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QUALITY OF WOODEN CHIPS PRODUCED BY CLAAS JAGUAR FITTED WITH EXPERIMENTAL CRA-ING ROTOR

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ABSTRACT The Agriculture Engineering Research Unit of the Agricultural Research Council (Rome) has designed a new innovative chipper device for mounting on Class Jaguar chipper harvesters for short rotation forestry harvesting. The new rotor differs from standard rotors as it has a lower number of blades and blade-holders, from 24 to only 10 and it has a different cutting angle and drum insertion. This study evaluates the particle-size distribution of chip produced by standard rotors compared to those with the experimental rotor. The scope of this study is to distinguish the particle size distribution of chips produced using the two types of chippers, thereby evaluating a possible influence of wooden species in the chip formation process. The tests were conducted using 860 and 890 Claas Jaguar chipper harvesters, both equipped with standard and CRA-ING rotors. Furthermore, the experiment was conducted on poplar cultivations on biennial shift and on arboreal cultivations, the latter being cut down previously. As opposed to using traditional rotors, CRA-ING rotors provide a significant product increase within particle sizes ranging from 12.5 to 25 mm, and an equivalent product reduction within the finest particle size classes. However, it is evident that the new rotor tends to concentrate dimensional increments along the longitudinal section of the chip, regardless of the species used. Therefore, following the results, a second rotor was devised to engrave a cleaner cut on the biomass introduced by the feeding rollers, thereby obtaining a superior quality of chip in terms of particle size and increasing the size of the chip even in radial or tangential sections.

Keywords: quality of wooden chips, chipper harvesters, experimental chippers, SRF (short rotation forestry)

INTRODUCTION The quality of chip is crucial in terms of energy return on energy invested, storability, the type of system capable of using it and in terms of market price formation. Good dimensional distribution and proper water content are key parameters for the correct combustion of chips in special boilers (Hartmann et al., 2001).

The results of SRF harvesting experiments using Claas Jaguar conducted in the past, revealed a reduced size of the final product and negative effects on storability (Jirjis R. et al., 2008; Pari L. et al., 2008). In view of the foregoing, Agricultural Engineering Research Unit designed and relied on the firm “Biomasse Europa” to manufacture a new innovative chipper device. As opposed to the standard rotor, the new rotor (see figure 1 and 2) is equipped with 10 fixed blades and consists of one steel drum with diameter of 403 mm and length of 670 mm, where a total of 10 processes are carried out (5 for each part, equally distributed on the drum’s mantle), hence providing proper positioning of the blade-holder on the subsequent welding phase. The inclination angle of the processes is 5° compared to generators of the cylinder, whereas the weight of the drum equals to 145 kg. Moreover, the blade-holders have a length of 320 mm and are fitted with 5 slots each, used to fix and adjust the blades. The blades have a length of 380 mm with a cutting angle of 32.5°, fitted with a series of 5 threaded holes used to fix the blades into the blade-holder on the slots. The blade-holder insertion angle on the cylinder was also modified (Pari L. et al., 2009).

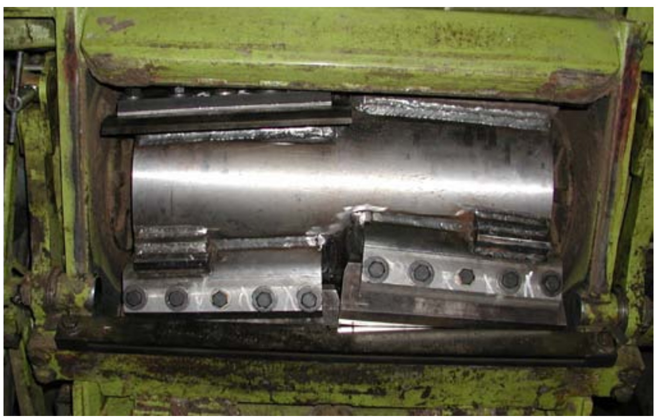
Figure 1. CRA-ING rotor propelled by 890 Claas Jaguar

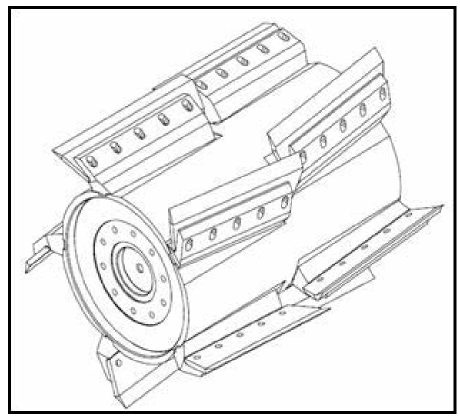
Fig. 2. CRA-ING rotor: 3D representation

Over the course of the year 2008, comparative tests were conducted on harvesting poplar at first cutting (plants with two years root and two years stem – R2S2) and at second cutting (plants with four years root and two years stem – R4S2), thereby using Class Jaguar chipper harvesters fitted with a standard rotor and a CRA-ING rotor. Numerous samples of chips were gathered throughout said site and analyses revealed favourable results for the CRA-ING rotor, reporting product increase within the particle size raging from 12.5 to 25 mm, +13.8% and +12.10% respectively for R2S2 and R4S2, and an equivalent product reduction within particle sizes ranging from 6.3 to 12.5 mm, 3.15 to 6.3 mm and < 3.5 mm, respectively -17.80%, -4.60% and -5.20% for R2S2 and-4.10%, -2.90% and -4.10% for R4S2 (Pari L. et al., 2009).

Nevertheless, the expected results were not accomplished completely as an increase of the average size of the chips was expected for all anatomical directions. However, the dimensional analysis of single chips revealed the separation of the wooden increment during the harvesting of poplar using the CRA-ING rotor (see figure 3) and therefore it led to the likelihood of increasing only the length of the chips significantly (+10 mm), therein limiting the increase to 1-2 mm in terms of thickness and width (see figure 4).

Figure 3. Crosswise section of a poplar chip produced by CRA-ING rotor

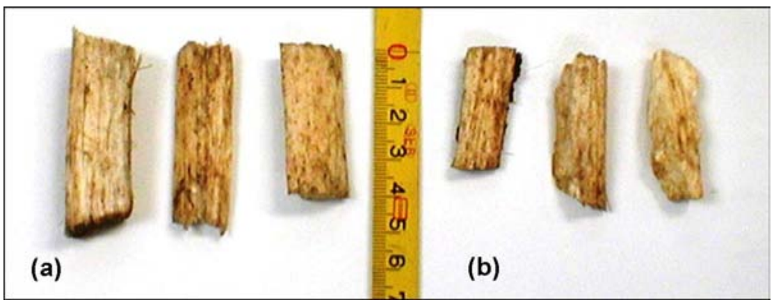

Figure 4. Poplar chips (length section) produced by standard (b) and CRA-ING (a) rotor

The reasons that could lead to said results could lie on the mechanical selections applied to the experimental shredding device or the characteristics of the cultivation in relation to the harvesting cycle, as poplar is a fast growing softwood species.
The species, the age, the humidity content, the type of chipper used, the sharpening of the blades and the presence of refinery devices, all these are factors that can affect the dimensional distribution of chips. In particular, growth processes involve a different level of density between sapwood and heartwood, thereby providing a different density to materials constituting the growth ring (Guilley E. et al., 2003).
In order to evaluate whether the wood species used in the experiment described above (fast growing softwood species) influence the ship formation process and is therefore the cause of the predominant increase of just the longitudinal section or if it is necessary to modify the rotor being tested, further tests were conducted using the two experimental rotors used to chop poplar cultivated in SRF and forest plants, or plants with different physical and mechanical characteristics than the first ones.

MATERIALS AND METHODS

The forest plants used in the tests had a base diameter between 70 and 100 mm; therefore, consistent with diameter sizes achieved by poplar on the second year of growth. The species examined included both "softwood” species (field maple) and “hardwood” species (black locust, turkey oak, downy oak and smooth leaf elm). Hardwood has a greater cutting resistance as it has a greater quantity of late wood and is thicker due to the presence of thick cell walls and small inner hollows. On the contrary, early wood has a lower resistance level due to thin walls and wide cellular hollows.

All wood species were chopped using the standard rotor fitted on the 860 Claas Jaguar chipper harvester and using the CRA-ING rotor fitted with the 890 Claas Jaguar chipper harvester. The material gathered in the forest was chopped using still machines (not in motion), therefore the materials were introduced manually into the feeding opening of the two operating machines (see table 2).

The chips obtained from each wood species were classified by registering the particle size distribution, the humidity content and the apparent density in accordance with the Technical Specifications of European Committee for Standardization (CEN/TS 15415/2006, 15414-1/2006, 15401/2006)**.**

RESULTS The results on the particle size of the chips obtained from forest plants and from SRF, generally confirm the results obtained in the experiments conducted in the previous year: as opposed to the standard rotor, the new rotor provides a better homogeneous distribution of the product with a less percentage of materials lower than 12.5 mm and greater percentage of materials within 12.5 - 25 mm (see table 1, table 2 and figure 5).

Table 1. Size distribution of chips produced by Claas Jaguar equipped with standard and CRA-ING rotor.

Tree species	**Field maple**		**Downy oak**		**Turkey oak**		**Black locust**		**Smooth leaf elm**	
Rotor	**Claas**	**CRA ING**	**Claas**	**CRA ING**	**Claas**	**CRA ING**	**Claas**	**CRA ING**	**Claas**	**CRA ING**
Size class	Product distribution among size classes (%)									
> 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50 a 100	0.00	0.00	0.00	0.00	0.00	1.60	0.00	0.00	0.00	0.00
25 a 50	5.30	3.30	7.80	8.60	4.40	7.10	10.20	12.50	17.80	14.50
12,5 a 25	40.60	52.20	52.40	58.30	51.90	57.10	48.30	58.10	46.00	49.20
6,3 a 12,5	42.90	35.20	33.90	26.80	33.10	30.60	34.10	25.90	27.80	25.40
3,15 a 6,3	8.80	7.40	5.20	5.20	8.00	3.20	6.20	2.90	5.10	7.90
< 3,15	1.90	1.60	0.70	0.70	2.50	0.50	1.30	0.50	1.70	3.00
Oversized	0.30	0.40	0.00	0.00	0.00	0.00	0.00	0.10	1.20	0.00
Impurities	0.00	0.00	0.00	0.40	0.10	0.00	0.00	0.00	0.30	0.00
Moisture Content	29.19%	30.11%	30.20%	30.47%	33.51%	29.16%	30.79%	30.41%	32.48%	33.11%
Bulk density kg/m^3	187	164	282	247	220	212	212	179	182	168

Table 2. Size distribution of chips produced by Claas Jaguar equipped with standard and CRA-ING rotor

	Poplar R2S2		Poplar R4S2	
Rotor	Claas	CRA-ING	Claas	CRA-ING
Size class	Product distribution among size classes (%)			
> 100	0.00	0.00	0.00	0.00
50 to 100	0.00	0.10	0.00	0.00
25 to 50	6.10	23.90	4.10	3.10
12.5 to 25	43.90	57.70	43.00	55.10
6.3 to 12.5	31.70	13.90	35.30	31.20
3.15 to 6.3	7.10	2.50	10.10	7.20
< 3,15	6.40	1.20	7.30	3.20
Oversized	1.30	0.50	0.20	0.20
Impurities	3.40	0.00	0.10	0.00
Moisture content	61,61%	61,17%	60,43%	60,03%
Bulk density (kg/m^3)	297	302	274	281

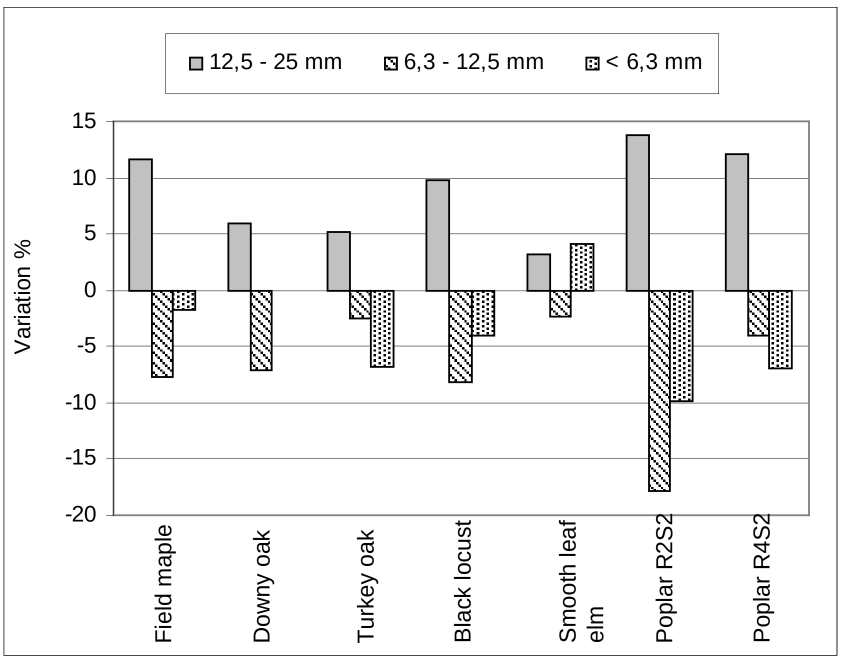

Figure 5. Percentage variation in chips size distribution, within the most representative classes, obtained by CRA-ING compared to Class Jaguar rotors.

Black locust and field maple were the wood species that revealed the most significant growth within 12.5 – 25 mm, respectively +9.8% and +11.6%, whereas, minor increases were revealed for elm (+3.2%), turkey oak (+5.2%) and downy oak (+5.9).

The reduction in the percentage of the product within a particle size class lower than 12.5 mm was variable from -7.1% for downy oak to -12.3% for black locust. Moreover, smooth leaf elm went against the trend, showing an increase of 1.7% within a range lower than 12.5 mm.

The analysis results of chips confirm the trend of the new rotor concentrating dimensional increments in the longitudinal section, regardless of the wood hardness that characterises the wood species being tested.

Softwood species like poplar and hardwood species like downy oak, revealed a predominant increase on the longitudinal section, going on average from 30 mm to 40 mm, whereas the diagonal and radial sections remained almost constant. Moreover, using the same rotor, downy oak chips had a more homogeneous distribution compared to poplar, but also revealed to have a smaller particle size within the same particle size class. The chips were indeed smaller in thickness and width (see figure 6); therefore, it can be associated with the greater wood harshness of downy oak.

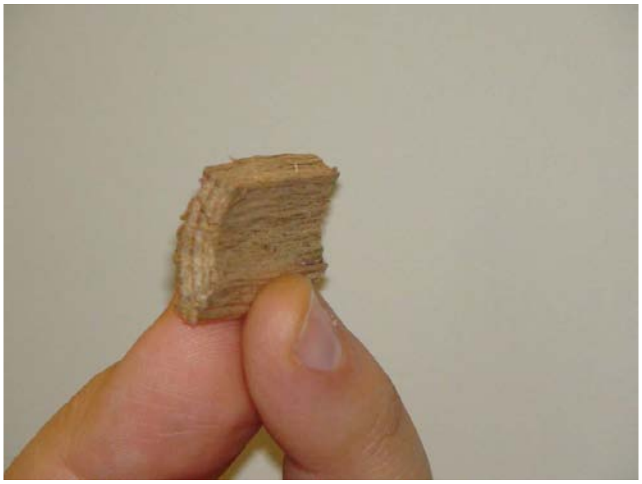

Figure 6. Crosswise section of downy oak chips produced by CRA-ING rotor

CONCLUSIONS The survey results confirmed the results obtained on previous experiments conducted on poplar plantations. As opposed to the standard rotor, the new rotor provides a better homogeneous distribution of the product, having less percentage of material with sizes lower than 12.5 mm and greater percentage of material with sizes raging within 12.5 - 25 mm, regardless of the wood species used. Nevertheless, the analysis of the product revealed a separation of the growth ring for all wood species, hence entailing an increase solely on the longitudinal section of the chips.

Therefore, the hypothesis whereby the separation of sapwood from heartwood during the chipping phase is due to the type of wood species can be ruled-out, as fast growth softwood species were used in the experiment.

This is why the experiment focused on the kinetics of the rotor cutting process and assessed the influence of the cutting angle as well as possible effects on the surface of the rotor and the thrower, which may cause the separation of sapwood from heartwood.

Therefore, another rotor was devised (see figure 7) in which, compared to the previous version (see figure 8), the blade-holders have a different angle, greater weight (+100 kg) and are arranged differently on the drum.

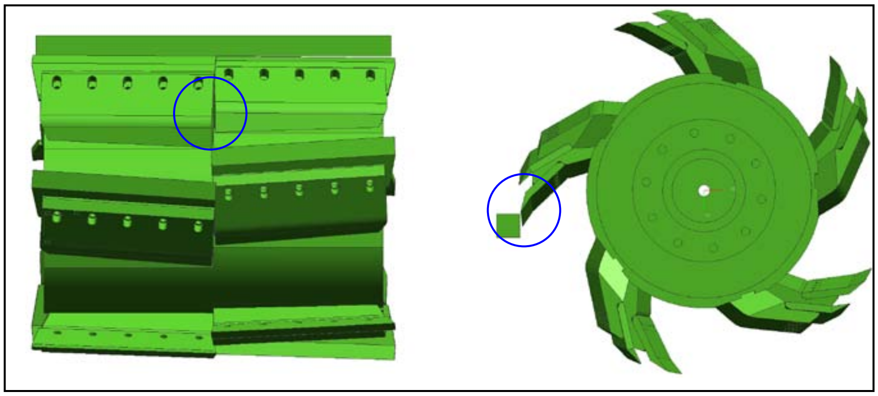

Figure 7. CRA-ING rotor of 2nd generation

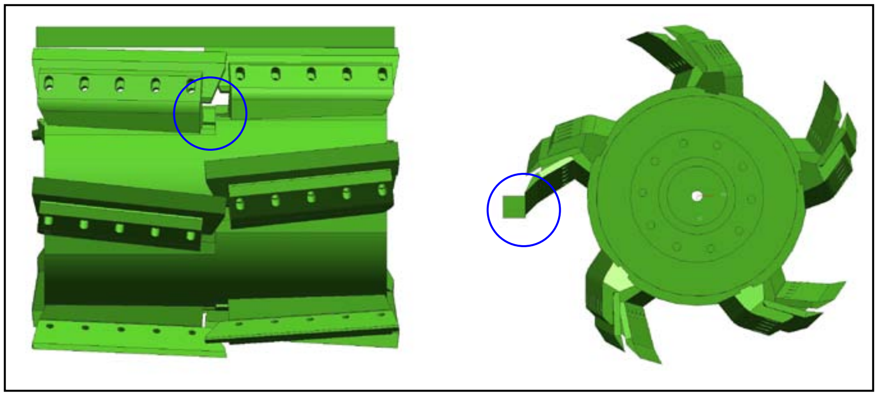

Figure 8. Standard CRA-ING rotor

The first experiments aimed at evaluating the effectiveness of mechanical modifications made to the new rotor will be conducted in March and April 2010; therefore, the results will be revealed on a later scientific experimentation.

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