ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 10 N° 3 2014
pp. 55-61

THEORETICAL CLARIFICATIONS REGARDING THE CONCEPT OF WORKING CAPACITY OF WOOD-WORKING MACHINE-TOOLS

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Abstract:
Due to persisting confusions between the concepts "labor productivity" and "working capacity" of a machine-tool, equipment or production line, the authors considered it necessary to define and explain these terms. Starting by defining the notions "working cycle" and "functioning cycle", the paper details: the theoretical, technological and real working capacity and also the term "working time norm" for wood-working machine-tools.

Key words: *working cycle; functioning cycle; working capacity; working time norm.*

INTRODUCTION

In the reference literature of the last decades of the last century (years 1980÷1990), during the period of the socialist economy in Romania, the concept of WORKING CAPACITY of a machine-tool (equipment or production line), was assimilated to the notion of the machine tool PRODUCTIVITY (Gherghea 1983, Radu 1977 etc.) and expressed by the formula:

$$Q = \frac{n}{t} = \frac{1}{T} \qquad \text{[pcs/min]} \qquad (1)$$

where: Q = productivity, in pieces/min.;
n = the number of identical pieces processed during the assessed period;
t = the necessary time for processing 'n' pieces, in min.;
T = the period of working cycle, in min.

The period of a working cycle T, represents the time needed for processing a single piece:

$$T = \frac{t}{n} \qquad \text{[min]} \qquad (2)$$

However, from the economic point of view, the concept of PRODUCTIVITY refers to the way labor is used and is expressed by the production volume reported to labor costs (Barba and Costea 1975).

Therefore, we consider that, technically and in accordance with new references (Budău 2008, Budău 2011), in order to define the notion of WORKING CAPACITY of a machine-tool, it is necessary to understand corectly the terms WORKING CYCLE and FUNCTIONING CYCLE, depending on the type of the processing on each machine-tool, namely processing by through-passing or steady processing.

Defining the concepts of WORKING CYCLE and FUNCTIONING CYCLE

Performing a processing operation on a wood-working machine-tool (WWMT) involves the simultaneous achievement of the cutting motion, usually performed by the cutting tool, and of the feed motion, usually performed by the workpiece. In order to further process other pieces on the same machine-tool (having the same or different size or other parameters of the working regime) a series of auxiliary movements are needed: positioning – fastening or detachment – evacuation (in case of steady processing), idle running (the withdrawal of the working head or the supply with workpieces at a certain distance etc.).

Therefore it is possible to define the following notions (Budău 2008, Budău 2011):

• the WORKING CYCLE – represents the totality of the generating movements, which are necessary for processing a workpiece (excluding the auxiliary motions), during the time that the cutting tool is in contact with the workpiece, performing the cutting;

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• the FUNCTIONING CYCLE – represents the totality of the generating and auxiliary movements necessary for processing a workpiece (excluding the auxiliary motions), during the working time and the auxiliary times (feeding – fastening, detachment – evacuation).

Fig. 1 exemplifies these definitions for steady horizontal drilling.

By analyzing the working scheme in Fig. 1, it can be noticed that the cutting movement is performed by the cutting tool - the drill bit and is characterized by the rotation speed of the tool, $\boldsymbol{n_s}$. The feed movement $\boldsymbol{u}$ is carried out by the machine table 4 on which the workpiece 2 is positioned and fastened by using the support 3. The displacement of the table 4 on the guides 5 of the table support is carried out both for working stroke, with the feed speed ***u,*** and the return stroke (withdrawal after processing), with the speed ***u'***, usually higher than the feed rate ***u*** (***u'*** > ***u***). Therefore a working cycle is given by the two movements: the working stroke (along the distance *a* + *h*) and the return stroke (along the same distance, *a* + *h*).

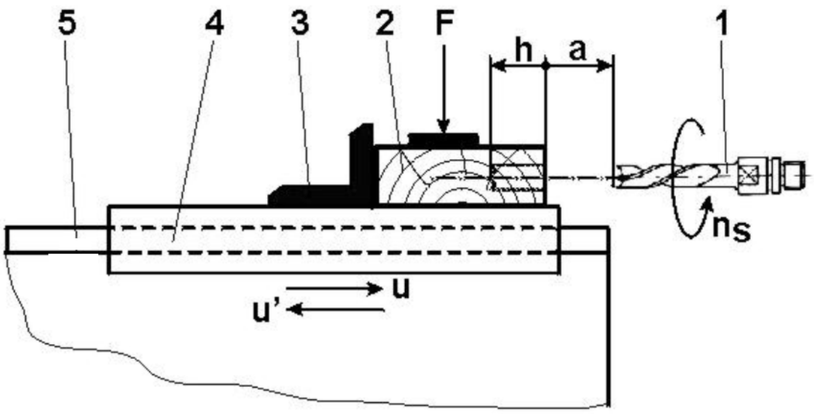

Fig. 1.
Working scheme of a steady machining operation (Budău 2008).

According to the definition of the working cycle, in the case of a steady processing (the case of drilling in the given example), the period of the working cycle $\boldsymbol{T_l}$ is given by the time in which the working stroke and return stroke are done, for a hole with the depth ***h***:

$$T_l = \frac{a+h}{u} + \frac{h+a}{u'} \text{ [min]} \tag{3}$$

where: *h* = the cutting depth (the distance covered by the machine table with the workpiece (towards the tool), in m;
a = the initial distance between the tool and the workpiece, in m;
u = the feed speed, in m/min;
u' = the speed of return to the original position, in m/min; (*u'* >> *u*).

In order to complete the drilling operation, besides the two basic movements (cutting and feeding) there are necessary a series of auxiliary movements, as:

• feeding – positioning of the workpiece 2 against the support 3;

• fastening the workpiece 2 on the machine table 4 by a mechanical, hydraulic or pneumatic fastening system;

• the idle running movement (approaching the workpiece to the tool on the distance ***a*** and the withdrawal to its original position on the distance ***h*** + ***a***, with the speed ***u'***;

• the detachment – evacuation movement of the workpiece from the machine table.

Therefore, the total auxiliary time to achieve the machining operation will be:

$$T_{aux} = T_{a-f} + T_{d-e} \quad \text{[min]} \tag{4}$$

where:
$T_{a\text{-}f}$ = the feeding – fixing time, in min;
$T_{d\text{-}e}$ = the detachment – evacuation time of the processed piece, in min.

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So, we can express the duration of the working cycle C_L for steady processing with the relation:

$$C_L = T_l = \frac{a+h}{u} + \frac{h+a}{u^{'}} \qquad \text{[min]} \tag{5}$$

and the duration of the functioning cycle C_F by the relation:

$$C_F = C_L + T_{aux} = T_l + T_{aux} \qquad \text{[min]} \tag{6}$$

or:

$$C_F = \frac{h+a}{u} + \frac{a+h}{u^{'}} + T_{a-f} + T_{d-e} \qquad \text{[min]} \tag{7}$$

Defining the WORKING CAPACITY

Considering the fact that the notion of WORKING CAPACITY of a machine-tool (or generally, of a working machine) can be defined as “the quantity of processed pieces per unit of time” (Mareş *et al*. 1977), we propose the following differentiation of notions:

The technological working capacity – Q_{th} – represents the quantity of processed wood pieces during a working cycle C_L, when T_{aux} = 0 (the case of processing by through-passing) and it is expressed by the relation:

$$Q_{th} = \frac{1}{T_l} \qquad \text{[pcs/min]} \tag{8}$$

respectively:

$$Q_{th} = \frac{1}{T_l} = \frac{u}{L} \qquad \text{[pcs/min]} \tag{9}$$

in the case of processing by through-passing, with pieces supplied head-to-head (with no spaces between pieces - Fig. 2).

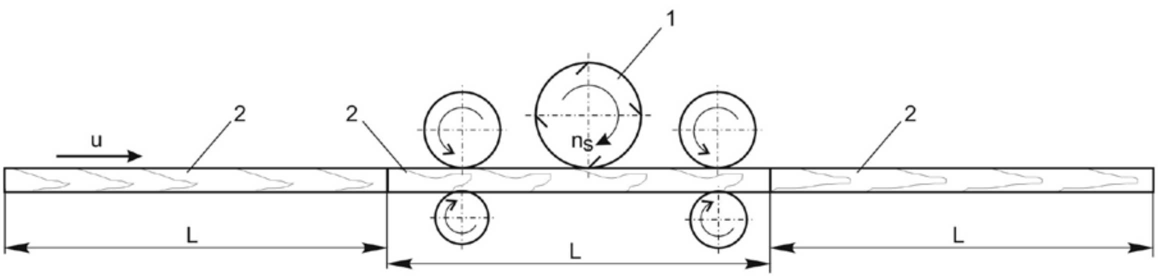

Fig. 2.
The machining operation by through-passing, with pieces supplied head-to-head.

The workpiece 2 (Fig. 2) moves towards the cutting tool 1 with the feed rate u, the pieces supplying being made continuously, without idle times T_g or auxiliary times T_{aux} (the cases of thicknessing, of planning on two, three or four faces, of processing on spindle moulders with mechanical feed etc.).

If the processing is done on position or by through-passing with distances/gaps between the workpieces, the THEORETICAL WORKING CAPACITY – Q_t – can be calculated by the relation:

$$Q_t = \frac{1}{T_L + T_{aux}}; \qquad \text{[pcs/min]} \tag{10}$$

Considering that during the work program of 8 hours/shift, a machine-tool can not operate continuously because operational interruptions occur (mounting – dismounting the tools, workplace preparation, supply of workpieces, current maintenance of the machine etc.), the working capacity will be diminished by a coefficient named “coefficient of machine utilization” – K_u (K_u = 0.45 … 0.85, depending on the type and complexity of the machine).

Also, if the working capacity is determined for a longer period of time (min. 8 hours – a shift), it has to be considered that the operator of the machine needs breaks for different reasons (physiological needs, lunch break, safety briefings etc.). In this case also, the working capacity will be reduced by a "coefficient of the working day utilization" – $\boldsymbol{K_z}$ – subunitary, with values: $\boldsymbol{K_z}$ = 0.8 ... 0.9.

Therefore, we can calculate the REAL WORKING CAPACITY – $\boldsymbol{Q_r}$ – of any machine-tool, by using the relation:

$$Q_r = Q_t \cdot K_u \cdot K_z \qquad \text{[pcs/min]} \qquad (11)$$

where: Q_t = the theoretical working capacity [pcs/min];
K_u = coefficient of machine utilization;
K_z = coefficient of the working day utilization.

When designing a technological flow it is necessary to calculate the working capacity for each type of machine-tool, in order to determine the number of machine-tools required for a specific production capacity. Some manufacturers of machine-tools indicate in the machine datasheet the working capacity, expressed in pieces/min, pieces/8h, m.l(linear meters)/min; m.l/8 ore; ; m^2/h or m^2/8h ; m^3/h or m^3/8h.

For instance, for a vertical framesaw fed with logs head-to-head and continuous feed motion, the idle time $\boldsymbol{T_g}$ = 0 and the auxiliary $\boldsymbol{T_{aux}}$ = 0 (the feeding and the evacuation of logs ovelap with the working time), the working capacity is calculated as follows:

$$Q_t = \frac{1}{T_L} = \frac{1}{\frac{L}{u}} = \frac{u}{L} \qquad \text{[logs/min]} \qquad (12)$$

where: $\boldsymbol{u}$ = the feed speed, in m/min;
$\boldsymbol{L}$ = the average length of logs, in m.

If one desires to calculate the working capacity in m^3/8h, the following equation will be used:

$$Q_t = 480 \cdot \frac{u}{L} \cdot \left(\frac{\pi d_b^2 \cdot L}{4} \right) = 480 \cdot \frac{\pi}{4} \cdot u \cdot d_b^2 \cong 377 \cdot u \cdot d^2 \quad [\mathrm{m^3/8h}] \qquad (13)$$

where: $\frac{\pi d_b^2 \cdot L}{4} = V_b$ (the average volume of one log, in m^3);
$\boldsymbol{d_b}$ = the average diameter of the logs, (in m).

The real capacity to be taken into account in the calculation of the production capacity of the section/workshop will be:

$$Q_r = Q_t \,.\, K_u \,.\, K_z \ [\mathrm{m^3/8h}] \qquad (14)$$

where: $\boldsymbol{K_u}$ = coefficient of machine utilization.
$\boldsymbol{K_u}$ = 0,91 (for vertical framesaws – (Norms and work regulations and united tariffs for the wood industry 1989)).

So, $$Q_r = 377 \cdot 0{,}91 \cdot 0{,}88 \cdot u \cdot d_b^2 \cong 302 \cdot u \cdot d_b^2 \qquad [\mathrm{m^3/8h}] \qquad (15)$$

Defining the WORKING TIME NORM

In order to ensure high efficiency of the productive activities in the wood industry field and a proper organization and standardization of work norms at each workplace, some unified working time norms were developed by the former Ministry of Forest Economy and Construction Materials, according to the national Romanian standard STAS 6909 – 1975. Standard working time norms $\boldsymbol{N_T}$ have been developed for each type of machine tool.

According to the structure of the working time norm $\boldsymbol{N_T}$ (Fig. 3) the significance of the specified times is:

☞ $\boldsymbol{T_{op}}$ = the operative time – it comprises elements of the basic time ($\boldsymbol{t_b}$) and of the auxiliary (helping) time ($\boldsymbol{t_a}$):

- the basic time $\boldsymbol{t_b}$ comprises the time spent by the worker in order to perform the processing/cutting operation;

ONLINE ISSN 2069-7430
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pp. 55-61

• the auxiliary (helping) time t_a comprises the time required to take the unprocessed parts from their stack, the time spent to position and fasten the parts on the machine table, the discharge of machined parts and their placement in the stack of processed parts etc.

☞ T_{dl} = maintenance time of the workplace – comprises the technical maintenance time t_{dt} and the organizational maintenance time t_{do}:

• the technical maintenance time t_{dt} represents the time spent to maintain the machine in normal functioning condition: checking and adjusting the operating parameters, replacement of used tools and devices, regular lubrication of the machine etc.

• the organizational maintenance time t_{do} comprises the time spent by the worker during the entire work shift to supply the workplace with workpieces, with various required materials etc.

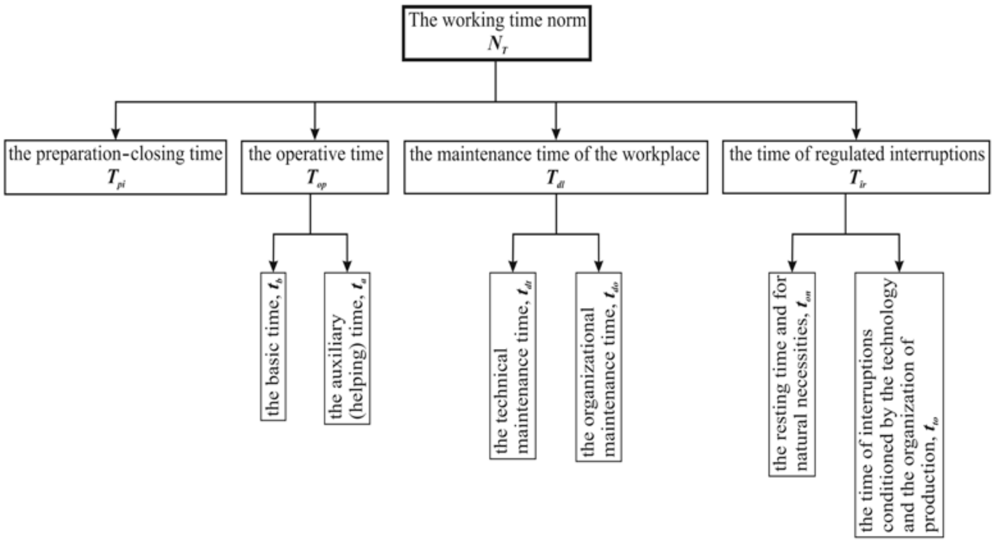

Fig. 3.
The structure of the working time norm N_T (STAS 6009-75).

☞ T_{ir} = the time of regulated interruptions comprises:

• resting time and for natural necessities t_{on};

• the time of interruptions conditioned by the technology and the organization of production t_{to}.

From the analysis of the time norm (see Table 1) one can notice that:

- the operative time T_{op} represents, actually, the functioning cycle, namely the working time, the idle running time and also the auxiliary supplying–fixing and detachment–evacuation times;

- the maintenance time of the workplace T_{dl} , the time of regulated interruptions T_{ir} and the preparation – closing time T_{pi} are reflected by the coefficient of machine utilization K_u and the coefficient of the working day utilization K_z .

Table 1

Correlation between the times for the calculation of the working capacity Q and the times for the calculation of the working time norm N_T

Computation times for working capacity	**The working time norm N_T (STAS 6909-75)**	
T_l Working time *quantification: time units*	t_b the basic time *quantification: time units*	T_{op} the operative time *quantification: time units*
T_g Idle time *quantification: time units*	t_a the auxiliary (helping) time *quantification: time units*	
T_{aux} The auxiliary time for supplying –		

fixing and detachment – evacuation *quantification: time units*		
K_u Coefficient of machine utilization *quantification: dimensionless subunitary coefficient*	t_{dt} the technical maintenance time *quantification: % din* T_{op}	T_{dl} maintenance time of the workplace *quantification: % din* T_{op}
K_z Coefficient of the working day utilization *quantification: dimensionless subunitary coefficient*	t_{do} the organizational maintenance time *quantification: % din* T_{op}	
	t_{on} resting time and for natural necessities *quantification: % din* T_{op}	T_{ir} the time of regulated interruptions *quantification: % din* T_{op}
	t_{to} the time of interruptions conditioned by the technology and the organization of production *quantification: % din* T_{op}	
	T_{pi} the preparation – closing time *quantification: % din* T_{op}	

The working time norm N_T is expressed – in all cases – in min/piece or sec/piece and represents the time required for processing a single part.

The working capacity determined on the basis of the working time norm:

$$Q_r = \frac{1}{N_T} \text{ [pieces/min] or [pcs/sec]} \qquad (16)$$

represents the <u>real</u> working capacity of the concerned machine-tool, because for the calculation of the working time norm N_T there were taken into account both the maintenance time of the workplace and the time of regulated interruptions.

Depending on the type of production and type of the supplied machine-tools, using the regulations (Unified time standards for the woodworking industry 1975, Norms and work regulations and unified tariffs for the wood industry vol. 1 1989, Norms and work regulations and unified tariffs for the wood industry vol. 2 1989) one can determine the working time norm for any product respectively the working capacity for each machine-tool.

CONCLUSIONS

The theoretical clarifications concerning the concept of “working capacity” referring to machine-tools, equipments or technological lines are necessary for both the design activity (calculation of the number of machine tools for a technological flow etc.) and for the establishment of the working time norms in any workshop/technological line/department/factory.

The correct understanding of the meanings of these concepts is possible only by knowing and understanding the notions of “working cycle” and “functioning cycle”, as explained in this paper.

In order to support the specialists in the field of work norming, the theoretical concepts related to the norm of working time were presented and their correlation to the notion of “actual working capacity”.

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