OPTIMAL STOPPING PROBLEM IN MACHINE MAINTENANCE DECISION MAKING TIME

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บทคัดย่อ

การศึกษานี้ได้ทำการศึกษาช่วงเวลา
สุดท้ายก่อนที่จะทำการซ่อมบำรุงเครื่องจักรให้
เหมาะสมที่สุด เนื่องจากเวลาที่ใช้ในการ
เปลี่ยนแปลงส่วนของเครื่องจักร ยังไม่สามารถ
อธิบายได้อย่างถูกต้องว่า เมื่อใดควรทำการ
เปลี่ยนแปลงในเรื่องต้นทุนการผลิต แบบจำลอง
คณิตศาสตร์ที่ทำการทดสอบสร้างขึ้นมานั้น
สามารถแก้ไขปัญหานี้ได้ โดยอาศัยแนวความ
คิดในเรื่องช่วงเวลาที่เหมาะสมที่สุด ในการ
หยุดกิจกรรมหนึ่งใด เพื่อไปทำกิจกรรมอื่นอีก
ซึ่งเรียกว่า "Optimal Stopping Problem"

Abstract

This study studied the Optimal Stopping Time before maintenance. Since the time which was used to change the part of machine can not explain appropriately when is the correct time to change it. Sometime the machine part was broken after the changing was carried out. Sometime the part of machine was changed so quickly, it means that the cost for this was very high. This model was made to solve this problem, using the idea of the optimal time to stop one activity to start another activity. This

performance is called Optimal Sopping Problem.

Key words : Optimal Stopping Problem, Optimal Stopping Time, Maintenance

Introduction

Maintenance is a necessary function required in factory. Machines must be maintained before it breaks down. If the machine breaks down, there will be not only cost for changing some part (or all parts of that machine), but also there will be many kinds of cost such as; –cost for lacking production, labor cost for waiting time of other workers, etc. But the most important thing is safety. In factory, there are plenty of accidents that happened from machine damage. Many workers lose some part of their bodies due to damage machine. Nowadays, the time planned for maintaining the machine has been done by every factory. Maintenance time is prepared roughly. But for the appropriate time, there is no factory which has worked it before. (For the example, the maintenance time is once a year. But we cannot know that time is correct or not because some parts of machine will be damaged after or before that time.) Optimal Stopping Problem is the

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method that concerns the time before the final time that can help in decision making. For example, Optimal Stopping Problem is used in hotel searching for seeking the cheapest one, gasoline station for filling the automobile tank before the gasoline will finish, the final time of house selling for the highest price which it can be. For the nature of the Optimal Stopping Problem, then it should be applied for the machine maintenance method.

It will be used to find the final day of machine maintenance before it breaks down. Because if the machine is maintenance too early before the machine breaks down, it will not so good. But if the machine breaks down, it will make a big problem which causes high cost paying and no safety.

The purpose of this study is to find the maintenance modeling which can tell what is the optimal stopping time that factory will stop the machine and

maintain the machine. This modeling must explain about :

a) Time to stop the machine.

b) The benefit to be gained when using this model comparing to the condition which has no model or uses another model.

Maintenance Control Systems

Benjamin shows that heart of sound engineering maintenance is the control system[1]. This control system must clearly identify what work is to be done, what materials are needed, when the work should be done, how long it should take, what skills are needed to perform the work, and what special tools are needed. The system should permit regular re-maintenance and quality of maintenance work is assured. Finally, the system should capitalize on the work accomplished by making improvements.
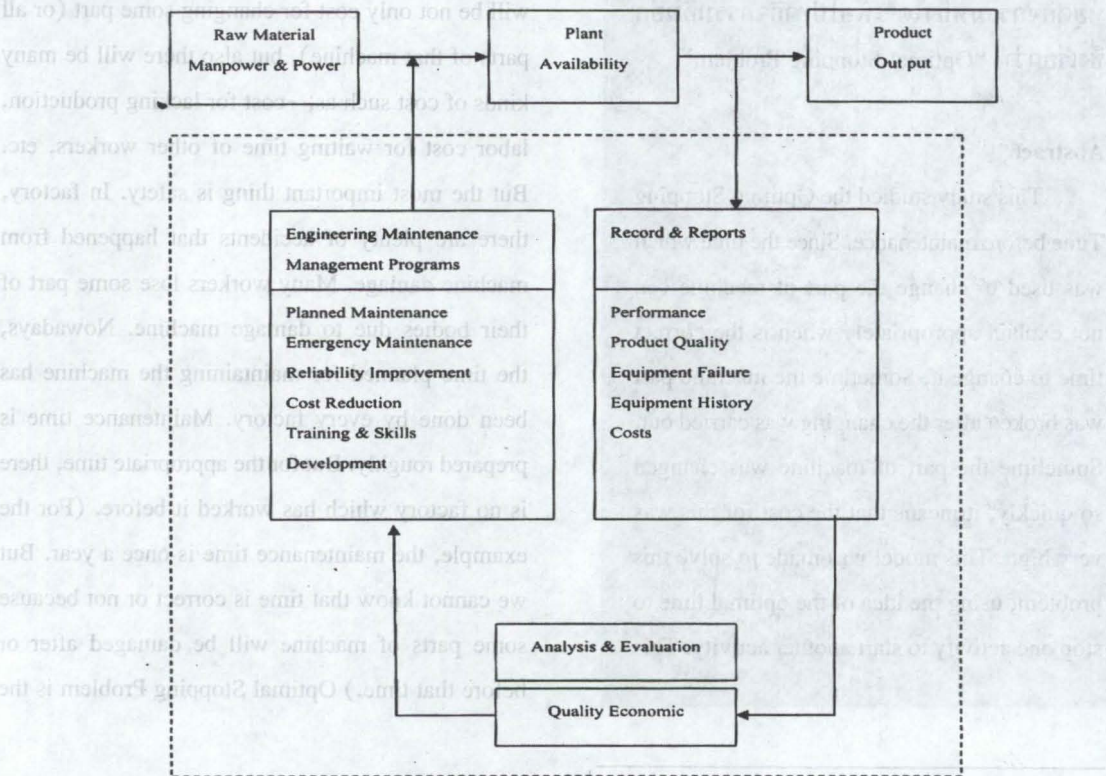

Figure 1 Activities included ina sound maintenance control system.

Figure 1 illustrates schematically what is embraced in a maintenance control system. This is illustrated by those programs, records, reports and evaluations that are contained within the dotted square. The various programs that facilitate plant availability include preventive or planned maintenance, emergency maintenance, reliability improvement, cost reduction, and training. Records and reports that need to occur as production takes place include maintenance performance, product quality, equipment history, and costs. There data permit an analysis and evaluation so that the various engineering maintenance management programs can be improved, thus allowing great plant availability.

craftsmen who do the actual work. Furthermore, methods engineering as undertaken by industrial engineering will continue to make improvements in both how maintenance work shall be accomplished and the materials utilized.

The theory of manufacturing progress function, sometimes referred to as the learning curve, proposes that as the total quantity of similar or identical work doubles, the time per unit declines at some constant percentage. For example, if it is expected that an 85% rate of improvement will be experienced, then as production doubles the average time per unit will decline fifteen percent.

Table 1

Cumulative Maintenance Of Same or Similar Work	Cumulative Average Hours Per Unit of Maintenance Work	Ratio to Previous Cumulative Average
1	100	-
2	85	85
4	72.25	85
8	61.41	85
16	52.20	85

Table 1 illustrates the decline in the cumulative average hours per unit of production with successive doubling of the maintenance quality where an 85% rate of improvement exists.

When linear graph paper is used, the manufacturing progress function is a hyperbola of the form ; $y^x = kx^n$

The Maintenance Progress Function

Since learning is time dependent, we can expect the planning function of maintenance work to become more and more efficient as well as the

Where :

Y^x = Cumulative average value of x units of maintenance work

k = time to perform the first unit of maintenance work

x = number of unit produced

n = exponent representing the slope

Table 2 Slope Values for Representative Manufacturing Progress Functions

Manufacturing Progress Function Percentage	Slope
70	0.514
75	0.415
80	0.322
90	0.152
95	0.074

By definition, the manufacturing progress function in percent is then equal to :

$$\frac{k(2x)^n}{k(x)^n} = 2^n$$

And taking the log of both sides : n = log of manufacturing progress/log2. For 85% manufacturing progress, n = log of 0.85/log of 2 = -0.2345.

In Table 2, the slopes of common manufacturing progress percentages are provided.

When working with the man hours required to perform a specific repair or overhaul, we are dealing with the "unit manufacturing progress function" which refers to the hours required to repair a specific unit. The log plot of the cumulative average is asymptotically parallel to the log plot of the unit curve. The cumulative average line is straight, while the individual line curves downward from unit one until it becomes parallel to the cumulative average line.

To plot the unit times versus the quantity, 2 points may be calculated and the plotting made on log-log paper. To calculate the unit time value of the selected points, multiply the cumulative average time of these points by a conversion factor. The conversion factor used for making the unit plot is 1+n. This is obtained as follows :

$Y^x = kx^n$ = cumulative mean for x planes.

$T = xy_x = kn^{n+1}$ = Total time for x planes.

Since the time for each individual plane is a function of x, $f(x)$ = time for each plane.

$$T = xy_x = \int_0^x f(x)dx = kx^{n+1}$$

In this way it is possible to estimate the time it should take for each repair of like facilities under a· multiple repair or overhaul situation once we measure or estimate the time for the first repair and know what manufacturing progress function prevails.

Result of Study and Discussion

5.1 Modeling of Optimal Stopping Problem in Machine Decision Making time

This study will use 3 main topic theories to make a new model. There are

a) Optimal Equation

b) Maintenance Model

c) Modeling of fatigue crack damage for real-time applications

5.2 Optimal Equation

Ikuta says that $u_t(w)$ represent the maximum expected present discounted reward starting from time t with a current offer w[z]. Then, clearly

$$u_o(w) = w \qquad (1)$$
$$u_t(w) = \max\{w, Ut\} \geq w, \quad t \geq 1, \qquad (2)$$

Where w and u_t are, respectively, the reward from stopping the search and the maximum expected present discounted reward from continuing the search by using the optimal stopping rule over the remaining planning horizon, expressed as

$$U_t = \beta \int_0^\infty u_{t-1}(\xi)\,dF(\xi) - c, \quad t \geq 1, \qquad (3)$$

Where ξ is an offer that will be obtained at the next point in time, i.e., time t−1. Then clearly we have

$$U_1 = \alpha \qquad (4)$$

Here, note that, if letting $U_0 = 0$, we can define Eq.(3) even for t = 0. Then we can express Eq.(3) as follows.

$$U_t = K(U_{t+1}) - U_{t-1'} \qquad t \geq 1 \qquad (5)$$

$$K(x) = \beta \int_0^\infty \max\{x, w\}\,dF(w) - x - c. \qquad (6)$$

Robert shows that

$$SC = \frac{PL}{\mu + z\sigma}(C_s + M) \qquad (7)$$

S = annual cost scheduled maintenance

P = number of parts change

L = number of hours required per machine per year

X = Life of machine

CS = cost of scheduled maintenance per unit

M = cost of part of machine, initially

$Z = \dfrac{\mu - R}{\sigma}$, Z value used to determine the probability of machine damage and requiring replacement before scheduled replacement

R = time between scheduled replacements

5.4 Modeling of fatigue crack damage for real-time applications

Asok[11] shows that [3]

$$du_c(t) = \widetilde{C}(\Delta K_{eff})^{\widetilde{m}}\,dt;$$
$$\text{given } \mu_c(t_0) = \mu_{c0} > 0 \text{ and } t > t_{o'} \qquad (8)$$
$$\Delta K_{eff} = (S_{max} - S_0)\sqrt{\pi\mu_c F}, \qquad (9)$$

5.5 Analysis of problem

Lemma 1

From Eq.(8) $\quad d\mu_c(t) = \widetilde{C}\left(\ddot{A}\hat{E}_{eff}\right)^{\widetilde{m}} dt;$

$$\int d\mu_c(t) = \int \widetilde{C}\left(\ddot{A}\hat{E}_{eff}\right)^{\widetilde{m}} dt;$$

$\widetilde{C}|$ and $\left(\ddot{A}\hat{E}_{eff}\right)^{\widetilde{m}}$ are constant variables

$$\mu_c(t) = \widetilde{C}\left(\Delta K_{eff}\right)^{\widetilde{m}} \qquad (10)$$

and

From Eq.(9) $\quad \Delta K_{eff} = (S_{max} - S_o)\sqrt{\rho\mu_c F}$

Then

$$\mu_c(t) = \widetilde{C}\left[(S_{max} - S_0)\sqrt{\pi\mu_c F}\right] \qquad (11)$$

Lemma 2

From Eq.(7) $\quad SC = \dfrac{PL}{\mu + z\sigma}\left(C_s + M\right)$

Because $Z = \dfrac{\mu - R}{\sigma}; \quad SC = \dfrac{PL}{\mu + \left(\dfrac{\mu - R}{\sigma}\right)}\left(C_s + M\right)$

$$SC = \frac{PL}{2\mu - R}\left(C_s + M\right)$$

$$2\mu R = \frac{PL\left(C_s + M\right)}{SC}$$

$$R = 2\mu - \frac{PL\left(C_s + M\right)}{SC}$$

Lemma 3

Because we would like to change parts of machine when it nearly broken. Then time that changes machine part−fatigue crack damage time = $\Delta t \to 0$, Then $\mu_c t = R$

$$\widetilde{C}\left[(S_{max} - S_0)\sqrt{\pi\mu_c F}\right]^{\widetilde{m}} = 2\mu - \frac{PL\left(C_s + M\right)}{SC}$$

$$SC = \frac{Pl\left(C_s + M\right)}{2\mu - C\left[(S_{max} - S_0)\sqrt{\pi\mu_c F}\right]^{\widetilde{m}}}$$

Lemma 4

From Eq.(9) $\quad U_t = \beta \int_0^\infty u_{t-1}(\xi) df(\xi) - c, t \geq 1,$

This study would like to find Optimal Stopping Time

Then

$$SC = u_{t-1}$$

$$U_t = \beta \int_0^\infty \frac{Pl\left(C_s + M\right)}{2\mu - C\left[\left(S_{max} - S_0\right)\sqrt{\pi\mu_c F}\right]^m} df(\xi) - c$$

$$(t \geq 1)$$

เอกสารอ้างอิง

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