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A NEW METHOD FOR DETERMINING EXTRA TIME BY CONSIDERING ERGONOMIC LOADS IN THE GARMENT AND METAL-WORKING INDUSTRIES

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The changing labour conditions in the garment and metal-working industries have led to the necessity of determining new extra times to establish the time standard. In this paper, a method of measuring stress and strain imposed upon the operator in new working conditions by determining the additional production coefficient is presented. The method gives criteria and grades to assess stress at the workplace. Physical stress (dynamic and static), thermal and visual stress, discomfort caused by noise, aerosols, gases and vapours, and the stress due to monotony are assessed. The stresses are expressed by ecological, physiological and psychological indexes. The indexes are pondered. Ponderation includes the factor of the magnitude and the time of exposure to stress. Ponderation is expressed by the number of points, the total being an adequate presentation of the stresses. Stress and strain decrease the working performance of the operator. Therefore they must be included in the standard to compensate for the operator's lower working efficiency due to physical and psychological strain at the workplace. Short breaks and stops allowed during work enable the operator to perform work tasks without getting excessively tired. The necessary correction of the production time is made by applying the ergonomic coefficient K_{er}.

Key terms: job analysis, production planning, stress assessment, time study, working conditions, working environment

Standard time is an important tool to organize modern production and business operations. In estimating production costs, planning terms and machine loads, controlling the production and analysing losses, the time standard should be precisely determined. It is used not only to assess the production efficiency but is, together with the preparatory and clean-up times, an important means for justifying the purchase of a new production resource. For the time standard to be used in this way, two scientific fields – work study and ergonomics, should be combined. Determining the time does not only imply having a profound knowledge of the technology and working methods but also knowing the psycho-physiological characteristics of the man involved in the working process. In our investigation, which took several years, we studied the impact of working conditions on man and subsequently on the production times. We proceeded according to five steps:

– analysis of the structure of working time and job analysis and evaluation

– measurement of the operator's stress and strain due to ecological conditions, i.e. thermal conditions, noise and dust

– measurement of postural, visual and auditory strain at work

– grading stress and strain and calculating the ergonomic coefficient K_{er} which is a correction factor in determining the time standard

– correcting the old equation for calculating the time standard by including the ergonomic coefficient K_{er}.

In this way new working conditions were included in time and work study, which will, hopefully, bring about an increase in the production efficiency and lead to a more humane work.

METHODS

Activity sampling and job analysis and evaluation

The structure of the time fund was analysed on the basis of activity sampling. The recordings of activities were made in two shifts during five subsequent working days. Before starting the recordings, all operations at individual workplaces were determined and grouped into work, planned and unplanned losses, and indiscipline. Also, all necessary observation forms were prepared and the route for the analyst was determined on the workplace layout plan (1).

Job analysis and evaluation were based on a questionnaire which helped assess the working process, work tasks, work requirements, and health hazards.

Special questions were used to identify the workplace, the selected characteristics of operators, and the need for the measurement and analysis of workplace conditions. Work was also described. The description included the specifications concerning plants, products and services, production resources, work tasks, and protective clothes.

The method is based on an interdisciplinary group approach. For the assessment, specific theoretical knowledge and experience are needed. Experience should be gained by frequent assessments of tasks which differ according to the grades in the scale. An analyst who has gained sufficient practical experience is more reliable and precise in his assessments. Therefore job analysis was performed by a team of experts including an ecologist, a physician – an occupational health specialist and a technologist.

In their description of work the members of the team first named the plant, the products manufactured and services provided. They continued by stating production resources (tools, machines, devices) and work tasks (preparation for work, main tasks and maintenance tasks). They also described the operator's protective clothes.

Having finished their description, the team examined the workplace and then sat down for a general discussion. The examination of the workplace was analytical. The evaluators systematically analysed work task features, of which they were to make an assessment later on. After the examination, the team returned to their study room to make an in-depth analysis of the working system, work tasks, work requirements, and health risks. Work task features were assessed, by using multi-step scales, according to the alternative, importance, intensity, duration, and frequency (2).

Measurement of workplace conditions – criteria and grades of eight stresses at the workplace

At his workplace the operator is exposed to ecological, physiological and psychological stresses that affect his organs of sense. Not only can those stresses be compared but they can also be measured and assessed.

Observation is a subjective method. Even in the case of an experienced observer, subjectivity cannot be completely avoided. The tendency therefore is to replace subjective methods by the objective ones, and to express the work load by physical, physiological and psychological indexes. The environmental factors, however, are more easily expressed in numbers than the psychological ones.

The method we used provides criteria and grades for investigating and evaluating stresses at the workplace. Physical stress (dynamic and static), thermal stress, visual stress, discomfort due to noise, aerosols, gases, vapours and monotony were evaluated. They were measured as ecological, physiological and discomfort indexes. With six to eight stress factors mostly physical work can be assessed (3).

Criteria and grades of eight stresses at the workplace – definitions and evaluation

Definitions for individual grades of physical, ecological and psychical strains are as follows:

PHYSICAL STRAIN – DYNAMIC

Grades available: 0 I I/II II II/III III III/IV IV

Grade 0: Very easy work. Oxygen consumption lower than 0.5 L/min. Pulse equals the level of pulse at rest (about 75/min). Rectal temperature 37.1 °C. Energy expenditure lower than 175 W.

Grade I: Easy work. Oxygen consumption 0.5–1.0 L/min. Pulse 75–100/min. Rectal temperature 37.5 °C. Energy expenditure 175–343 W.

Grade II: Moderately hard work. Oxygen consumption 1.0–1.5 L/min. Pulse 100–135/min. Rectal temperature 37.5–38.0 °C. Energy expenditure 350–518 W.

Grade III: Hard work. Oxygen consumption 1.5–2.0 L/min. Pulse 125–150/min. Rectal temperature 38.0–38.5 °C. Energy expenditure 525–693 W.

Grade IV: Very hard work. Oxygen consumption 2.0–2.5 L/min. Pulse 150–170/min. Rectal temperature 38.5–39.0 °C. Energy expenditure 700–868 W.

PHYSICAL STRAIN – STATIC

Grades available: 0 0/I I I/II II II/III III

Grade 0: Non-existent or minimal static strain, bearable indefinitely long without subjective feeling of fatigue in affected muscles.

Grade I: Static strain of lower intensity and duration, followed by short pauses or dynamic moves of the same muscle groups. No significant feeling of fatigue.

Grade II: Static strain of higher intensity, followed by short pauses or dynamic moves of the same muscle groups. Fatigue in the muscles increasing.

Grade III: Serious static strain leading to cessation of work.

THERMAL STRAIN

Grades available: 0 I II III IV

Grade 0: 18 °C,
Grade I: up to 20.4 °C,
Grade II: 20.5 – 25.2 °C,
Grade III: 25.3 – 29.9 °C,
Grade IV: 30 °C ET and more

VISUAL STRAIN

Grades available: 0 0/I I I/II II

Definitions are given for the three basic grades. A more detailed division is also possible.
Grade 0: Daylight or artificial light in accordance with the former standard.
Grade I: Light deviating by 10% from the former standard.
Grade II: Severe visual disturbance owing to glare and bad contrast.

DISCOMFORT DUE TO NOISE

Grades available: 0 I II III

Grade 0: Noise up to 50 dB (A).
Grade I: Noise 51–70 dB (A), not hampering conversation.
Grade II: Noise 71–90 dB (A), restraining conversation, without being very annoying.
Grade III: Loud noise 91–120 dB (A), very annoying, restraining conversation considerably.
Grade IV: Noise above 120 dB (A).

DISCOMFORT DUE TO AEROSOLS, GASES AND VAPOURS

Grades available: 0 0/I I I/II II

Grade 0: Concentration lower than 50% MAC. No health damage.
Grade I: Concentration 50.1–100% MAC. Health damages rare and not serious.
Grade II: Concentration higher than 100.1% MAC. Health damages frequent and serious.

MONOTONY

Grades available: 0 I I/II II

Grade 0: Work moderately monotonous, or not monotonous at all.
Grade I: Work consisting of a low number of grasps, equal in motion and time. Moderate timing pressure.
Grade II: Work consisting of the simplest elements, absolutely unchanging. Great timing pressure.

The values for individual grades of physical, ecological and psychical strains depending on exposure time are given in Table 1.

Table 1. *Individual grades of eight stresses at the workplace in dependence on the time of exposure*

	Time of exposure in hours per shift							
	1	2	3	4	5	6	7	8
Dynamic physical strain								
Grade 0	0	0	0	0	0	0	0	0
I	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0
II	0.3	0.6	0.9	1.2	1.5	1.8	2.2	2.7
III	0.6	1.2	1.8	2.4	3.1	3.8	4.6	–
IV	1.0	2.0	3.0	4.1	5.3	6.5	–	–
Static physical strain								
Grade 0	0	0	0	0	0	0	0	0
I	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0
II	0.2	0.4	0.6	0.8	1.0	1.2	1.5	1.8
III	0.5	1.0	2.0	–	–	–	–	–
Thermal strain								
Grade 0	0	0	0	0	0	0	0	0
I	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4
II	0.2	0.3	0.5	0.6	0.8	1.0	1.3	1.5
III	0.6	0.8	1.2	1.4	1.8	2.2	–	–
IV	0.8	1.5	2.2	3.0	–	–	–	–
Visual strain								
Grade 0	0	0	0	0	0	0	0	0
0/I	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.6
I	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.2
I/II	0.3	0.5	0.8	1.0	1.2	1.4	–	–
II	0.4	0.8	1.1	1.5	–	–	–	–
Discomfort owing to noise								
Grade 0	0	0	0	0	0	0	0	0
I	0	0.1	0.1	0.2	0.2	0.3	0.3	0.4
II	0.2	0.3	0.4	0.6	0.7	0.9	1.0	1.2
III	0.4	0.7	1.0	1.3	1.7	2.0	–	–
Discomfort owing to aerosols, gasses and vapours								
Grade 0	0	0	0	0	0	0	0	0
0/I	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4
I	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
I/II	0.2	0.3	0.5	0.7	0.9	1.1	1.3	1.4
II	0.3	0.5	0.7	1.0	1.2	1.5	1.8	2.0
Monotony								
Grade 0		0	0	0	0	0	0	0
I		0.1	0.2	0.3	0.4	0.6	0.8	1.0
I/II		0.6	0.7	0.8	0.9	1.1	1.3	1.5
II		1.1	1.2	1.3	1.4	1.6	1.8	2.0

Calculation of K_{er} and its use in the prediction and determination of time

Stress and strain play an important role among the factors that reduce work performance efficiency. Therefore they must be included in the standards to compensate for the operator's decreased efficiency due to physical and mental overload. A tired operator uses more energy to maintain the correct rhythm of work. As we do not want the operator to overexert himself and to become excessively tired before the main break, we must give him the possibility to make several short stops during work to accomplish his task at normal effort. The necessary correction of the production time is made by the ergonomic coefficient K_{er}.

The ergonomic coefficient is calculated from the equation:

$$K_{er} = \frac{\text{Number of load points}}{\text{Maximum number of load points}} \times 0.3423^{*} \qquad (1)$$

* the constant that compensates for extra coefficients K_n and K_o used up to now (1) instead of K_{er}

$$\left(0.3423 = \frac{(K_n+K_o)\max}{(D_{ph}+S_{ph}+T+A+G+V)\max} = \frac{0.59+5.4}{6.5+2.0+3.0+2.0+2.0+2.0}\right)$$

where

K_n – strain coefficient
K_o – environmental coefficient
D_{ph} – dynamic physical strain
S_{ph} – static physical strain
T – thermal strain
A – strain due to aerosols
G – strain due to gases
V – strain due to vapours

The standard time is calculated from the equation:

$$t_1 = (t_t+t_p)(1+K_{er})(1+K_d) \quad /\text{min}/ \qquad (2)$$

where

t_1 – standard time
t_t – technological time
t_p – unproductive time
K_{er} – ergonomic coefficient which includes 6 or 8 items of stress
K_d – extra coefficient which includes organizational losses and physiological needs

Table 2. *Calculation of load points for the operation of sewing (4)*

Branch: Textile – Garment Factory: PIK, Vezenina Workplace: Tailoress			Plant: Sewing room															
No.	Description of work		1		2		3		4		5		6		7		8	
			Dynamic strain		Static strain		Thermal strain		Visual strain		Noise		Aerosols		Vapours and gases		Monotony	
	Operation	min	s	min	s	min	s	min	s	min	s	min	s	min	s	min	s	min
1	Preparing work	8.5	0	8.5	1	8.5	2	8.5	0	8.5	2	8.5	0	8.5	0	8.5	2	8.5
2	Machine technological time	97	0	97	1	97	2	97	0	97	2	97	0	97	0	97	2	97
3	Manual technological time	137	0	137	1	137	2	137	0	137	2	137	0	137	0	137	2	137
4	Selfcontrol	5.5	0	5.5	1	5.5	2	5.5	0	5.5	2	5.5	0	5.5	0	5.5	2	5.5
5	Pattern drawing	3	0	3	1	3	2	3	0	3	2	3	0	3	0	3	2	3
6	Preparing workplace	1	0	1	1	1	2	1	0	1	2	1	0	1	0	1	2	1
7	Changing thread, needle	7	0	7	1	7	2	7	0	7	2	7	0	7	0	7	2	7
8	Setting device	1	0	1	1	1	2	1	0	1	2	1	0	1	0	1	2	1
9	Cleaning machine	1	0	1	1	1	2	1	0	1	2	1	0	1	0	1	2	1
10	Correcting sewing defects	9	0	9	1	9	2	9	0	9	2	9	0	9	0	9	2	9
11	Changing workplace	1	0	1	1	1	2	1	0	1	2	1	0	1	0	1	2	1
12	Correcting sewing defects found in final control	5	0	5	1	5	2	5	0	5	2	5	0	5	0	5	2	5
13	Other	173	0	173	0	173	2	173	0	173	2	173	0	173	0	173	2	173
14		Σ 450																
15	Number of points		0		0.45		1.4		0		1.1		0		0		1.9	

Σ = 4.85

RESULTS

Calculation of load points in the garment industry

Work load can be expressed by means of ecological, physiological and psychological indexes. The indexes are pondered. Ponderation includes the factors of load intensity and of the time of exposure to load. Ponderation is expressed by the total of points, the maximum being 21, obtained by summing up all load points in the table. The sum is supposed to be an adequate assessment of six or eight discussed loads respectively.

Table 2 shows the calculation of load points for the operation of sewing.

Calculation of the ergonomic coefficient K_{er} in the garment industry

By using equation (1), the ergonomic coefficients for thirteen workplaces in the garment industry were calculated. The results are shown in Table 3 (the product of the strain coefficient K_n and the environmental coefficient K_o is given in the table to be compared to the new ergonomic coefficient K_{er}).

Table 3. *Calculation of the ergonomic coefficient in the garment industry*

No.	Workplace	Number of $K_n \cdot K_o$ load points	Max number of load points	Correction factor	Ergonomic coefficient K_{er}	$K_n \cdot K_o$
1	Cutting	3.1	21	0.3423	0.051	0.132
2	Bonding	3.25	21	0.3423	0.053	0.1375
3	Sewing	4.85	21	0.3423	0.079	0.1375
4	Interphase ironing	4.4	21	0.3423	0.072	0.1375
5	Overlocking	4.4	21	0.3423	0.072	0.1485
6	Sewing buttons	5.35	21	0.3423	0.087	0.132
7	Inserting zip fastener	5.9	21	0.3423	0.096	0.132
8	Sewing buttons	5.95	21	0.3423	0.097	0.132
9	Sewing blind seam	5.95	21	0.3423	0.097	0.132
10	Other hand work	5.4	21	0.3423	0.088	0.132
11	Hand ironing	4.5	21	0.3423	0.073	0.154
12	Packing	3.9	21	0.3423	0.064	0.154
13	Final control	4.85	21	0.3423	0.079	0.1375

Calculation of load points in the metal-working industry

The calculation of load points is shown in Table 4.

Table 4. *An example of calculation of load points in the metal-working industry*

Branch: Metal-working industry
Plant: TAM
Workplace: CNC – Spindle lathe at 4001

No.	Description of work		Plant 1		2		3		4		5		6		7		8	
			Dynamic strain		Static strain		Thermal strain		Visual strain		Noise		Aerosols		Vapo-urs and gasses		Mono-tony	
	Operation	min	s	min	s	min	s	min	s	min	s	min	s	min	s	min	s	min
1	Direct automated machining	222.0	1	222.0	1	222.0	2	222.0	2	222.0	2	222.0	0	222.0	0	222.0	1	222.0
2	Direct manual operations	1.1	1	1.2	1	1.2	2	1.2	2	1.2	2	1.2	0	1.2	0	1.2	0	1.2
3	Clamping and unclamping tools	2.0	1	2.0	1	2.0	2	2.0	2	2.0	2	2.0	0	2.0	0	2.0	0	2.0
4	Clamping and unclamping workpiece	35.4	1	35.4	1	35.4	2	35.4	2	35.4	2	35.4	0	35.4	0	35.4	0	35.4
5	Dimensional control	13.0	1	13.0	1	13.0	2	13.0	2	13.0	2	13.0	0	13.0	0	13.0	0	13.0
6	Testing NC program	2.9	1	2.9	1	2.9	2	2.9	2	2.9	2	2.9	0	2.9	0	2.9	0	2.9
7	Absence from automated operation	27.8	1	27.8	1	27.8	2	27.8	2	27.8	2	27.8	0	27.8	0	27.8	0	27.8
8	Preparing workplace	1.8	1	1.8	1	1.8	2	1.8	2	1.8	2	1.8	0	1.8	0	1.8	0	1.8
9	Studying instructions	–	1	–	1	–	2	–	2	–	2	–	0	–	0	–	0	–
10	Preparing tools	4.3	1	4.3	1	4.3	2	4.3	2	4.3	2	4.3	0	4.3	0	4.3	0	4.3
11	Lifting and centering machine	1.5	1	1.5	1	1.5	2	1.5	2	1.5	2	1.5	0	1.5	0	1.5	0	1.5
12	Cleaning machine	9.5	1	9.5	1	9.5	2	9.5	2	9.5	2	9.5	0	9.5	0	9.5	0	9.5
13	Other	128.6	1	128.6	0	128.6	2	128.6	0	128.6	2	128.6	0	128.6	0	128.6	0	128.6
14	Σ =	450																
15	Number of points		1.0		0.55		1.5		1.5		1.2		0		0		0.3	

Σ = 6.05

Calculation of the ergonomic coefficient K_{er} in the automated metal-working industry

By using equation (1) the ergonomic coefficients for three groups of computerized numerically controlled machines (CNC machines) were calculated. The results are shown in Table 5 (the product of the strain coefficient K_n and the environmental coefficient K_o is given in the table to be compared to the new ergonomic coefficient K_{er}).

Table 5. *Calculation of the ergonomic coefficient in the automated metal-working industry*

No.	Workplace	Number of load points	Max. number of load points	Ergonomic coefficient K_{er}	Kn . K_o
1	CNC–Spindle lathe	6.05	21	0.097	0.148
2	CNC–Turntable lathe	6.1	21	0.099	0.143
3	CNC–Working centre (medium)	6.1	21	0.099	0.143

DISCUSSION AND CONCLUSION

To perform an operation in due time it is necessary to determine the standard time if optimal organization of work is to be achieved. Due to different meanings of time, the analysis and good knowledge of time in designing production processes is of great importance. The analysis is the more successful the more accurately the time is determined. Here it is very helpful if we know the ergonomic coefficient K_{er} which determines extra time for the operator's recovery due to overload at work. The strain coefficient K_n and the environmental coefficient K_o have been in use for quite a long time. Yet, owing to a considerable change of work conditions in modern industry, new criteria had to be set up and new workload grades established.

In the garment industry the ergonomic coefficient K_{er} shows a time allowance lower by about 44 per cent compared to the allowance established by the coefficients K_n and K_o. In the metal-working industry the time allowance is lower by about 31 per cent. This means that the proportion of time for machine-manual and manual operations in the total production time is decreased accordingly. Consequently, the productivity is increased, yet under the condition that the required working methods are used. Short breaks and stops allowed during work enable the operator to achieve normal efficiency, without being tired above the permitted level.

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Sažetak

NOVA METODA ODREĐIVANJA DODATNOG VREMENA ZBOG ERGONOMSKIH OPTEREĆENJA

S izmijenjenim uvjetima rada u konfekcijskoj i metaloprerađivačkoj industriji mijenjaju se i potrebna dodatna vremena pri postavljanju norme. Zato predstavljamo metodu utvrđivanja opterećenja i opterećenosti čovjeka u novim uvjetima rada s određivanjem novog dodatnog koeficijenta te njegovo uključenje u jednadžbu za određivanje vremena obrade. Metoda daje kriterije i stupnjeve za ocjenu opterećenja na radnom mjestu. To su fizička (dinamička i statička), toplinska, opterećenja vida, opterećenja uslijed buke, opterećenja zbog eksplozije aerosolom, plinom i parama, opterećenja zbog monotonije. Opterećenja su izražena ekološkim, fiziološkim i psihičkim indeksom. Indeksi su ponderirani. Ponder sadržava faktor težine i vremena izloženosti opterećenju. Ponder je izražen brojem bodova, zbroj kojih je adekvatan odraz promatranih opterećenja. Opterećenja i opterećenosti smanjuju učinak radnika. Zato ih moramo uzeti u obzir u normi, da bi kompenzirali manji učinak radnika zbog tjelesnog i psihičkog napora tijekom radnog dana. S više stanaka i odmora moramo radniku omogućiti da s normalnim nastojanjima izvrši radnu zadaću. Potrebna korekcija vremena izrade obuhvaćena je ergonomskim koeficijentom K_{er}. Utvrđeni ergonomski koeficijent K_{er} iznosi u prosjeku 44% manji dodatak od dosadašnjih koeficijenata napora K_n i okruženja K_o u konfekcijskoj i oko 31% manji dodatak u automatiziranoj metaloprerađivačkoj industriji, što znači da je za toliki udio smanjen i vremenski iznos strojno-ručnih i ručnih zahvata u okviru vremena izrade. Iz toga slijedi odgovarajuće povećanje produktivnosti, dapače uz poštovanje predviđene metode rada, gdje određeni počinak i odmor tijekom radnog vremena omogućavaju radniku normalan učinak, a da pritom umor ne prekorači dopuštene vrijednosti.

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Ključne riječi: analiza radnog mjesta, ocjena stresa, planiranje proizvodnje, radna okolina, radni uvjeti, vremenska studija