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# Investigation of harmonic pollution produced by power tools

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**Abstract.** The paper analyzes the influence of power tools operating mode on the power quality, especially on the harmonic pollution. The measurements were carried out with the CA 8334B three-phase portable AC power quality analyzer. The low utilization factor of power tools (due to the short duration of operations) introduces complexity in the study of their impact on power quality. Although the absorbed powers are small, the cumulative effect produced by a large number of power tools can be substantial.

## 1. Introduction

Number and variety of nonlinear equipment used in the residential and commercial domains had a constant increase in the last decades, these being the main sources of harmonic distortions in low voltage distribution systems [1-6]. Simultaneous, has increased the use of equipment very sensitive to electromagnetic disturbances, in industrial automated processes, digital communications, computer networks and multimedia. Under these circumstances, power quality assurance becomes more and more complicated [7-11].

The most common types of power quality problems are: voltage dips, very short interruptions, long interruptions, voltage spikes, voltage swells, harmonic distortions, voltage fluctuations, noise and voltage unbalances [1-3].

To estimate the economic impact of harmonics is much more difficult than other power quality costs, such as voltage interruptions and dips. Harmonic distortion effects on the distribution system equipment and connected loads can be short and long term. Short-term effects include equipment malfunction (e.g., malfunction of electronic equipment based on voltage zero crossing detection or sensitive to wave shape; errors in measures; mis-operation of protective relays), loss of efficiency, electromagnetic interference with communication systems and power losses caused by harmonic currents and voltages [12], [13]. Long-term effects include thermal losses (in cables and equipment), premature aging and reduced life span of equipment [12], [13].

Among the most sensitive equipment at harmonic distortion are computers and programmable controllers, which typically require AC sources with a total harmonic distortion factor (THD) of 5%, the highest harmonic level being at most 3% of the fundamental voltage [2].

Electronic equipment can be disturbed by harmonics due to conduction coupling (via the equipment power supply) and magnetic coupling [1], [2].

The emission and propagation of harmonics through the network are influenced by multiple factors, such as network impedance, voltage distortion, time-variation of number and type of connected equipment, which complicate the analysis of harmonics effects in the network [5], [6], [14-18].



The situation becomes even more difficult in the case of small harmonic sources, because of their random nature and time variability [16], as well the propagation and partial cancellation of harmonics due to phase angle diversity (diversity effect) [15]. Also, for small distributed harmonic sources, the design of mitigation measures is very complex, as and the optimal location of capacitors for power factor correction, due to possible resonances [3].

Although it is very difficult to estimate the cumulative effect produced by a large number of small harmonic sources, it is essential to identify and analyze the sources of the harmonics and their effects. The purpose of this work is to determine, through measurements, the harmonic contributions of power tools.

## 2. Experimental measurements

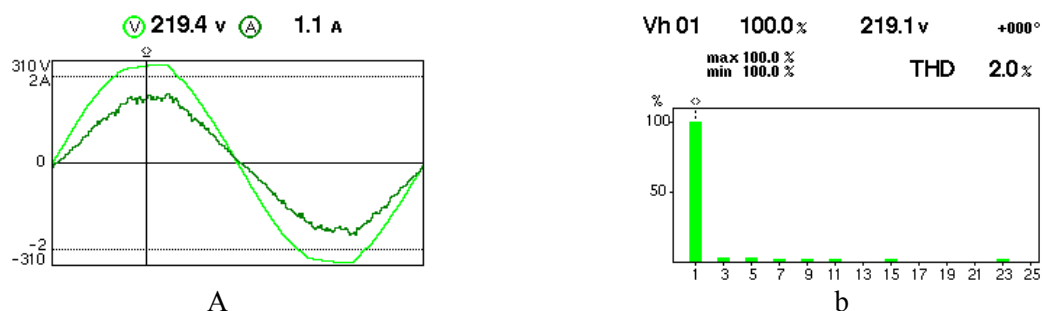
The laboratory measurements were carried out using the power quality analyzer CA 8334B. To measure the current was used current probes MN 93A (5 A) [19].

Power quality analyzer CA 8334B gave an instantaneous image of the main characteristics of power quality for the analyzed power tools. The main parameters measured by CA 8334B analyzer were: True RMS AC phase voltages and True RMS AC line currents; active, reactive and apparent power per phase; harmonics for voltages and currents up to the 50th order; Fresnel diagrams. This analyzer provide numerous calculated values and processing functions in compliance with EMC standards in use (EN 50160, IEC 61000-4-15, IEC 61000-4-30, IEC 61000-4-7, IEC 61000-3-4). The values computed by the CA8334B analyzer were: total harmonic distortion (THD) of voltages and currents; power factor (PF) and displacement power factor (DPF). This analyzer allows the recording, time stamping and characterization of electromagnetic disturbances (swells, dips and interruptions, overrun of power and harmonic thresholds), detection of transients and recording of the associated waveforms.

Below are presented the results of measurements for various types of grinders, electric saws, drilling machines, milling and finishing machines, operating in an isolated mode.

### 2.1. Angle grinder

It was analyzed an angle grinder (AG 115 Faust) with the following technical characteristics: rated active power 580 W, rated (no load) speed 10,000 rpm, rated voltage 230 V, frequency of the supply voltage 50 Hz.



**Figure 1.** Voltage and current waveforms (a) and harmonic spectrum of supply voltage (b) for angle grinder (idle operation)

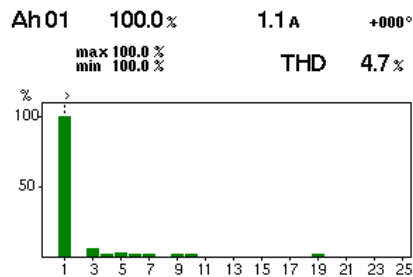
The waveforms of voltage and current (Figure 1.a) are very close to the sine wave, in idle operation of angle grinder.

The voltage harmonics are insignificant, within the EMC limits [20], [21] (Figure 1.b), and total harmonic distortion factor of voltage is very low ( $THD_V=2\%$ ).

Harmonic analysis of current (Figure 2) in idle operation of angle grinder shows that its distortion is within the EMC limit ( $THD_I=4.7\%$ ).

It is noticed that the reactive power is much lower than the active power absorbed by the network, when the angle grinder is in idle operation (Table 1). For this reason, power factor is very good, above the neutral value ( $PF=0.996$ , inductive).

Because the harmonic pollution of current is very low, DPF and PF differs very little ( $DPF=0.997$ ) in this case.

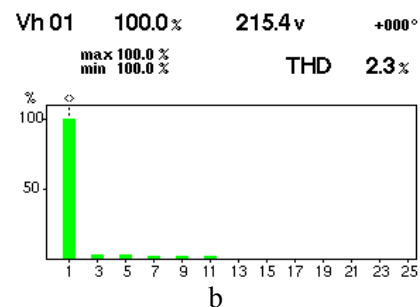
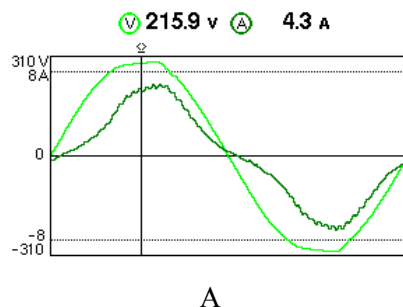


**Figure 2.** Harmonic analysis of the current drawn by angle grinder in idle operation

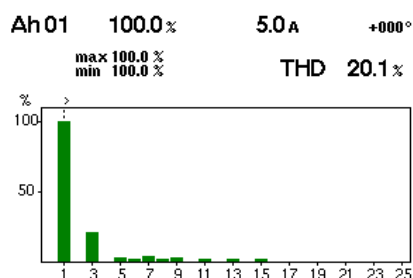
**Table 1.** Angle grinder

Operation mode	Idle operation	Load operation
Active power, P[W]	234.2	296.3
Reactive power, Q[VAR]	21.9	55.1
Apparent power, S[VA]	235.2	301.4
Power factor, PF[-]	0.996	0.983
Displacement power factor, DPF[-]	0.997	0.972

When the angle grinder is in load operation, the waveform of supply voltage is almost sinusoidal (Figure 3.a), but the current waveform is distorted. Voltage harmonics do not exceed the EMC limits (Figure 3.b), but total harmonic distortion factor of supply voltage is slightly higher in load operation compared to idle operation of angle grinder ( $THD_U=2.3\%$ ).



**Figure 3.** Voltage and current waveforms (a) and harmonic spectrum of supply voltage (b) when angle grinder is in load operation



**Figure 4.** Harmonic analysis of the current drawn by angle grinder in load operation

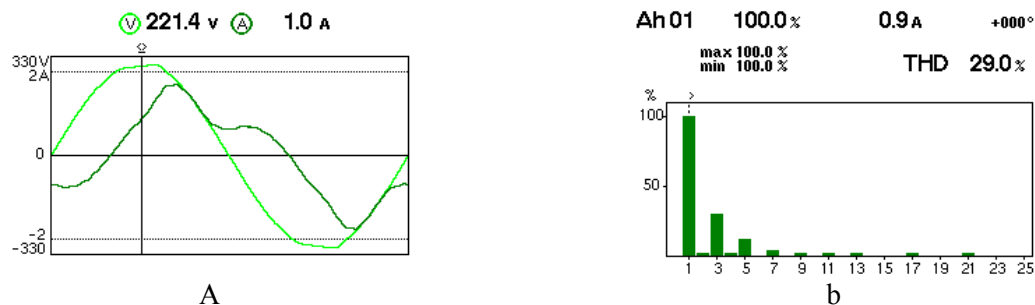
It is observed (from the harmonic analysis of current, Figure 4) that the 3<sup>rd</sup> harmonic exceeds the compatibility limit and total harmonic distortion factor of current is much higher in load operation compared to idle operation of grinder ( $THD_I=20.1\%$ ), exceeding very much the EMC limit.

In load operation of angle grinder, current RMS is almost 4 times higher compared to idle operation. Active and reactive powers also increase compared to idle operation.

PF and DPF exceed the neutral value, but are lower in this case ( $PF=0.983$  inductive,  $DPF=0.972$ ), because the reactive power doubles and the harmonic pollution is much higher in load operation, compared to idle operation of angle grinder.

## 2.2. Bench grinder

Bench grinder (Jupiter) had the following technical characteristics: rated input power 370 W, grinding wheel diameter 150 mm, no load speed 3000 rpm, rated voltage 230 V, frequency of the supply voltage 50 Hz.



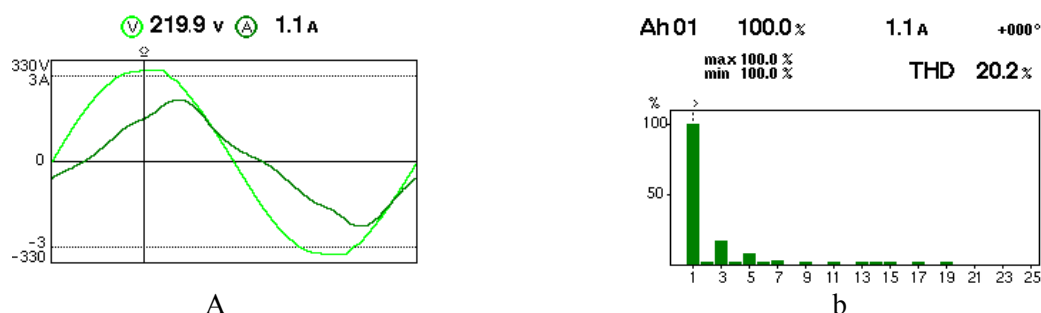
**Figure 5.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for bench grinder (idle operation)

The supply voltage is almost sinusoidal in idle operation of bench grinder, but the current waveform is distorted (Figure 5.a). The 3<sup>rd</sup> and 5<sup>th</sup> harmonics of current and its total harmonic distortion factor exceed the EMC limits (THD<sub>I</sub>=29%, Figure 5.b).

**Table 2.** Bench grinder

Operation mode	Idle operation	Load operation
Active power, P[W]	132	211.6
Reactive power, Q[VAR]	160.2	146.6
Apparent power, S[VA]	207.6	257.4
Power factor, PF[-]	0.636	0.822
Displacement power factor, DPF[-]	0.659	0.836

The reactive power is larger than the active power in the case of idle operation of bench grinder (Table 2), and power factors are of similar values, much less than the neutral value (PF=0.636 inductive, DPF=0.659).



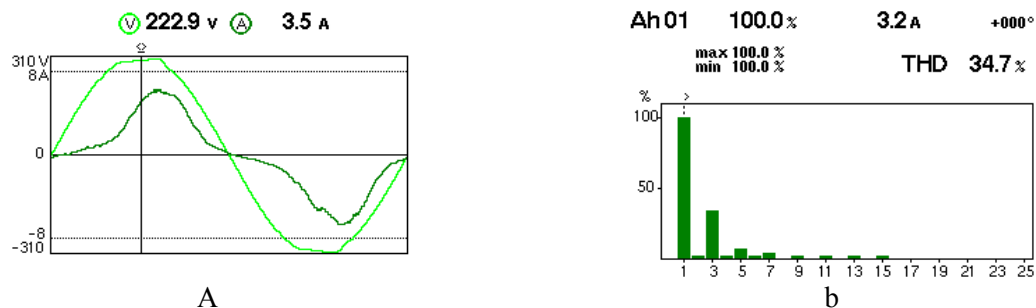
**Figure 6.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for bench grinder (load operation)

If bench grinder is in load operation (6 mm flat plate was polished), the supply voltage remains sinusoidal and the current is less distorted than in the previous case (Figure 6.a). The 3<sup>rd</sup> and 5<sup>th</sup> current harmonics exceed the limits set by EMC standards, but total harmonic distortion factor (THD<sub>I</sub>=20.2%) is lower than in the idle operation.

In this operating mode, the active power doubles almost compared to the idle operation of the bench grinder (Table 2), but the reactive power decreases by 13.6 VAR. In these conditions, an increase of DPF and PF was observed (PF=0.822 inductive, DPF=0.836), although their values remain below the neutral value.

### 2.3. Chainsaw

In idle operation of chainsaw (PKS 1840/1 Einhell, with technical characteristics: rated active power 1800 W, blade length 400 mm, chain speed 9 m/s, rated voltage 230 V, frequency of the supply voltage 50 Hz), the waveform of supply voltage is sinusoidal, but the waveform of current is distorted (Figure 7.a).

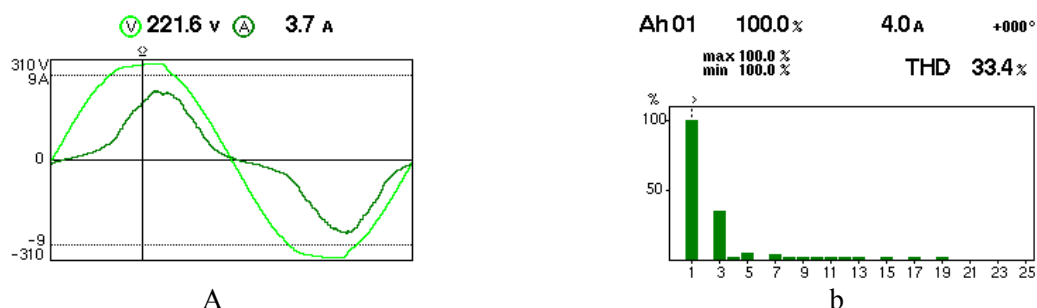


**Figure 7.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for chainsaw (idle operation)

Harmonic analysis of current (Figure 7.b) reveals that 3<sup>rd</sup> harmonic level is very high (above 30%), and total harmonic distortion factor of current exceeds very much the compatibility limit (THD<sub>I</sub>=34.7%).

**Table 3.** Chainsaw

Operation mode	Idle operation	Load operation
Active power, P[W]	649.9	870.6
Reactive power, Q[VAR]	319.1	411.8
Apparent power, S[VA]	764.6	963.1
Power factor, PF[-]	0.909	0.904
Displacement power factor, DPF[-]	0.962	0.955



**Figure 8.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for chainsaw (load operation, chain of 4 mm thickness)

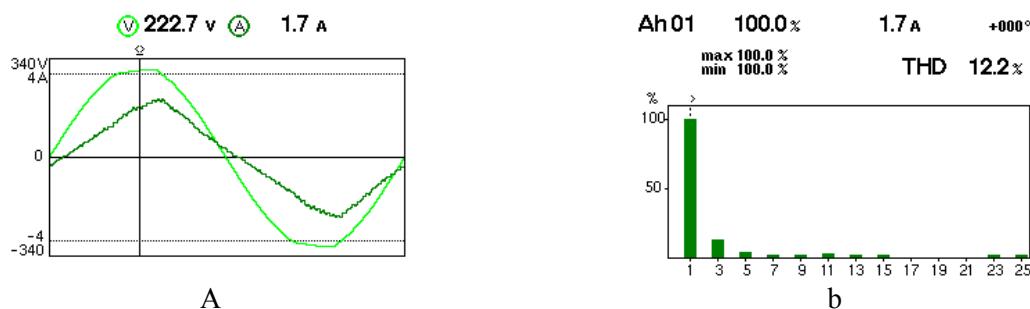
In idle operation of electric chainsaw, real power factor is PF=0.909 (inductive), slightly lower than the neutral value (Table 3). It is observed that displacement power factor (DPF=0.962) is higher than power factor (PF) due to harmonic pollution generated by the electric chainsaw.

The voltage waveform remains sinusoidal and the current waveform is still distorted (Figure 8.a) in load operation of chainsaw. It is observed that the 3<sup>rd</sup> harmonic current exceed the EMC limit and total harmonic distortion factor of current is slightly lower than in the idle operation ( $THD_I=33.4\%$ ).

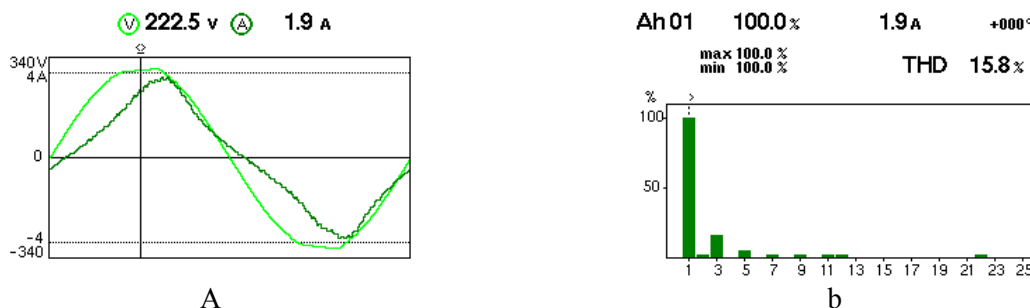
Active and reactive power consumption increases on load operation compared to idle operation, and power factor is slightly lower ( $PF=0.904$  inductive) than on the idle operation (Table 3). Displacement power factor remains greater than power factor ( $DPF=0.955$ ), due to harmonic pollution of current absorbed by chainsaw.

#### 2.4. Percussion hammer drill

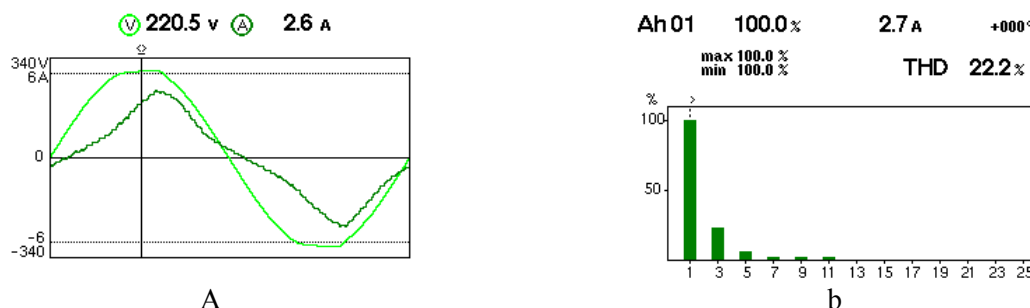
Was analyzed a percussion hammer drill (BMH 750) with the following technical data: rated active power 750 W, no load speed 800 rpm, rated voltage 230 V, frequency of the supply voltage 50 Hz, maximum diameter of the drill 26 mm.



**Figure 9.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for percussion hammer drill (idle operation)



**Figure 10.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for percussion hammer drill in load operation (6 mm drill, in stone)



**Figure 11.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for percussion hammer drill in load operation (18 mm drill, in stone)

Total harmonic distortion of voltage is much below the EMC limit, but it is observed a significant harmonic distortion of current in all operating conditions of the hammer drill (Figures 9-11).

If the load is higher, it can be noted the increase of RMS value and harmonic distortion of current absorbed by hammer drill (Figures 10, 11). In all analyzed situations, the 3<sup>rd</sup> current harmonic and total harmonic distortion of current exceed the compatibility limits.

There is a similitude between the electrical parameters measured in idle operation and low load operation of hammer drill (6 mm drill, in stone, Table 4). Also, it is found very small differences between the measurements done in high load operation of hammer drill (with 12 mm drill, respectively 18 mm drill, in stone, Table 4).

Reactive (inductive) power is double in the latter two cases, compared to situation where the 6 mm drill was used. Also, in these situations, total harmonic distortion factor of current is about 1.4 times greater, due to the increase of 3<sup>rd</sup> and 5<sup>th</sup> harmonics.

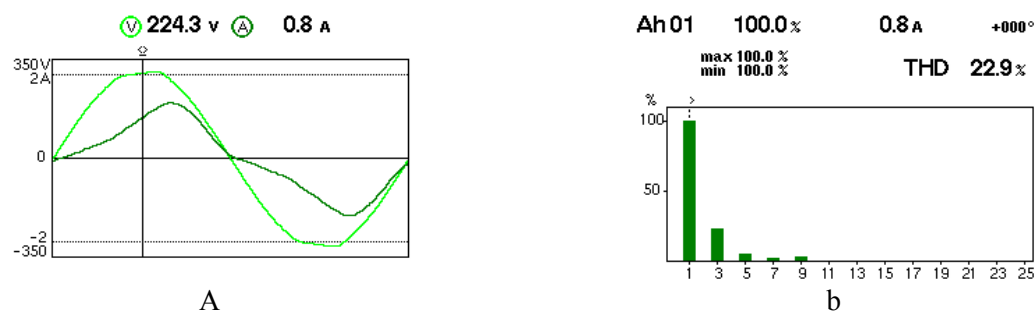
Power factor and displacement power factor decrease with increasing of load, but have higher values than the neutral power factor. As the harmonic distortion increases, there are increasing differences between displacement power factor and real power factor.

**Table 4.** Percussion hammer drill

Operation mode	Idle operation	Load operation		
		6 mm drill in stone	12 mm drill in stone	18 mm drill in stone
Active power, P[W]	371.3	386.4	572.3	569.7
Reactive power, Q[VAR]	106.6	111.7	228.9	233.1
Apparent power, S[VA]	386.3	402.2	616.4	615.5
Power factor, PF[-]	0.961	0.961	0.929	0.926
Displacement power factor, DPF[-]	0.969	0.969	0.951	0.940

## 2.5. Column drilling machine

Analyzed column drilling machine (TB13/5) had the following technical data: rated active power 350 W, motor speed 1420 rpm, mandrel speed 515-2580 rpm, rated current 1.5 A, maximum drilling depth 50 mm, rated voltage 230 V, frequency of the supply voltage 50 Hz.

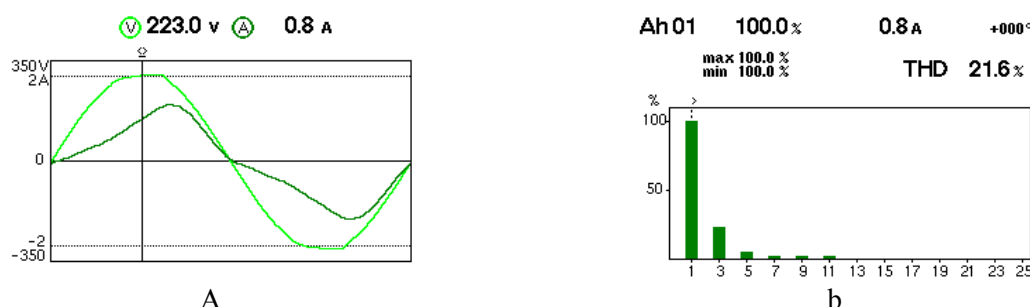


**Figure 12.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for column drilling machine (idle operation)

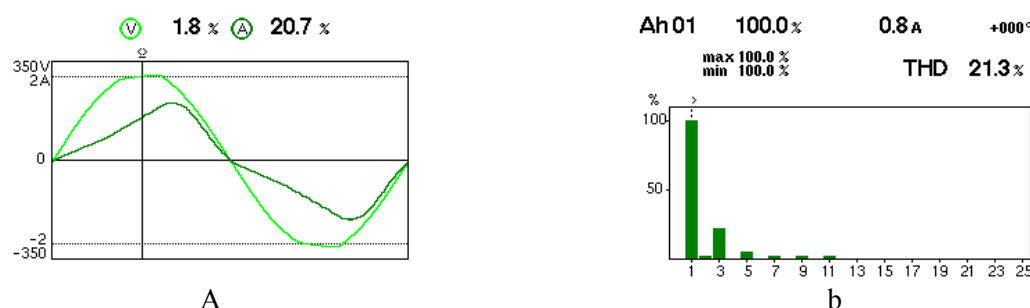
**Table 5.** Column drilling machine

Operation mode	Idle operation	Load operation		
		3 mm drill in wood	5 mm drill in wood	10 mm drill in wood
Active power, P[W]	161.5	168.8	180.3	183.0
Reactive power, Q[VAR]	67.1	62.2	59.5	58.6
Apparent power, S[VA]	174.9	179.9	189.9	192.1
Power factor, PF[-]	0.923	0.938	0.950	0.952
Displacement power factor, DPF[-]	0.945	0.959	0.968	0.970

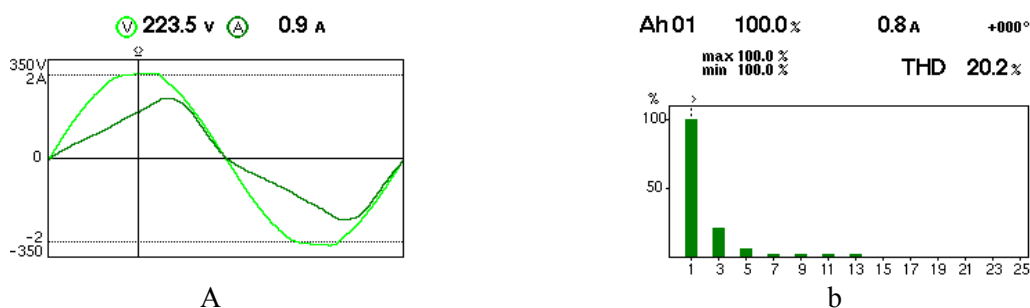




**Figure 13.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for column drilling machine in load operation (3 mm drill, in wood)



**Figure 14.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for column drilling machine in load operation (5 mm drill, in wood)



**Figure 15.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for column drilling machine in load operation (10 mm drill, in wood).

Electrical parameters of column drilling machine are not influenced too much by its operating mode (Table 5). The current (RMS value) absorbed by column drilling machine is about the same in all analyzed cases (Figures 12-15).

Active power and apparent power increase slightly when the load increases (drilling with a 5 mm drill and with a 10 mm drill in wood), but reactive (inductive) power decreases slightly (Table 5).

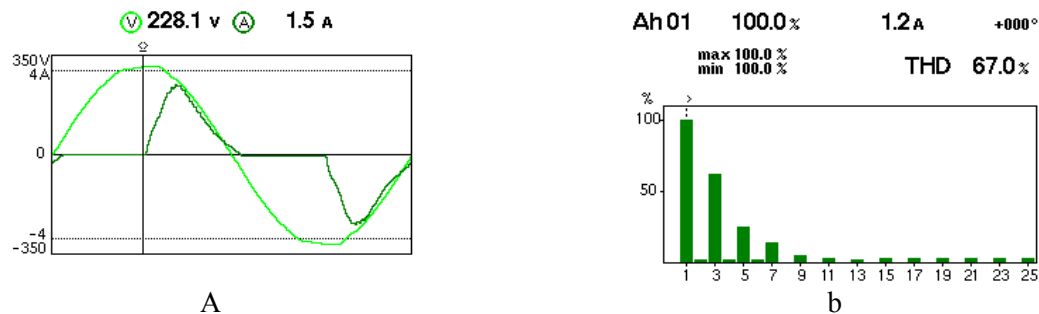
The values of power factor and displacement power factor are much higher than the neutral value in all analyzed cases, and increase slightly as the load increases (Table 5). Harmonic distortion of voltage is extremely small ( $THD_U=1.8\%$ ) in all operating modes of this column drilling machine, but current waveform is highly distorted ( $THD_I$  exceeds 20%). The level of 3<sup>rd</sup> harmonic, and, hence, total harmonic distortion factor of current, decrease when the load increases (Figures 12-15).

## 2.6. Pendulum jigsaw

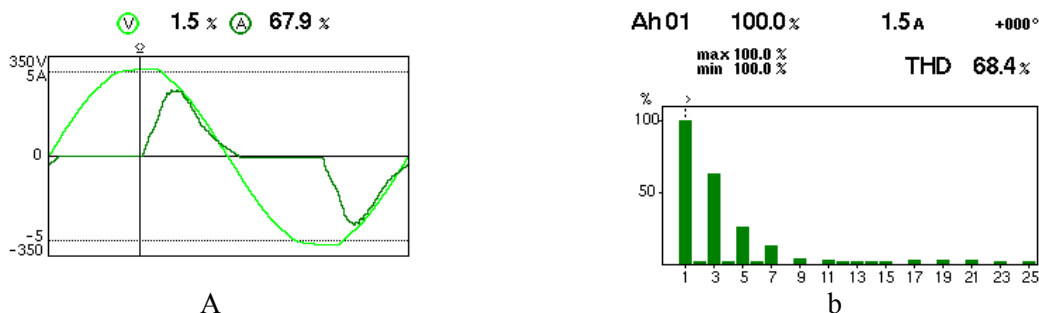
Analyzed pendulum jigsaw (PSTS 710) had the following technical characteristics: rated active power 710 W, no load speed 1200-3000 rpm, saw blade length 80 mm, rated voltage 230 V, frequency of the

supply voltage 50 Hz.

The experiments were carried out at a set speed of 2000 rpm. The operation of pendulum jigsaw greatly deteriorates the indicators of power quality, in terms of current harmonic pollution and reactive power consumption.



**Figure 16.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for pendulum jigsaw (idle operation)



**Figure 17.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for pendulum jigsaw (load operation, in wood)

For idle operation of pendulum jigsaw (Figure 16) it is noted that the voltage waveform is approximately sinusoidal, having a small total harmonic distortion factor ( $THD_U=1.5\%$ ). The phase angle deviation between voltage and current is very high and inductive.

Harmonic current analysis indicates a high odd harmonic content. The 3<sup>rd</sup>, 5<sup>th</sup> and 7<sup>th</sup> harmonics are the dominating components, their levels far exceed the limits imposed by EMC standards (3<sup>rd</sup> harmonic level exceeds 60%, 5<sup>th</sup> harmonic level exceeds 25% and 7<sup>th</sup> harmonic level exceeds 14%). In these conditions, total harmonic distortion factor of current is extremely high ( $THD_I=67\%$ ) at idle operation of pendulum jigsaw.

In load operation of pendulum jigsaw (wood), the voltage waveform remains sinusoidal and the current waveform is strongly distorted (Figure 16). Total harmonic distortion factor of current has a higher value in this operating mode of jigsaw ( $THD_I=68.4\%$ ), due to the increase of 5<sup>th</sup> harmonic level.

**Table 6.** Pendulum jigsaw

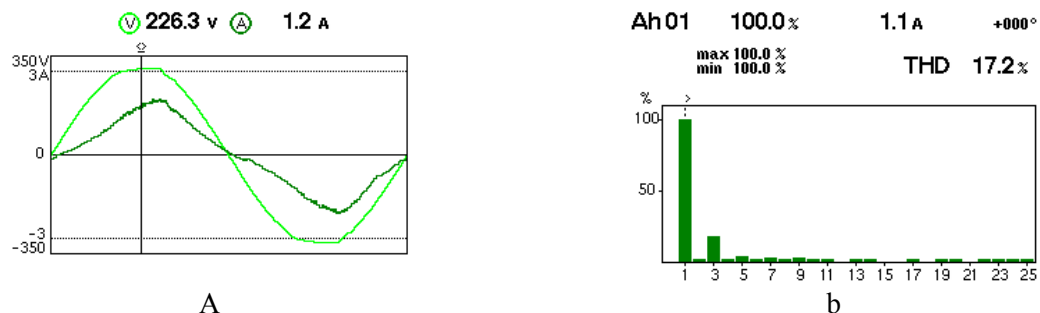
Operation mode	Idle operation	Load operation
Active power, P[W]	213.4	247.9
Reactive power, Q[VAR]	264.2	321.1
Apparent power, S[VA]	339.6	405.7
Power factor, PF[-]	0.628	0.611
Displacement power factor, DPF[-]	0.752	0.734

Pendulum jigsaw behaves as a strong inductive load both in idle and in load operation. In idle operation, the reactive power is greater than the active power of approximately 1.24 times and increases 1.21 times in load operation (Table 6).

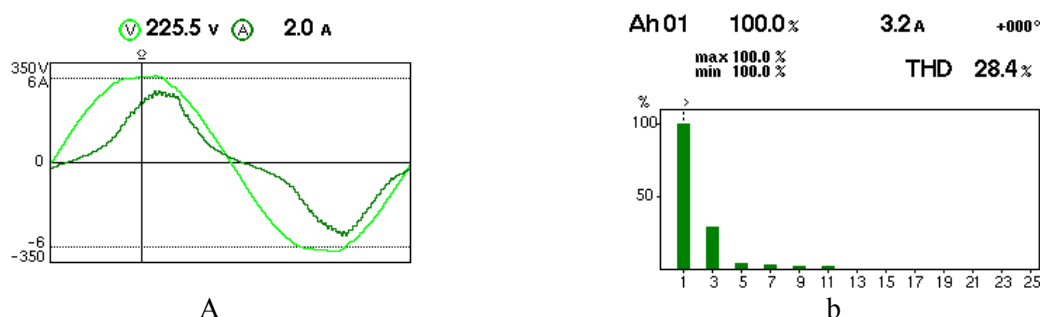
Consequently, the values of power factor and displacement power factor are much lower than the neutral value in both operating modes of pendulum jigsaw (in idle operation: PF=0.628, DPF=0.752, and in load operation: PF=0.611, DPF=0.734). Increasing of reactive (inductive) power consumption and current harmonic distortion leads to worsening of displacement power factor and power factor, at load operation of jigsaw (Table 6).

### 2.7. Circular saw

Was analyzed a circular saw (DMC 1400) with the following technical data: rated active power 500 W, no load speed 3200 rpm, saw blade diameter 140 mm, rated voltage 230 V, frequency of the supply voltage 50 Hz.



**Figure 18.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for circular saw (idle operation)



**Figure 19.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for circular saw (load operation)

**Table 7.** Circular saw

Operation mode	Idle operation	Load operation
Active power, P[W]	245.6	761
Reactive power, Q[VAR]	63.5	334
Apparent power, S[VA]	253.7	831.1
Power factor, PF[-]	0.968	0.916
Displacement power factor, DPF[-]	0.983	0.953

Although the harmonic pollution is much lower in the case of circular saw (Figures 18 and 19), compared to the case of jigsaw, total harmonic distortion factor of current exceeds the limit imposed by EMC standards in all operating modes.

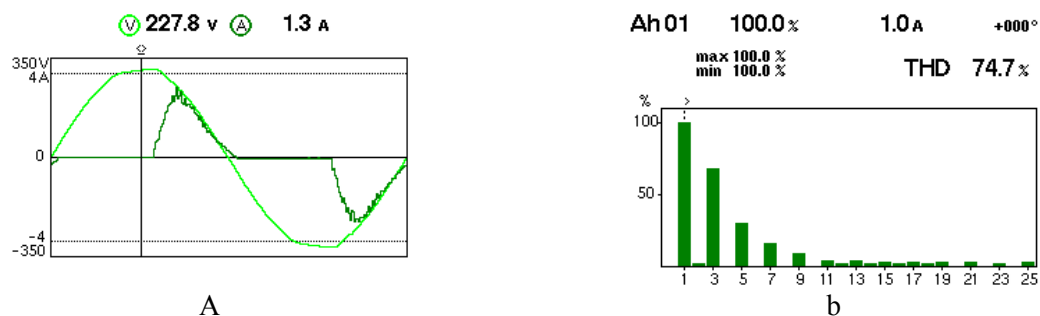
Total harmonic distortion factor of current increases 1.65 times in load operation, compared to idle operation, due to the increase of 3<sup>rd</sup> harmonic level, in particular. Voltage harmonic distortion is extremely low in both operating modes of circular saw.

Reactive power consumption is much lower at this type of saw, which results in much higher values of power factor and displacement power factor (DPF exceeds the neutral value in both analyzed regimes, Table 7).

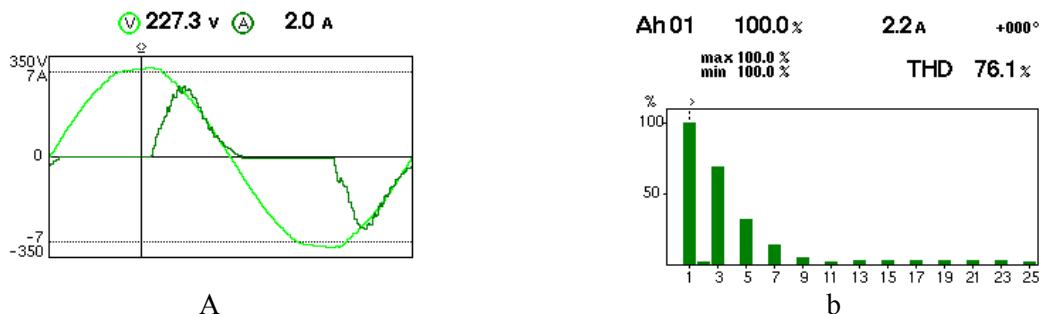
In load operation (wood, 40 mm thick), active power increases 3 times, reactive (inductive) power increases more than 5 times, and apparent power increases more than 3.2 times, compared to idle operation (Table 7). Consequently, displacement power factor and power factor decrease in this operation mode.

## 2.8. Milling machine

Milling machine (ASIST AE4F102) had the following technical parameters: rated active power 1020 W, no load speed 11500-30000 rpm, maximum stroke of the milling 40 mm, rated voltage 230 V and frequency of the supply voltage 50 Hz.



**Figure 20.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for milling machine (idle operation)



**Figure 21.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for milling machine (load operation)

The supply voltage is almost sinusoidal, with a very low total harmonic distortion factor (max. 1.5%) in both operating modes of the milling machine (Figures 20 and 21). Instead, the current waveform is pulsating and total harmonic distortion factor has an extremely high value (over 74%) both in idle operation (Figure 20) and in load operation (was used a 7 mm milling, the cutting depth being 20 mm, Figure 21).

The levels of 3<sup>rd</sup>, 5<sup>th</sup> and 7<sup>th</sup> harmonics greatly exceed the compatibility limits (3<sup>rd</sup> harmonic level exceeds 70%, 5<sup>th</sup> harmonic level exceeds 30% and 7<sup>th</sup> harmonic level exceeds 13%).

It is found that reactive (inductive) power is greater than active power of about 1.48 times at idle operation of milling machine, and reached more than 1.56 times at load operation.

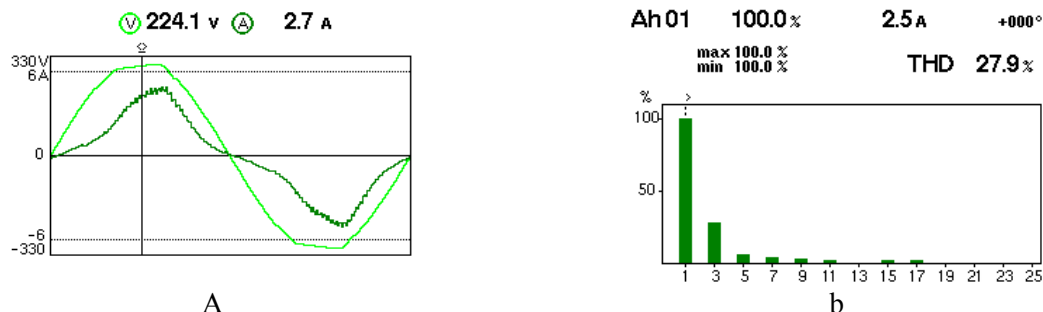
Consequently, the power factor and displacement power factor have extremely low values (well below neutral) in both analyzed situations (Table 8).

**Table 8.** Milling machine

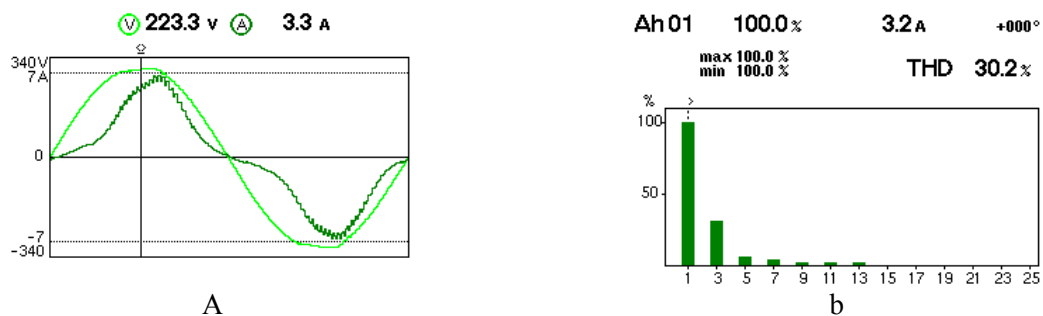
<i>Operation mode</i>	<i>Idle operation</i>	<i>Load operation</i>
Active power, P[W]	168.7	325
Reactive power, Q[VAR]	249.9	507.8
Apparent power, S[VA]	301.5	602.9
Power factor, PF[-]	0.56	0.539
Displacement power factor, DPF[-]	0.695	0.674

### 2.9. Belt sander

Belt sander (BS 75) had the following technical parameters: rated active power 760 W, idle speed 420 m/min, sanding belt 76 mm x 533 mm, rated voltage 230 V and frequency of the supply voltage 50 Hz.



**Figure 22.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for finishing machine (idle operation)



**Figure 23.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for finishing machine (load operation, wood finishing)

**Table 9.** Belt sander

<i>Operation mode</i>	<i>Idle operation</i>	<i>Load operation</i>
Active power, P[W]	549.2	680.3
Reactive power, Q[VAR]	179.5	242.5
Apparent power, S[VA]	577.8	722.2
Power factor, PF[-]	0.951	0.942
Displacement power factor, DPF[-]	0.987	0.985

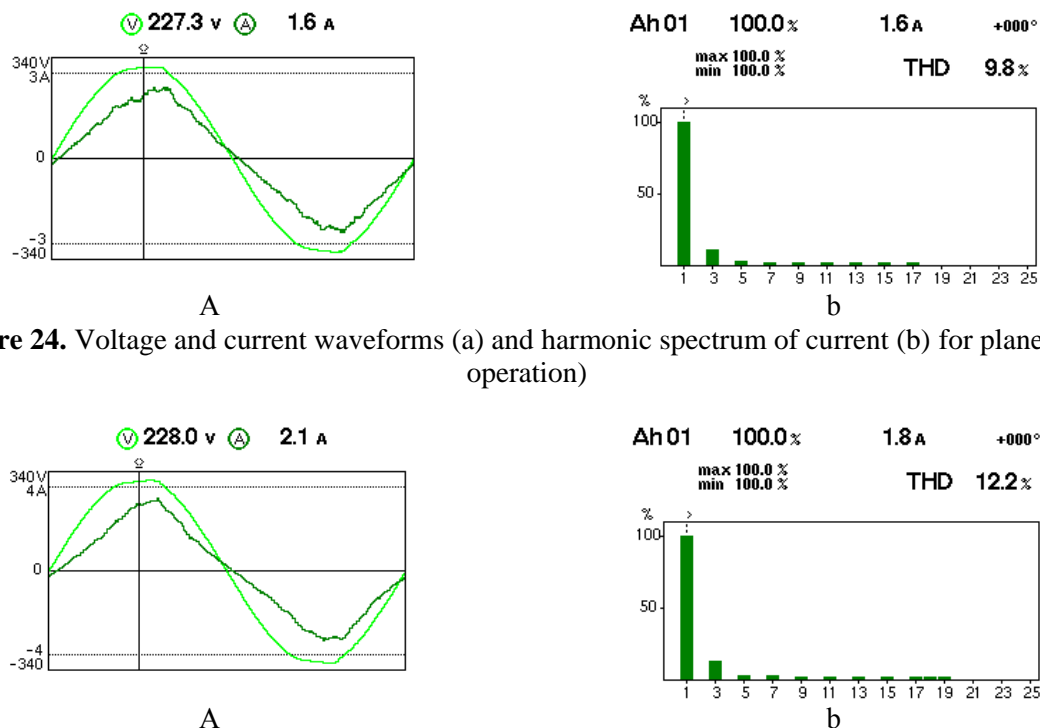
It is noted that the waveform of supply voltage is sinusoidal, but the waveform of current is distorted, having a total harmonic distortion factor of over 27% both in idle operation ( $THD_I=27.9\%$ ,

Figure 22), as well as in load operation (wood finishing,  $THD_i=30.2\%$ , Figure 23) of belt sander. In both operation modes of this belt sander, the 3<sup>rd</sup> harmonic level exceeds the compatibility limit.

The reactive (inductive) power is less than the active power of about 3 times in idle operation, respectively 2.8 times in load operation. For this reason, the values of power factor and displacement power factor are above the neutral value, in both analyzed situations (Table 9). The differences between these power factors are due to the harmonic distortion of the current, being slightly more pronounced in the load operation.

### 2.10. Planer

The analyzed planer (EH 616) had the following technical specifications: rated active power 600 W, no load speed 16000 rpm, maximum planing width 82 mm, maximum planing depth 2 mm, rated voltage 230 V, frequency of the supply voltage 50 Hz.



**Figure 24.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for planer (idle operation)

**Figure 25.** Voltage and current waveforms (a) and harmonic spectrum of current (b) for planer (load operation, wood finishing)

**Table 10.** Planer

Operation mode	Idle operation	Load operation
Active power, P[W]	358.6	396.3
Reactive power, Q[VAR]	58.2	71.3
Apparent power, S[VA]	363.3	402.6
Power factor, PF[-]	0.987	0.984
Displacement power factor, DPF[-]	0.992	0.991

Harmonic pollution produced by the operation of planer is lower compared to the previously analyzed power tools. Supply voltage is sinusoidal, both in idle operation and in load operation. Total harmonic distortion factor of current exceeds the compatibility limit in both operating modes of this

planing machine, due to the 3<sup>rd</sup> harmonic (the level of 3<sup>rd</sup> current harmonic does not fall within the compatibility limit).

Reactive (inductive) power is less than active power of about 6.16 times in idle operation, respectively 5.56 times in load operation (Table 10).

Because of low harmonic pollution and low reactive power consumption, the values of power factor and displacement power factor are much higher than the neutral value, in both operating modes of the planer; the differences between the power factor and displacement power factor are relatively small in this case (Table 10).

### 3. Conclusions

In order to maintain the harmonic distortion within the limits imposed by electromagnetic compatibility standards, it is necessary to know the sources of electromagnetic disturbances and how the disturbances levels vary depending on time, location and the connected loads.

Analyzing the impact of low-power nonlinear loads on harmonic distortion is very important, because new nonlinear loads (some of low-power i.e., LED lamps) will be progressively incorporated to power networks, with increasing of negative effects for power quality indicators.

The analyzed power tools are characterized by highly distorted waveforms of absorbed currents. Total harmonic distortion factor of the current were influenced by the operation mode (idle or load operation) of power tools, but also depends on their constructive characteristics. Most of the analyzed tools contain single-phase electric motors. Harmonic distortion in this case depends on the characteristics of the motor and varies with the voltage level. Because the 3<sup>rd</sup> harmonic exceeds the compatibility limits, neutral conductor overheating may occur, which is an important risk of fire.

Harmonic distortion caused by multiple low-power nonlinear loads has mainly negative impacts, such as reducing the life-span of various equipment of the distribution network (transformers, conductors, protective systems, etc.).

The random nature and low utilization factor of power tools (because of the short duration of operations) introduces complexity in the study of their impact on power quality.

Although the absorbed powers are small, the cumulative effect produced by a large number of tools can be substantial, because the currents THD exceeds 20% and can reach 76%. Due to high harmonic distortion, tools should be used only with network filters.

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