The Distribution of the Adjustement Work Time in a Machine Assembly Process

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1 Introduction

Adjustment works are divided into the following classes.[1)]

1) Adjustment works in a machine assembly process.
2) Adjustment work in handling of cutting machines.
3) Adjustment wroks in process controls in plant engineerings.
4) Inspects and adjustment works in starting time of machines.

These adjustment works have many factors which unstabilize the work time duration, so it is a characteristic that the work time duration is distributed widely. This means that it is difficult to set up the work standrard time. In this paper the distribution of the adjustment work time are described in a machine assembly process. As the methd of the research of the work distribution, it is used that the method of sensory test that uses sensuous judge of workers. Because adjustment works involve many unsolve problems, for example, the accuracy of parts and machines, the problem of the skill and the flexibility of the worker, design techniques, cost problems, the process controls, etc. There are some factors which are measured using the physical quantities, but almost factors's physical measurements are difficult. Especialy, it is difficult that these problems are analyzed synthetically. So using worker's sensuous judegs as a measuring gauge, the actual conditions are investigated. The estimate of the work time duration is determined by the policy of the enterprises. In that cace theinformation of the distribution of the work time makes an important part in the matter,

2 Procedure of Investigation and Analysis

2.1 Assumptions of the distribution of the work time duration

Generally the adjustment work time distribute as shown[2)] in Fig. 1.

In order to determine the distributions, three time estimate are used in the same way in PERT assumptions[3)]. RERT uses two time estimates, the optimistic time and the pessimistic time, to specify a and b. The optimistic time is that the earlier than a time in which the activity could not be completed, and the pessimistic time is the longest time the activity could ever take to com-

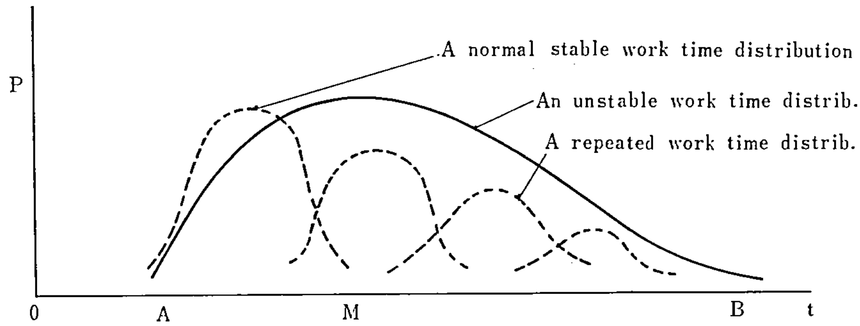

Fig. 1

plete. A third time estimate m, the most likely time, is also obtained. The value of m is the mode of the distribution.

2.2 Time estmates of a, b and m by the paired comparison

The paired comparison uses three basic time estimates to specify A, B and M. A; the optimistic base time, B; the pessimistic base time, M; the most likey base time.

The working base time estimates A, B and M are determined by the stop watch time study. And it is assumed that the work time estimates of a, b and m are the following extent;

$$0.8A \leq a \leq 1.2A, \quad 0.8B \leq b \leq 1.2 \quad B, \ 0.8M \leq m \leq 1.2M$$

and arrange the time estimates as table 1.

WORK NAME	BASE TIME	TIME ESTIMATES	COMING RATE
	A	0.8A 0.9A A 1.1A 1.2A	p_{at}
W_t	B	0.8B 0.9B B 1.1B 1.1B	p_{bt}
	M	0.8M 0.9M M 1.1M 1.2M	p_{mt}

Table 1

Workers compare the base time estimates A, B, M with the time estimates a, b, m and chose his time estimates from table 1.

2.3 The distribution of the work time based on the time estimates

In order to analyze the result of the paired comparison, the averages of time estimates of work W_t are denoted by $\bar{a}_t$, $\bar{b}_t$ and $\bar{m}_t$, and the averages of the probability by, $p_{\bar{a}t}$, $p_{\bar{b}t}$ anb $p_{\bar{c}t}$. Now by the PERT assumption, work time estimates t_t distribute the following extent;

$$\bar{a}_t \leq t_t \leq \bar{b}_t$$

and in this range approximates the distribution with distibution with the straight line equations y_1 and y_2 as in Fig. 2.

Lines y_1 and y_2 are denoted next equatons;

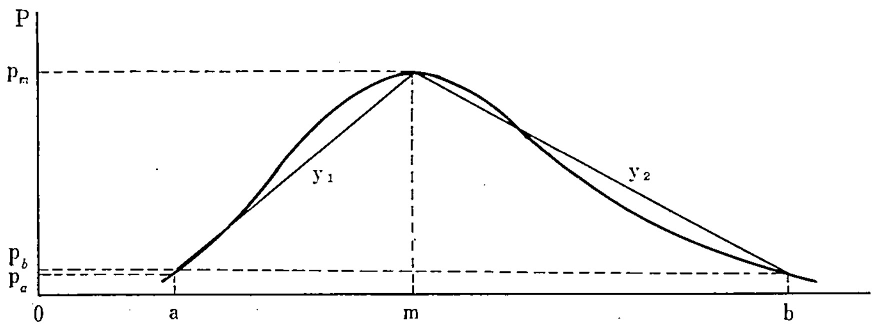

Fig. 2

$$y_1=\frac{p_{\bar{a}t}-p_{\bar{m}t}}{\bar{a}_t-\bar{m}_t}t_t+\frac{\bar{a}_t p_{\bar{m}t}-\bar{m}_t p_{\bar{a}t}}{\bar{a}_t-\bar{m}_t}\quad(\bar{a}_t\leq t_t\leq\bar{m}_t)\tag{2.3.1}$$

$$y_2=\frac{p_{\bar{m}t}-p_{\bar{b}t}}{\bar{m}_t-\bar{b}_t}t_t+\frac{\bar{m}_t p_{\bar{b}t}-\bar{b}_t p_{\bar{m}t}}{\bar{m}_t-\bar{b}^t}\quad(\bar{m}_t\leq t_t\leq\bar{b}_t)\tag{2.3.2}$$

2.4 Probability fundtions

In order to express y_1 and y_2 by a probability function f(t), it must satisfy the following two conditions;

1) $f(\mathrm{t}) > 0$ 2) $\int_{-\infty}^{+\infty} f(\mathrm{t})=1$

So a new function defined is introduced by the following equation;

$$f(\mathrm{t})=\begin{cases} 0 & (t<\bar{a}_t,\ \bar{b}_t<t) \\ y_1/\left(\int_{\bar{a}t}^{\bar{m}t} y_1 dt+\int_{\bar{m}t}^{\bar{b}t} y_2 dt\right) & (\bar{a}_t\leq \mathrm{t}\leq \bar{c}_t) \\ y_2/\left(\int_{\bar{a}t}^{\bar{m}t} y_1 dt+\int_{\bar{m}t}^{\bar{b}t} y^2 dt\right) & (\bar{c}_t\leq t\leq \bar{b}_t) \end{cases}\quad\cdots\cdots(2.4.1)$$

If a probability density function is f(t), that cumulative distribution function F(t) are denoted as follow;

$$F(\mathrm{t})=\begin{cases} 0 & (t<\bar{a}_t) \\ \frac{1}{K}\int_{\bar{a}t}^{t} y_1 dt & (\bar{a}_t\leq t\leq \bar{m}_t) \\ \frac{1}{K}\int_{\bar{a}t}^{\bar{m}t} y_1 dt+\frac{1}{K}\int_{\bar{m}t}^{t} y_2 dt & (\bar{m}_t\leq t\leq \bar{b}_t) \\ 1 & (\bar{b}_t<t) \end{cases}\quad\cdots\cdots(2.4.2)$$

write $K=\int_{\bar{a}t}^{\bar{m}t} y_1 d\mathrm{t}+\int_{\bar{m}t}^{\bar{b}t} y_2 dt$

3 The Qustionnaire

The questionnaire of the work time duration of the assembly of a computer input machine put in operation at March, 1971. And 8 unit works and 14 workers were chosen. Fig. 3 formal questionnaire was used.

THE QUESTIONNAIRE OF THE ADJUSTMENT WORK TIME

NAME (M, FM) AGE ADJUSTMENT WORK EXPERIENCE

The following table expresses the adjustment work time of machine name A. Compare the basic time estimates A, B and M with your estimates and chose the most suitable work time and write the coming rate of that work time.

A; It is that time earlier than a time in which working duration could not be completed.

B; It is the longest time the work could ever take to complete.

M; The most likely time.

NO.	WORK NAME	BASIC TIME	TIME ESTIMATES	COMING RATE
1	BS KEY ADJ.	A= 4.0 B= 8.0 M= 6.0	3.2 3.6 4.0 4.4 4.8 6.4 7.2 8.0 8.8 9.6 4.8 5.4 6.0 6.6 7.2	
2	SD CD ADJ.	A=10.0 B=20.0 M=15.0	8.0 9.0 10.0 11.0 12.0 16.0 18.0 20.0 22.0 24.0 12.0 13.5 15.0 16.6 18.0	

Fig. 3

4 The Arrangement of Data

4.1 The results of the statistical data is arranged and tabulate as the following table 2.

WORK NAME	TIME ESTIMATES AVERAGE			COMING RATE AVERAGE		
W	$\bar{a}_i$	$\bar{b}_i$	$\bar{m}_i$	$p\bar{a}_i$	$p\bar{b}_i$	$p\bar{m}_i$
1	3.6	8.1	4.9	0.05	0.11	0.84
2	9.4	20.7	14.6	0.06	0.37	0.57
3	5.2	14.1	8.1	0.19	0.13	0.68
4	3.4	13.6	6.3	0.20	0.09	0.71
5	2.8	8.6	4.2	0.17	0.21	0.62
6	11.3	27.3	16.7	0.33	0.06	0.61
7	35.8	74.6	48.7	0.08	0.41	0.51
8	14.2	27.3	18.6	0.14	0.18	0.68

Table 2

4.2 Approximating equations y_1 and y_2 are obtained by equation (2.3.1) and (2.3.2). Table 3.

4.3 The probability density distribution $f(t)$ is obtained by equation (2.4.1). Table 4.

4.4 The cumulative distribution function $F(t)$ is obtained by equation (2.4.2). Table 5.

5 Results and Discussion

By the results of the questionnaire, the probability function $f(t)$ and the cumulative distribution $F(t)$ are obtained. The condition of the distribution of

WORK NAME	y_1	y_2
1	0. 608t−2. 138	−0. 228t+1. 958
2	0. 098t−0. 862	−0. 033t+1. 049
3	0. 169t−0. 689	−0. 092t+1, 423
4	0. 168t−0. 383	−0. 085t+1. 245
5	0. 321t−0. 730	−0. 093t+1. 011
6	0. 064t−0. 314	−0. 053t+1. 493
7	0. 033t−1. 113	−0. 004t+0. 698
8	0. 123t−1. 603	−0. 057t+1. 749

Table 3

f(t)

WORK NAME	$\bar{a}_i \leq t_i \leq \bar{m}_i$	$\bar{m}_i < t_i \leq \bar{b}_i$	$t_i < \bar{a}_i$ $\bar{b}_i < t_i$
1	0. 2889t−1. 0160	−0. 1083t+0. 9306	0
2	0. 0220t−0. 1940	−0. 0074t+0. 2361	0
3	0. 0460t−0. 1876	−0. 0250t+0. 3875	0
4	0. 0410t−0. 0935	−0. 0207t+0. 3040	0
5	0. 1348t−0. 3067	−0. 0390t+0. 4247	0
6	0. 0096t−0. 0475	−0. 0080t+0. 2262	0
7	0. 0021t−0. 0726	−0. 0002t+0. 0455	0
8	0. 0216t−0. 2833	−0. 0100t+0. 3091	0

Table 4

F(t)

WORK NAME	$t_i < \bar{a}_i$	$\bar{a}_i \leq t_i \leq \bar{m}_i$	$\bar{m}_i < t_i \leq \bar{b}_i$	$\bar{b}_i < t_i$
1	0	0. 1444t^2−1. 0161t+1. 7865	−0. 0541t^2+0. 6306t−2. 9854	1
2	0	0. 0110t^2−0. 1940t+0. 8517	−0. 0037t^2+0. 2361t−2. 2944	1
3	0	0. 0230t^2−0. 1876t+0. 3536	−0. 0125t^2+0. 3875t−1. 9756	1
4	0	0. 0205t^2−0. 0935t+0. 0810	−0. 0103t^2+0. 3040t−6. 2008	1
5	0	0. 0674t^2−0. 3067t+0. 3303	−0. 0196t^2+0. 4247t−1. 2086	1
6	0	0. 0048t^2−0. 0475t—0. 0762	−0. 0040t^2+0. 2262t−2. 1928	1
7	0	0. 0010t^2−0. 0726t+1. 3174	−0. 0001t^2+0. 0455t−1. 7765	1
8	0	0. 0108t^2−0. 2833t+1. 8451	−0. 0050t^2+0. 3091t−3. 7073	1

Table 5

adjustment work time is expressed by Fig. 4.

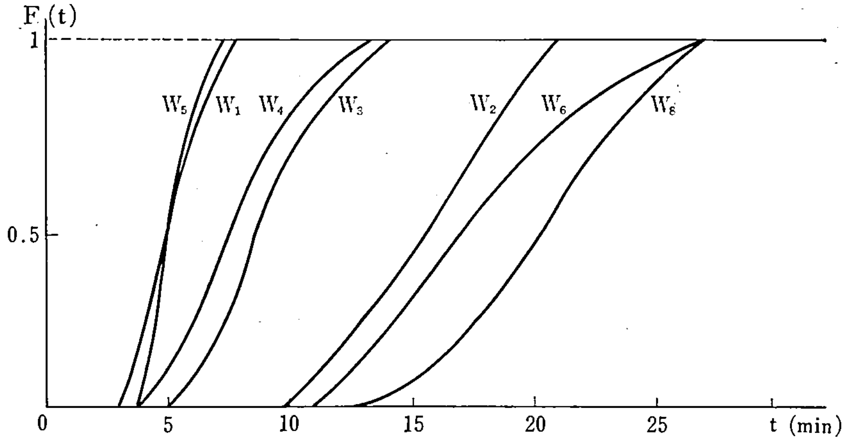

Fig. 4 The cumulative distributions

Numerizing of adjustment work process is difficult, but understanding the condition of distributions are possible by using this paper methods. Of course functions include errors but this paper don't discuss about it. Obtaining these errors are future reserch.

Merit of this methods.

1) Understanding work time distributions.
2) The work time is estimated by distribution functions.
3) Calculations are simple for approximating with a straight line equation.
4) The work time estimates satisty workers, because these time are determined by workers.
5) The adaptation and skill of workers can be analyzed.

Demerit of this methods

1) It is difficult to determine basic time estimates A,B and M.
2) Approximating equations lead to errors.

6 Refernces

1) S. Ono: A handbook of measurement, Nikkan-Kougyou-Shinbunshiya, (1963) 1073 (In Japanese)
2) T. Ttmura: Same as (1), 1152.
3) K. R. MacCrimmon and C. A. Ryaves: An analytical study of the PERT assumptions, Researh Memorandum RM-3408-PR, The Rand Coporation, (1962) AD 293