Concept of a Foldable Transmission Chain Used Inside Tobacco Leaves Harvesting Machine

Simone Pascuzzi, Katarzyna Łyp-Wrońska, Francesco Santoro, and Francesco Vicino

Abstract Italy is the first tobacco producing Country in the European Union with high quality standards of the product. A foldable facilitating arm suitable for the black tobacco "Kentucky" leaves harvesting has been studied in this paper together with the articulated chain placed inside. This chain underwent to a patented modification to make it consistent with the characteristics of the foldable facilitating arm. Experimental tests during a tobacco leaves harvesting campaign were carried out to evaluate both the performance of the modified articulated roller chain and the harvesting chain as a whole, which consisted of the aforesaid facilitating arm made connected to a four-wheel drive tractor and to a trailer, which supported a steel structure suitable to arrange the harvested leaves. Throughout the work phases, the forward speed of the tractor was $V_a = 0.46$ m s^{-1} (1.66 km h^{-1}), whereas the running velocity of the chain $V_c = 0.45$ m s^{-1}. In these operative conditions the work capacity of the harvesting chain employed was 0.48 ha h^{-1} and its harvesting capacity 765 leaves h^{-1}. During the tests carried out, the articulated chain inside the facilitating arm operated constantly without discrepancy.

Keywords Joint · Roller shackles · Motion efficiency · Foliage picking

1 Introduction

In 2021, the total area dedicated to tobacco cultivation in Italy has been 12,857 ha with a harvested production of 41,012 ton. Italy is the first tobacco producing Country in the European Union, but it faces competition from various realities such as India, Brazil, Southern Africa, where production and labor costs as well quality standards of the product, with reference to its traceability, are lower than the Italian ones [1, 2].

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The Italian Region most suited to tobacco cultivation is Umbria, with cultivated area of 35% and harvested production of 31% respectively, of the Italian ones [1]. Virginia Bright and Kentucky tobaccos are mainly produced in Umbria, as well as in Tuscany for the production of the famous Tuscan cigars. Currently, many tobacco farmers in Umbria and Tuscany harvest leaves manually aided by facilitating machines, which are self-propelled or mounted to agricultural tractors [3, 4]. Generally, the self-propelled machines are equipped with hydrostatic traction and during harvesting, seated operators manually detach the leaves from the plants and unload them in a basket [5, 6]. Conversely, the mounted machines mainly consist of a conveyor belt of about 12–15 m in length that hydraulically can be folded [7]. During the harvesting operations, the conveyor belt is placed transversely with respect to the tractor forward direction at an height of 1.0 to 1.70 m above the soil. To collect the leaves, the machine is followed at the rear by workers on foot that manually detach the leaves from the plants and place them on the conveyor belt. The leaves are then unloaded at one of the two ends on a trailer pulled by a tractor that moves on the side road that flanks the fields [8].

In this regard, the Pulcinelli Giovan Battista Ltd. manufacturer, located in S. Leo di Anghiari (Arezzo province, Italy), designed and developed an agricultural implement, suitable for the harvesting of black tobacco "Kentucky" leaves devoted to cigars production. This machine was equipped with a foldable arm supporting an articulated roller chain at its inside [9, 10]. The articulated roller chain, in turn, which worked as a conveyor belt for the detached leaves, underwent to a patented modification to make it suitable for the motion transmission and simultaneously consistent with the possibility to fold the arm. This paper reports the main characteristics of the modified roller chain and the evaluation of its performance inside the facilitating arm during the tobacco leaves harvesting operations.

2 Materials and Methods

2.1 The Agricultural Implement for Facilitating the Tobacco Leave Harvesting

The agricultural implement designed and developed by "Pulcinelli Giovan Battista Ltd." manufacturer mainly consists of a steel box profiles support frame, which has to be connected to the rear 3-point hitch of an agricultural tractor ("fully mounted coupling") (1 in Fig. 1). A facilitating arm built with two steel truss beams, each long about 6 m and jointed each other was linked to this support frame by a cylindrical joint. The beam directly connected to the support frame (2 in Fig. 1) can only rotate around a vertical axis [11, 12]. Therefore, it can be positioned transversely to the tractor forward direction during the leaf harvesting operations or be arranged parallel to the tractor forward direction in order to allow the transportation of the agricultural implement on public roads (Fig. 1). The other end of this steel truss beam is linked

Fig. 1 Kentucky Black tobacco leaves facilitating arm manufactured by Pulcinelli Giovan Battista Ltd.: 1. support frame linked to the rear 3-point hitch of the tractor; 2. folded truss beam arranged parallel to the tractor forward direction

to a second steel truss beam, through another cylindrical joint can rotate with respect to the first one in a vertical plane by way of a hydraulically operated mechanism. Therefore, it can be positioned horizontally aligned with the other beam for the harvesting operations or be positioned overturned so to reduce the overall size of the arm (Fig. 1). The mutual rotation of the two truss beams in the vertical plane is an effective solution because it allows to considerably reduce the sizes of the agricultural implement for the transport phases [13].

The truss beams horizontally aligned arranged support a conveyor belt, which is mainly composed of an articulated roller transmission chain connecting two toothed wheels located at the opposite ends of both the truss beams [14]. A hydraulic motor, which is connected through a control unit to the hydraulic linkage of the tractor, gives the motion to the drive toothed wheel, mounted near the support frame. Conversely, the idler toothed wheel is positioned at the far end of the second beam [14].

2.2 Alteration Applied to the Articulated Roller

The use of the roller chain for the transmission of motion between toothed wheels requires a suitable coupling between the teeth of the wheels and the empty spaces between the links of the chain itself [15, 16]. Due to their structure, the main limitation of the articulated chains is that they can undergo pleats, allowed by the reciprocal rotations between the individual links, only in their operational plan [17]. Conversely, bendings or complete folds are not possible in any plane other than the operational one.

Inside the agricultural implement made by Pulcinelli Giovan Battista Ltd., the articulated roller chain fulfils the entire path between the toothed wheels in the horizontal operative plane, involving both beams horizontally aligned arranged. Obviously, this occurs throughout the working conditions of the machine. On the other hand, the arm was built using two truss beams hinged to each other at one end, so as to overturn one beam on the other one. But this overturning of the beam would

not be allowed according to the characteristics of the roller chain. To overcome this mismatch, it has been necessary to study a mechanical solution that would permit also to the chain to bend in correspondence of the joint connecting the beams.

The solution consisted in replacing two portions of equal length L_n, arranged symmetrically on opposite sides of the roller chain with corresponding portions of ring chains having lengths that did not change the original overall length L of the articulated roller chain (Fig. 2).

Therefore, on each of the opposite sides of the roller chain, N links corresponding to 4 teeth in succession of the toothed wheels, were replaced by two sections of ring chain. Figure 3 shows the detail of the roller chain highlighting the removal of 4 consecutive links replaced by two sections of chain with rings. The two ring chains sections are connected, by means of solid pins, on the external sides of the disconnected links, so as to leave a free space consistent with the thickness of the wheels. The teeth of the wheel corresponding to the missing section of the roller chain then can enter between the two sections of the ring chain, without hindering the motion (Fig. 3).

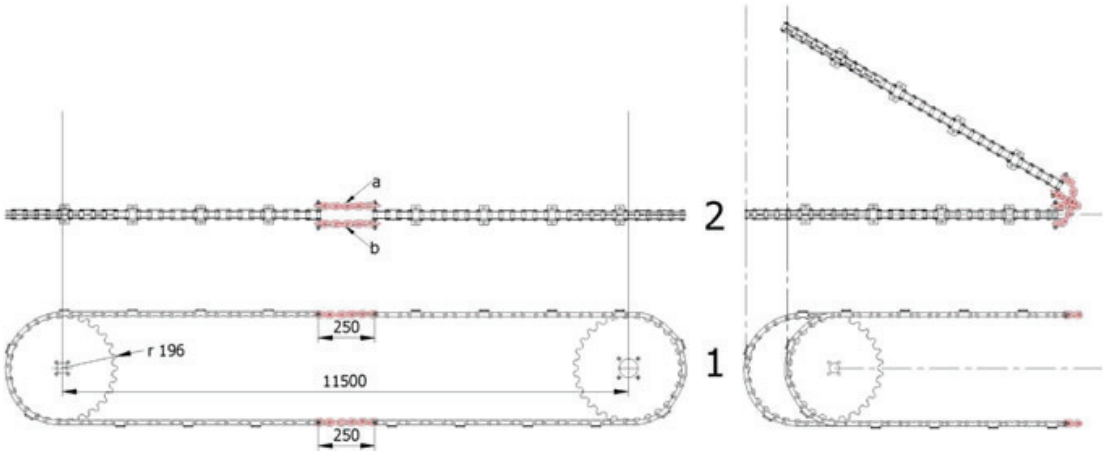

Fig. 2 Roller chain coupled with the toothed wheels, with the portions on opposite sides replaced by ring chain portions. 1. Front view. 2. Side view. Not folded chain at the left, folded chain at the right

Fig. 3 Teeth of the wheel entered between the two sections of the ring chain

2.3 Field Tests

In the 31st week of 2021, experimental tests of tobacco leaves harvesting were carried out in a black tobacco "Kentucky" plantation devoted to Tuscan cigars production, located on a farm in the territory of Anghiari (Arezzo Province, Tuscany, Italy). The tobacco plants were placed on a flat cultivable land with controlled growth weed and irrigation with a layout of 1.0 m × 1.0 m, giving a density of about 10,000 plant ha^{-1}. Furthermore, the cultivation was arranged on soil bands having width 25.0 m. Each band was separated from the adjacent one by a lane having width of about 2.5 m for the machines transits (Fig. 4). The harvesting chain consisted of the agricultural implement built by Pulcinelli Giovan Battista Ltd., linked to the rear 3-point hitch of a four-wheel drive tractor and by a drawbar to a trailer equipped with a steel frame suitable to arrange the harvested leaves. The length of the facilitating arm, i.e. its working front, was 12.5 m and then the tractor first advanced in a direction laterally outside along the tobacco band. Subsequently, at the headland, the tractor with the aggregates rotated and transited the other lane adjacent to the same band in the opposite direction. In this way, the entire tobacco plants bandwidth was undergone to the harvesting operations (Fig. 4). During the tests, the tractor forward speed V_a and the running velocity of the chain V_c were kept constant and chosen according to the owner farmer's experience. These two parameters, very important for evaluating the implement work capacity, were closely related both to the amount of leaves to be harvested, in turn linked to the phenological state of the tobacco cultivation, and to the available labour at the time of harvesting. Furthermore, the functioning of the modification made to the articulated chain inside the facilitating arm was evaluated from a qualitative point of view.

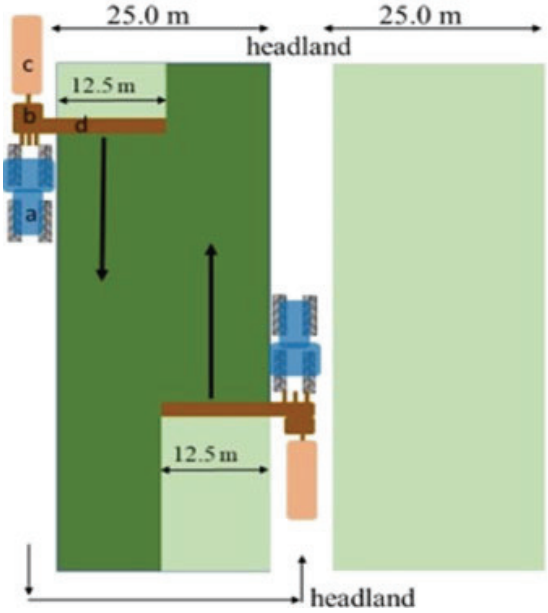

Fig. 4 Scheme of the tobacco leaves harvesting operations with sizes of the crop and of the implement working front. a. tractor; b. support frame; c. facilitating arm; d. trailer for the harvested tobacco leaves storage

3 Results and Discussion

Throughout the work phases, the tractor slowly advanced laterally outside the tobacco field and 3 workers followed on foot the facilitating arm among the tobacco plants, choosing, harvesting, and hanging the leaves on hooks, in turn strictly linked to the articulated roller chain (Fig. 5a). Conversely, other 2 workers, which were on the support frame, detached the leaves from the hooks of the chain and placed them on special iron bars about 1.70 m long (Fig. 5b). Each bar was filled with about 20–24 leaves in a time of 50 s and then another worker hauled it on the frame mounted on the trailer (Fig. 5c). The forward speed of the tractor was $V_a = 0.46$ m s^{-1} (1.66 km h^{-1}), whereas the running velocity of the chain $V_c = 0.45$ m s^{-1}. In these operative conditions the work capacity of the harvesting chain employed was 0.48 ha h^{-1} and the harvesting capacity was 765 leaves h^{-1}. The harvested leaves, arranged on the frame placed on the trailer, were then ready for the subsequent drying process, required to give the valuable final characteristics to the tobacco. At the end of the harvesting operations the arm was folded and arranged for its transport on the road.

Finally, throughout the tobacco leaves collection operations carried out, the articulated chain inside the facilitating arm worked continuously without jamming problems. The ring chain sections inserted along the articulated roller chain did not create any mismatches in the coupling with the teeth of the wheels and the transmission of motion between the toothed wheels took place with evenness.

Fig. 5 Tobacco leaves harvestings

4 Conclusions

An articulated joint suitable for installation in roller chains has been studied, engineered, and patented in Italy, making it possible to fold the widespread and widely used roller chains on planes other than the operational one. The good performance of the facilitating arm for the harvester of tobacco leaves, in which the roller chain fitted with the created articulated joint has been mounted, did not show any deterioration in terms of productivity, strength and reliability, and therefore highlighted the correct behavior of the device.

Other tests are planned to evaluate the efficiency of the described alteration made on articulated roller chain when used to transmit the motion between toothed wheels, which involve torques and speeds higher than those ones required by the tested facilitating arm.

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References

1. ISTAT (Italian Central Statistics Institute) (2022). http://dati.istat.it/Index.aspx?QueryId=33707. Accessed 14 Sept 2022
2. FAO 2018: Food and Agriculture Organization of the United Nations. https://www.fao.org/faostat/en/#data/QCL. Accessed 14 Sept 2022
3. Masanotti, G.M., Abbafati, E., Petrella, E., Vinciguerra, S., Stracci, F.: Intensive tobacco cultivations, a possible public health risk? Environ. Sci. Pollut. Res. **26**, 12616–12621 (2019)
4. Bulgakov, V., Pascuzzi, S., Ivanovs, S., Santoro, F., Anifantis, A.S., Ihnatiev, I.: Performance assessment of front-mounted beet topper machine for biomass harvesting. Energies **13**, 3524 (2020). https://doi.org/10.3390/en13143524
5. Schmitt, N.M., Schmitt, J., Kouimintzis, D.J., Kirch, W.: Health risks in tobacco farm workers: a review of the literature. J. Public Health **15**, 255–264 (2007)
6. Bulgakov, V., Pascuzzi, S., Ivanovs, S., Nadykto, V., Nowak, J.: Kinematic discrepancy between driving wheels evaluated for a modular traction device. Biosyst. Eng. **196**, 88–96 (2020). https://doi.org/10.1016/j.biosystemseng.2020.05.017
7. Lecours, N., Almeida, G.E.G., Abdallah, J.M., Novotny, T.E.: Environmental health impacts of tobacco farming: a review of the literature. Tob. Control **21**, 191–196 (2012). https://doi.org/10.1136/tobaccocontrol-2011-050318
8. Damalas, C.A., Georgiou, E.B., Theodorou, M.G.: Pesticide use and safety practices among Greek tobacco farmers: a survey. Int. J. Environ. Health Res. **16**, 339–348 (2006)
9. Kanehira, M., Otani, T., Yoshikawa, M., Takahashi, T.: The Complete Guide to Chain. U.S. Tsubaki, Inc. Wheeling Illinois (1997)
10. Pascuzzi, S., Anifantis, A.S., Santoro, F.: The concept of a compact profile agricultural tractor suitable for use on specialised tree crops. Agriculture **10**, 123 (2020). https://doi.org/10.3390/agriculture10040123
11. Bulgakov, V., Pascuzzi, S., Adamchuk, V., Ivanovs, S., Pylypaka, S.: A theoretical study of the limit path of the movement of a layer of soil along the plough mouldboard. Soil Tillage Res. **195**, 104406 (2019)
12. Bulgakov, V., Pascuzzi, S., Anifantis, A.S., Santoro, F.: Oscillations analysis of front-mounted beet topper machine for biomass harvesting. Energies **12**(14), 2774 (2019). https://doi.org/10.3390/en12142774

13. Bulgakov, V., Pascuzzi, S., Adamchuk, V., Kuvachov, V., Nozdrovicky, L.: Theoretical study of transverse offsets of wide span tractor working implements and their influence on damage to row crops. Agriculture **9**, 144 (2019)
14. Lodge, C.J., Burgess, S.C.: A model of the tension and transmission efficiency of a bush roller chain. J. Mech. Eng. Sci. **216**(4), 385–394 (2002)
15. Tsubakimoto Chain Company: The Complete Guide to Chain - Reference Handbook. Sachio Shimura, Osaka Japan (2006)
16. Hollingworth, N., Hills, D.A.: Forces in a heavy duty drive chain during articulation. J. Mech. Eng. Sci. **200**(5), 367–374 (1986)
17. Naji, M.R., Marshek, K.M.: Experimental determination of the roller chain load distribution. J. Mech. Transm. Autom. Des. **105**, 331–338 (1983)