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| 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). |

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# A METHOD FOR CHOICE OF OPTIMUM STRATEGY ON TOOLS CHANGING FOR MACHINING CENTERS

GHENADI ADRIAN, SILAV CONSTANTIN
University of Bacau

**Issue:** MOCM, Number 13, Volume I

**Section:** Issue No. 13 - Volume I (2007)

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**Code [ID]:** MOCM200713V01S01A0025 [0001462]

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# MODELLING AND OPTIMIZATION IN THE MACHINES BUILDING FIELD

**Volume 1** **MOCM – 13**

**2007**

# A METHOD FOR CHOICE OF OPTIMUM STRATEGY ON TOOLS CHANGING FOR MACHINING CENTERS

**GHENADI ADRIAN, SILAV CONSTANTIN**

*Universitatea Bacău, Facultatea de Inginerie*

**Abstract:** 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 or on each machine. The results of this paper should be useful to production engineers and operation managers who are concerned with productivity.

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## 1. INTRODUCTION

Metal machining systems present complex problems in terms of mathematical modelling and analysis. Random tool failures on production equipment, together with scheduled tool changes, complicate 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 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 asses the effect of various tool changing policies on the output rate of production line. Analysts have been using computer simulation to obtain meaning fl solutions for real life problems without too restrictive assumptions.

Davis developed a dynamic programming algorithm for the tool-change scheduling problem in machining centers Sheikh 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 Fuji have used Monte Carlo Simulation to study the effect of tool change strategies on productivity of an automated line. Commare also studied the effect for various tool-change strategies on productivity and developed some general models for stochastic tool life distribution. Gupta developed a computer algorithm which includes a simulation routine to evaluate the effect of various tool change policies on the output rate of a multistage 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 machining system. This paper, however, considers a multi-station automated line which

could be synchronised or non-synchronized and could have intermediate buffers of infinite capacity. Thus, the compound effects of tool-change policies as well as the buffer capacities are studied through a computer optimisation and simulation algorithm which is generalised to be used for other production lines. Fig 1 shows a three-station production flow line which is considered in this study.

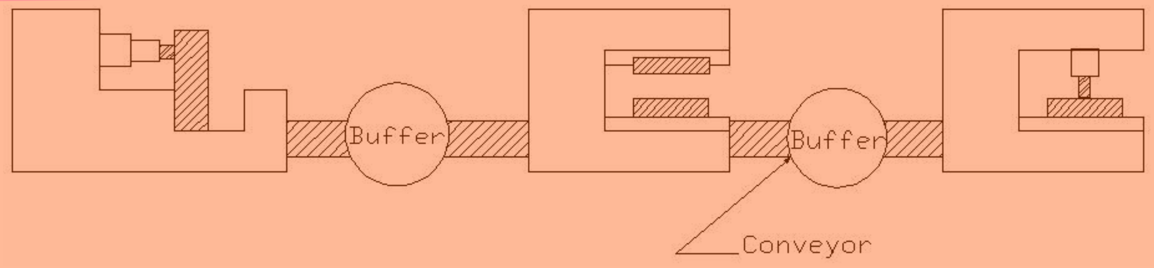


Fig.1. Production flow line

## 2. 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 optimisation routine for each station on the line. Tool life is then assumed to follow a specified distribution, with mean T and standard deviation of 0.I2T. The assumption of the standard deviation being 0.12T 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 stimulation routine incorporates the following tool-change policies.

### 2.1. Unscheduled Tool Change

A tool is changed only when it fails. Tool operation time before a failure is obtained by generating a random variate form 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.

### 2.2. Scheduled Tool-Change with equal tool reliability in all stations

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

### 2.3. Scheduled Tool-Change with equal tool-change time for all stations

Tools are scheduled to be changed after a fixed time in all stations on the line. Thus, the tool-change time interval is the same in all stations with different tool reliabilities. If the stations are not synchronized, the number of parts produced may differ. Tool reliability will be different since each station will have a different mean tool life and standard deviation. During the simulation process, loot 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 T= average tool life (as obtained from optimisation)
s=0.12T, standard deviation of tool life.

$$Z = \frac{T - \overline{T}}{\sigma} \qquad (1)$$

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

Pr (Tool life>T) =1 – Pr ( Tool life < T)

$$= 1 - \Pr\left(Z < \frac{T - \overline{T}}{\sigma}\right) = \text{Tool Reliability} \qquad (2.)$$

If a 90% reliability is specified, then the corresponding reliability would be calculated.

In order to determine the best tool-change policy, which correspond to the maximum production rate, the following algorithm is implemented on the related to the machines and the tools for each station on the line.

An optimization routine is used to determine the optimum cutting computer:

1. The algorithm first read the input conditions for each machining station which may be a turning, a milling, data which include several parameters or a drilling center
2. Step 2 is repeated for all stations on the production line.
3. 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.
4. Step 4 is repeated for all the tool-change policies under considerations.
5. The best policy whit respect to line production rate is then selected.

The optimization routine, included in the algorithm, is capable of determining minimum machining conditions for turning, drilling, and milling operations. For optimizing the turning operations, geometric programming technique is used; for drilling, unidirectional search technique is employed; and for milling operations, classical gradient type optimization technique is utilized. Selecting a different optimization method for each type of operations 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 machines and intermediate buffers. It calculates iteratively, the total time that each part spends on each station, 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.

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 form 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
Input for simulation
a) Number of stations on the line
b) Cutting time for each station
c) Machine time for each station
d) Tool life distribution and parameters
e) Tool-change time
f) Buffer stock capacities
g) Simulation period and number of runs
Outputs of Simulation
a) Line output rare (parts/hour)
b) Machine/Station utilization

## 3. CONCLUSIONS

This paper presents a computer algorithm, which is developed to determine the effect of various tool changing polices on the productivity of a multistage automated manufacturing system. An optimisation 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 simulated the line for a period of time to determine the line output rate for each tool changing policy.

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