travel time of AGVs between each machine and loading/unloading units for different layout is considered for speed 20 m/min. and 50 m/min.

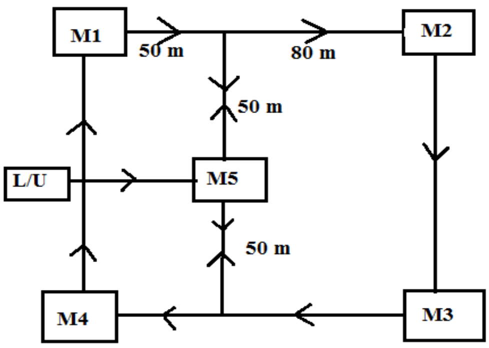

Fig.1. Cluster layout for machines and clockwise path rotation of AGVs

***Table.3. Travel Time (in Min.) matrix for speed 20 m/min. Travel Time (in Min.) matrix for speed 50 m/min*.**

	L/U	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**
L/U	0	2.5	9	14	7.5	2.5
M_1	12.5	0	6.5	11.5	10	5
M_2	14	16.5	0	5	11.5	11.5
M_3	9	11.5	13	0	6.5	6.5
M_4	2.5	5	11.5	16.5	0	5
M_5	7.5	5	6.5	11.5	5	0

	L/U	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**
L/U	0	1	3.6	5.6	3	1
M_1	5	0	2.6	4.6	4	2
M_2	5.6	6.6	0	2	4.6	4.6
M_3	3.6	4.6	5.2	0	2.6	2.6
M_4	1	2	4.6	6.6	0	2
M_5	3	2	2.6	4.6	2	0

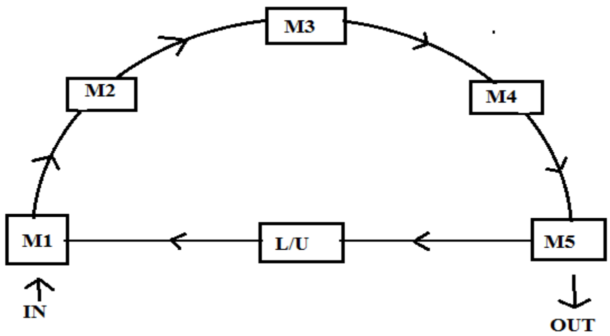

Fig.2. Circular layout for machines and clockwise path rotation of AGVs

Table.4. Travel Time (in Min.) matrix for speed 20 m/min. *Travel Time (in Min.) matrix for speed 50 m/min*.

	L/U	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**
L/U	0	3	5.5	8	10.5	13
M_1	13	0	2.5	5	7.5	10
M_2	10.5	13.5	0	2.5	5	7.5
M_3	8	11	13.5	0	2.5	5
M_4	5.5	6.5	11	13.5	0	2.5
M_5	3	6	8.5	11	13.5	0

	L/U	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**
L/U	0	1.2	2.2	3.2	4.2	5.2
M_1	5.2	0	1	2	3	4
M_2	4.2	5.2	0	1	2	3
M_3	3.2	4.4	5.4	0	1	2
M_4	2.2	2.6	4.4	5.4	0	1
M_5	1.2	2.4	3.4	4.4	5.4	0

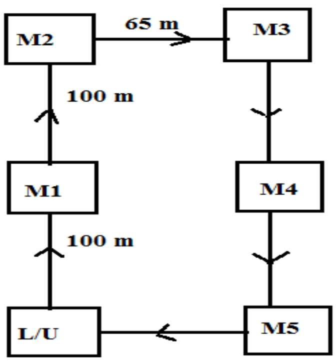

Fig.3. Simple and straight layout for machines and clockwise path rotation of AGVs

Table.5. Travel Time (in Min.) matrix for speed 20 m/min. Travel Time (in Min.) matrix for speed 50 m/min.

	L/U	M_1	M_2	M_3	M_4	M_5
L/U	0	5	10	13.25	18.25	23.25
M_1	21.25	0	5	8.25	13.25	18.25
M_2	16.5	21.5	0	3.25	8.25	13.25
M_3	13.25	18.25	23.25	0	5	10
M_4	8.25	13.25	18.25	21.5	0	5
M_5	3.25	8.25	13.25	16.5	21.5	0

	L/U	M_1	M_2	M_3	M_4	M_5
L/U	0	2	4	5.3	7.3	9.3
M_1	8.5	0	2	3.3	5.3	7.3
M_2	6.6	8.6	0	1.3	3.3	5.3
M_3	5.3	7.3	9.3	0	2	4
M_4	3.3	5.3	7.3	8.6	0	2
M_5	1.3	3.3	5.3	6.6	8.6	0

4. Factorial Analysis of AGV in manufacturing time for FMS

Table.6. Treatment Combination for Different Factor

Factor S N	Treatment Combination	Replicate			Total	
		I	II	III		
- -	Low, Low	2561	2487	2581	7629	1
- +	Low, High	2485	2423	2475	7383	b
+ -	High, Low	2430	2400	2438	7268	a
+ +	High,High	2399	2375	2396	7170	ab

Main Effect of Number of AGV [S]: The effect of N at low level of S is: [(b) - 1]/n , and the effect of N at high level of S is: [ab-(a)]/2n. So,

N = [(ab-a)+(b-1)]/2 : N= -57.33

Main Effect of Speed of AGV [S]: The effect of S at low level of N is: [(a) - 1]/n , and the effect of S at high level of N is: [ab-(b)]/2n. So,

S = [(ab-b)+(a-1)]/2n: S= -86.5

To find the combined effect of S and N as the average difference between the effect of S at the high level of N and the effect of S at the low level of N. Thus

SN = [(ab-a) – (b-1)]/2n ; SN = 24.666

The effect of N is low as comparison of effect of S and combined effect of S,N is so much low as comparison to effect of s and Effect of N so that, it is observed that speed factor must be high to improve optimum time and this factor improves the production time in optimum zone.

Considering the sums of square for S,N and SN . So, contrast is used to estimating S

Contrast S = ab + a- b- (1),

The contrast sum of squares is equal to the contrast squared divided by the number of observation in each total in the contrast times the sum of the squares of the contrast coefficients. So,

$SS_S = [ab+a-b-(1)]^2/4n$, $SS_N= [ab+b-a-(1)]^2/ 4n$, $SS_{SN}= [ab + (1) -a-b]^2/ 4n$;

So, $SS_S = 27456.33$, $SS_N = 9861.33$ $SS_{SN} =1825.33$

The total sum of square is found in the usual way, that is:

$SS_T = \Sigma\Sigma\Sigma\ Y_{ijk}^2 - Y^2_{...}/4n$, $SS_T= 47407.66$

In general SS_T has 4n-1 degrees of freedom. The error sum of squares, with (4n-1) degree of freedom is usually computed by subtraction as:

$SS_E = SS_T - SS_N - SS_S - SS_{SN}$,

$SS_E = 8264.667$

The SS_E is to be positive then the model says that the force interaction is possible with improvement of most positive treatment.

Table.7.The complete analysis of variance

Sources of Variation	Sum of squares	Degree of freedom	Mean squares	F_o
S	27456.33	1	27456.33	**26.577**
N	9861.33	1	9861.33	9.545
S,N	1825.33	1	1825.33	1.7668
Error	1033.083	8	1033.083	
Total	47407.657	11		

Now we will fit a multiple linear regression model –

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$$

Table 8. Time Data According to Combination of Factors

Observation	S	N	Time
1	20	1	2561
2	50	1	2430
3	20	2	2485
4	50	2	2399
5	20	1	2487
6	50	1	2400
7	20	2	2423
8	50	2	2375
9	20	1	2581
10	50	1	2438
11	20	2	2475
12	50	2	2396

The X matrix and Y vector are –

The X^1X matrix is –

$$\begin{bmatrix} 12 & 420 & 18 \\ 420 & 17400 & 630 \\ 18 & 630 & 30 \end{bmatrix}$$

And, X^1Y vector is –

$$\begin{bmatrix} 29450 \\ 1022140 \\ 44003 \end{bmatrix}$$

The least square estimate of β is –

$$\beta^1 = (X^1X)^{-1}.\ X^1Y$$

$$\beta^1 = \begin{bmatrix} 2651.8 \\ -3.1889 \\ -57.333 \end{bmatrix}$$

So, $Y = 2651.8-3.1889\ X_1 - 57.333\ X_2$

The relationship between speed and number of AGVs variables coaded is:

$$X_1 = \frac{S-(20+50)/2}{(50-20)/2} \ ;$$

$X_1 = (S-35)/25$

Similarly $X_2 = (N-1.5)/0.5$

So that after solving:

Y = 425468.39 – 01275 S – 114.66 N

Where the intercept is grand average of all 12 observations and regression coefficients β_1 and β_2 are one half the corresponding factor effect estimates.

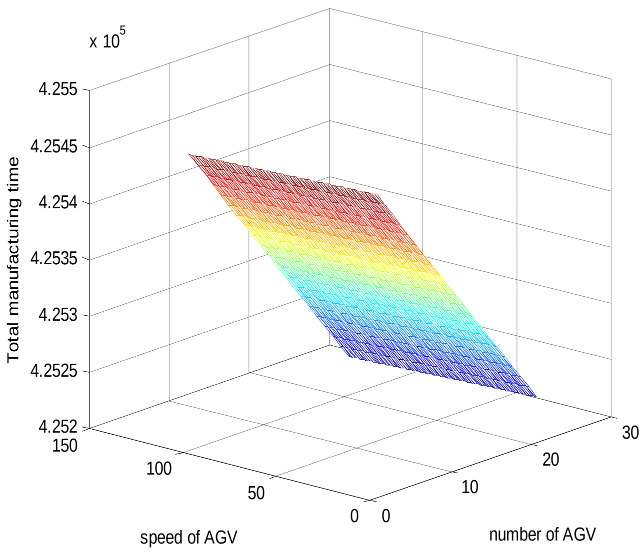

Fig.4. Regression model for Speed , Number of AGVs and Total Manufacturing Time

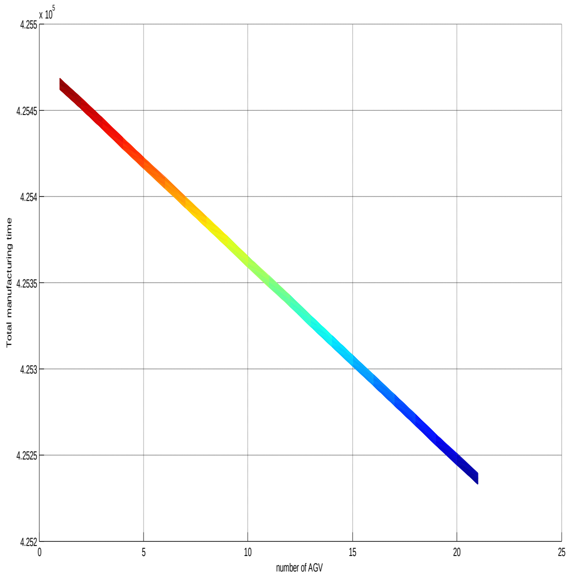

Fig.5. Relation between Total Manufacturing Time with Number of AGVs

5. RESULT AND DISCUSSION

The analysis of variance in table may be used to confirm the magnitude of their effects. From table we note that the main effects are highly significant. The S interaction is significant about 70 % level, thus there is some mild interaction between numbers of AGVs is also accountable. The effect shows that the speed is not only an important factor according to the effect of N.

Estimation of speed it is a notable factor that circular layout is also an important factor for travelling time of AGVs and in various type of layouts constant destination layout i.e. circular pays vital role to optimize the travel time. It is also considerable factor that multiple of speed pays more effect than increment of numbers of AGVs. A Regression model is established a relation between speed and number of AGVs which is beneficial to get out the value of factors with corresponding relation.

6. CONCLUSION

Measurement of speed and numbers of AGVs in FMS is quite difficult and different constraints like layout, loading/unloading time of jobs on machine is proposed. With this estimation it is clear that speed of AGVs has great impact on number of AGVs. AGVs have path tracing vehicles and that depends on the speed of AGVs which is interrelated to layout and path tracer. It is clear that in Flexible Manufacturing Systems increment of Speed of AGVs have more impact on number of AGVs, whereas it is also accountable that it is not a expensive to increase the speed as comparison to number of AGVs and second point is also considerable that with speed flexibility of FMS is not more accountable where as possible with number of AGVs.

REFRENCES

1. Y.L.Chang, R.S. Sullivian, U. Bagchi and J.R. Wilson, Experimental investigation of real time scheduling in Flexible Manufacturing Systems, Annals of operations Research 3, P.N. 355-377 (1985)
2. Andrew Kusiak, Sunderesh S. Heragu, The Facility Layout Problem, European Journal of Operations Research 29, P.N. 229-251, 1987
3. Andrew Kusiak, Parts and tool handling Systems, Modeling and Design of Flexible Manufacturing Systems, edited by Andrew Kusiak Elsevier Science Publishers B.V. Amsterdam P.N. 99-109, 1986
4. Design and Analysis of experiments, by Douglas C. Montgomery, Wiley India edition.