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THE ASSESSMENT OF FIRE RISK OF NON-ROAD MOBILE WOOD CHOPPING MACHINES

Summary

The increase of green infrastructure in urban areas, increases the demand for machines implementing agriculture processes. For such procedures mobile machines with internal combustion unit are most used. While working, these drives are exposed to contamination resulting from the crushing process gets through on both the engine surface and the reach high temperatures. The paper presents the results of convection testing of 400°C on pollutants originating from wood crushing process of pear, pine, aspen, oak, alder, walnut, birch, hornbeam, spruce needles, young spruce branches, leaves and young plum branches. Showing that a few minutes of exposure to the temperature can cause the emission of flammable gases and flame or flameless combustion. It was confirmed that the type of hardness of wood according to Janki's classification does not significantly affect the course of the combustion process as a result of contact with the heated surface. The described issues are significant and up-to-date, as these machines are also used in landfills and waste disposal areas, where till the end of May 2018, 63 fires were recorded.
***Keywords**: wood chopping machines, non-road combustion engines, risk of fire*

OCENA POZADROGOWYCH MOBILNYCH MASZYN ROZDRABNIAJĄCYCH DREWNO W ASPEKCIE MOŻLIWOŚCI WYSTĄPIENIA POŻARU

Streszczenie

Wzrost infrastruktury zielonej na terenach miejskich zwiększa zapotrzebowanie na maszyny realizujące zabiegi agrotechniczne, takie jak np. przycinanie lub rozdrabnianie gałęzi. Maszyny te najczęściej współpracują ze spalinową jednostką napędową. Niektóre podzespoły jednostki napędowej nagrzewają się do wysokiej temperatury podczas pracy, a drobne frakcje rozdrabnianego drewna mogą osiadać na rozgrzanych powierzchniach, co stwarza niebezpieczeństwo wystąpienia pożaru maszyny lub otoczenia. W artykule przedstawiono wyniki badań oddziaływania wysokiej temperatury (400ºC) w procesie konwekcyjnej wymiany ciepła na rozdrobniony materiał roślinny. Wykazano, że już kilkuminutowe działanie wysokiej temperatury na resztki roślinne może być przyczyną emisji gazów łatwopalnych oraz spalania płomieniowego lub bezpłomieniowego. Potwierdzono także, że rodzaj twardości drewna, wg klasyfikacji Janki, nie wpływa znacząco na przebieg procesu spalania w wyniku kontaktu z rozgrzaną powierzchnią. Opisywana problematyka jest istotna i aktualna, gdyż maszyny te są użytkowane również na terenach składowisk i przetwarzania odpadów, na których do końca maja 2018 roku odnotowano 63 pożary.
***Słowa kluczowe**: maszyny do rozdrabniania drewna, maszyny mobilne ze spalinową jednostką napędową, ryzyko pożarów*

1. Introduction

Increased awareness of threats related to exceeding emission standards of harmful compounds in the air, especially in large cities, forces the politicians and local authorities to take radical ecological actions. One of the directions of such works is the reduction of anthropogenic harmful emissions in cities [2, 10, 18], and the other - natural cleansing of these areas by the development of the infrastructure of green urban areas. Trees in such areas, absorbing fumes, dust and noise, must be subjected to agriculture processes, i.e. cutting or pruning. The resulting wastes in the form of branches are processed by working machines. Processing mechanisms consist in crushing them to facilitate further transport, storage, composting or energy production processes [5]. These machines are most often driven by internal combustion engines, whose selected components are characterized by high temperatures, and this is associated with the danger of a machine or environment fire [6]. During the process of wood crushing with non-moving mobile wood crushing machines, small fractions of crumbled material are observed to get into the heated elements of the drive unit (Fig. 1). Thermal tests of the drive unit used in this type of machine indicate that during operation selected components of the machine, i.e. the exhaust system exceeds the temperature of 330ºC (Fig. 2) [19]. In the literature, there are available studies of the discussed plant materials: wood ignition temperature [9] and explosive properties of wood dust [12] and their effect on the operation of fire smoke detectors [15, 20]. The effect of fire hazard depending on the moisture content of plant material is analyzed [8], the problem of exploitation of plant materials in the form of dust [13, 14, 16] or emitted gases during storage of biomass for energy purposes [1, 4]. There is no analysis or information as contamination by the material crushed affects the possibility of a fire during the exploitation of wood chopping mobile machines. The article presents the results of research on high temperature impact (400ºC) in the process of convection heat exchange on shredded plant material. Nine species of wood, pine needles, leaves and young branches were exam-

ined. All tested samples were subject to a seasoning process and were characterized by a 4% moisture level.

2. Methodology and research objects

The tests were carried out on a bench designed to determine the minimum ignition temperature of the dust layer on a hot plate with a constant temperature in accordance with the PN-EN 50281-2-1 standard (method A) [11].

The stand was made of: a heating plate with temperature regulation, thermocouple for measuring the temperature of the heating plate and the layer of the material to be tested, a ring shaping the layer of the tested material 20 mm and a recorder, according to Fig. 3.

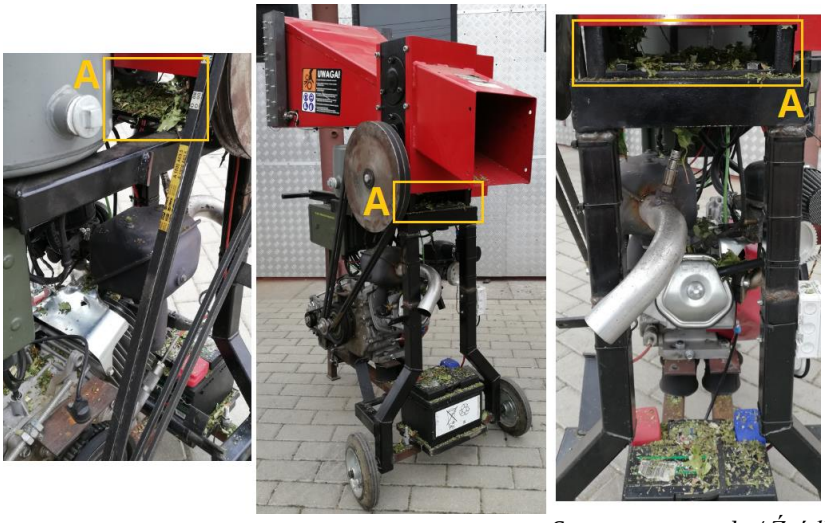

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Fig. 1. Mobile wood chopping machines driven by an internal combustion engine where A detail indicates the place where pollutants get from the working unit to the power unit

Rys. 1. Mobilna maszyna do rozdrabniania drewna napędzana silnikiem spalinowym – oznaczenie A wskazuje miejsce przedostawania się zanieczyszczeń z członu roboczego na jednostkę napędową

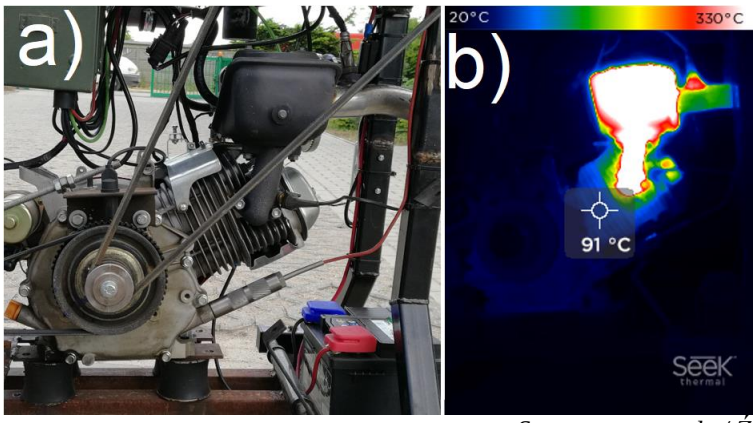

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Fig. 2. Non-road drive unit designed for e.g. mobile wood chopping machines: a) view of the drive unit, b) results of thermographic tests of the drive unit during operation

Rys 2. Niedrogowa jednostka napędowa przeznaczona do mobilnych maszyn do rozdrabniania drewna: a) widok jednostki napędowej, b) wyniki badań termowizyjnych jednostki napędowej podczas eksploatacji

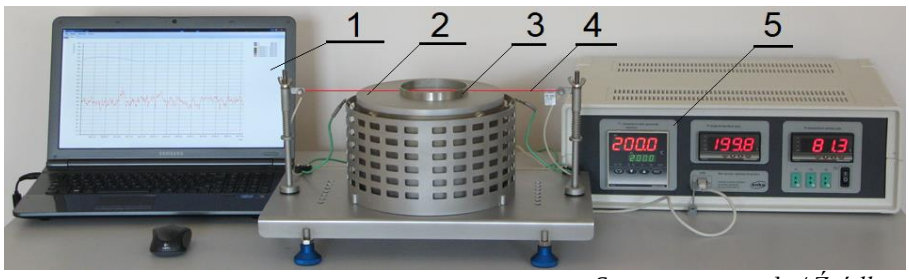

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Fig. 3. Test stand: 1 - recorder, 2 - heating plate, 3 - ring shaping test material, 4 - thermocouple for measuring the temperature of the tested material layer, 5 - heating plate temperature controller

Rys. 3. Stanowisko badawcze: 1 – rejestrator, 2 – płyta grzejna, 3 – pierścień kształtujący badany materiał, 4 – termopara do pomiaru temperatury warstwy badanego materiału, 5 – regulator temperatury płyty grzejnej

The samples tested are plant material originating from the wood chopping process, identified in accordance with Table 1. The material is characterized by a diverse fraction in which there are larger fragments that do not meet the dust criteria. Therefore, the measurement test is not carried out in accordance with the guidelines of EN 50281-2-1 standard (method A) [11] to determine the minimum ignition temperature of the dust layer on a constant temperature hotplate. The sample is adapted to the tested samples and is aimed at determining the impact of the high temperature effect on the hotplate on the plant material coming from the grinding process. It mimics the contamination that penetrates the elements of mobile shredding machines. The test is carried out on a heating plate with a constant temperature of 400°C, for 10 minutes. Loose test material is placed in a 20 mm high shaping ring, and a temperature measuring device is led through the center of the sample, the results of which are recorded as a function of time. In addition, the test sample was monitored in parallel, because the procedures for PN-EN 50281-2-1 (method A) [11] consider ignition as:

- burning or smoking observed,
- the measured temperature of the dust layer reaches 450°C,
- the measured temperature will exceed the temperature of the heating plate by 250K.

In order to unify the test sample, the tested material was characterized by an equal level of humidity (4%), the measurement was carried out with the Extech MO55 resistive moisture meter, whose ratios were expressed in percent by ± 1% accuracy [3]. Additionally, they were divided according to their hardness according to Janki's classification. This method involves pressing a steel ball with a diameter (11,284 mm) into a sample of wood. The speed of loading should be 320-480 kG/min, the result is expressed in MPa [7].

3. Research results

As a result of the conducted research, the temperature change of the tested material layer was obtained at a distance of 10 mm from the heating plate at a temperature of 400°C (Fig. 4) and changes in the tested samples were observed (Table 2).

Table 1. Plant material to be tested, derived from chopping processes
Tab. 1. Badany materiał roślinny pochodzący z procesów rozdrabniania

Wood type	Type of hardness according to Janki's classification [17]	Humidity (after seasoning)
Hornbeam	very hard wood (66 – 146 MPa)	4%
Pear	hard wood (60 – 65MPa)	4%
Oak	medium-hard wood (50 – 59 MPa)	4%
Nut	medium-hard wood (50 – 59 MPa)	4%
Birch	medium-soft wood (36 – 49 MPa)	4%
Pine	medium-soft wood (36 – 49 MPa)	4%
Alder	medium-soft wood (36 – 49 MPa)	4%
Aspen	very soft wood (up to 35 MPa)	4%
Spruce - needles	-	4%
Spruce - small branches	-	4%
Plums - young branches with leaves	-	4%

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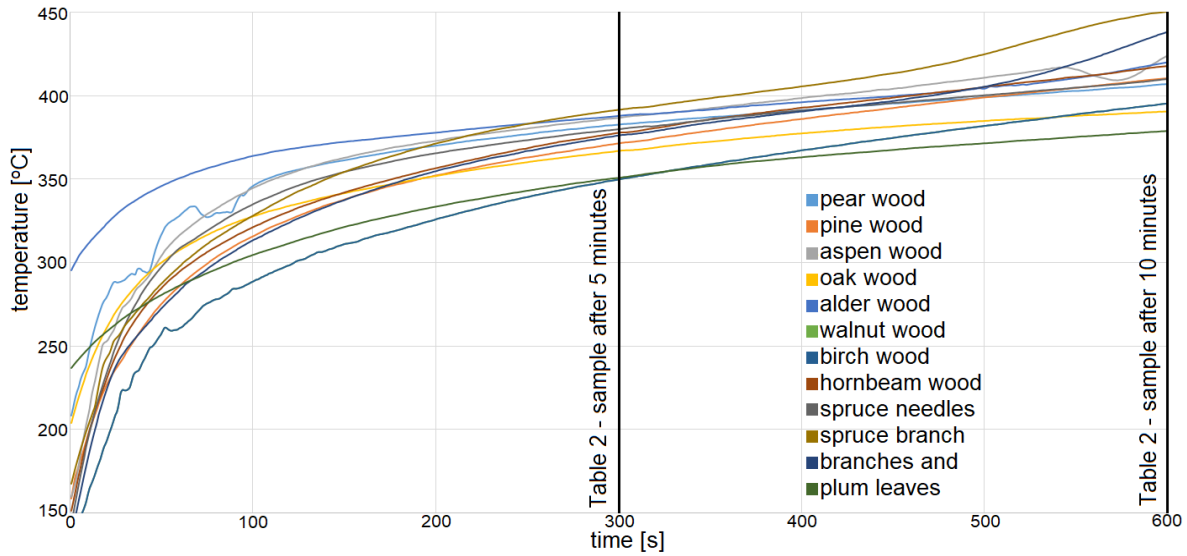

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Fig. 4. Characteristics of the temperature change of the examined plant material under the influence of the effect of the heating plate at a temperature of 400°C as a function of time

Rys. 4. Charakterystyka zmiany temperatury badanego materiału roślinnego pod wpływem oddziaływania płyty grzejnej o temperaturze 400°C w funkcji czasu

Table 2. Changes of plant material under the influence of a heating plate at a temperature of 400°C after selected time intervals

Tab. 2. Zmiany materiału roślinnego pod wpływem oddziaływania płyty grzejnej o temperaturze 400°C po upływie wybranych przedziałów czasowych

	after 5 minutes of exposure to 400°C	after 10 minutes of exposure to 400°C
pear wood		
pine wood		
aspen wood		
oak wood		
spruce needles		

Table 2 cont. / *Tab. 2 cd.*

	after 5 minutes of exposure to 400°C	after 10 minutes of exposure to 400°C
alder wood		
walnut wood		
birch wood		
hornbeam wood		
spruce branch		
branches and plum leaves		

4. Analysis of results

The plant material tested differed in structure from the dust used in the test method compliant with the PN-EN 50281-2-1 standard, because it contained fractions of different sizes in its structure. The use of such a material structure better reflected the real conditions of contamination of the surface of the crushing machine. In the assessment of the possibility of its ignition, the same criteria were used with PN-EN 50281-2-1 (method A) [11]. From the observations of the tested samples (Table 2) and the characteristics of temperature changes of the tested materials as a function of time (Fig. 4) it can be concluded that all investigated materials ignited after about 1 min of convection with a temperature of 400°C. The basic processes occurring during this test are the emission of flammable gases (Fig. 5a), flame combustion (Fig. 5b) and flameless combustion (Fig. 5c). Alder wood is characterized by the highest increase in temperature in the initial phase of contact with the heating plate, whereas nut wood the smallest. However, after 10 minutes of contact with the hob the highest temperature reaches the spruce needles, the lowest young branches and plum leaves. The average temperature change of the tested materials is shown in the characteristics in Fig. 6, described by the logarithmic function (1), whose average standard deviation equals 17,6°C.

Source: own study / Źródło: opracowanie własne

$$T = 45{,}122 \ln(t) + 118{,}12 \quad (1)$$

where:
T - temperature,
t - time.

Source: own study / Źródło: opracowanie własne

Fig. 5. Effects of heating plate with temperature of 400°C on plant material: a) emission of flammable gases, b) flame combustion, c) flameless combustion (heterogeneous)
Rys. 5. Skutki oddziaływania płyty grzejnej o temperaturze 400°C na materiał roślinny: a) emisja gazów łatwopalnych, b) spalanie płomieniowe, c) spalanie bezpłomieniowe (heterogeniczne)

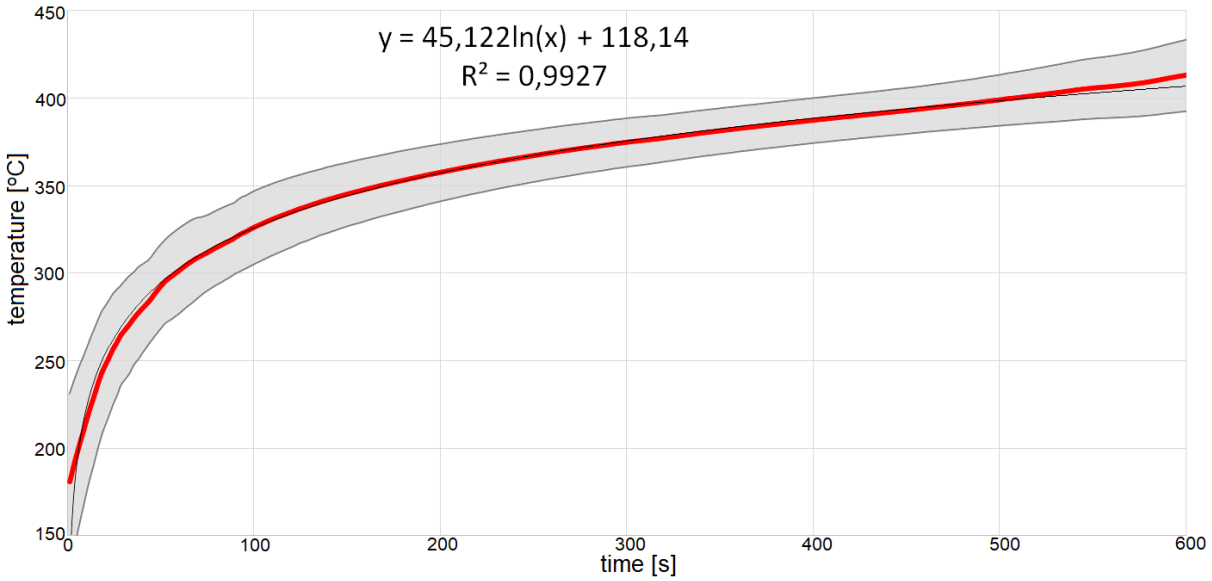

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Fig. 6. The average temperature change of the tested plant materials as a function of time where: red line - average value, black line - logarithmic trend line, gray lines - standard deviation

Rys. 6. Średnia zmiana temperatury badanych materiałów roślinnych w funkcji czasu: linia czerwona – średnia wartość, linia czarna – logarytmiczna linia trendu, linie szare – odchylenie standardowe

5. Conclusions

Contamination depositing on the machines chopping branches of deciduous and coniferous trees may cause a fire of the machine or the environment. Dry plant material (4% moisture) transformed into a dust structure with elements of larger fractions in contact with a surface heated to 400°C in a few minutes starts the combustion process. This process is characterized by the emission of flammable gases, flame burning or flameless combustion. The hardness and type of wood does not significantly affect the course of the combustion process, and the standard deviation from the average temperature change of the tested materials equals 17.6ºC. Therefore, when designing mobile shredding machines driven by non-road combustion engines, it is necessary to pay special attention to the thermal insulation of the exhaust system before contact with contaminants from the grinding process. The research may be used or contribute to the development of guidelines for approval standards allowing mobile crushing machines and an indication of the dangers arising from the operation of these machines for constructors.

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