[1.] Alexandra–Liana VISAN, [1.] Ana ZAICA, [1.] Radu CIUPERCĂ

RESEARCH AND DEVELOPMENT OF AN INNOVATIVE PAM's POSITION ADJUSTMENT SYSTEM POWERED IMPLEMENTED ON GRAIN FLATTENING MACHINE

[1.]National Institute of Research – Development for Machines and Installations Designed to Agriculture and Food Industry, Bucharest, ROMANIA

Abstract: In this paper will be presented an innovative coupling and position adjustment system powered by Pneumatic Artificial Muscles (PAM's), that started from researching the wet graine processing unit, used often in graine ensilage technologies in silo–bags. Taking in to consideration that nowadays this technology is used to large scale row silage materials, as: cereals (wheat, barley, oats, rye, corn, soybeans, peas), to oilseeds, (rapeseed, sunflower, etc.) and animal feeding row materials (marc, beer mash, beetroot noodles, corn paste, corn silage etc.) in hermetic conditions, that assures agriculture equipment's versatility direct influenced by the system automatization performance that is implemented, their adaptability to different cereal varieties/hybrids, for this reason it is necessary to develop and design an innovative system for coupling and adjusting the distance between the fluted rollers powered by a pneumatic drive system, designed to be operated by PAM's so the operating parameters to be adjusted according to the processing feeding material specificity (graine dimensions, humidity, hardness, etc.). Those equipment's are used at international level, in the newest cereal ensilage agriculture technologies, suited to farmers that do not have a grain storage and preservation infrastructure, with minimal investment in infrastructure.
Keywords: graine flattering machine, rewound drums, PAM's positioning system, silo–bag graine processing, sustainable agriculture

1. INTRODUCTION

The silo–bag technology is a new technology considerate a cost–effective and flexible agricultural storage method, which use large airtight polyethylene tunnels/bags to store various agricultural bulk materials (grains and silage) in an oxygen–free environment. So, is achieved a sealed environment that preserves its content with/without needing chemical treatments and costly fixed infrastructure. The core working principles is the hermetic sealing that usually assured by:

- Oxygen– free environment. A special bagging machine packs the graine/forage in this long tube /tunnel bag, removing excess air and controlling pressure;
- Low microorganism/insect population. The oxygen dependency of the microorganisms or insects that can be ensilage will consume the low concentration trapped oxygen, so in long term these pests will not survive; [1,4]
- The CO_2 concentration will also inhibit the moulds/fungi growth, so is preventing the biodegradation;
- Preservation process highly efficient. The multi–layer plastic film with UV protection, maintain inside a controlled atmosphere, so to preserve the initial nutritional value and cereal quality up to 12 months or longer.

Divergences and key feature of this technology:

- Flexibility and scalability, provide a personalized stored solutions on–demand which can be easily scaled to capitalised all harvest yields and conserved the graine properties, without the large capital investments like in traditional silos; [1,2,3]
- Mobility and easy applicable, these mobile technologies (all equipment's are in motion, easy to relocate and divided, in accordance with capitalization strategy) and can be used in different locations (directly in the field, on rigid platforms, farms unused lands, fact that simplifies farmers logistics, reduce silage and transport costs, long period verification on market or in food industry; [1,3,20,32,33]
- Quality control, theoretically is assured by minimizing the post–harvest losses due to oxygen low quantity which leads to minimal pest attacks, fungal and moulds damage, resulting an active preventing grain quality and conservation of market value; [18]

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- Cost Efficiency, in literature is presented that this technology is significantly more economical per stored graine ton, compared to permanent silo–building infrastructure; [1,3]
- Environmental impact, reduce dependency on chemical pesticides and fumigation, the silo–bags themselves represent an evolution in material science, represent a recyclable material manufactured on thee–laminated materials;
- Modern monitoring, is also a new point of view of this technology in which are implemented SMART systems [21] that are connected to a sensor network that can transmit signals to remote devices of internal silage environmental conditions (temperature, humidity, CO_2 levels, etc.) via mobile networks.[32,33] Also, the PLC can provide real–time alerts, that can assure an efficient intervention, especially if the seal, tunnel or other elements are damaged by external factors, to assure high storage value.

An innovative method to graine & fodder storing technology in silo–bags was first invented and tested in Argentina over 50 years ago, and gradually this concept was worldwide adopted and its machinery. This technology is used in min 40 % from crop storage capacity, so the know–how and agronomic good practices are directly transferred in Romania and specific equipment's produce by companies Mainero, Akron and Martines and Staneck. This technology also was directly transferred and implemented in US and developed dedicated equipment's as Duon Lift

Keeping up with innovative and cost–effective technologies, major equipment manufacturers and agro–market players (HORSCH, GmbH "Industriepark 100", Bayer from Germany, ELHO from Finland, AGRIPAK from Poland, EuroBagging and ROMILL – Czech Republic, e AGRAR–BAG from Bulgaria, etc.) have aligned with this trend and their efficiency has been proved and confirmed by all users. For this reason, the silo–bag technology becoming a reliable alternative to traditional storage (warehouses and silos) and is aligned with EU agro–food and industrial strategy can be easily adapted to new technological development trends from "Food security and food safety".[3]

Alo analyzing the key directions of development in Precision Agriculture (PA) sector, the silo–bag technology complies within this trend and its directions:

- combining innovative and integrated agricultural strategies in key regional area, so the EU to rich global food and nutrition security by 2050 and agricultural global Total Factor Productivity (TFP);
- innovative agricultural silage technologization, easy to reconfigure to farmer's needs, remote intelligent network, quality assurance silage in real time, crop sustainability and superior capitalization;
- optimize farmers inputs management (preservatives solutions, insecticide, fungicides, cereals–grains, etc.) and increase food safety properties at lower silage costs. [18,19,23]
- technical resources and costs, the EU commission identified in agriculture the risk–taking aspect that in these days is high, due to an increased conflictual state, social and environmental instability (drought, floods, hail, pests, reduced accessibility to inputs, devaluation, world market instability and predictability, etc.). Here in, the silo–bag technology is in align with this point, and maintain a balance and stimulates and rewards the progress.

In Romania, farmers have also adopted silo bag storing technology, in this way can apply the same strategy of European farmers and superior value of their goods, to carefully commercialized the grains at a good price evolution on stock exchange. In this sector of economic activity were identified several regional actors such as: Grain Bag company (working points in Iasi and Cluj); SILOBAG company, Super farm Land (Cluj), etc., that collaborates with above Australian companies and with EU partners. Its implantation is done mostly, by farmers (especially young ones that had gained experience in European farmers and return in Romania to be involved in agriculture sector of activity) which are open to implement new technologies that can add value to agricultural products (graine, animal feeding, secondary materials, industrial plants and row food industry) and offer an alternative solution and Know–how–ul bring from Argentina and Bayer company, for those

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which do not have access to conventional silage infrastructure.[1] Form this collaboration with this economic agent, the 500 Romanian farmers have an–brace this technology and crop management strategy, that represents over 1.5 million graine tones. By aping an alternative storing solution with low cost, in global context, increases efficiency and reliability, taking in to consideration that the harvesting begins exactly in the same time when the Constanta port is busy if we want to export, especially Ukraine wore context.

Now, the innovative silo–bag technology is integrating SMART monitoring systems big data management systems using AI and long distances command and control from on common devices and using friendly interfaces. [21,27,32,33] So, the silo–bag technology feasibility increases, is worldwide certified, the investments are justified form the revenue point of view, and in–trend with today technology requirements. Another innovative development direction, is to create sustainable future machinery to minimize energy consumption [7] or to implement mechatronic systems easy adapted to alternative power sources, so to benefit both the environment and the agricultural producers.

Appling those principles the INMA researchers conducted research activities on this field, starting from 2016 and designed an innovative equipment to load–crimping–treat–storage cereals with high humidity in silo–bag applying dehydrating solutions to be used as fodder in the mixt farms. [28–31]

Nower days at European level were identified two trends graine storage hole graine and crimped graine/fodder (cereals or greens with high humidity mare then 14%, ideal value to store as a hole). The second trend presents a much more complexity because it designed to meet the requirements of 3 machines, such as:

- A grinder and silage machine, equipment that presents several technical options (different sets of rollers: a set for fine grain crushing and a set for coarse grain cracking);
- Bagging dry equipment for whole grains, when the feeding material has low humidity (≤14 %);
- preservative/ biopesticide spaying systems (for high–moisture forage as: fodder corn, marc, beer mash, etc.). These solutions are essential during the preservation period because can increase the silage quality, inhibited anaerobic fermentation and pests can be eradicated. [18, 19]

In this way the fodder processed with this technology can conserve the quality and shorter processing time, conserve processed material value for a long time period, so the farmers to obtain a fair price on it.

2. MATERIALS AND METHODS

In this part is will be described the methods used to conduct research activities to establish the actual technological development state of the art and applied scientific research papers published on the crimping and chopping products equipped with grooved rolls (by consulting the books dedicated to agricultural machinery, internet browsing of patents, published papers, product data sheet, flayer, web sites, and other informatic sup–port).

From technical investigation phase, where identified various companies dedicated to manufacture grooved rollers agriculture machinery and installations dedicated for:

- crimping/crumble/crush/chop vegetable crops, namely: fodder, cereal, and grass crops. Following this direction were identified roller crushing systems for wet or dry cereals, manufactured by representative companies such as ROMILL and EUROBAGGING from the Czech Republic, MURSKA from Slovenia, Martinez and STANECK from Argentina, and RENN from Canada, U.S.A., and so on, see Tabel 1.
- energy crops (energy willow, sorghum, etc.), which are equipped with classic roller distance adjustment systems: mechanical elastic couplings at VGM (spring pretensioner systems), hydraulic at VUH, pneumatic at VUP, but also electro–mechanical.

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For the first category was made a short presentation of technical working parameters of some relevant models presented on the international market, see Table 1. All these grooved rollers are equipped with: coupling and distance adjustment electro–mechanical systems (so that the equipment's does not operate without raw material), the raw material crushing degree adjustment for every crop humidity state that also depends on their physical–mechanics characteristics, which generally is influenced by: the harvest period; the operation mode; working environmental conditions and the destination of the processed material. [21]

Table 1. Relevant Load–crimping–treat–storage cereals crops loaders studied [1, 5, 9–17]

Name / Tech. parameter unit		Bunker capacity and supply way	Silo bag supply/Outlet flow rate			observation
			Crimping unit	Silo–bag unit	Spraying system	
Martinez & Staneck[1]	MS 699	1,851 tones	30 ÷ 35 t/h; cardan transmission from tractor PTO	Bag diameter 1.52 m	–	60÷70 HP; trailer nail support; 3.6 m length; granulometry at 50% broken (grain in two parts); adjustable Granulometry; graine humidity 29%;
	TWIN 699	1,564 tones	40÷45 t/h;	Bag diameter 1.83/ 2.74 m	–	110–120 HP; Two rollers –fine grain crush; Two rollers coarse graine cracking; also bags dry grains or bulk fertilizers (Blind mill – without a roller)
ROLMIL	CP 1[1]	3.7 m^3	15–20 t/h; 1 crushing unit (2 rollers 900 mm);	Bag diameter 1.2/1.5/2 m	–	Min 100 HP; 0.7–0.9 l/t diesel; 15–20 t/h –coarse crushing; 7.5–15 t/h – fine crushing; adapter for bagging of by–products; Medium production
	CP 2	3.4 m^3	30–40 t/h; 2 crushing units (4 rollers)	Bag diameter 1.5/2/2.4 m	2 IBC barrels with preservative/ hydration	Min 160 HP; 0.7–0.9 l/t diesel; 30–40 t/h –coarse crushing; 15–30 t/h – fine crushing; Large agricultural company
	CP 2 Plus	10 m^3	45–60 t/h; 2 crushing units (4 rollers)	Bag diameter 1.5/2/2.4 m		Min 200 HP; 0.7–0.9 l/t diesel; 45–60 t/h –coarse crushing; 30–45 t/h – fine crushing; Large agricultural company.
AGRAR–BAG [1]	SILO FORCE MILL	5 m^3	20÷40 t/h, 25÷35% moisture	Bag diameter 1.2÷2.4 m	At request	Min 210 HP; Silage and fodder preparation and storage (dry/wet grain, corn, cut products, grass, alfalfa, silage corn, and pressed sugar beet pulp); Attachment silage mill; Adjustable granulation size system
AGRIPAK[2]	G–6,5	Flow rate adjustment system	15÷40 t/h,	Bag diameter 1.2÷1.95 m,	preservative/ hydration systems	140 HP; sone protection system; adjustable belts to shaft clean; drum distance and rolling adjustment system 4 processes: crimping; conserving/ hydrating solution application; mixing, loading;
	G–6,5 Full	slanting	25–40 t/h	Bag diameter 1.2÷1.95 m, 1000 rpm	Water and conserving container	Adaptor loading adaptive device for cereal/semolina/beetroot noodles
Richiger Cereal Bagging Machine	R950 M		30 t/h	2,7432 m	–	45 HP
	R950 MX		80 t/h 780mmx ϕ219 mm	Bag diameter 1.95 m	–	120 HP; 80 t/h grain crimping; 250 t/h whole grain
	R1050		600t/h	Bag diameter 3,048 m	–	80 HP; Auger 450 mm, 10t/min capacity

[1] commercialized by Grain Bag, [2] commercialized by SILOBAG

The most complex equipment in this moment is the M&S Twin 699 machine, which can be used in two directions:

— optimal grain breaking and high subsequent compaction, obtaining in this way high–quality pre–digested feed (high energy value and digestibility of practically 96%). So, the grain

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fragmentation allows fermentation to take place and transforms flour–type in rumen fact that reduce grain beans percentage in manure.[10]

— grass kit (carrier). So, the hopper and mill will be replaced with the hay kit, in this case is changed the chopping direction from the side, so the processing inlet can be made directly from forage wagons. In this regime allows to stuff alternative forages such as: finely chopped whole–plant corn, sorghum, sugarcane; even pastures. This is the only machine of its kind capable of ensuring excellent stuffing quality in alfalfa.

Appling this design solution, the Twin 699 machine is considerate to be most economical and versatile equipment, especially in areas and special environmental situations, where it is impossible to obtain very good quality hay. The grass kit can be also used to stuff other foods of very low economic value, but high nutritional value, such as: malt dregs, corn gluten, cottonseed, horticultural production waste, citrus peel and pulp, potato peel, grape pomace, sunflower expeller, among other by–products of the food industry. [10]

Taking in to consideration the Australian silo–bag technology developing strategy focused on capitalization both agricultural crop management systems (biomass and fodder industry) but also the secondary material and bulk material storage, so to be compliance with farmers needs, but also to be an leading machine building industry to develop innovative equipment's and services (crop long time storage, flexibility and light manufacturing systems, mechatronics and automation control systems, alternative energy supply fluids) for customized products.

Result of a sustained RDI activity, the INMA engineers, which had been working in more than two RDI project connected to this sector of activity, had obtain and designed an innovative grooved roller coupling and distance adjustment system powered by Fluid Artificial Muscles (FAM). The FAM are adequate to work in the dusty and heavy work conditions; this is an innovative industrial power actuator, that is manufactured by FESTO company, easy to connect either to a hydraulic or pneumatic powering system connected to tractor PTO (so this technical solution can be easily adapted to available power source). If it is endorsing the hydraulic solution, the FAM works as Hydraulic Artificial Muscles (HAM) and are connected to hydraulic power group unit and reservoir, if is used the pneumatic actuation, the FAM works as an Pneumatic Artificial Muscles (PAM), the reservoir is not necessary and the maintenance it is more accessible.

In the next part will be presented a Romanian patent technical solution [26], designed based on a wide theoretical and practical experience in laboratory and computational mechanism design (3D PAM's models and mechanism in SolidWorks) and establishing PAM's mathematical model using the experimental data to draw force–stroke characteristics.

3. RESULTS

The invention relates to a coupling and distance adjustment system powering a pair of grooved rollers operated with FAM, designed to be integrated in a crushing/chopping equipment's for ensilage the energetic and grain crops. The aim of this technical solution is to improve working parameters and performance of pressing technologic process using latest class of innovative actuators. The grooved rollers coupling system is important during the equipment transportation faze, especially in field conditions, where the FAM work like dampers. The grooved rollers working distance can be adjusted using the FAM (light compliance powering actuation system) in accordance of crimping coefficient (humidity release cracks) that helps evaporation, anaerobe fermentation and increase effectiveness of conversant applying solution surface.

Another important aspect is increasing equipment automation degree and versability in order to adapt to a wide feeding materials, development trend started from M&S equipment's, like: energetic, fodder and cereals crops, but also the spontaneous flora management, using an PAM's power system easy to use in hydrotonic/pneutronic command and control units (CCU), that incorporate innovative sensors, transducers connected to a PLC that usually monitor the working parameters and command the powering units using a friendly user interface, trend that is

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promoted by all automative industrial partners (SMS, FESTO, Symens, etc.). Taken in to consideration this industrial design principle was patent here in presented crumped mechanism, presented din Figure 1 and 2. [26]

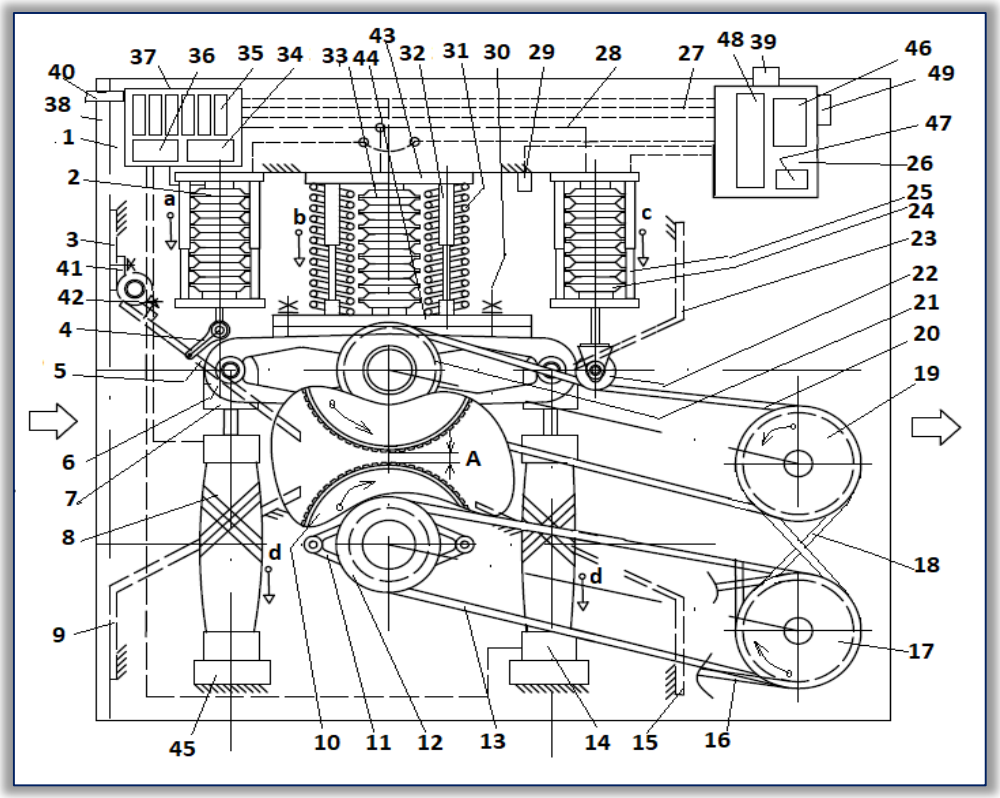

Figure 1. Grooved rollers coupling and distance adjustment system operated with PAM's – working position [26]

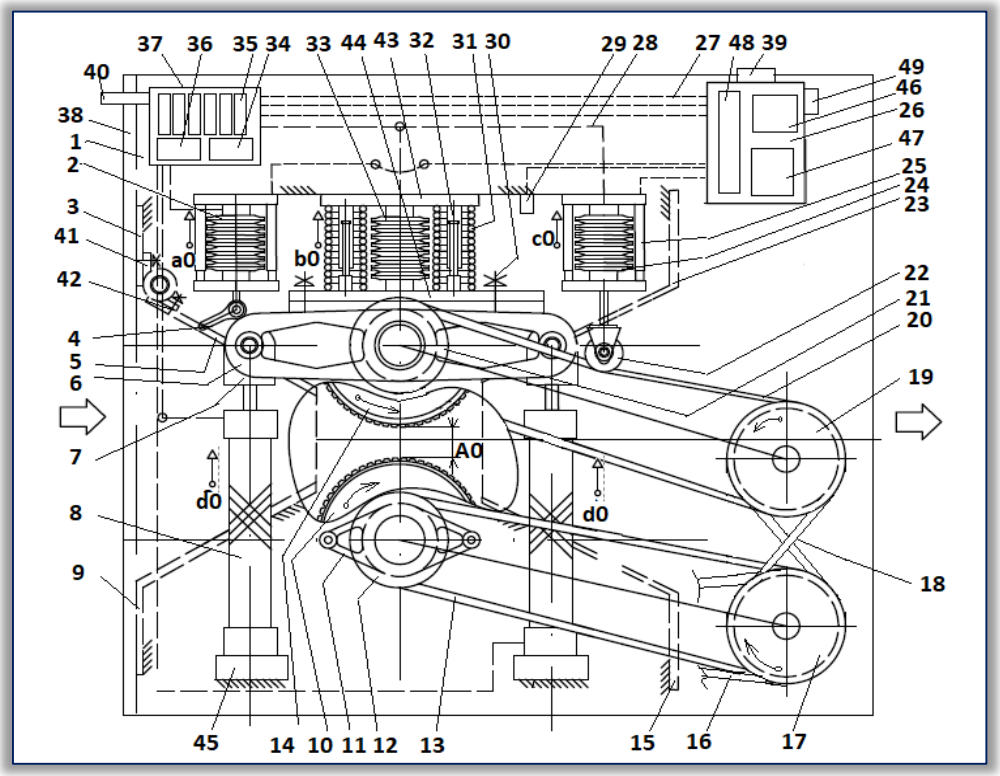

Figure 2. Grooved rollers coupling and distance adjustment system operated with PAM's – Transport position [26]

The mechanism is placed on metal or reinforced case 1, on which are placed two rotational inlet and outlet plates *5* and *23*, provided with hinge 41 on which is placed a removable clamping system *42*. The eyelet part 4 is connected to a traction PAM 2, that performs a translational movement in

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a direction, (see Figure 1), only when it is fluid supplied through the tubes 28 by servo valve block 35 mounted on fluidic control unit 37 that is provided with a quick supply coupling element 40. When it receives a signal from the CCU 26 an electrical outlet signal from 39. The electrical connections are made using electrical cables 27, to control the traction PAM's 2, 33 and 24, which perform a guided vertical translational movement using a spring telescopic linear system guided made form: telescopic axes 32, helically springs 31, plates 44 and 43.
The vertical active stroke A, see Figure 1, of the active grooved roller can be adjusted following the supply processing material (dimensions of the crimple cereals and diameter of the crush plants), following the rolling grooved roller generator 10.
On the inferior level of the metal casing 1 are placed: a rotational casing bearing 11; two mounting plates 45; three weld profiles 3, 9 and 15; fixed support 43, on which is positioned displacement transducers 25 that detect the stroke of PAM's 33. The transducer 25 signal other to stop the mobile support 44 mounted on a gliding mobile grooved roller case bearing 21, using a hex–screw demountable system 30. The distance A0, from Figure 2, is an important constructive parameter in situations like: system transportation, taken out of service, or when is undergoing maintenance (the a0, c0, d0 are assured). So, the vertical movement of the gliding grooved roller 14, depends on the: type of feeding material dimensions (stiffness, height and diameter); crimping degree (feeding material humidity); feeding material flow rate; that is actuated by a compression PAM's 8 that is screwed to a clamping fork 7 provide with radial bearing 6, when are supplied with fluid powered, in this way is realized the guided vertical displacement movement d and b, presented in Figure 1 .The helical compression springs 31 ensure the equilibrium position (supporting the grooved drum 14 weight when the equipment is not working, assuring a maximum height A0) and a controlled displacement in b0 direction, see Figure 2.
The flow and pressure parameters of the PAM's 33 and 8 are monitored by valve block 34 and throttles 36, so that the crushed/crimpled raw materials, which are not represented in the Figure 1 and 2, are introduced through the adjustable feeder opening so that to ensure a continuous processing flow and to prevent system blocking.
The grooved drum crimping process, is realized by contrary rotating the drum pare through: the fixed grooved drum 10 is connected to a belt wheel 12 that is rotated by toothed belt 13, three–sector distribution belt wheel 17 which is driven using belt 16. At the same time from 17 is rotated the mobile roller 14 in a contrary direction using a crossed double belt 18, using belt wheel 19 that is in connection with belt 20 which spines the belt wheel 21. The pre–tensioning system is applied on the belt 20 and is made from: a tension roller 22 which has a guided vertical translational movement c which can be actuated by the artificial traction muscle 24. The stroke is measured using a displacement transducer 25 and the generated force is adjusted by throttles 36 controlled by valve blocks 34.
To ensure the parallel plane movement of the grooved mobile roller 14 up on the grooved roller 10, and to generate a constant and uniform distribution crushing forces on drum generator, the pneutronic actuation system is provided on the other side of the metallic structure, in mirror configuration, fact that is not presented in this paper.
The command and control panel 26 is configured to ensure an optimal operating regime of the system depending on the type of processed crop, by adjusting the working parameters utilizing a mini mobile computer 48 that is connected, either to a touchscreen display type operating terminal 46 (to visualize and adjust the working parameters by an operator), or to an distance transition unit of data acquired and memorized by module 47, that can be connected to: a satellite transmission; wireless internet networks; an industrial process computer if it is integrated within a technology with a logical sequence of equipment, or an through a dedicated data processing unit or a deep learning platform thou jack 49.

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4. CONCLUZII

The technical problem intended to be solved is developing an innovative grooved roller coupling and distance adjustment system powered by PAMs and controlled by pneumatic automation systems was theoretically resolved, and the technical solution will ensure:

- The coupling and adjustment system operated with PAM's presents a constructive variant with low mass.
- PAM's present a "slim" design, and the "stick–slip" phenomenon does not occur, compared to classic actuators;
- Develops high and uniform initial longitudinal forces, high precision positioning without shocks and vibrations, because PAM's are compliant actuators in practical applications;
- Minimal maintenance, because the coupling and distance adjustment system operated with PAM's, allows for quick coupling and decoupling from the command–and–control system as well as the use of easily maneuverable tools and disassembly devices;
- Low maintenance, because, for the coupling and adjustment system with PAM's, the mechanical and fluidic part of the difficulty is low, and the experience of the personnel can be gained with minimal training, which usually presents a low risk of injury;
- Low fuel consumption when rollers are positioned with PAMs, because there are currently efficient fluidic energy recovery systems, a very important aspect, especially when the installation or equipment works in the field, and its autonomy must be high;
- There is a way of local control by an operator who does not have to monitor and pro–vide maintenance on–site.
- It presents possibilities of interconnection with automation and monitoring systems specific to agricultural technological flows, and interconnection to remote communication networks.
- Re–technologization of agricultural machinery, so that the chopping/crumping equipment responds to farmers and biomass beneficiaries;
- Assuring the quality of the crushed/crimped material following national and international requirements and regulations for drying, ensiling, recovery, and pressing for the processed material;
- Reduce electrical energy consumption (by reducing the number of electric motors) and increase the mobile equipment's power autonomy when working in the field;
- Enlarge the grooved roll active stroke range of the crushing/flattening parameters following the raw material particularities to be used for a wide range of cereals/biomass;
- Implementing the advanced production methods and technologies.

Further research direction on this technology will be to develop the 3D model patent and to presents the functionality of this solution implemented on crimping equipment's respecting the 3D virtual prototyping steps, by:

- making a simulation of the model and the functionality of the patent solution, here in the presented, by applying the compression and traction PAM's stroke–force experimental characteristics;
- making the vibration simulations during equipment transport and in most difficult working regime;
- developing a command–and–control configuration unit appropriate for pneutronic applications working in long range distance;
- to design a decision algorithm and an Automation of Sequential Processes with GRAPH to be used for an adaptable processing manufacture system, using a multi–criteria decision strategy (dimension the active parts, as grooved rollers profile and dimensions, crop specificity of processed material, PAM's active stock, mechatronics and automation con–figurations, power source capacity, and energy storage recovery system).

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