DESIGN OF AN INDUSTRIAL PROTOTYPE MACHINE USED FOR ROD CUTTING OPERATIONS IN SRC NURSERIES

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REZUMAT. Lucrarea descrie designul unui prototip de maşină industrială (ROD Picker), care va fi utilizată pentru o recoltare exactă a culturilor cu ciclu scurt (SRC). Prototipul va încorpora fluxul de lucru şi caracteristicile tehnice specificate de către partenerii din proiect: Egedal Maskinfabrik A/S – Danemarca, Salix Energi Europa AB - Suedia, Lempe Gbr - Germania, TTZ Bremerhaven – Germania, TU Dresden – Germania si U.P. din Timişoara – România. Culturile SRC joacă un rol tot mai important în dezvoltarea agriculturii prin eficienţa producţiei de biomasă. Folosind creşterea rapidă a speciilor de arbori (salcie, plop) poate fi produsă bioenergie, contribuind astfel la două direcţii majore ale strategiei UE, şi anume: triplarea folosirii resurselor de energie regenerabilă până în 2020 şi reducerea impactului cerinţelor din industria lemnului cu privire la resursele forestiere interne. Cu toate acestea, cultivarea plantelor energetice presupune un proces tehnologic complex, o etapă fiind tăierea automată exactă a nuielelor conform dimensiunilor specificate. Aceasta contribuie la viteza pregătirii produselor şi eficienţa de distribuţie a pieţei.

Cuvinte cheie: culturi de plante energetice , biomasă, maşini de tăiat nuiele, pepiniere SRC.

ABSTRACT. The present paper describes the design of an industrial machine prototype (ROD Picker) which will be used for precise cutting in Short Rotation Coppice (SRC) farms. The prototype will incorporate the functionality workflow and technical features specified by the project partners: Egedal Maskinfabrik A/S – Denmark, Salix Energi Europa AB - Sweden, Lempe Gbr - Germany, TTZ Bremerhaven – Germany, TU Dresden – Germany and U.P. from Timişoara – Romania. SRC farms play an increasingly important part in the agricultural development of efficient biomass production. Using fast growing trees species (willow, poplar) bio-energy can be produced, thus contributing in two major directions of the EU strategy: tripling the use of renewable energy resources by 2020 and decreasing the impact of wood industry requirements on domestic forest resources. However, cultivation of such energy plants involves a complex technological process, one stage being the automated precise cutting of rods according to specified dimensions. With the help of the ROD Picker this task will become automated. This contributes to the overall product preparation speed and market distribution efficiency.

Keywords: Energy Plants Farms, Biomass, Rod Cutting Machinery, SRC Nurseries.

1. INTRODUCTION

Over the last decades, biomass has become an important and viable source of energy. Technological innovations in the domain of exploiting renewable energy resources have generated the requirement for more biomass production. Furthermore, in the EU, there is a recommendation for tripling the use of biomass energy in the overall energy consumption from renewable resources. This target is set to be achieved by the year 2020. Considering conditions of commercial advantages, sustainability or technical limitations, about 85% of biomass quantity is generated by wood. With this idea in mind, there is an increased pressure for developing rapid and efficient solutions, either in the form of plants or wood processing machinery. Farmers need to adapt their existing plantations in order to obtain an increased quantity of biomass. So SRC farms have become an attractive option [1-3].

SRC farms are defined as efficient biomass production sources with a rotation period of under 30 years. Fast growing species of high density trees like poplar or willow also contribute to the protection of soil. In the EU, an analysis of the demand for such SRC farms has led to the conclusion that in the next 10 years more than 176000 hectares are necessary. This means that current plantations will increase by 30% in size, yearly, for the following decade.

The basis of any SRC farms resides in the planting material (or cuttings). Presently, after harvesting the wood material during winter months, cutting of plants at specific dimensions is done manually. With obvious limitations, this manual labor is to be

replaced by an automated process which integrates the latest industrial technologies with the purpose of increasing biomass production efficiency. The ROD Picker prototype is an innovative machinery designed for harvesting, cutting and packaging the wood material coming from SRC farms [4-5].

The remaining part of this paper is organized as follows: Section II presents an overview of the system for the rod cutting operation. Section III discusses proposed technical approaches and technologies. Conclusions concerning both the functionality performance and the future developments are mentioned in the final section.

2. ROD PICKER GENERAL OPERATION PRINCIPLES

The ROD Picker system is a multifunction machinery that incorporates state of the art technologies. It will be capable of performing *harvesting, cutting, sorting* and *packaging* of wood material resulted from SRC cultivation. Figure 1 presents harvested rods which are ready for the *cutting, sorting* and *packaging* stages. Figure 2 shows manually bundled rods prepared for shipping in carrier boxes. This is the final product form that energy plants farms are delivering. A high throughput automation of the production process, with as little as possible manual intervention represents the aim of the proposed ROD Picker system.

Fig. 1. Freshly harvested rods prior to cutting, sorting and packaging.

Fig. 2. Manually bundled rods prepared for shipping.

The proposed schematic of the *cutting* stage is presented in Figure 3. Note that prior to *cutting* the harvested rods are manually loaded on a conveyor belt and inspected with special industrial cameras (presented in Section III) which will signal the presence of unwanted smaller branches. Since the final rod should be free of any small branches and fit within specific dimensions one has to consider the use of a series of sensors and video inspection devices in order to prevent any deviations from the proposed objectives. The length of a processed rod should not exceed 2.4 m and should not be smaller than 1.2 m. These limits will be adjusted according to user specifications since they depend on the position of length sensors on the actual cutting component. The diameter of the rods will also be measured. Specified limits will be adjusted but will not exceed a 7 mm minimum and a 25 mm maximum size.

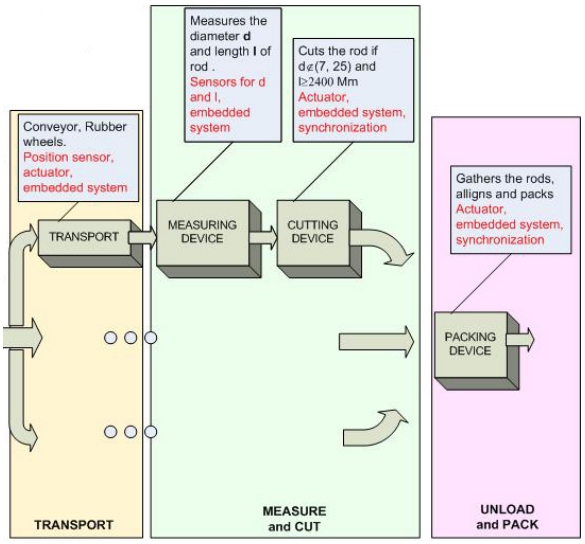

Fig. 3. Principle operation of the final production stages.

From Fig.3 one can notice that several processing lines will be considered. This idea was considered for increased efficiency of the production process. Manual labor of 6 workers delivers 2 boxes of material daily, each box containing about 6000 m of rods. The ROD Picker system should be capable of delivering 1 box daily for each production line with fewer workers involved. A total of 3 to 5 production lines have been discussed.

Finally, processed rods will be selected and directed towards the packaging module. A splitter device will push aside all residual material resulted from the cutting process.

The ROD Picker is designed as a modular and flexible machinery which integrates different sensor based measurement technologies. A collection of actuators (mechanic, hydraulic), sensors (rod proximity, position, speed, diameter and length) and video

inspection devices (rod quality) constitute a robust concept involving precise and synchronized operation capabilities. The entire process involves the use of an industrial PLC which provides execution commands, system diagnosis testing and the user interaction interface. The system user will benefit from specific information: number of processed rods, machinery diagnosis details, processing speed or meters of processed rods. Work health and safety regulations were considered as essential when designing the proposed system.

3. PROPOSED TECHNOLOGICAL APPROACHES

A first version of the ROD Picker was designed with a focus on production speed optimization. The customization process is intended to respect the guidelines set by specialists in the domain of SRC nurseries and agriculture machines construction. The following paragraphs present a series of measurement technologies which will be incorporated in the final prototype. Note that some changes are to arise as the development process continues.

Figure 4 presents the schematic for the loading module of the cutting system. Rods will travel one after another on a transport mechanism containing rotational fixed wheels. A video inspection using the Systronics LeanXCam devices ensure that the rods have no additional branches. If branches are detected a cutting mechanism will remove the unwanted parts. For this purpose, image edge detection is to be performed real-time on the LeanXCam processing unit.

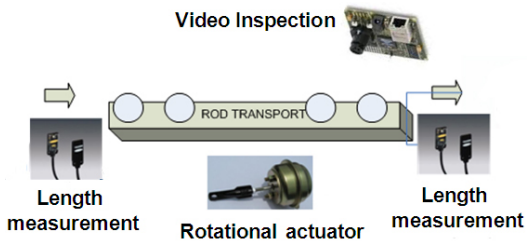

Fig. 4. Rod quality inspection and length measurement prior to actual cutting.

Rod length is also measured in this stage. This information is needed for ulterior processing when the actual cutting is performed. Note that the cutting process is restricted by the conditions mentioned in Section II. The Omron E3F1 photoelectric sensors have been considered for signaling and measuring the length of a rod that has entered the transport system.

The most important component of the cutting module is the diameter measurement for the determination of actual rod cutting points. For this purpose two solutions will be studied.

The first one involves the LeanXCam device which will cam take up to 60 images each second. These images have to be processed and the detection of the target diameter has to be signaled. Image processing needs to be synchronized with the speed of rod movement along the processing line. A problem which could affect the measurement accuracy of this approach is the environmental conditions in which the cameras operate. For example, dust particles resulting from rod cutting operations might cover the lens and thus cause unwanted image blurring.

A second approach involves the Omron ZX GT smart laser diameter measurement system. Figure 5 shows the operation of diameter measurement using the ZX GT sensors. The rod passes on the transport line and enters the laser curtain. At this time this curtain will be interrupted/blocked by the rod so there will be a difference between what the Emitter generates and what the Receiver perceives. This difference is proportional to the rod diameter. This approach also requires considerable testing since the maximum width of the laser curtain is 28 mm and the maximum allowed rod diameter is 25 mm. Perfect alignment of rod and laser measurement system is required. Furthermore, any irregularities on the surface of the rod will be reflected in the output signal of the ZX GT. Detection of these amplitude erroneous peaks is mandatory since such a peak can signal that a target diameter has been found.

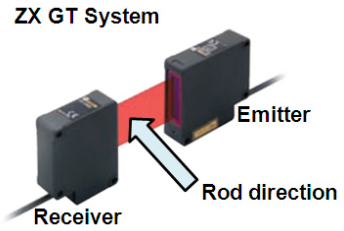

Fig. 5. Diameter measurement principle using the ZX GT System.

Other components which will be used in this stage of processing, is the Omron E3X area sensing fiber. The purpose of this sensor is to detect the presence of the rod as it approaches the cutter and to signal that the transport line must be slowed (just for the precise cutting moment). Sensors like the Omron E3JM-10M4-G-N will be used for signaling if the rod has been cut and has moved on the line. Also, starting from the first cut point, the useful part of the rod needs to be measured again and the maximum and minimum length limitations (see Section II)

should be considered. Any excess material is considered junk and is to be removed from the line using automated pistons which will push away the remaining wood. The system uses the Omron E6B2-CWZ5B encoders for measuring the movement speed of the line. This detail is important since calculation of rod length and arrival times is mandatory. Inductive sensors (the Omron E2A-M12KS04-M1-B3) will signal if the cutting mechanism has stopped working. For work safety purposes, switches, relays, limiters, emergency stop buttons, protection cases and light warnings have been considered and will be included in the final working prototype.

Finally, the operation of the machinery will be performed under the control of the SIMATIC S7-1200 PLC from Siemens. The setup includes the SINAMICS V60 motor driver and the FL5 servo motor. These components have been considered ideal for rods transportation and operation control.

4. CONCLUSIONS AND FUTURE DEVELOPMENT

This paper presents the design considerations for a machine prototype (ROD Picker) which will be used in energy plants farms. The proposed system is being developed under the cooperation of three private companies, one technology transfer institute and two technical universities. The purpose of the machine was generated by the urgent need of automation in the production process for fast growing plants. An increased speed in production will generate a higher and more efficient throughput. The quantity of fast growing species, prepared for market distribution will increase thus impacting the overall biomass production resources.

Researchers and engineers, together with experienced people working in energy plants production have agreed upon the functionality, features and operation principles of the system. This translates to a complicated implementation requiring knowledge in mechanical engineering, computer programming, sensors, measurement systems or image processing. From product design, to testing and validation, the ROD Picker is a modular system, adaptable and customizable. It will include state of the art technologies ranging from laser based measurements, optical sensors to real-time image processing.

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