Rotational speed control system for wood chipper with a spark ignition engine

Phd. Eng. Łukasz Warguła*, PhD. Eng. Mateusz Kukla, PhD. Eng. Bartosz Wieczorek, Prof. Piotr Krawiec
*PUT, Piotrowo 3 St. , 60–965 Poznań, Poland, lukasz.wargula@put.poznan.pl, tel.: +48 61 665 2042

Increased awareness of the risks associated with exceeding the emission standards of harmful compounds in the air, especially in large cities, forces politicians and local authorities to take radical pro–ecological measures. One such direction is the reduction of anthropogenic harmful emissions in cities, and the other is the natural purification of these areas by developing green urban infrastructure. Trees in such areas, which absorb fumes, dust and noise, must undergo agriculture processes, i.e. cutting or pruning. The waste generated in the form of branches is processed by working machines. Processing mechanisms rely on their comminution to facilitate further transport, storage, composting or energy extraction processes. These machines are most often driven by internal combustion engines that consume non–renewable energy sources and emit harmful exhaust gases. They are dangerous especially for operators of these machines and for the immediate environment.

Reducing the energy consumption of wood shredding processes and limiting the quantitative exhaust emissions generated by mobile shredding machines indicates the need to modify their design. For this purpose, it is necessary to interfere in the structure of the system and the algorithm for controlling the chipper's propulsion unit. Without taking such measures despite meeting the approval standards, which are much less stringent than in the case of motor vehicles, it will not be possible to limit the harmful effects of shredding machines on human life and health. The authors note that mobile shredding machines adapt to operating conditions in a limited way. Therefore, a decision was made to conduct development work in this direction.

The goal of the developed constructions is to achieve high ecological and economic effects through the use of developed solutions based on **innovative injection systems**, **adaptive systems responding to current working conditions** and **the use of alternative fuels**.

Fig. 1 Classic wood chipper with low power drive

Innovative wood chippers with low power engines

The solution in accordance with the patent application P.433586 **reduces fuel consumption and the quantitative emission of exhaust gas** from shredding machines, characterized by periodically variable work. Additionally, it can be powered by alternative fuels: LPG and CNG or biofuels. It can also work with innovative fuel injection systems for this type of drive (small engines). The closest solution to the invention is the system described in patent description P.423369 (also developed by the authors). The system uses an object detection sensor in the chipper's feed channel, which works with the air damper controller that changes the angular position of the damper flap. The control in this system takes place without detecting the engine load. In the course of research, it has been shown that controlling the rotational speed, while taking into account its changes resulting from the load on the system, allows to achieve additional benefits.

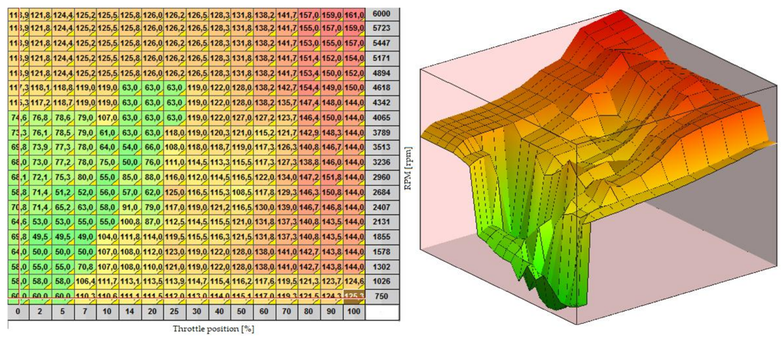


Fig. 3 Three–dimensional function of the volumetric efficiency of the motor depending on the rotational speed and engine load

Benefits of the used solution:

- **regarding the change in rotational speed due to the branch in the feed channel**: *reduction of fuel consumption, reduction of quantitative emission of toxic exhaust gases, reduction of operator stress resulting from operating costs, automatic changea of rotational speed (maintenance-free);*
- **regarding the change of rotational speed due to the load**: *ensuring work with maximum power or torque of the machine, in the case of shredding machines insufficient torque during cutting of the branch stops the cutting mechanism, the system responds to the load delay lowering the risk of blocking the cutting mechanism and increases the machines ability to work under load, e.g. enabling the shredding of more branches at the same time, the load-responsive system reduces the likelihood of stopping the working unit resulting from overloading, the system positively affects the productivity of the machine, because the reaction to the reduction in rotational speed resulting from the load is reduced ensuring optimal processes production;*

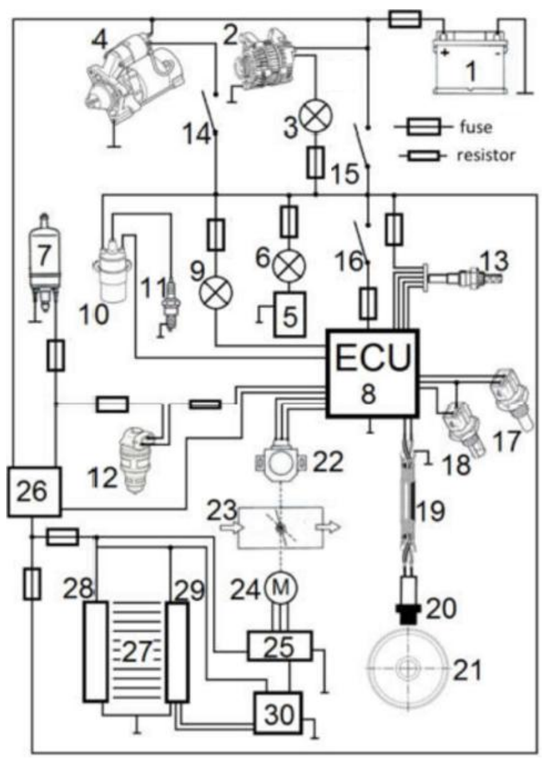


Fig. 2 Schematic of the innovative injection–ignition system

Summing up, the drive load with such a system reduces its rotational speed, which slows down the working unit of the machine. The reduction in the engine speed also causes the drive to operate in a different range of engine characteristics, which contributes to work with lesser torque or power. The essence of the invention is the chipper drive speed control system for wood with a spark ignition engine containing the object detection sensor in the chipper's feed channel and a throttle controller regulating the angular position of the carburetor throttle flap. In the system, the throttle controller is connected with a stepper motor cooperating with the speed control lever. The lever is connected with a centrifugal mechanism regulating the position of the throttle flap in the carburetor by means of a cable. The preferred solution of the invention is when LPG gas is supplied to the carburetor through a pressure reducer from the LPG gas tank. An alternative possibility to use CNG gas is also envisaged. In this case, the CNG gas from the CNG gas tank is supplied to the carburetor through a high pressure reducer and a low pressure reducer.

Fig. 2 presents schematic of the innovative injection–ignition system used in the German GX390 with a maintenance–free detection and ada–ptive chipper drive control system; List of markings: 1 – 12V battery, 2 – 65A alternator, 3 – charging indicating lamp, 4 – starter, 5 – oil level sensor, 6 – oil level indicating lamp, 7 – electric fuel pump, 8 – electronic control unit, 9 – MIL (malfunction indicating lamp), 10 – high voltage ignition coil, 11 – spark plug, 12 – injector, 13 – broadband sensor of oxygen contents in exhaust gases, 14 – starter switch, 15 – system switch, 16 – emergency switch, 17 – engine temperature sensor, 18 – intake air temperature sensor, 19 – shielded cable, 20 – engine rotation speed and crankshaft angular position sensor, 21 – impulse wheel, 22 – throttle position sensor (TPS), 23 – throttle flap, 24 – servomechanism, 25 – servomechanism controller , 26 – fuel pump and injector relay, 27 – object in the workspace detection unit, 28 – optical system transmitter, 29 – optical system receiver.

Adaptive system compatible with the P.423369 fuel injection system

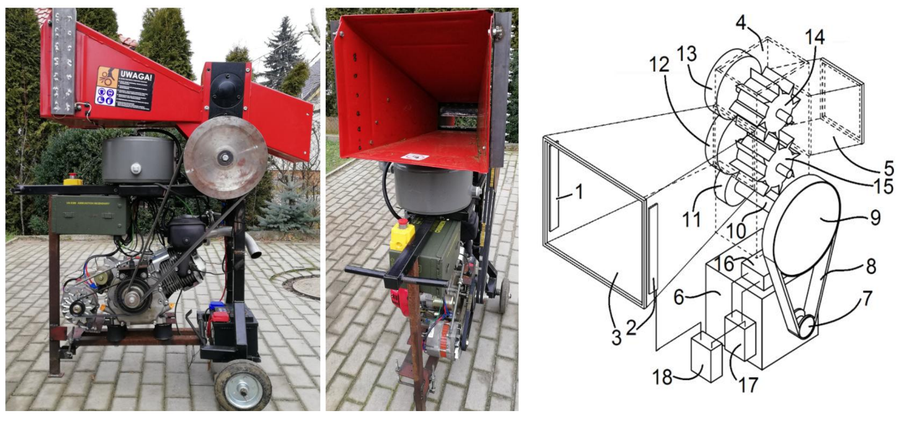


Fig. 5 Presentation of the maintenance–free and adaptive wood chip drive control system: 1 – object sensor in the working space (optical sensor – trans-mitter), 2 – object sensor in the working space (optical sensor – receiver), 3 – chi-pper feeding channel, 4 – housing of the member working pressure, 5 – outlet channel, 6 – spark–ignition internal combustion engine, 7 – transmission pulley, 8 – transmission belt, 9 – driven transmission gear, 10 – drive shaft, 11 – gear drive wheel, 12 – the cogwheel driving the first mowing cutter, 13 – the cog wheel driving the second mowing cutter, 14 – the second mowing cutter, 15 – the first mowing cutter, 16 – the combustion engine internal control unit, 17 – electri-cally controlled throttle air, 18 – air throttle controller

Adaptive system compatible with carburetor systems for LPG and CNG fuels, P.433586

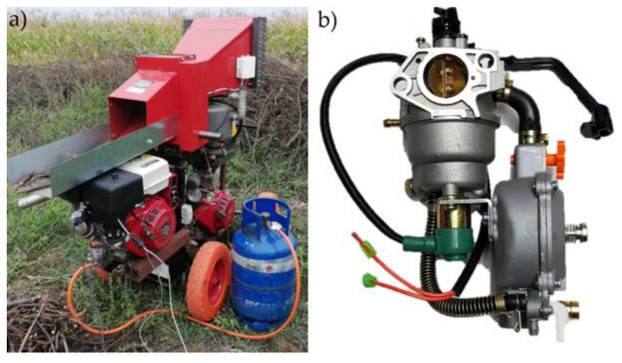


Fig. 4 Red Dragon RS–100 type cylindrical chipper: a) with German GX 390 type engine, b) carburetor powered by LPG; in the a) picture in the wood chipper two engines are mounted, but only the one connected to the cylinder took part in the tests

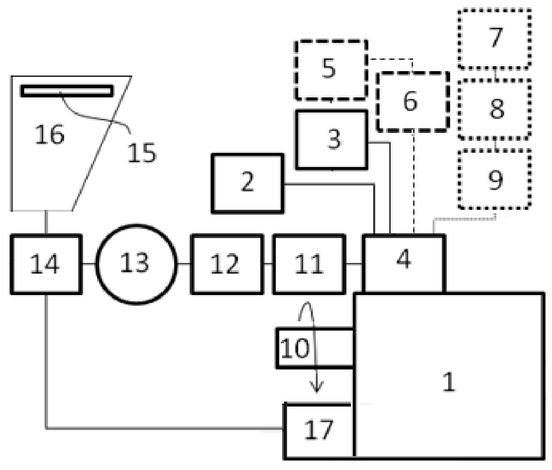
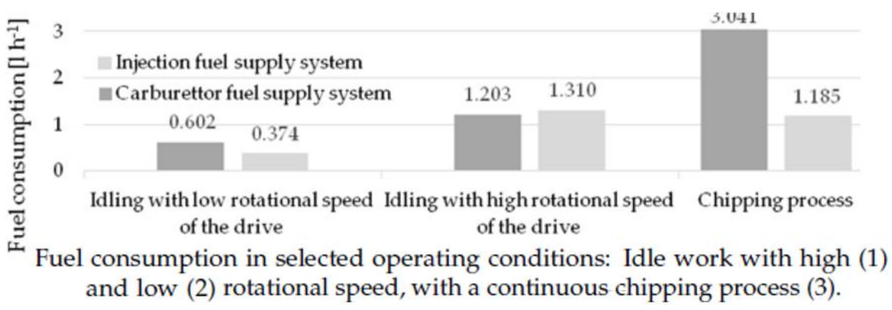
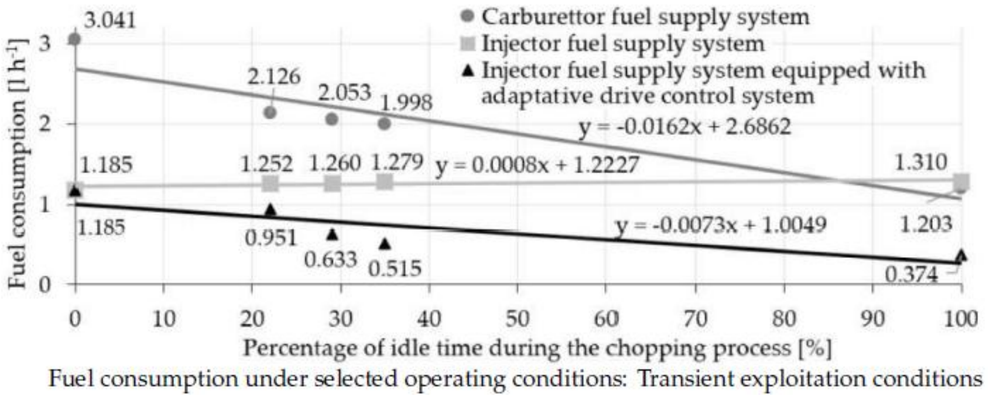


Fig. 3 Schematic diagram of the speed control system of wood chipper drive with a spark–ignition internal combustion engine; 1 - spark ignition engine, 2 - air filter, 3 - gasoline tank, 4 - carburetor, 5 - LPG gas tank, 6 - pressure reducer, 7 - CNG gas tank, 8 - high pressure reducer, 9 - low pressure reducer, 10 - output shaft, 11 – cen-trifugal mechanism, 12 - speed control lever, 13 - stepper motor, 14 - controller, 15 - sensors, 16 - supply channel, 17 - oil temperature sensor

The effects of developed solutions while working in real conditions



Fuel consumption in selected operating conditions: Idle work with high (1) and low (2) rotational speed, with a continuous chipping process (3).



Fuel consumption under selected operating conditions: Transient exploitation conditions

Prototypes are still being tested and their results are published in scientific journals, e.g.

1. Warguła, Ł., Krawiec, P., Waluś, K. J., & Kukla, M. (2020). Fuel Consumption Test Results for a Self–Adaptive, Maintenance–Free Wood Chipper Drive Control System. *Applied Sciences*, *10*(8), 2727.
2. Warguła Ł. (2019) Innovative Injection–Ignition System in a Non–Road Small Engine – Construction System. Transport Means 2019: Proceedings of the 23rd International Scientific Conference, October 02–04, 2019, Palanga, Lithuania. Part 2, p. 931 – 935
3. Wargula, L., Walus, K. J., & Krawiec, P. (2019). Working conditions of mobile wood chipping machines in the aspect of drive control operating systems. *Sylwan*, *163*(09).

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