Fişa suspiciunii de plagiat / Sheet of plagiarism's suspicion	Indexat la: 2/06

Opera suspicionată (OS)	Opera autentică (OA)
Suspicious work	Authentic work

OS	Ghenadi A., Silav C., A method for choice of optimum strategy on tools changing for machining centers, In: Modelling and optimization in the machines building field (MOCM) 13, vol 1, 2007, pp.132-135.
OA	Savsar M., Kilic S.E., Simulation of Multi-Stage Manufacturing Systems to Evaluate Different Tool-Changing Policies, In: Journal of King Saud University. Engineering Sciences. Volume 3, No 2. (1991/1411).

Incidența minimă a suspiciunii / Minimum incidence of suspicion

p.132:13-p.134:05	p.203:15 – p.206: 06
p.133: Fig.1	p.204: Fig.1
p.134: 10 – p.134:18	p.206:13 – p.206:22
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Fişa întocmită pentru includerea suspiciunii în Indexul Operelor Plagiate în România de la www.plagiate.ro

J. King Saud Univ., Vol. 3, *Eng. Sci.* (2), pp. 203-216 (1411 A.H./1991).

MECHANICAL ENGINEERING

Simulation of Multi-Stage Manufacturing Systems to Evaluate Different Tool-Changing Policies

Mehmet Savsar and Sadik Engin Kilic
Department of Mechanical Engineering, College of Engineering, King Saud University, P.O. Box 800, Riyadh 11421, Saudi Arabia

Abstract. This paper presents a computer algorithm, which is developed to determine the effect of various tool changing policies on the productivity of a multi-stage automated manufacturing system. The computer algorithm includes an optimization and a simulation routine. An optimization routine is used to determine the optimum machining conditions, which include the optimum tool life and the machining time for each station. The results are then fed into a simulation routine which simulates the line for a period of time to determine the line output rate for each tool changing policy. The policy which results in maximum prodution rate is selected as the best policy. Computerized simulation and optimization have proved to be very effective in solving tool-change planning problems in manufacturing.

Introduction

Metal machining systems present complex problems in terms of mathematical modeling and analysis. Random tool failures on production equipment, together with scheduled tool changes, complicate the problem of selecting an appropriate tool-change policy which would result in maximum production output rate. In multi-stage production flow lines, the choice of tool-change procedures and the tool-change time intervals are particularly critical to the overall efficiency and economy of production.

Tool changes are frequently scheduled to be carried out while machine tools are out of operation. However, tool failure may occur during machining, which will then necessitate an unscheduled tool change. Furthermore, every time a tool fails, the machine has to be stopped to change the tool. Those machines which have good tools would also interrupt their production while waiting for the failed machine if there are no buffer stocks available on the line.

Because of the random nature of tool failures and the complex configurations of production systems, it is generally difficult to develop analytical models which could be used to assess the effect of various tool changing policies on the output rate of production line. Analysts have been using computer simulation to obtain meaningful solutions for real life problems without too restrictive assumptions.

Davis *et al.* [1] developed a dynamic programming algorithm for the tool-change scheduling problem in machining centers. Sheikh *et al.* [2] studied the effect of the probabilistic nature of tool life on tool replacement strategies and optimum machining conditions. Several tool-change strategies are studied for single and multiple tool systems. Okushima and Fujii [3] have used Monte Carlo Simulation to study the effect of tool change strategies on productivity of an automated line. Commare *et al.* [4] also studied the effect of various tool-change strategies on productivity and developed some general models for stochastic tool life distribution. Gupta [5] developed a computer algorithm which includes a simulation routine to evaluate the effect of various tool change policies on the output rate of a multi-stage synchronous machining line.

In all of the above models, there is one aspect in common: tool-change problem is considered either on a single machine or on a rigidly linked machining system. This paper, however, considers a multi-station automated line which could be synchronized or non-synchronized and could have intermediate buffers of finite capacity. Thus, the compound effects of tool-change policies as well as the buffer capacities are studied through a computer optimization and simulatin algorithm which is generalized to be used for other production lines. Fig. 1 shows a three-station production flow line which is considered in this study.

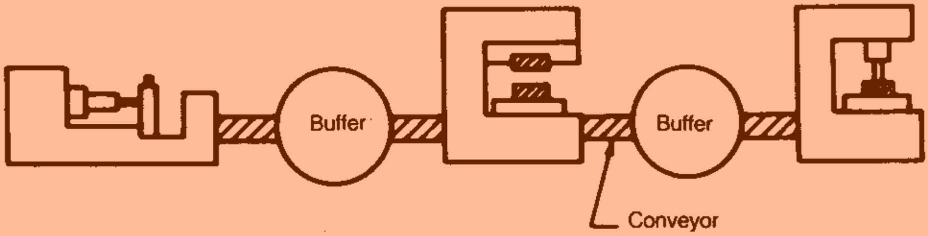

Fig. 1. Production flow line considered for the case example

Model Description

The computer algorithm developed in this study consists of two routines. The optimum tool life T and the optimum machining time are determined by the optimization routine for each station on the line. Tool life is then assumed to follow a specified distribution, with mean $\bar{T}$ and standard deviation of $0.12\bar{T}$. The assumption of the standard deviation being $0.12\bar{T}$ is arbitrary and only based on the author's intuition that it can reasonably approximate a real case. However, if there becomes available a real statistical tool life data, those should replace the assumed ones. These values and other line parameters are then fed into a simulation routine to determine the production output rate for a certain tool changing policy. Presently, the simulation routine incorporates the following tool-change policies.

Unscheduled Tool Change

A tool is changed only when it fails. Tool operation time before a failure is obtained by generating a random variate from the appropriate distribution that describes the tool life. Tool change time could be assumed as either a constant value or a random variable with a suitable probability distribution.

Scheduled Tool-Change With Equal Tool Reliabilities in All Stations

An appropriate tool-change time is selected for each station so that all stations have the same reliability. Tools are then changed at the time when they fail or when they reach the specified time, whichever comes first.

Scheduled Tool-Change With Equal Tool-Change Time for All Stations (Unequal Reliabilities)

Tools are scheduled to be changed after a fixed time in all stations on the line. Thus, the tool-change time intervals are the same in all stations with different tool reliabilities. If the stations are not synchronized, the number of parts produced may differ. Tool reliabilities will be different since each station will have a different mean tool life and standard deviation. During the simulation process, tools are changed again either when they fail, or when their cutting time reaches the specified time, whichever comes first.

Tool reliability and the corresponding cutting time are calculated as follows:

Let $\bar{T}$ = average tool life (as obtained from optimization)
$\sigma = 0.12\,\bar{T}$, standard deviation of tool life.

Then, for normal distribution,

$$Z = \frac{T - \bar{T}}{\sigma} \qquad \text{where } Z = \text{standard normal random variate}$$

Tool reliability at time T is the probability that the tool does not fail by time T or the probability that the tool life is greater than T, that is,

$$\Pr(\text{Tool life} > T) = 1 - \Pr(\text{Tool life} < T)$$

$$= 1 - \Pr\left(Z < \frac{T - \bar{T}}{\sigma}\right) = \text{Tool Reliability}$$

If a 90% reliability is specified, then the corresponding Z would be 1.282 from the standard normal distribution table. Thus, the tool life which assures 90% reliability can be determined from $T = Z\sigma + \bar{T}$, since Z, $\bar{T}$ and σ are known.

For the third tool change policy, T would be fixed and the corresponding reliabilities would be calculated.

In order to determine the best tool-change policy, which corresponds to the maximum production rate, the following algorithm is implemented on the computer:

1) The algorithm first reads the input data which include several parameters related to the machines and the tools for each station on the line.

2) An optimization routine is used to determine the optimum cutting conditions for each machining station which may be a turning, a milling, or a drilling center.

3) Step 2 is repeated for all stations on the production line.

4) The production line is simulated under the specified tool-change policy for a specified simulation time, *i.e.* 8 hours, to determine the line production rate.

5) Step 4 is repeated for all the tool-change policies under consideration.

6) The best policy with respect to the line production rate is then seleted.

Fig. 2 shows the general computer flow chart for this algorithm.

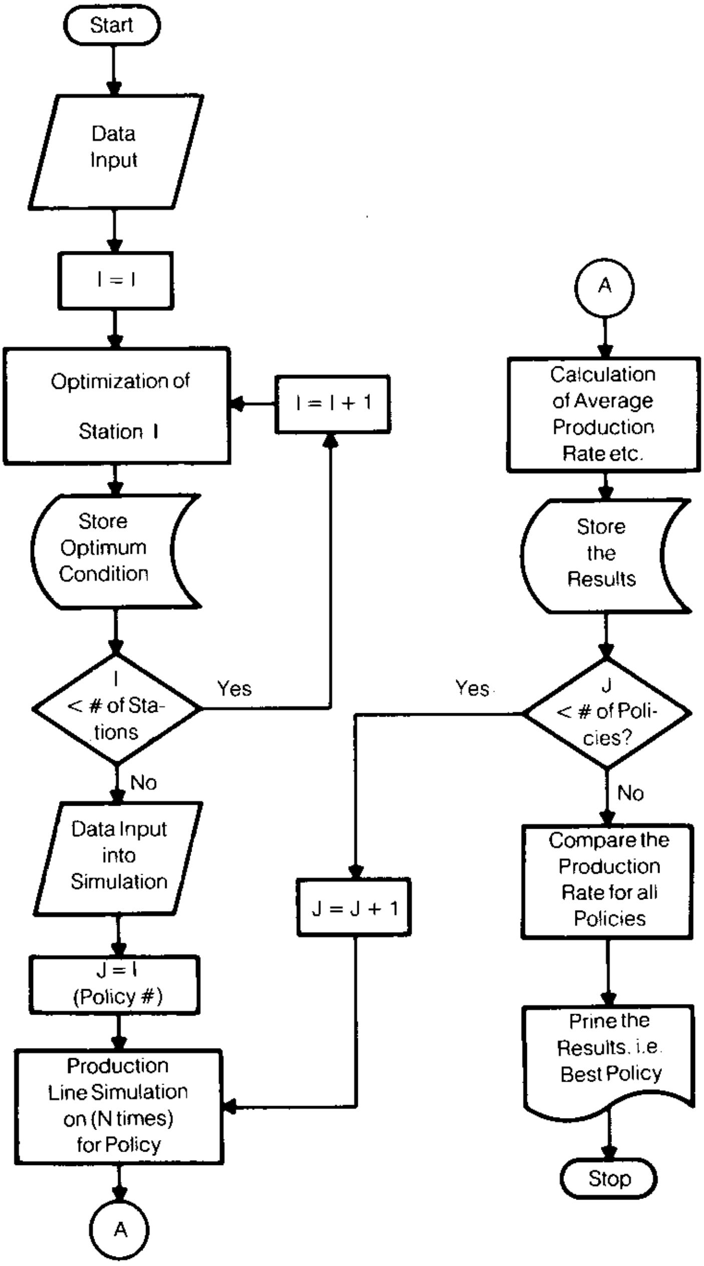

Fig. 2. Computer flow chart for the best tool-change policy selection algorithm

The optimization routine, included in the algorithm, is capable of determining optimum machining conditions for turning, drilling, and milling operations. For optimizing the turning operations, geometric programming technique is used [6]; for drilling, unidirectional search technique is employed [7]; and for milling operations, classical gradient type optimization technique is utilized. Selecting a different optimization method for each type of operation is simply due to the availability of those routines for the respective operations only. In a future study however, the optimization routines will be unified and the user will have the option of choosing any of those optimization methods for an operation.

The simulation routine is capable of simulating a production flow line with m machines and intermediate buffers. It calculates iteratively, the total time that each part spends on each station, the time instant at which each part is completed on each station, and the time instant at which each part leaves each station. This iterative procedure is repeated for the duration of simulation specified by the user. The number of simulation runs can be as many as desired [8], [9].

The computer programs are written in BASIC language and implemented on a Microcomputer which provides easy access to all engineers.

The general inputs and outputs of the computer algorithm are outlined below. The inputs are entered in an interactive query-response mode. The user does not need to have computer programming experience.

Inputs for Optimization

a) Machine tool specifications
b) Tool specifications
c) Workpiece specifications
d) Cost and time parameters

Outputs from Optimization

a) Optimum tool life
b) Optimum cutting time
c) Optimum speed and feed
d) Machine time, *i.e.* the total time each part spends on each station, excluding tool-change times
e) Minimum unit production cost

Inputs for Simulation

a) Number of stations on the line
b) Cutting time for each station
c) Machine time for each station
d) Tool life distributions and parameters
e) Tool-change time
f) Buffer stock capacities
g) Simulation period and number of runs

Outputs of Simulation

a) Line output rate (parts/hour)
b) Machine/Station utilization

Case Example

The production flow line selected as a case study consists of three stations: a turning station, a milling station, and a drilling station. Fig. 1 shows the selected line with intermediate buffers. Fig. 3 shows the part assumed to be produced on this production flow line. Machine and workpiece related parameters are listed in the Appendix.

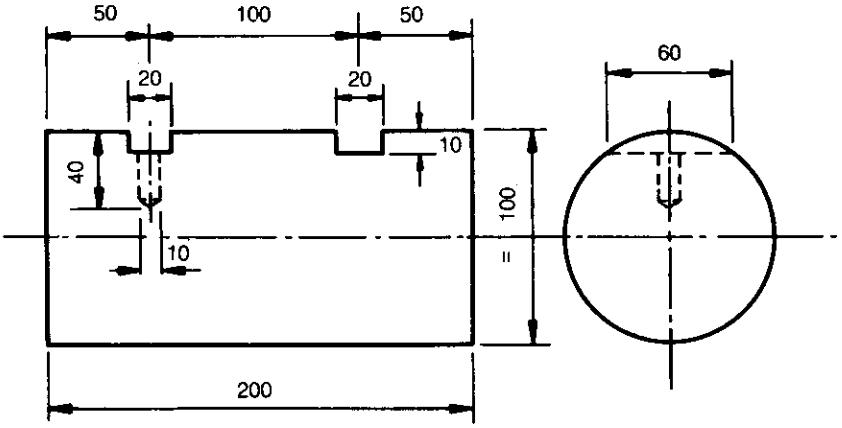

Fig. 3. The part considered in the case example

After entering the specified data into the computer algorithm, the optimization routine calculates optimum parameters, such as the cutting time, machine time, feed, speed, and tool life. Tool-change time is assumed to be constant for this example. Table 1 shows the optimized parameters for the selected part.

Table 1. Optimum parameters as obtained from the optimization routine (case 1)

Production flow line stations	Cutting time (min)	Machine time (min)	Tool life (min)	Speed r.p.m.	Feed mm/rev	Tool-change time (min)
Turning	2.29	3.0	92	436	0.2	0.5
Milling	0.76	2.9	88	305	0.52	8.0
Drilling	0.12	2.8	45	982	0.346	0.5

Tool life is assumed to be normally distributed with mean $\bar{T}$ (optimum tool life) and standard deviation of 0.12 $\bar{T}$. All the three tool-change policies, as described above, are simulated. For the scheduled tool-change policy with equal reliabilities, three reliability levels: 80%, 90%, and 95%, are considered. For the scheduled tool-change policy with fixed tool-change time interval for all stations, two time intervals are considered: T = 45 min and T = 80 min. In order to determine the combined effects of the buffer capacities and the tool-change policies on the production output rate, simulation was carried out at different buffer capacities for each policy. The two buffers were assigned equal capacities for this example. Table 2 shows the results of simulation. As it can be seen from this table, production rate increases as the buffer capacities are increased for all the policies. However, policy II, which is the scheduled tool-change with equal reliabilities for all stations, gives the maximum production rate. For this particular example, 80% reliability resulted in maximum production rate. Fig. 4 shows these results graphically.

Table 2. Production rates (parts/hr) for different tool-change policies (case 1)

Buffer capacity (parts)	Policy I	Policy II Sch., eq. rel			Policy III Sch., diff. rel.	
	unscheduled	80%	90%	95%	T= 45 min	T= 80 min
0	16.67	17.70	17.65	17.68	16.33	16.92
1	17.10	18.25	18.16	18.01	16.72	17.31
2	17.49	18.38	18.31	18.17	16.82	17.33
3	17.49	18.38	18.31	18.17	16.82	17.41
4	17.49	18.38	18.31	18.17	16.82	17.41
5	17.49	18.38	18.31	18.17	16.82	17.41

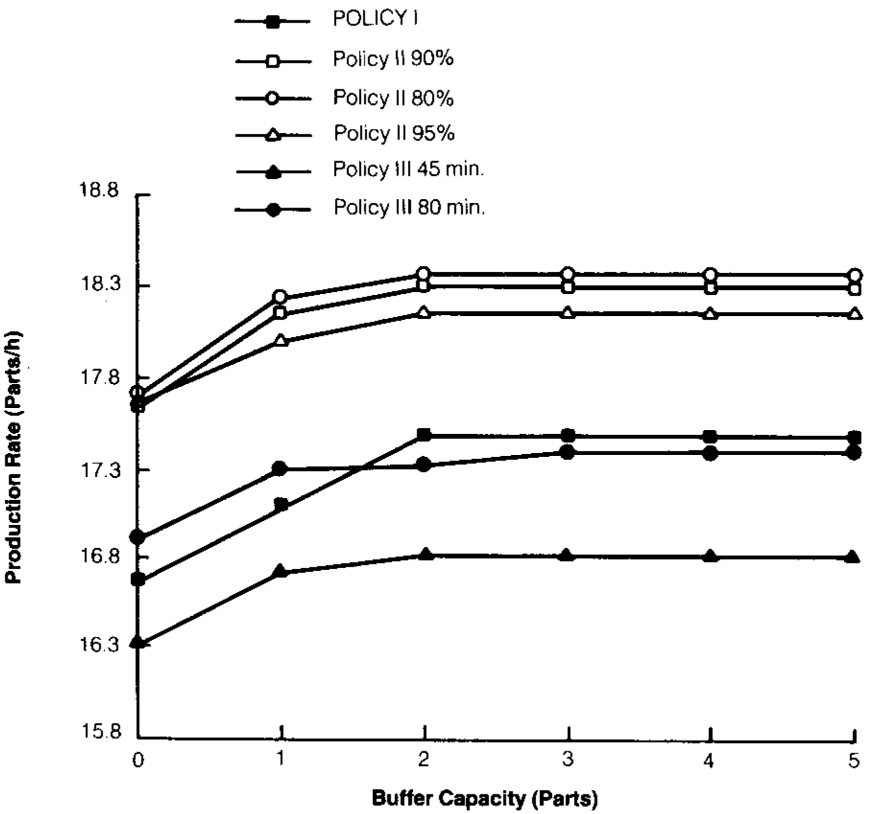

Fig. 4. Effect of buffer capacity on the production rate for the conditions given in Table 1 (case 1)

In order to further assess the effect of the tool-change policies and the buffer capacities on the production rate, machining time and tool life were altered for each station by changing the feed and the speed at that station. As the machining time increases, so does the tool life; but the production rate decreases. Fig. 5 shows the results when the machining time is reduced as given in Table 3 and Fig. 6 shows the results when the machining time is increased as given in Table 4. As it is seen from these figures, policy II gives the best results in terms of production rate for all cases considered. The production rate tends to become steady after the buffer capacity is increased to two and more units in all cases. This is mainly due to the fact that the tool life has been assumed to follow a normal distribution with a relatively small standard deviation. In the case of an exponential distribution with high variability, which has not been shown here, buffer capacity had larger effect on the production rate.

Table 3. Optimum parameters as obtained from the optimization routine (case 2)

Production flow line	Cutting time (min)	Machine time (min)	Tool life (min)	Speed r.p.m.	Feed mm/rev
Turning	1.14	2.1	64.5	547	0.32
Milling	0.40	2.0	65.0	410	0.72
Drilling	0.08	1.9	34.2	1145	0.43

Table 4. Optimum parameters as obtained from the optimization routine (case 3)

Production flow line	Cutting time (min)	Machine time (min)	Tool life (min)	Speed Feed r.p.m.	mm/rev
Turning	3.74	4.1	125.8	356	0.15
Milling	3.20	3.9	127.0	117.3	0.32
Drilling	0.35	3.7	66.6	491	0.23

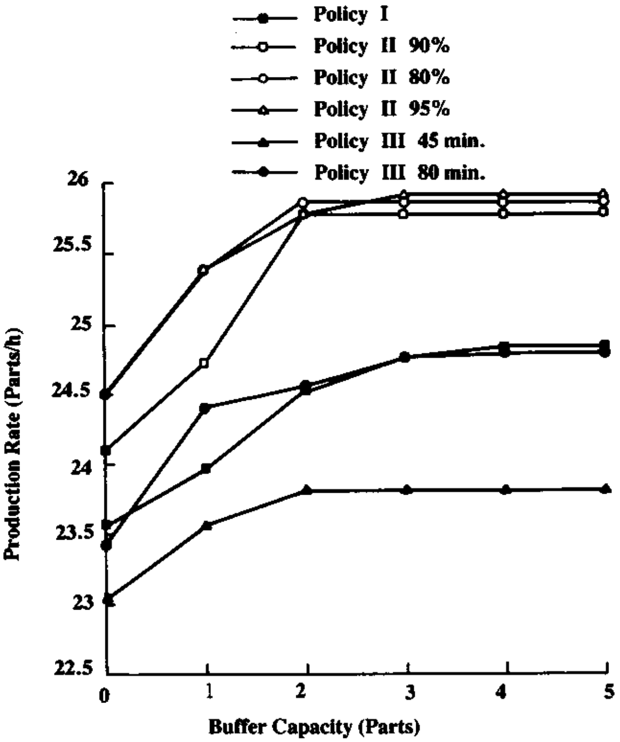

Fig. 5. Effect of buffer capacity on the production rate for the conditions given in Table 3 (case 2)

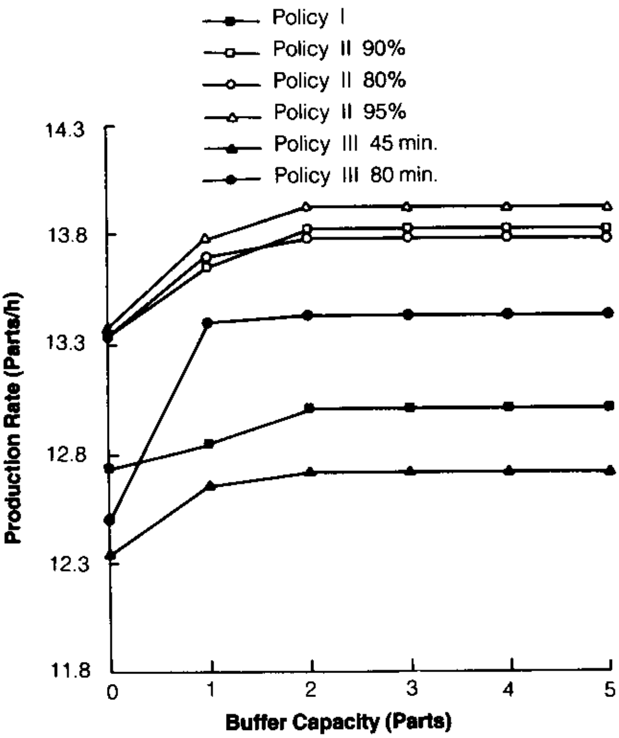

Fig. 6. Effect of buffer capacity on the production rate for the conditions given in Table 4 (case 3)

Conclusion

This paper presents a computer algorithm that has proved to be very useful in determining the best tool-change policy for a production flow line. Past experience has shown that this type of problems can not be solved analytically. Therefore, computerized algorithms, such as the one given in this paper, are required. The authors anticipate that this algorithm could be further expanded to include several other tool-change policies and the possibility of having more than one tool on each machine. Since the computer algorithm presented here is coded in BASIC language and implmented on a microcomputer, it provides easy access to all engineers. The results of this paper should be useful to production engineers and operation managers who are concerned with productivity.

Appendix

Process data for the case example

Process parameters	Process data		
	Turning	Milling	Drilling
Workpiece material	SAE 1040	Carbon steel	140 BHN
Tool material	HSS		
Tool diameter (mm)	–	150	10
No. of teeth on tool	–	20	2
Length of tool (mm)	–	20	100
Length of cut (mm)	200	60	40
Initial work dia. (mm)	100	–	–
Depth of cut (mm)	2.5	2	–
Width of cut (mm)	–	20	–
Motor power (kW)	7.5	4.5	3.7
Spindle speed range (rpm)	9–900	–	65–1200
Feed range	<2.24 mm/rev	<760 mm/min	<1.2 mm/rev
Cost of labor and overheads (SR/min)	5		
Tool changing time (min)	0.5	8	0.5
Cost of tool/tool change (SR)	1.5	5	2

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محاكاة نظم الإنتاج متعددة المراحل لحساب السياسات المختلفة لتغيـر إدارات القطع

محمد سافسار و صادق انجن كلك
قسم الهندسة الميكانيكية، كلية الهندسة، جامعة الملك سعود، ص.ب ٨٠٠
الرياض ١١٤٢١، المملكة العربية السعودية

ملخص البحث. تتضمن هذه الورقة نموذج لاستخدام الحاسب الآلي استنبط لدراسة تأثير استراتيجيات تغيير أدوات القطع على أداء نظام تصنيع آلي ذي مراحل متعددة. يشتمل النموذج على برنامجين أحدهما لتحديد القيم المثلى والآخر للمحاكاة يقوم برنامج تعيين القيم المثلى بتحديد أحوال القطع المثلى مثل عمر أداة القطع وزمن القطع لكل محطة.

يتم إدخال هذه النتائج إلى برنامج المحاكاة والذي يقوم بمحاكاة خط الإنتاج لفترة محددة لحساب معدّلات الإنتاج لكل استراتيجية على حده، ومن ثم يتم اختيار الاستراتيجية ذات أكبر معدّل إنتاج. أثبتت هذه الطريقة جدواها لحل مشكلات التخطيط لتغيير أدوات القطع في الصناعة.