Energy Efficiency Level As A Criterion For Selecting Power Tools Driven By Different Types Of Driving Media

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Abstract: *Energy is becoming more and more expensive, leading to the result that production costs and therefore product prices rise and become less competitive on the market. This is a contribution to the efforts of achieving energy savings when designing and selecting manufacturing equipment. This paper looks at the energy efficiency level as a criterion for selecting manufacturing equipment. The energy efficiency level, in its function as a criterion for selecting equipment, is being described through the example of selecting power tools that are driven by different driving media.*

Key words: *energy, pneumatic tools, high-frequency tools, efficiency.*

1. Introduction

When selecting equipment, machines and tools, most often the price, shipping time, financing conditions and similar issues are considered to be important factors, while the energy consumption of the purchased equipment, the energy efficiency level, energy consumption per unit and all other energy criteria, have lower priority. Equipment users mostly concentrate on cutting production costs, while rationalization of raw material and energy consumption gets very little attention. With energy becoming more expensive all the time, the price of energy becomes one of the crucial factors for the evaluation of production costs. Rational production requires the designers to rationalize the consumption of all types of energy that are being used in industry, when designing manufacturing processes. Accordingly, the energy efficiency level of a machine, device or tool becomes an important criterion when selecting equipment.

2. Power tools

Today, mounting and assembling processes are unthinkable without modern power tools driven by different driving media. Most widely used are the following driving media:

- compressed air,
- high-frequency current (200 Hz or 300 Hz),
- standard frequency current (40 Hz, 50 Hz or 60 Hz)

Based on the type of driving media and the type of energy used for operating them, power tools can be divided in three classes:

- pneumatic power tools,
- high-frequency power tools, and
- universal electric power tools.

Pneumatic power tools are among the most widely used power tools. They use the energy of compressed air to produce linear or, in most cases, rotary motion of the motor axle.

High-frequency power tools use a three phase electromotor and have to be connected to special high-frequency mains (200 Hz or 300 Hz). There is no similarity between high-frequency technology and these tools, which only work at a higher frequency. In physics high frequencies cover a range starting from1000 Hz. But, as this term has been widely accepted, in manufacturing and commerce, it does not make sense to give these tools a new, more accurate name. These tools are generally a little heavier than pneumatic tools, but they are much lighter than universal electric tools.

Universal electric power tools are not used often at assembly workshops in industry. For an electromotor to be used in power tools, it must have a limited mass and together with the reductor, it mustn't exceed a strictly determined weight, that allows comfortable handling, in order to reduce excessive physical tiredness of the operator using it. The operating characteristics of the electromotor and its mass, are determined by the torque and the specific weight of the material, power tools with universal electric engines haven't found their place in industry, because an increase of power on the electromotor causes an increase of its mass, too, and so the tool can't be used because the operator will be tired out very soon. The advantage of these tools is that they can be plugged into any 220 V single-phase current wall socket, grounded or not grounded. Therefore, they found their place in home workshops and tasks where high-power tools are not needed.

3. Energy efficiency

Energy efficiency (η) is the ratio of effective energy consumption (E_{ef}) and the total energy consumption (E_u) needed to operate the equipment, e.g. power tools, and can be calculated using:

$\eta = E_{EF} / E_U$

where:

$E_{EF} = P\ e$ (kWh/day) – average effective energy per day
P (KW) – power of one power tool
e (h /day) – effective operating time per day

- For pneumatic power tools:

$E_U = E_{RH} + E_{PH}$ (kWh/day) – total energy needed to operate the power tool

where:

$E_{RH} = P_K \cdot T_{RH}$ (kWh/day) – energy consumed in compressor operation
P_K (kW) – compressor power
T_{RH} (h/day) – operating time of compressor
$E_{PH} = P_{OK} \cdot T_{PH}$ (kWh/day) – energy consumption during idle run of compressor
$P_{OH} = 0{,}25\ P_K$ (kW) – required input power for compressor
T_{PH} (h/day) – idling time of compressor

- For high-frequency power tools:

$E_U = E_{EF} + E_{RH} + E_{PH}$ (kWh/day) – total energy needed to operate high-frequency tool

where:
$E_{RH} = E_{EF} / (\eta_A \cdot \eta_G)$ (kWh/day) – energy loss in operation of generator
$\eta_A = 0{,}7$ – efficiency of high-frequency power tool,
$\eta_G = 0{,}85$ – efficiency of the high-frequency power tool's generator
$E_{PH} = P_{OG} \cdot T_{OG}$ (kWh/day) – energy loss during idle run of generator
$P_{OG} = 0{,}2\ P_G$ (kW) – power of generator during idle run
P_G (kW) – generator power
$T_{OG} = t - Trg$ (h/day) – idling time of generator
t (h/day) – total operating time

4. Resarch results

The task is to put 12 power grinders (of three different types) into function at the welding department of the "Zmaj" agricultural machinery factory. There are two possibilities: to implement pneumatic or high-frequency power grinders. To come closer to the solution of the dilemma, let's calculate, from the viewpoint of energy cost, the energy efficiency and the cost-effectiveness of using power grinders.

Based on the previous calculations and on the analysis of a grinder's operation, it becomes obvious that, in pneumatic power tools, the impact of inconsistency between consumption and production of driving media, is significant. Besides, in power grinders, there is additional loss of energy, and also loss of compressed air caused by loss in the distribution network. The total energy efficiency ratios for the different grinder types are:

$\eta^{v} : \eta^{p} = 0{,}21 : 0{,}033$

$\eta^{v} : \eta^{p} = 100 : 16{,}5$

	High-frequency power grinders			Pneumatic power grinders		
	MSh_o- 840-2	MSF- 840-2	MSf_o-852-d	LSF-16S	LSV-41	LSS-53
1	2	3	4	5	6	7
Quantity	2	6	4	2	6	4
max. power output (kW)	0,36	0,7	1,7	0,25	0,9	1,6
RPM (min^{-1})	18.000	7.100	8.500	20.000	4.200	12.000
tool weight (kg)	2,1	2,2	5	0,6	3,1	4,3
compressed air consumption(m^2/h)	-	-	-	30	76	112
operating frequency (Hz)	300	300	300	-	-	-
price (€)	670	700	960	650	690	1010

The practical significance of these ratios is showed in the energy flow chart for certain types of tools. The decision to use one of the alternatives is based on the expected effects. These effects, i.e. the outcome of the decision-making process, can be illustrated through a quantitative measure, usually money.

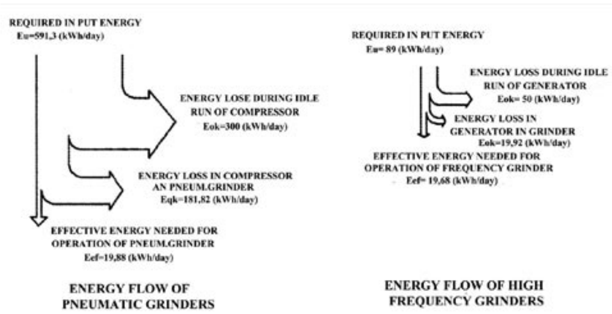

Figure 1

$E^{P} Ce : E^{V} C e = 591{,}3 \cdot 2 : 109{,}2 \cdot 2$

$E^{P} Ce : E^{V} Ce = 1182{,}6 : 218{,}4$

Following this analysis, we come to the conclusion that, performing the same task, high-frequency power grinders consume less energy and are incomparably less expensive than pneumatic power tools. Using high-frequency power grinders allows a significant reduction of energy consumption, and makes the manufacturing process more cost-effective. Only by reducing the consumption of energy, the sum invested in high-frequency grinders can be returned in only 130 working days. That means, some 18.000 € could be saved per year (260 working days).

Based on the above considerations, it is obvious that a number of various factors emerge in the process of using pneumatic power tools, leading to energy consumption greater than in the case of high-frequency tools. Considering the efficiency of input energy needed for power tools to operate, we can conclude that implementing high-frequency tools in manufacturing processes, is a good solution. The disadvantage to this solution is that high-frequency power tools are much heavier compared to pneumatic (fig. 2) power tools, and that there is a certain risk for high-frequency power tools to overheat, when they are being overloaded, or handled unprofessionally.

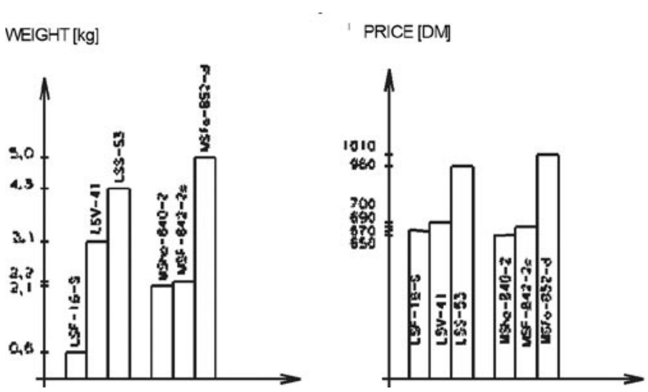

Figure 2

The reduction of cost relating to electric energy, is significant. In our example (12 grinders) the total energy consumption is E_u= 591,3 (kWh / day) The price of electric energy is: C_{EE}= 0,16 €.

The price of electric energy consumed in daily operation of pneumatic tools (12 grinders) is:

$C_{EPA} = E_{uPA} \cdot C_{EE} = 591{,}3/16 \cdot 0{,}16 = 6$ €/h

For the same working time and the same task performed, the price of electric energy consumed in operation of high-frequency power grinders (12 units) is:

$C_{EVA} = E_{uVA} \cdot C_{EE} = 109{,}2 / 16 \cdot 0{,}16 = 1{,}1$ €/h

From the previous calculation, it is obvious, that by using high frequency tools, we save the following amount of money:

$C_{EU} = C_{EPA} - C_{EVA} = 6 - 1{,}1 = 4{,}9$ €/h

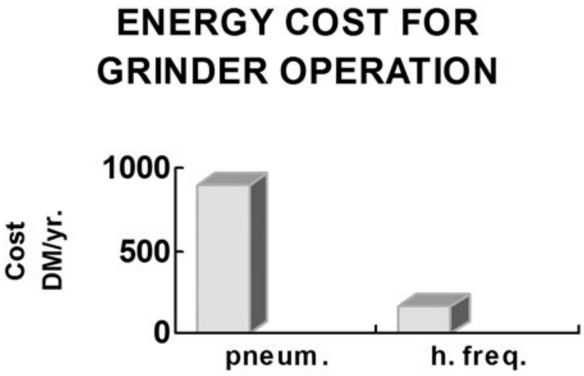

Figure 3

Per year, on one tool, working in one shift (Km = 1800 h/year), considering the consumption of electric energy, we can save:

$U_{TOOL} = (C_{EU} / 12) \cdot 1800 = 734$ € / year.

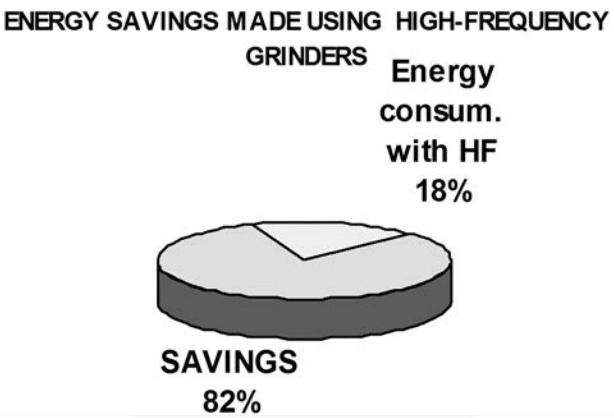

Figure 4

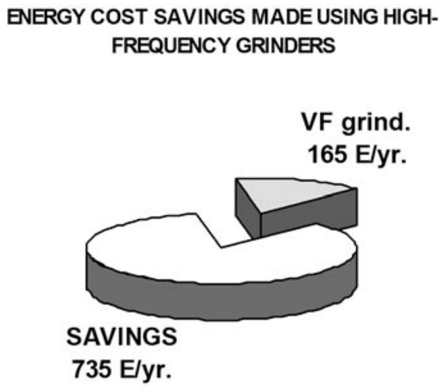

Figure 5

At the factory, they have a total of 282 grinders, so we can make an evaluation (not all pneumatic grinders are in function) of the amount of money saved:

$U_{(\text{for 282 grinders})} = U_{TOOL} \cdot 282 = 734 \cdot 282 = 206.988$ €/year.

If we take the other pneumatic tools into consideration, too (wrenches, screwdrivers etc.), of which a total of 1033 units are used at the factory, we get an approximate saving of:

$U_U = U_{TOOL} \cdot 1033 = 734 \cdot 1033 = 758.222$ €/year.

5. Conclusion

It is obvious that the energy efficiency as a criterion for selecting manufacturing equipment can't be ignored. Using the energy efficiency as a criterion for selecting and purchasing manufacturing equipment, it is possible to make significant savings in energy consumption, and thus make the manufacturing process significantly cost-effective. Looking at the energy efficiency level during operation of power tools, there is no doubt that solutions including high-frequency power tools into the manufacturing process, should be preferred.

6. Reference

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