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POSSIBILITY TO USE MAXIMUM POWER OF MAIN SAW MOTIVE POWER DURING THE CUTTING PROCESS

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ABSTRACT
In a study is given analysis of electromotive power (EMP) of mechanism a saw main motion at stationary and non-stationary work conditions.Base theoretical displays are given and experimental tests power consumption of electromotor (EM) during cutting pieces with different tmechanical properties, in conditions increased productivity of a rolling mill, are shown.Work of EM have been analysed: on natural characteristic and work with included resistance in the rotor circle.Research results point out that even in conditions of increased productivity, on the average 70%, degree of EM power use is considerably low, which is a good base basement for re-designing of those very important rotary dynamic structures.Authors have not been engaged with a problem of tool wear.
Key words: electromotive power, non-stationary work, maximum power.

1. THE INTRODUCTION

The production enlargement at rolling mill previously use to be solved by improvement of production capacities like heating, rolling and adjusting until the mechanical capacity, in which hot saw is included, use to be neglected.

To coordinate those capacities it is necessary to improve saw productivity, usually increasing power of main motive. This has as a consequence: re-construction of main saw motive power by increasing shaft dimensions, mounting of bearings with bigger static and dynamic load capacity, selecting of adequate flywheel mass to eliminate movement nonlinearity of rotating elements etc. All this means a big investments. It is enough reason for examination of possibility to use maximum power of main saw motive power, keeping existed and installed capacities: in conditions of increased productivity of processing center (PC), but not reducing of whole system stability.

A functional analysis of PC have been executed with determination of required number of hot saws in conditions of increased production of rolling mill [1].

2. THEORETICAL BASES

In common case saw motion power can be represented as a sum of: idling power, cutting power, penetration power and power of subsidiary motion [2]

$$P = P_0 + P_T + P_R + P_Q \; . \qquad ...(1)$$

Idling power P_0 is used for surmounting of friction resistance and other resistance of machine. Cutting power P_T depends from velocity v and main cutting resistance T. Penetration power P_R is caused with influence of radial force on saw disc. Power of subsidiary motion P_Q, is power required for surmounting of friction resistance during subsidiary motion. During rotation of a saw disc, power is changing and reaching a maximum value at the moment when cutaway during cutting is maximum

$$P_m = 2\pi n \cdot M_m / 60 \,. \qquad ...(2)$$

Due to relatively big inertia of EM rotor and inertia other rotating parts of main saw motive power, EM has to be dimensioned in accordance with average power, where W_1 is work during one rotation of saw disc

$$P_m = W_1 \cdot n / 60 \,. \qquad ...(3)$$

In the rolling mill working process is performed continuosly and hot saws are permanently working with interrupted loading. When saw EM is not loaded (pause phase), the same one is not turned off but working in idle motion (stationary situation $d\varphi/dt$=const.). At that moment a saw opposes to the rotary moment of EM with friction resistance in bearings, the same value. During the cutting process of metal profile (non-stationary situation $d\varphi/dt \neq$const.) in addition to, motor moment M_m which is opposed with load moment M_t, as well appear acceleration moment or deceleration moment M_u as a result of action moment inertia from EM and rotating elements of transmission mechanism ($M_u = M_m - M_t$). With the characteristic of motor start-up is defined a alteration of electric current and torque from the moment when is motor turned on electrical network until motor is reaching a full speed. The alteration this moment is given in form of curve M_m=f(n), Figure 1.

Characteristic points on curve M_m=f(n) are the following: start-up (moving) moment Mp, turn-up (maximum) moment M_{pr} and nominal (named) moment M_n. The turn-up moment M_{pr} as important value for motor selection, is given in a list of manufacturer as a form of relation M_{pr} / M_n.

Start-up moment can be estimated by testing of EMP approach, in condition that power inertia moment of all rotary mass is known, with recording of rotary speed curve in function of time n=f(t) from the moment of turning on when the motor is resting (n=0) until reaching a idling velocity n_0. A part a-c moment curve during EM operating on natural characteristic, can be estimated enough exactly by testing of approach but steeply part of moment curve c-e can not be exactly estimated by testing of motor approach. However, d-e part can be obtained in the load testing, so c-d part can be approximately supplemented. In consideration of own natural characteristic and feature that is possible by inserting of resistance into the rotor circle, this characteristics can be changed, asynchronous slide ring EM are normally used for power mechanism of main saw motive. Accordingly, starting-up of this EMP is executed with resistance included in the rotor circle during approach time but the same one is gradually excluded during that period. Curve 2 represents characteristic with included resistance in the rotor circle. At lower voltage (curve 3) instead 380 V at triangle connection (curve 1 is natural characteristic M_m=f(n)), EM is now connected on 500 V at star connection so phase voltage is $500/\sqrt{3}$. In that case, maximum sliding is not changed but maximum moment is reduced with square voltage relation. After reaching a speed of rotation, which correspond to turn-up moment M_{pr}, during the time of motor start-up, a acceleration moment M_u is abruptly starting to fall with the increasement of rotation speed and at the moment of reaching rotation speed near asynchronous (n_o=994 min^{-1}, n_{sin}=1000 min^{-1}) M_u=0.

It can be concluded that EM is working with a changeable loading, that's why the same one is not dimensioned on the basement of maximum loading but equivalent power, in reference to equivalent moment. Near by, with changeable loading which periodically can be considerably bigger than nominal, EM is heating on stationary overtemperature on which he should be heated at equally permanent nominal loading. EM selection considering allowed heating, must satisfy the criterion $M_{ekv} \leq M_n$. Short duration maximum moment can be reaching four nominal (named) moments $M_{max} \leq 4M_n$. Thus, calculation of possibility to use EM maximum power is based on method of equivalent moment, considering that EM should be dimensioned according to medium (square medium) power [3], in reference to equivalent medium squarely moment (equation 4.)

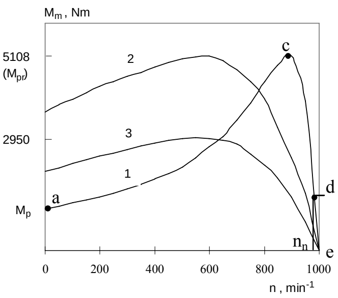

Figure 1. EM moment characteristics

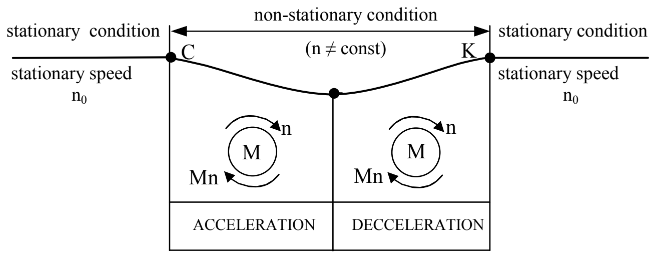

Figure 2. EMP condition during cutting process

$$M_{ekv} = \sqrt{\frac{\Sigma\left(M_{sri}^2 t_{ri}\right) + M_0^2 T_{pc}}{\sum t_{ri} + T_{pc}}} = \sqrt{\frac{\Sigma\left(M_{sri}^2 t_{ri}\right) + M_0^2 T_{pc}}{T_c}} \qquad \ldots(4)$$

implementing: M_{sri} medium value of motor moment for specific loading period, t_{ri} duration of i-loading period, M_0 idle moment, T_{pc} break period during one working cycle of PC (processing center), $\sum t_{ri} = T_{rc}$ actual cutting period during one working cycle, $T_c = T_{rc} + T_{pc}$ period of duration for one working cycle PC. Medium value EM moment is:

$$M_{sri} = \frac{1}{t_{ri}}\left[M_{ti}t_{ri} - T_{emeh}\left(1 - e^{-\frac{t_{ri}}{T_{emeh}}}\right)\left(M_{ti} - M_{pi}\right)\right]. \qquad \ldots(5)$$

idle motion moment is

$$M_0 = 9550\frac{P_0 - P_{FeTV}}{n_0} \qquad \ldots(6)$$

At idle motion, power, because of symmetricaly loaded EM, can be measured with Watt-meter which show only one phase, so complete idle motion power is $P_0 = 3P_W$. Losses in the power P_{FeTV} are related to losses in the stator iron and friction in the bearings and motor ventilation, they are not changing at load alternation reaching 4,2% from nominal power EM. If electromagnetic processes in the EM are neglected with acceptance that his moment characteristic during operational time is linear, at constant loading moment in the unit period of time it is possible to calculate motor moment as a function of time during i-loading period

$$M_{mi} = M_{ti}(1 - e^{-\frac{t_{ri}}{T_{emeh}}}) + M_0 \cdot e^{-\frac{t_{ri}}{T_{emeh}}} \qquad \ldots(7)$$

implementing: M_{ti} - loading moment in constant amount for specific period of loading duration time

T_{emeh} - electromechanical time constant without added resistance in rotor circle.

Based on equation (7), considering additional resistances in the rotor circle, at i-loading period it can be calculated a loading moment from the following equation

$$M_{ti} = \frac{M_{mi} - M_{počo} \cdot e^{-\frac{t_{ri}}{T'_{emeh}}}}{(1 - e^{-\frac{t_{ri}}{T'_{emeh}}})} \qquad \ldots(8)$$

implementing: T'_{emeh} - electromechanical time constant with added resistance in the rotor circle

M_{pi} - motor moment at the end of previous loadng period; in starting period of cutting time equal to the idle motion moment M_0.

3. EXPERIMENTAL TESTS

Experimental tests have been executed on hot saw, sliding type, German company "SACK". A mechanism of main saw motion previously have been reconstructed [4], consisting from asynchronous EM type ZP 355 L-6 power P_n=132 kW (n_n=986 min^{-1}), belt transmission i=1, periflex coupling type 28-1 and shaft with flywheel including a saw disc Ø1900 mm, mounted on shaft bracket. A mechanism of subsidiary motion is consisting of saw sledge which is wearing a mechanism of saw main motion. Saw sledge is moving on sliding tractors by cylinder powered with the hydraulic unit. To coordinate a capacities of rolling mill and processing center, on existing hot saws is increased capacity from projected 2500 mm^2/s to average 4200 mm^2/s, in the percentage 70%. Measured idle motion power P_0 = 18 kW. At new working conditions,experimental tests for estimation of EM power consumption in dependence of saw productivity (Figure 1), are executed on metal profiles with different mechanical properties but in this study are presented only two (curve 1 and 2, concerning 3,4 and 5). From diagram can be concluded that power consumption is increasing with enlargement of saw productivity but that increase is not quite directly proportional.

At cutting of harder metals (curve 1 and 2) power consumption at same productivity is much bigger than at cutting of softer metals (curve 3,4 and 5). The examinations have shown that softer metals is better to cut with higher speed of subsidiary motion because of distinctly reduced motor power consumption. Explanation is laying in accumulation of kinetic energy which is given from flywheel to the system, during a cutting period.

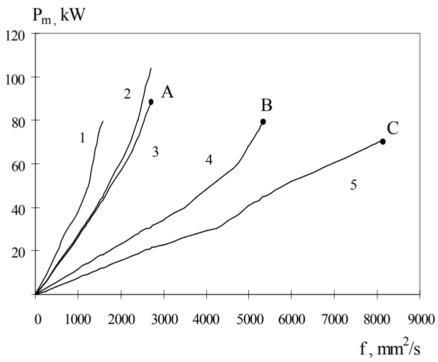

Figure 3. Power consumption P_m related to productivity f at cutting of metal profiles with different mechanical properties

4. CONCLUSION

- Enlargement of saw productivity for 70% have not essential influence on EM over-loading;
- All over-loadings appearing during cutting of heavy square profiles can be eliminated with permanent increasing of resistance in EM rotor circle or with mounting bigger flywheel mass on saw disc shaft;
- It is possible to build-in EM with lower power thus his degree of efficiency could be increased;
- Low-thickness metal profiles should be cuted at higher speed of subsidiary motion.

5. REFERENCES

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