EFFICIENT PELLET MILL FOR WOOD. Part 1.

Influence of temperature on pelletizing energy costs and pellet mill specific productivity

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Energy efficiency is actual task in production in every time. This is a direct path to a competitive cost of production. Currently it has become one of the main indicators of the modern approach to respect for nature and the preservation of life on the planet. Especially this is true for "green" renewable energy sources, in this case wood pellets.

In addition, there is another actual problem in pellet production. The productivity potential of a single wood pellet mill does not grow for a long time. The cause is the drive power stagnation after 2010, when wide use of 355 kW drives were started (for machines with round dies).

Since then, the next step - increasing the power to 400 kW - has not been made. Such elevated drive power is available now for only compound feed pellet mills. At first glance, the situation looks like this: no progress in power – no progress in productivity.

Does a way exist to get around the power limit to increase productivity?
To answer a comparative analysis was carried out, where the operating parameters of various pellet mills models were considered.

As a result, it has been shown that some of the models have a higher specific product capacity (kg/kW) then others, and therefore higher energy efficiency and higher productivity at the same drive power. But the initial idea comes from a study of wood pelletizing energy.

STUDY OF WOOD PELLETIZING ENERGY

In 2009, a group of scientists from Denmark and the USA, led by Niels Nielsen and with the participation of Andritz Feed & Biofuel, conducted a series of studies of wood pelletizing process. (Wood and Fiber Science, № 41(4), 2009, pp. 1–12 и Bioenergy International, No 38, 3 – 2009).
The goal was to study the effect of various factors, including temperature, on pelletizing energy. To do this, the process was divided into compression, flow and friction phases, and experiments were carried out for each phase and the expended energies were calculated and summed up.

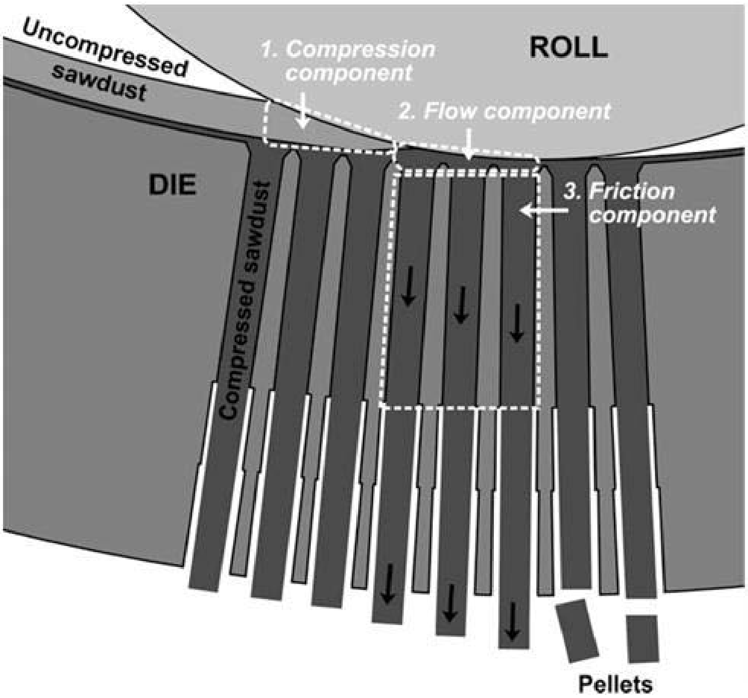

Fig.1. Illustration of the pelletizing process and its phases (components)

It can be seen from the scheme (Fig.1) that most of the sawdust (>50%) in a compressed form is distributed over a die surface between the press-channels. To enter the press-channels, the material must become fluid. Compression of sawdust and material pushing through the press-channels requires overcoming of friction forces, and there are viscous friction forces in a flow phase.

INFLUENCE OF TEMPERATURE ON PELLETIZING ENERGY COSTS AND PELLET QUALITY

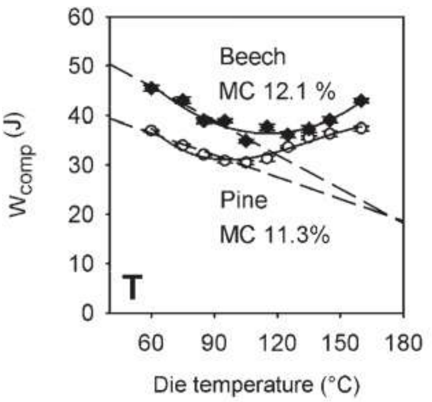

Fig.2. Importance of temperature (T) for the compression energy W_{comp}

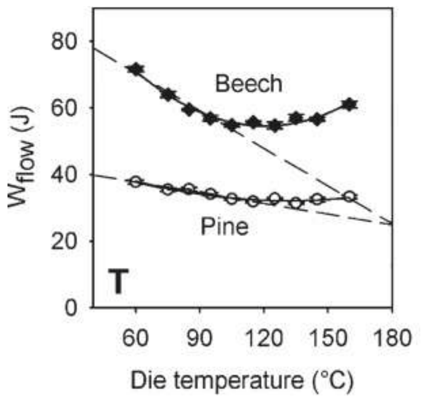

Fig.3. Importance of temperature (T) for the flow energy W_{flow}

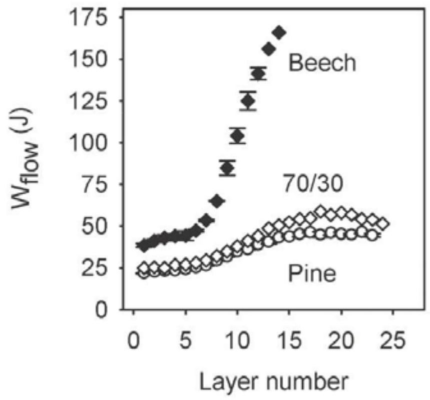

Fig.4. The increase in the flow energy W_{flow} when pressing layers successively into the press-channel at T=125°C (on the scale - the number of layers of 3.5 mm)

1. One of the experimental series was the pressing of individual wood portions (reduced to 0.25 g for diagrams at Fig.2 and 3).
In two phases (compression and flow), the process energy minimum was found at T=105°C. The same one was found for friction energy for pine.

2. Another series was the sequential pressing of 0.25 g portions, one after another (Fig.4). Each portion (layer) increased the pellet length by 3.5 mm.
This experiment has showed that flow energy, together with friction energy, grows exponentially in the range of pellet lengths from 25 to 60 mm (actually, this is the press-channel length).
The scarcity of this experiment was the study of the process only at 125°C.

3. After all experiments, the pellets were checked for quality. It met the established requirements over the entire temperature range of experiments from 60 to 160°C.

ADDITIONAL CONCLUSIONS

1. To get the required density and strength of a pellet, the proper friction must be created in the press-channel. This friction is provided by the press-channel length; in this case, the friction force can be estimated as a positive factor;
Friction force is higher at a lower temperature, so the less press-channel length is required;
Friction varies non-linearly along the press-channel (the material drying inside the channel leads to a change of friction coefficient), a shorter press-channel is preferable to ensure stable pellet quality and machine load.

2. The experiment did not take into account the energy costs for heating of the die: it was carried out by heating elements for temperature control. To sustenance the die working temperature, additional energy is required at the rate of 0.04 kWh per 1°C per 1 ton of pellets, which gives additional 2.38 kWh/t at T=125°C (at initial temperature 65°C in mixer, Fig.5).

3. Specific energy costs in the steady mode of pine pelletizing were determined in the amount of 45 J per 0.25 g at T=125°C or 50 kWh/t (pine, excluding die heating and drive efficiency). The same, taking into account die heating, was ~ 52.4 kWh/t.

4. To calculate the pellet mill drive power, a recommended load factor LF = 0.6 should be taken (62% and 57% at Fig.5), which gives an installed power of 87.3 kW/t/h according the experimental conditions (T=125°C).

5. The process creates high pressure up to 210 - 450 MPa, which significantly increases the fluidity of wood. In most studies about melting and fluidity of wood components (cellulose, lignin, etc.), the pressure factor is not taken into account. That is why these studies are not fully applicable to the pelletizing process, the melting and fluidity temperatures are varied after the pressure changing in every process point.
The study revealed a well-defined physics of wood pelletizing. What kind of pellet mill will meet the expectations of higher energy efficiency?

ENERGY EFFICIENCY OF PELLET MILLS

Consider the design features and operating modes of two different pellet mills (Table 1). Let's designate them according there operating temperature T_{work} as:

LT – low temperature and

HT – high temperature (Fig.5)

Table 1. Design and operating parameters of LT and HT pellet mills

Parameter	LT	HT
Drive power, KW	355	355
Die working diameter, cm	95	82,5
Die working circle, cm	298	259
Die working width, cm	10	11,5
Die working area, cm^2	2985	2980
Press-channel length at d=8, mm	≥ 40	≥ 55
Number of press-rollers	3	2
Maximum operating temperature, °C	105[1]	180[2]
Operating temperature T_{work} for soft wood, °C	85 – 95, average 90	up to ≈ 145, average 125
Roller cooling	not required	desirable[3]

[1] Self-limited by the pelletizing process

[2] Controlled stop by automatics

[3] In case of roller cooling, the temperature does not reflect the energy costs, since it is lowered forcedly

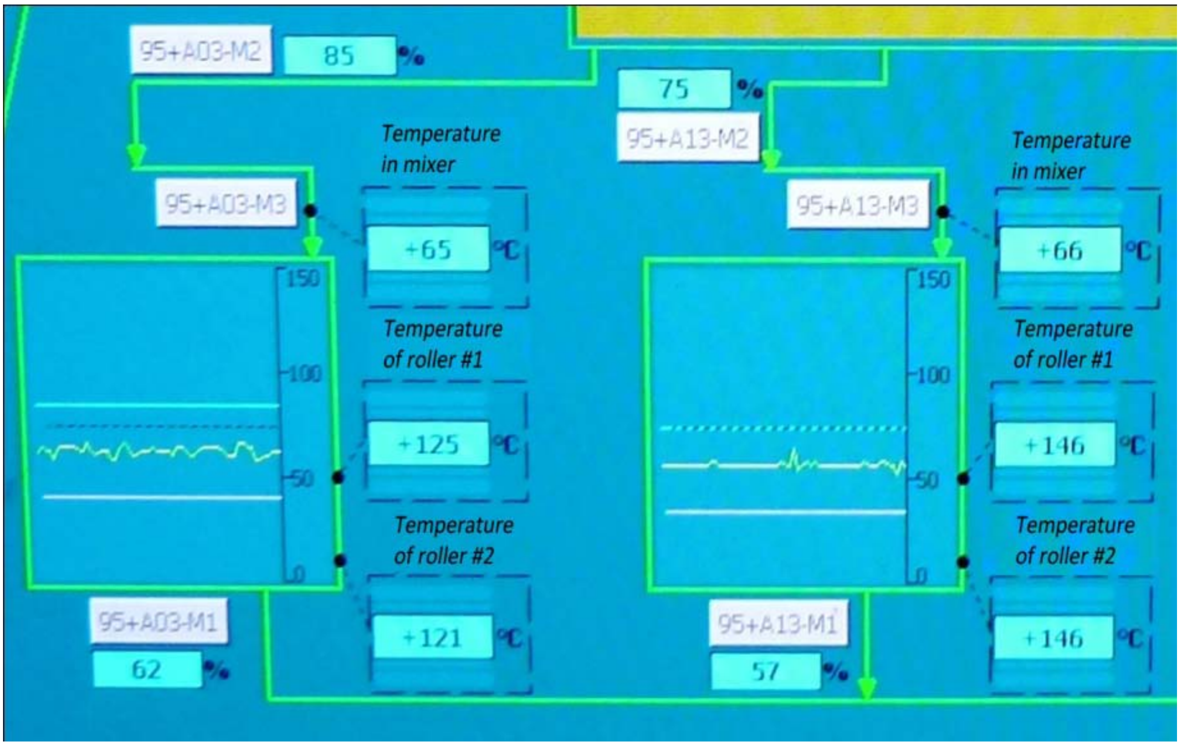

Fig.5. HT pelletizing parameters (soft wood)

The greatest differences are noticeable in the number of rollers and the operating temperature T_{work}, obviously, they are interconnected (but not only ones). To discover the relations, we estimate the reduced linear pelletizing speed by means of **working front**, which is equal to the multiplication of die working width by number of rollers (Table 2).

Table 2.

Parameter	LT	HT
Working front (die working width x number of rollers), cm	10 x 3 = 30	11,5 x 2 = 23
Reduced coefficient of the working front	1,3	1,00
Reduced coefficient of the die working circle	1,15	1,00
Reduced coefficient of the linear pelletizing speed	0,67	1,00

RESULTS OF THE COMPARATIVE ANALYSIS OF LT and HT PELLET MILLS

1. If all else were equal the relative linear speed of the die and rollers could be 33% (1.5 times) slower in LT pellet mill.
Since it is indeed slower, the pelletizing process is shifted to a more energy efficient area with lower temperature, thereby reducing the specific energy costs. This result is explained by properties of friction forces, which, by definition, depend on the pressure of the bodies on each other and on the speed of relative motion. And all the machine drive work, after overcoming the friction forces, turns into heat.

A pellet mill with a narrower working front and a smaller die diameter must provide a higher process speed in order to ensure equal productivity. Thus, the process temperature rises, and the energy efficiency drops. It means, with equal drive power and other things, the HT machine cannot provide equal productivity with LT one, but only less. Definitely this energy extra costs are wasted up.

2. High temperature is not useful for the technological process and the machine, but really harmful. The roller cooling used in HT machines is direct evidence.

3. Practice and statistics confirm the difference in output capacity. LT pellet mill with a 355 kW motor provides an average practical productivity at least 4.5 t/h for pine, which corresponds to 36 kilotons per annum with operating time of 8000 hours.

For comparison, the annual productivity of HT pellet mill is declared in the amount of 30 kilotons, which implies an average practical productivity 4 t/h at most. The same value can be obtained from the study, namely 355 kW / 87.3 kW/t/h = 4.07 t/h, excluding drive efficiency.

Table 3. Productivity of pellet mills (soft wood)

Parameter	LT	HT
Average practical productivity, t/h	≥ 4,5	≤ 4
Annual productivity (8000 hours), kiloton	≥ 36	≤ 30

Fig.6. LT pellet mill

FEATURES OF LT PELLET MILLS

1. No roller cooling system required.
2. Steam supply is more efficient due to the greater temperature difference. According to the results of the operation of 3-roller mills with the addition of steam, the productivity increased by 20% on pine. At the same time, the workflow became more flexible and did not require precise adjustment of the die parameters (the length of the press-channels).
3. The use of three rollers instead of two is no more expensive to operate, since their wear depends on the amount of pellets produced by each roller. And low speed and temperature contribute to less specific metal wear and roller grease consumption.
4. The 3-roller design minimizes the possibility of roller displacement from working loads in all directions.
The 2-rollers machines are only able to minimize displacements in a plane passing through the roller axes, but much worse in a perpendicular plane. This is often the cause of excessive displacements from bending and torque moments and induces vibrations.