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MACHINING OF FERRITIC-MARTENSITIC STEEL IN POWER INDUSTRY - IN LIGHT OF LOAD OF CUTTING PROCESS

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Abstract: *The main aim of this article is to describe an influence of cutting conditions and material of cutting tool on load of cutting process. The influence of these technological conditions on total load and efficient cutting power of machining is monitored. It is realized during semi-finishing plane milling of ferritic-martensitic stainless steel. Generally, these all things can have an impact to operating costs at total sum. Nowadays ferritic-martensitic steels are most frequently used as construction materials in power industry.*
Keywords: *milling, energy intensity, ferritic-martensitic steel, cutting force*

1. INTRODUCTION

Nowadays it is important to look at ecological aspects of manufacturing. Energy intensity is possible to influence with correct choice of the technological conditions of the manufacturing process. Needed power for realization of the cutting process is directly proportional to absorbed energy [5].

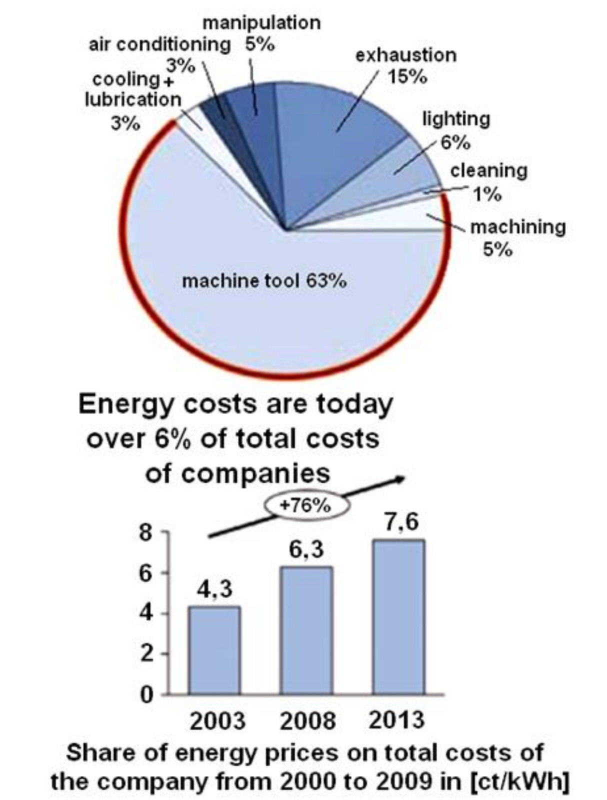

Fig.1. Absorbed energy vs. manufacturing costs [5]

The European Union is preparing a new regulation. This regulation should be about energy intensity of machine tools. The main aim of this regulation is to reduce electricity consumption regarding reducing emission of greenhouse gas [7].

The users are firstly interested in accuracy of machining, reliability, power, productivity and price of the machining tool when they are choosing the right machining tool for their company. Power consumption is not meanwhile important for them. One of the possibilities, how to reduce energy intensity of production, is to monitor energy intensity of machine tools in term of their construction. The second possibility is to monitor energy intensity of the cutting process and here is quite number of factors [7].

1.1 Steel P91 in power industry

Steel, with trade-name P91 (9%Cr – 1%Mo), is a modified ferritic-martensitic steel. This kind of steel is ranked among modern high-temperature steels which are based on 9% content of chromium. P91 is designed for manufacturing of forgings, castings, sheets and tubes, which works in temperature between 550°- 650°C, especially in power industry. This steel was developed because of rising of thermal efficiency of power plants. Power plants always represent the main source of electrical energy. Steel P91 is ranked among stainless steel and also it is difficult-to-machine material. Commonly it is suitable to use sharp cutting tools and also use lower cutting speeds, higher depths of cut and feed rates during machining of stainless steels, so be ensure maximal productivity of machining [1], [2], [3]. This article deals especially with issues of machining of this steel.

2. EXPERIMENT

2.1 Characterization of the experiment

The particular experiment at regime of semi-finishing machining was divided into two phases. The phase of a pre-experiment and an experiment itself. The task of the first phase was to select appropriate type of the cutting material. The task of the second phase was selection of appropriate cutting conditions for semi-finishing machining of the steel P91 with respect to initial conditions. These initial conditions are:

a. •the supplier of cutting tools: Ingersoll
b. •volume of material removal: 600cm3 (equivalent to the amount of material added to the dividing plane)
c. •criteria value of the tool wear: 0.5mm

d. •productivity of machining

Workpiece, which was fixed on the work-table of the machining centre, was machined by a milling cutter with diameter of 80 mm. External and internal cooling was running. The milling cutter was fitted with tangential inserts. In the initial stage were available seven kinds of inserts. That number was narrowed down to two types of inserts. These two inserts were subsequently subjected to detailed testing. During test there was studied mainly tool life of the cutting edge. Further, there were measured roughness, hardness and topography of machined surface, cutting forces and effective cutting power.

For further (more detailed) tests were, from pre-experiment phase, chosen two types of sintered carbides: type "PK" and type "MK". Type "PK" is a type of carbide P10 – P20/ K10 – K25, it is PVD – coated high performance multi-range grade, with high wear resistance and high toughness for milling alloyed steels as well as cast iron materials. It is designed for higher cutting speed rates, for finishing up to medium rough milling under mainly stable application conditions. Type "MK" is a type of carbide M15 – M35 / K20 – K40, it is coated micro-grain carbide grade with good toughness and excellent wear resistance for machining steels with increased tenacity, stainless steels as well as grey cast iron and nodular cast iron [6].

At this stage of the experiment the milling cutter was fully fitted (8 inserts), and tests were done under variable cutting conditions, see Tab.1.

	 PK		 MK
v_c [m/min]	140	180	220
f_z [mm]	0,1 0,15 0,2	0,15	0,15

Tab.1 Cutting conditions for experiment

Criteria value of tool wear on the flank was fixed at 0.5mm. After reaching this value to any cutting edge the experimental measurement, for given cutting conditions, were finished. Experimental measurements were also limited by the time (material) demand factor, i.e. where, the curves do not intersect value 0.5mm, there tests were stopped for the above reason.

2.2 Tool wear

In the figure 2 the realized results are displayed. Graph on left side describes the influence of variable feed rate on tool wear at constant cutting speed. In this diagram is also evident that tool life decrease with increasing feed rate. It is perceptible especially for carbide type "MK". In this case, the value of tool wear 0,4 mm was achieved in 30 minutes when feed rate 0.1mm/teeth was used, while similar value of tool wear but with feed rate 0.15 mm/tooth was achieved approximately in 10 minutes. Thus striking difference was not observed when carbide "PK" was used. It is also necessary to say that in the case of "PK" the experiments were stopped earlier because of poverty of time and workpiece material.

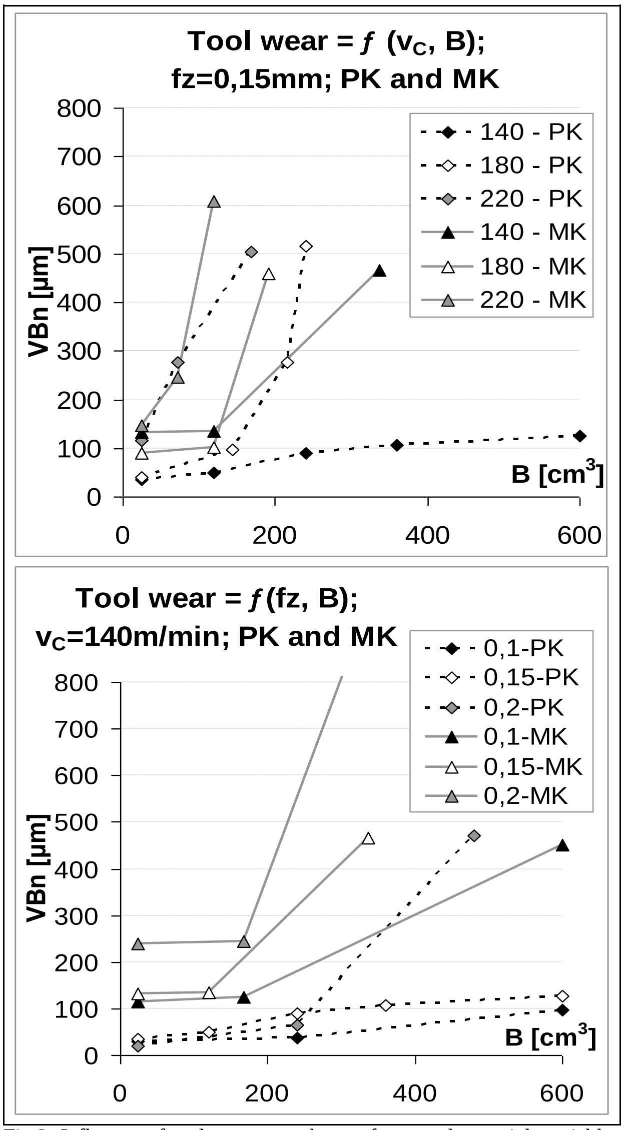

Fig.2. Influence of tool wear on volume of removal material; variables are the cutting speed and the feed rate for both "PK" and "MK" sintered carbides

In the right side of figure nr.2 is displayed the influence of cutting speed on tool life at constant feed rate. The highest value of tool life was achieved at cutting speed 140 m/min for both types of carbides – "PK" and "MK". With increasing cutting speed is possible to say - the higher the cutting speed, the higher the tool wear. After comparing the total results for these both sintered carbides is clear, that the type "PK" reached better results in comparison with type "MK". Classification of the tool wear: combination of wear by ridge rents along with crumbling of edge.

2.3 Total force load and effective cutting power

The tool life, the reliability and the productivity are influenced with magnitude of cutting forces. That can be also included total evaluation of service, for example the tool life of spindle. The lower load of cutting tool, the lower load of spindle and the lower machining input for the machine. The lower input power means the lower energy intensity of production. All of it can be seen in the total costs for service. It appears from this that it is important to use the cutting tools and the cutting conditions, which have as small as load of spindle. These cutting tools also have lower cutting forces [4]. The evaluation of the force load of the cutting tool is done by watching the total force load of the cutting tool F. This value F is resultant of the values which were measured during the experimental machining.

$$F = \sqrt{F_X^2 + F_Y^2 + F_Z^2} \; [N] \qquad (1)$$

where: F total force load [N]

$F_{X,Y,Z}$ components of the cutting force which were measured in axes x, y, z [N]

In term of cutting stability the increasing tool wear has negative influence on the force load of cutting process [4]. That is why the cutting forces increase depending on increasing the volume of removal material. The volume of removal material is directly depending on the tool life, or the tool wear. The sintered carbide type “PK” at vc = 140 m/min and fz = 0.15 mm wore at the least and the slowest. It matches the force load. This force load did not exceed the value of 1000N (see in Fig.3)

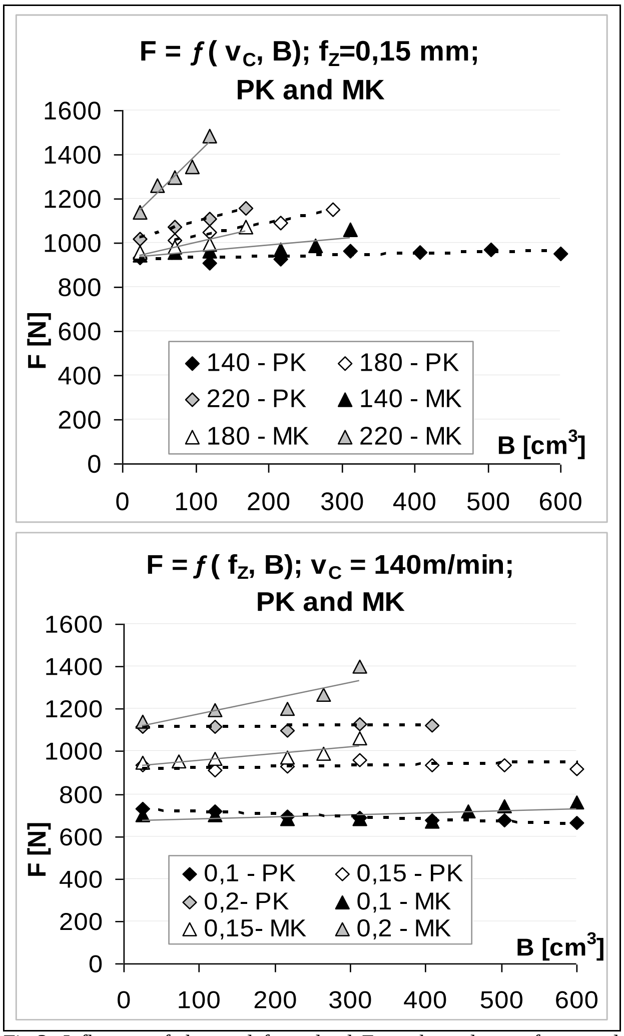

Fig.3. Influence of the total force load F on the volume of removal material; variables are the cutting speed and the feed rate for both “PK” and “MK” sintered carbides

Influence of the cutting speed vc on F is also brightly seen. The higher cutting speed the higher tool wear and then the higher force load. It is consistent with both cutting materials. The influence of the feed rate fz on the magnitude of force load is clear. The increasing feed rate fz induces the increasing force load.

It is caused in that with increasing feed rate the cross section of cut layer is also increasing. In the case of insert type “PK” the force load of the cutting tool is dependent on the value of the feed rate. The force load for type “PK” is also constant for the whole tool life. There can be seen the influence of the tool wear for the type “MK”. At the higher values of feed rate, there is expressive rising of tool load in dependence on increasing volume of removal material.

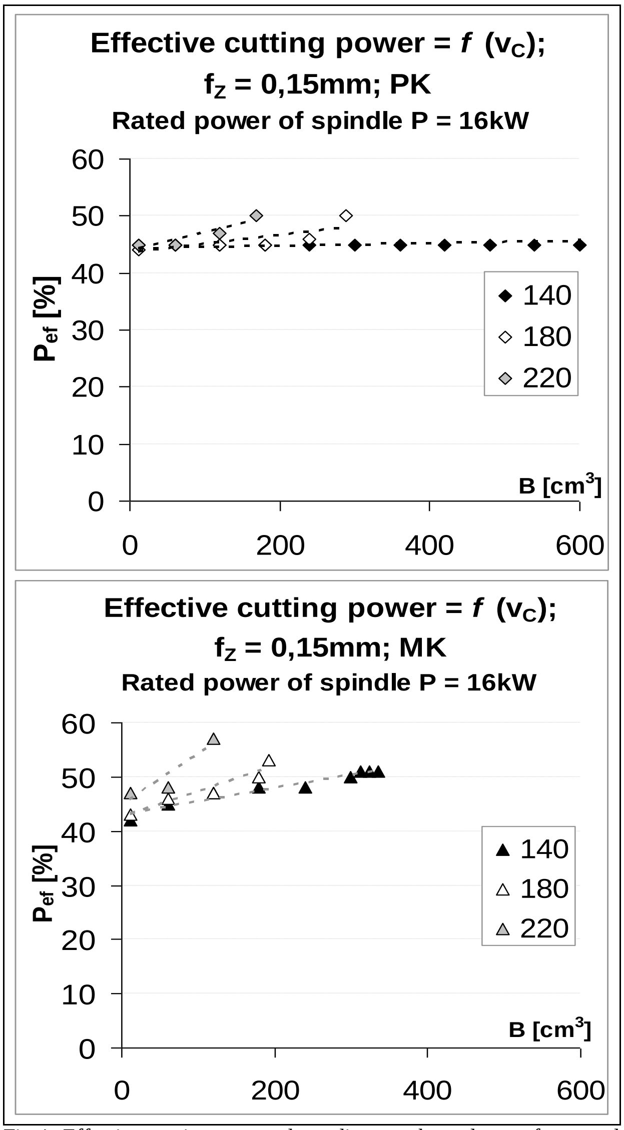

Fig.4. Effective cutting power depending on the volume of removal material and the change of the cutting speed vc; fz= 0.15mm; “PK” and “MK”

Effective cutting power increases depending on the volume of removal material. This rising is more intensive with increasing cutting speed. It corresponds to behaviour of the tool wear. The increasing cutting speed has negative influence on the tool wear and it induces rising of the tool force load. Rising of the force load has an influence on increasing effective cutting power on the spindle.

Dependence of the effective cutting power of the machine on the change of the feed rate fz is brightly seen. For both types of sintered carbides “PK” and “MK” is given that the higher value of the feed rate fz, the higher effective cutting power.

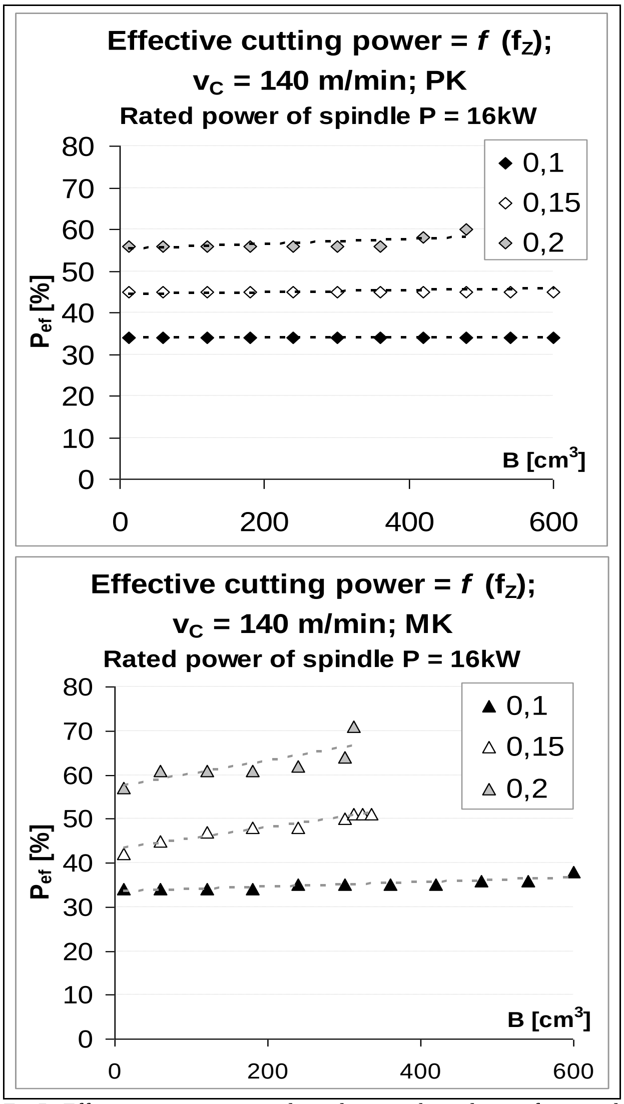

Fig.5. Effective cutting power depending on the volume of removal material and the change of the feed rate fz, vc = 140 m/min; “PK” and “MK”

As you can see in the graphs, the increasing of the feed rate fz for about 0.05mm means increasing of the power about 10% (it is true for tested cutting conditions). In addition, “MK” is approximately about 5% more exacting of power at higher values of feed rate in comparison with type “PK”.

3. CONCLUSION

Ecology aspects expressively influence all human activities, nowadays. To use steel P91 in the power industry is also because of ecology reasons. Energy intensity is generally increasing. It will be necessary to focused on energy intensity in all human activities, including machining. Energy intensity is possible to influence by right choice of technological conditions during the production process. In term of total force load is possible to say, that in the interval of cutting speed vc = 140 ÷ 180m/min and the feed rate fz = 0.1 ÷ 0.15mm both “PK” and “MK” sintered carbides are behaving similar. In case that the criterion for right choice of cutting conditions should be only total force load, would be appropriate to choose lower values of cutting conditions and cutting tool type “PK”. And what about effective cutting power? The best one is also type “PK”. The value of cutting speed vc does not have direct influence on effective cutting power. The value of the cutting speed expressively influences the tool life. Expressively influence on effective cutting power has the value of the feed rate fz. Here is the best to choose lower values.

As it is well known the cutting tool edge preparation can increase cutting efficiency. If cutting efficiency is increased it means that it can improve achieved results. The next research will be focused on preparation of cutting tool edge.

4. AKNOWLEDGEMENT

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