The ITB Journal

Volume 1 | Issue 1 Article 5

2000

AGV Controlled FMS

Fergus G. Maughan

Recommended Citation

Maughan, Fergus G. (2000) "AGV Controlled FMS," *The ITB Journal*: Vol. 1: Iss. 1, Article 5.
doi:10.21427/D7890S
Available at: https://arrow.tudublin.ie/itbj/vol1/iss1/5

AGV CONTROLLED FMS

[1]Fergus G. Maughan,

[1] School of Informatics and Engineering, ITB Blanchardstown, Dublin, Ireland.

Keywords: Automatically Guided Vehicle, Flexible Manufacturing Systems, CIM, LAN

ABSTRACT

One of the key factors that prevent the implementation of Flexible Manufacturing Systems (FMS) is the elaborate cost associated with the control software. In a FMS there is often a wide range of equipment such as personal computers Programmable Logical Controllers (PLCs), CNC Machines or robots, each of these having their own "intelligence" and library of data. Providing a means of communication between these individual controllers has traditionally been achieved using a Local Area Network (LAN). This proves more expensive when traditional manual operated machines have to be integrated into the system. The model described in this paper provides an alternative to the conventional use of a LAN in a FMS environment. In the design solution an Automatically Guided Vehicle (AGV) is used as both the materials handling unit and the communications line linking each station to the host controller. Communications between the AGV and peripheral equipment is achieved using a standard infrared data link, eliminating hard-wiring and network protocols.

A simulation model has been developed to demonstrate the feasibility of such a system, using industrial data. The software package Witness is used to develop the simulation model. The objective from developing this simulation model is to test whether an AGV is capable of meeting the demands of such a scenario. The research undertaken aims to test this by modeling an existing factory layout. Using this layout and captured machining times and part routes, from the factory database, the feasibility of such AGV controlled production system is established. The model shows that such a system is plausible in a scenario where machine times are high and the distance between machines is large.

1. INTRODUCTION

Computer Integrated Manufacturing (CIM) incorporating the flexible manufacturing concept has not yet provided the expected benefits for small to medium volume discrete parts manufacturing operations. Typically, these flexible computerised systems come in over budget and yet do not provide the promised flexibility [1].This can be directly attributed to the high cost of control software development for integrated systems. In recent years, as a result of worldwide industrial competition, there has been an increased interest in Flexible Manufacturing Systems (FMS). With a rapidly changing market there is a need for manufacturers to change their production systems from systems that are capable of producing a wide variety of products at a relative low cost to those of mass production. It is therefore necessary for production systems to change from, job shop operations, which have high flexibility at high cost, to flexible manufacturing system which also have high flexibility but at a low cost. [2]

Flexible Manufacturing Systems (FMS) are generally composed of CNC machines (Computer Numeric Control), automatic tool changing facilities and automatic materials handling units. Integrating these machines and facilities generally involves the use of complex software as a control system. Providing a means of communication between a series of these individual controllers and the host controller has traditionally been achieved using a Local Area Network (LAN). The complexity of successful integration of each work station using a LAN results in a relatively high cost system.

Traditional shop floor systems incorporate some form of control system such as, hierarchical control, centralised control, hierarchical control, or hybrid control,[1][2][3]. Due to the high cost of converting all machines to CNC control and implementing a full scale networked Flexible Manufacturing System with an expensive complex control systems it is necessary to develop a low cost control system for implementing a Flexible Manufacturing System to the shop floor. Kathryn *et al.* [4] defines an FMS as,

> *"...an integrated, computer controlled complex of automated materials handling devices and numerically controlled machine tools that can simultaneously process medium-sized volumes of a variety of parts..."* Chen *et. al.,* describes a Flexible Manufacturing Systems as, *"...a class of highly automated systems which consist of (1) numerically controlled (NC, CNC, NC) machining tools, (2) an automated materials handling system (MHS) that moves parts and sometimes tools through the system, and (3) an overall computer control network that coordinates the machine tools, the material handling, and the parts..."* [5]

However these philosophies, which describe Flexible Manufacturing Systems, neglected to include the human intervention in FMS. In order for small to medium sized Irish firms to adapt to Flexible Manufacturing Systems, stand-alone manually operated machines will have to be incorporated into the flexible manufacturing concept. This may be achieved by the use of manually operated machines which use a human link the FMS system. The operators receive their instructions from the FMS host in the form of a print out sheet or a instruction from a user interface. Each time the operator performs an operation on a batch of parts it informs the host, as to update the hosts scheduling algorithms, by placing the pallet of parts into an *out station* at the machining station. In the described system an AGV is used as the transport medium. The AGV used is a single load vehicle and acts as the sole materials transportation unit. The operator is not permitted to transport pallets manually. It is also noted that all parts are introduced into the FMS by the AGV and all parts are removed from the system by the AGV. The AGV used has been both developed and simulated at the University of Limerick for demonstration purposes in a working environment. The AGV uses reflective tape laid in a loop layout on the shop floor as a guidance system.

2. CONTROL SYSTEM ARCHITECTURE

As Wysk *et al.*[6] described, planning has been attributed to the selecting of tasks that the manufacturing system will perform, scheduling as identifying a good sequence for these planned tasks based on some performance criteria and execution as performing the scheduled tasks through the direct interfaces with the physical equipment. These specific functions will be performed by the AGV on board computer.

There are two main components in the FMS controller, each customised to support the configuration of the FMS system. These components being the, system host controller and the AGV controller. The system host controller's primary function will be to link the AGV to the CIM system. Job instructions are loaded from the stationary host-controller to the AGV on-board computer through an infra red data link. At the user interface of the host controller user information is transmitted in the form of a Manufacturing Work Order. A copy of the Manufacturing Work Order is stored on the AGVs on board computer which is updated as the batch of parts progress through the production system and also stored on the host controller for future reference.

The AGV controller contains a database of Manufacturing Work Orders with the associated CNC machine code and drawings for each individual batch. It is not necessary for the AGV controller to be aware of the capabilities if each individual machine. The AGV simply identifies the required machining station from the Manufacturing Work Order and delivers the pallet of grouped parts to the appropriate destination. The AGV identified each particular station by my means of a binary address embedded on the floor of the machine shop.

The execution system of the AGV controller as described by Maughan *et al.*,[7] consists of two levels of hierarchical control consisting of the instructor and the transporter. The instructor, which determines where a particular part must be delivered to, depending on its Manufacturing Work Order, instructs the AGV to begin transportation.

It should be remembered that each pallet of parts has a unique Manufacturing Work Order number associated to it whether the pallet carries one part or a number of parts. On completion of machining the operator placed the parts back on the pallet where the AGV treats them again as a part group.

3. OPERATING PROCEDURE

When Manufacturing Work Order files are generated they may be transferred to the AGV on board computer my either of two methods being, through the infra red data transmission link or by copying the from a diskette. The relevant CNC programs and CAD drawings are also transferred in this manner. On initial assessment of the Manufacturing Work Order and machine file data, the AGV controller can identify the following relevant manufacturing information,

1) Pending Jobs (i.e. jobs started, but put on hold)
2) Work In Progress (Jobs being worked on)
3) Status of each Machine (busy / idle)
4) Estimated finish time for the pallet or batch of parts

5) Where pending jobs need delivered to
6) Due date (Necessary if scheduling using EDD rule)

Once the AGV receives Manufacturing Work Order information it operates on a "stand alone" basis until its knowledge needs updating or editing. A schematic of the shop floor layout is shown in Figure 1.

When the AGV is switched to "run mode" a digital Manufacturing Work Order is selected from the AGV database. The criteria for selection of particular Manufacturing Work Order depends on the AGVs task allocation decision rules which may be shortest processing time (SPT), longest processing time (LPT), first come first serve (FCFS) earliest due date (EDD) etc.. The parts processed in the FMS are scheduled in real-time mode as opposed to off-line techniques. (See Chen *et al.*[5] for off-line planning and scheduling problems of Flexible Manufacturing Systems). When scheduling using real-time, decisions are made at the occurrence of a discrete event, which may be the completion of an operation, the failure of a machine or particular tool, the entry of a part group to the system etc.. The use of a real-time approach is a more suitable approach to a model that uses skilled operators under minimal supervision.

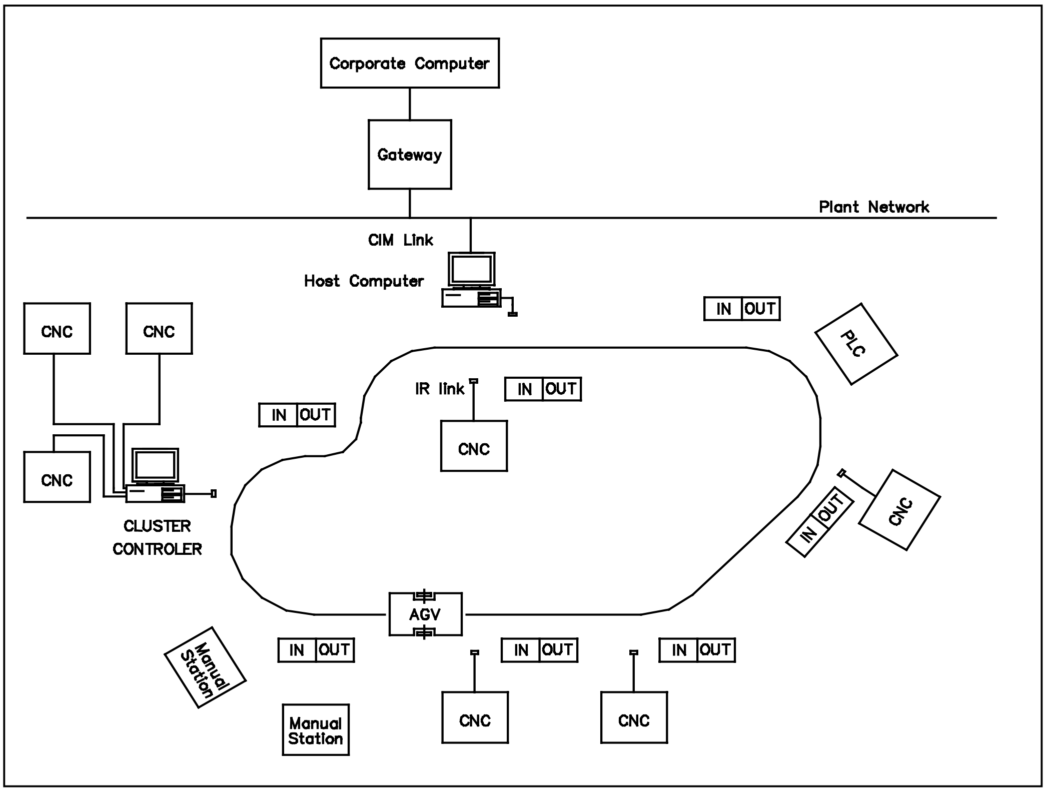

Figure 1: FMS Layout

The AGV on receiving a start instruction identifies the job contained on a pallet located at the load station of the FMS. When the job is identified the relevant Manufacturing Work Order is selected. The Manufacturing Work Order is identified by use of the bar-code on the pallet. The AGV identifies the first work station the pallet of parts is to be delivered to from the digital Manufacturing Work Order . When the pallet is delivered to the work center, the pallet is logged as being busy. The operator on completion of the work on the pallet of parts, places the pallet into the out station of the machining station. The AGV can then identify that the work has been successfully completed and re-allocate the pallet to the next required machining station.

The AGV, on identification of a pallet at the out station of a work center buffer, scans the relevant digital Manufacturing Work Order and identifies the next work station in the sequence of manufacturing operations.

As the AGV travels through the FMS, when executing a transportation function, the status of each buffer station is logged. There are four states that the AGV can identify. These being,

1. in station vacant : *allows a pallet to be assigned to the work center*
2. in station engaged : *pallet has been assigned to the work center*
3. out station vacant : *futile knowledge*
4. out station engaged : *pallet is requiring transportation and assignation to a work center*

4. Development of the Simulation model using Witness

The loading of parts/pallets into the FMS was set to be 1.75 hours (105 minutes.) between each orders release. This was achieved by generating a part release file, which released pallets into the system at the required time interval. This interval was set at 105 minutes sampling from a negative exponential distribution with a mean of 105 and a standard deviation of 10.

The initial system model comprised twenty-eight pieces of equipment distributed over eight work centres. The data represented in the tables below were taken from actual machining times retrieved from a local machine shop database [8]. The first model simulated was the representation of this machine shop using the machining times and frequencies of the five manufactured parts and also using the distances the machines are apart. The part routing and frequencies are shown in Table 6.1 below.

Table 1 Component routing and frequencies

Part No.	OP 1	OP 2	OP 3	OP 4	OP 5	OP 6	OP 7	Ops	Frequency
8S498247	1	3	4	2	5			7	0.10
8S498514	2	1	3	4	6	5		8	0.15
8S498538	2	7	4	6	4	5		6	0.50
8S498544	2	4	6	3	1	5	8	7	0.10
8S498554	5	2	6	3	4	8		6	0.15

The processing times for a particular component at a particular work centre are presented in Table 2. The expected inter-arrival time between components was 1.75 hours. A FIFO queuing discipline was assumed with no job having priority over another. The distance each machine is from its preceding machine was set between 5 and 20 meters..

Table 2: Machining times per part at each Work-Centre (Minutes)

	WORK CENTER							
Part No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
8S498247	222.0	73.0	417.0	271.0	281.0			
8S498514	222.0	73.0	208.0	271.0	292.0	445.0		
8S498538		73.0		270.0	292.0	445.0	327.0	
8S498544	222.0	73.0	417.0	271.0	281.0	445.0		
8S498554		73.0	208.0	273.0	281.0	445.0		540.0

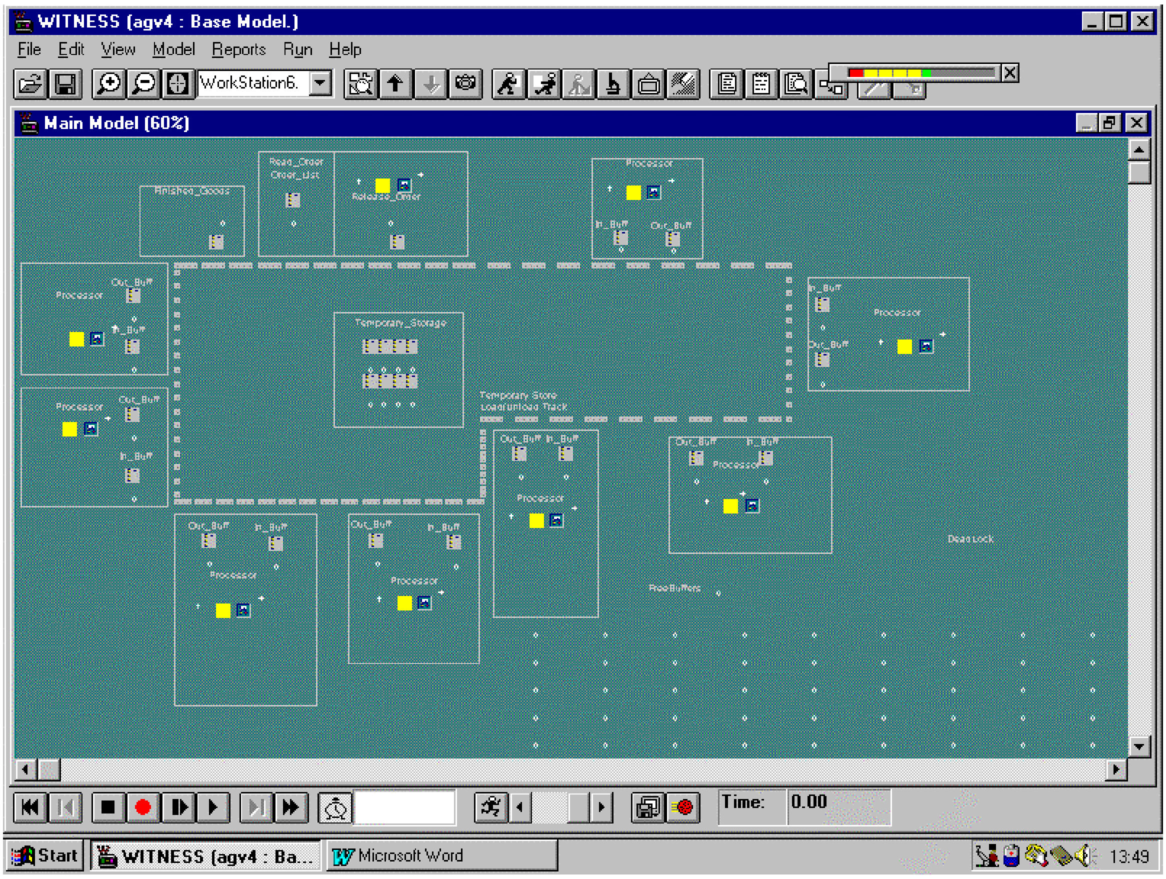

Figure 2: The modeled layout showing the temporary storage area.

Deadlock avoidance was achieved by the use of a temporary storage area. If a pallet is waiting on the *out buffer* of a work-centre and the required *in buffer* is full, the AGV moves the pallet requiring transportation to this dedicated area. Figure 2 shows the location of the temporary storage area located in the centre of the AGV track.

Each work centre has an in and out buffer which mate with the AGV during material exchange. The load time of the AGV was set to 30 seconds and the unloading time to 1 minute to accommodate any program downloads that may be requires Setup up times were modeled as a constant time per part change. That is, each time a new part type enters a work centre a setup time is associated to it prior to machining. Breakdown times were modeled from a log normal distribution with a mean time between breakdowns of 10000, with a standard deviation of 15 hours. The repair time was set to 60 minutes for each breakdown.

5. Results simulation model

It was proven from the model that using the AGV as the sole transport medium within a FMS environment could work. Table 6.4 below shows the percentage of time each work-centre and the AGV was idle, busy or blocked. The system flowed continuously without deadlocking. The model was executed 5 times using the factory data. It can be seen that there is a zero amount of backlog. This indicated that the consumption capacity of the work centres is not being exceeded by the arrival time of the production orders. Saturation occurs when there is a constant backlog of pallets queued at the release order buffer.

Table 3: Average values over five cycles

Average values over 5 cycles

	% Idle	% Busy	% Blocked
WC 1	60	35	5
WC 2	61	35	4
WC 3	31	67	2
WC 4	42.3	54	3.7
WC 5	42	54	4
WC 6	39	56	5
WC 7	46	54	0
WC 8	63	37	0

No of pallets processed:	**965**
Model run time:	**10 weeks**
Average processing time per pallet:	**920 min**
Backlog-log of orders at release order buff:	**0**

These results prove that the concept of using an AGV as the sole transport mode in an FMS is viable. The AGVs response time to demands for transportation by bidding pallets is sufficient not to cause a backlog of orders.

The main reason for success is the high machining times per pallet of parts and the relatively short distances between machines which keeps the transportation time low. The short travel time between work centres also reduces the knowledge update lag time of the AGV.

Optimisation of real life model

A screening experiment was conducted to see which factors affect the capability of the system. It was the intent of the screening experiment to identify a combination of variables where the AGV controled system deadlocks or operates in an inefficient fashion. One such combination of variables, which would cause the system to fail, would be the use of short machining times such as 10 minutes with transportation times between work centres at 2 minutes.

Using the throughput as a measure of performance is not accurate, since the average machining times for a product mix can vary significantly. For example, comparing the throughput from an experiment with average machining times set at 10 minutes against machine times of 500 minutes, would not be a accurate measure of performance. It was therefore necessary to conduct grouped experiments with the machining time fixed. This allowed throughput to be used as a performance measure.

Five variables were identified for screening as follows.

1. Travel time (load times and un-load times)
2. Machining time (Including setups)
3. Capacity of temporary storage
4. Breakdown frequency
5. Pallet arrival time

The values for throughput from Table 6.6 were analysed using SPSS software. An ANOVA was chosen for data analysis. It was concluded from the results of the ANOVA that there are two factors that are statistically significant, i.e. they have the greatest influence on the throughput. These factors are machine time and travel time. A full factorial array was developed for these variables at three levels. It was also noted that reducing the pallet arrival time significantly, below the average machining time, starved the system of product. This resulted in reduced throughput and lower machine efficiency. Increasing the pallet arrival time saturated the system, with product queuing at the release order buffer. This resulted in higher machine efficiency but at the expense of increased WIP reducing the overall average pallet throughput time.

Summary of results

Two simulation experiments were conducted. Firstly a model was developed replicating a real system which is currently operational. Real data including machining times, part routes, part arrival time and part frequency was used.

The model was executed for a run time to simulate 10 weeks production. The average processing time per pallet of parts was 920 minutes. The AGV response time to transportation function was sufficient as not to cause the system to deadlock or to create an unrecoverable backlog of parts.

The second simulation experiment involved identifying the factors in the system which if changed would contribute to the effectiveness or ineffectiveness of the system. This was achieved by running the experiment at different levels and analysing the output. It was noticed that machining time and transportation time had the greatest effect.

6. CONCLUSION

With the AGV controller operating on a “stand alone” basis with Manufacturing Work Order on board, allows greater maneuverability of the system, for example the FMS control hardware and software could be relocated in a different section of the plant to accommodate seasonal demands.

This system offers the advantage of the ability of operators to interact with the AGV without upsetting its actions. The problem of conflict between the two controllers, the AGV controller and the host computer, can be prevented by the use of *in and out buffers* at each work center. The FMS host computer could be linked to a central database for use as a Shop Floor Data Collection System while also acting as the host for the FMS, with machining times at each work station being logged by the AGV and by the host computer.

The solution described of integrating operators with the single AGV would also be similar to that of a FMS containing more than one AGV. The AGVs, communicating through a infrared data link , could be updated of the others actions.

Should it be desired to add more machines to the system, the software changes necessary are minimal. It is not necessary to shut down the system to adopt these changes of implementing extra machines. A new machine file need only be generated off line, listing the machines binary address and its machining capabilities, and copied into the host controller database. When a machine is being removed from the manufacturing system, the machine file is simply moved from the working directory of the host controller to a temporary directory to prevent the machine file being selected as a destination for future task allocation.

REFERENCES

[1] Upton, D.M., *A Flexible control structure for computer-control manufacturing systems*: Manufacturing Review Volume 5(1), pp 58-74, 1992.

[1] Smith, J.S., Joshi, S.B., A Shop Floor Control Architecture for Computer Integrated Manufacturing, *International Journal of Computer Integrated Manufacture*, (1994).

[2] Upton M.D., A Flexible Control Structure for Computer-Control Manufacturing Systems: *Manufacturing Review Volume* 5(1), (1992) pp. 58-74

[3] Askin R.G.. and Manbir S.S., A Hierarchical Model For Flexible Manufacturing System Control,. *Proceedings FAIM Conference*, University of Limerick, Ireland. (1991) pp. 934-

[4] Kathryn E. Stecke J. and Solberg J., The Optimally of Unbalanced Workloads and Machine Group Sizes for Flexible Manufacturing Systems, *Working Paper No.290 Division of research*, Graduate School of Business Administration, The University of Michigan, (1982).

[5] Chen I.J., Chung C.S., Sequential Modeling of the Planning and Scheduling Problems of Flexible Manufacturing Systems, *Journal of the Operational Research Society* (1996) 47, pp 1216-1227

[6] Wysk R.A., Smith J.S. *A formal Functional Characterisation of Shop Floor Control.* Computers in Industrial Engineering, Vol.28, No. 3, (1995), pp 631-644.

[7] Maughan, F.G. and Lewis, H.J., Architecture for Low Volume AGV Controlled FMS, *Proceedings of 7th FAIM Conference*, University of Teesside, Middlesbrough, (1997) pp 652-659.

[8] Crawford W.J., *Bias Reduction and Confidence Interval with Reductions in Stochastic Simulation Studies.* Phd. Thesis, Department of Manufacture and Operations Engineering, University of Limerick, 1997.