Development of a stationary fully automated Hop Picking Machine Prototype

Z. Gobor [1], J. Fuß [2], G. Fröhlich [1] and J. Portner [1]

[1] Bavarian State Research Center for Agriculture, Germany

[2] Fuß Fahrzeug- und Maschinenbau GmbH & Co. KG, Germany

Mailing address and email address of corresponding author:
Bavarian State Research Center for Agriculture (LfL)
Institute for Agricultural Engineering and Animal Husbandry (ILT)
Vöttinger Str. 36, 85354 Freising, Germany
zoltan.gobor@lfl.bayern.de

ABSTRACT

Harvest in hop production takes place in late summer. The hop wines together with the supporting wire cut or pulled from the overhead cables of the trellis system, loaded on to a trailer and transported to a static picking machine. Harvesting on the traditional picking machines implies manual putting of each individual vine into a clamp which pulls the vines into the picking machine. This work is very labour-intensive, with a high risk of injury and considering the ergonomics unfavourable. The Bavarian State Research Center for Agriculture and the company Fuß started 2011 a cooperation project in which a novel prototype of a system for automatic picking based on the preliminary work of the company was developed and tested. Main idea is to replace the manual placement of the vines into the clamps with fully automated feeding of the picking machine. The first prototype of the system consists of a conveyer, a cutting subsystem including a pre-picking unit and transport conveyer with a pre-separator for cones for transporting the cut hop vines into the picking machine for further processing. In this paper the concept, methods which were used during the development and preliminary test results of the system will be described and presented.

Keywords: Automation; Hop; Picking machine, Ergonomics, Germany.

1. INTRODUCTION

The Hallertau in Bavaria is the worldwide largest continuous hop-producing area and currently comprise more than 15000 ha. In Germany hop is typically grown in hop gardens, consisting of a horizontal mesh of longitudinal and transversal cables, anchored on a system of poles. Each season supporting strings are attached to the overhead cables and on such a way a 7-8 m high trellis systems is created. Regular maintenance of the poles and cables allows utilization of the gardens for more than 20 years. Depending on the hop variety and shape of the garden about 2000 rootstocks are

Z. Gobor, J. Fuß, G. Fröhlich and J. Portner. “Development of a stationary fully automated Hop Picking Machine Prototype”. EFITA-WCCA-CIGR Conference “Sustainable Agriculture through ICT Innovation”, Turin, Italy, 24-27 June 2013.

planted on one ha. During the seasonal preparation of the garden about 4000 supporting strings per ha need to be replaced after the harvest between October and March and anchored to the ground. In spring, the two best developed vines from each rootstock are selected and trained to climb and twist around the supporting strings. The harvesting takes place in August and September. Both the vines and supporting strings are severed approximately 50cm from the ground and then cut or pulled from the overhead cables and loaded on to a trailer in one continuous process using a pull-off implement. After fully loaded, the trailers transport the hop wines to a static picking machine.

1.1 Description of the Problems and Objectives

To ensure harvesting of the optimally matured cones the harvest needs to be carried out in 3 to 4 weeks with sometimes 20 working hours per day. Harvesting with the traditional picking machines implies manual placement of each individual vine into a clamp which pulls the vines into the picking machine. This work is very labour-intensive, with a high risk of injury due to the monotonous cyclical repetition of the task and in the same time uncomfortable, considering the ergonomics during the separation of single vines out of the bulk.
Additional facts which need to be taken into consideration are the availability of seasonal workers willing to work on the loading of the picking machine and the expenditure on manual labour in the sector of hop production in Germany, which increasing constantly. Furthermore, the number of the farms involved in the hop production decreased from 8591 to 1294 in the period from 1973 to 2012, while the total area under hop stayed on the same level in this period, affecting the processing quantities and machine capacities on each farm. Hop is a speciality crop, cultivated on relatively small concentrated areas by a modest number of farmers in relation to the major crops and because of this it can not be considered as a market interesting for leading agricultural machinery manufacturers. Hence, the introduction of new technologies and machines in the field of hop production is slow and stays on the moderate level.
On the other hand the introduction of sophisticated systems in the production of high value crops to carry out repetitive manual tasks was recognised as an economically justifiable objective of agricultural mechanisation already in the last decade (Blackmore et al., 2005).
Analysing the situation, problems and development tendencies pointed out above, an automated feeding of the hop picking machine was determined as an important objective which can advance the hop production in future.

2. DEVELOPMENT OF THE SYSTEM

Traditional hop picking machines are complex and expensive systems, integrated into a building. Adequate maintenance of the complete system is required, especially during the harvesting season which lasts only four to six weeks per year. The company Fuß Fahrzeug- und Maschinenbau GmbH & Co. KG (Pfeffenhausen, Germany) is involved in the development and optimization of hop picking machines for a long time. The problem of manual placement of vines into the clamp occupied the employees of the company and they developed a concept which can automate this step. Based on the preliminary work the Bavarian State Research Center for Agriculture and the company Fuß started a joint development project in 2011, with the goal to replace the manual putting of vines into the clamp with fully automated feeding of the picking machine based on the preliminary work of the company.

2.1 Concept of the stationary fully automated Hop Picking Machine

The manual feeding of the picking machine by placing of the vines into the clamps can be improved and automated through implementing of additional mechanisms and processing steps as follows. The bulk of hop vines needs to be unloaded from the trailer (Phase 1 see figure 1) onto a conveyor which transports (Phase 2 see figure 1) the hops to the mechanism for cutting the hop vines into pieces. The cutting mechanism moves vertical upwards and cuts the entire bulk through (Phases 3, 4 and 5 see figure 1). The size of the hop vine pieces (cutting length) can be defined and adjusted depending of the variety of hops and yield quantity. Another conveyor on which the hop vines pieces are spread out over the entire width transports them longitudinally and provides continuous feeding of the picking machine.
After a cut through the entire bulk is completed the cutting mechanism moves to the initial position and the conveyer moves the bulk into the next cutting position stepping of one cutting length. After the positioning is finished, steps 3, 4 and 5 are repeated. This processing cycle is repeated until the length of the remaining hop vines in the bulk is shorter than the cutting length. Meanwhile the next trailer can unload the bulk to the conveyer (Phase 6) to provide continuous utilization of the machine.
During the concept development lifting systems from the construction, packaging and assembly industry were analysed in order to provide modularity of the system.

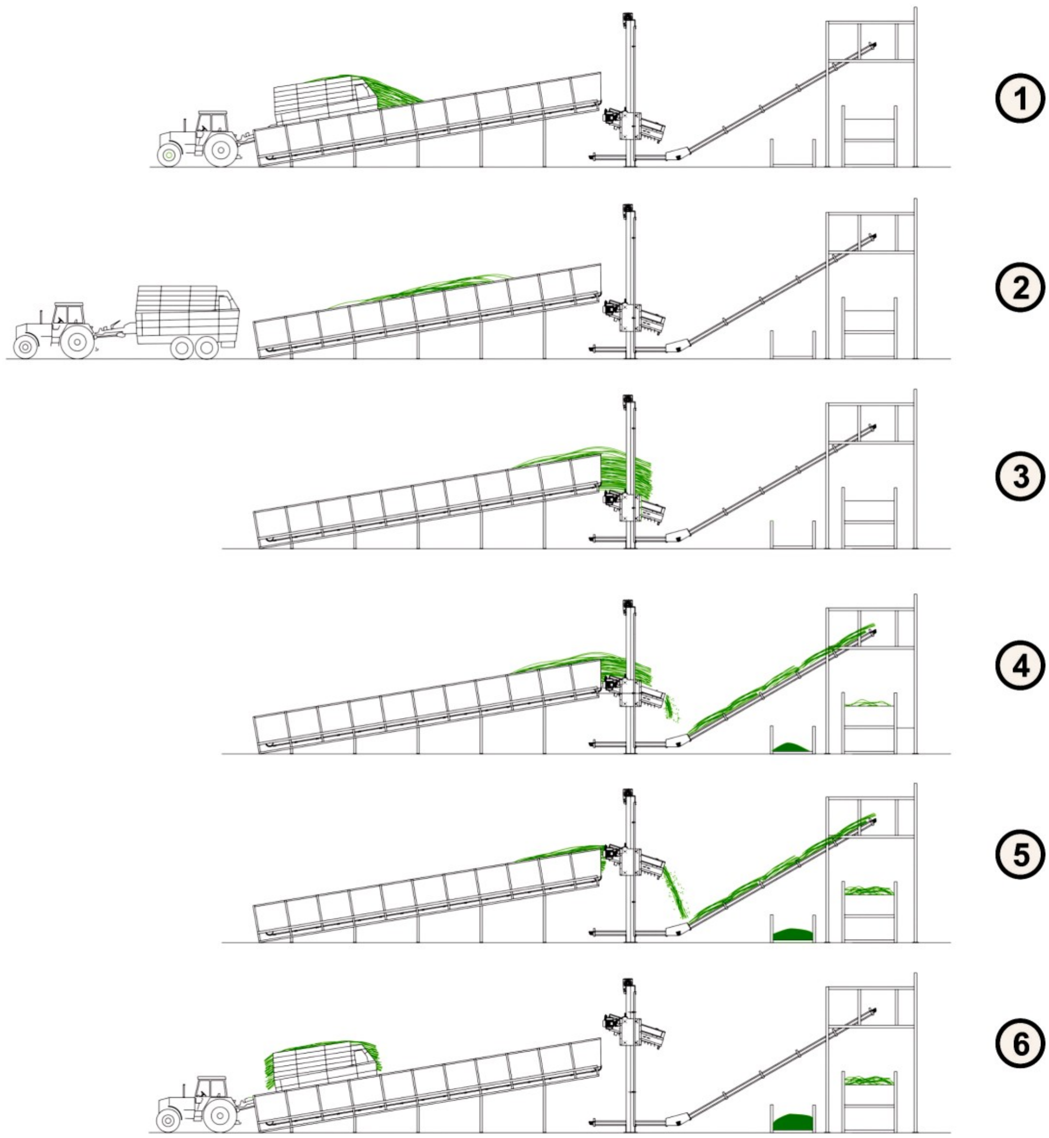

Figure 1. Concept of the automated hop picking machine feeding with processing steps

2.1 Digital Prototyping

In the first phase of the project a concept of the system was defined and sketches and existing technical drawings of the main subsystems were reviewed and converted into 3D solids, and the digital prototype built step by step. The information about the existing parts without technical documentation was collected using reverse engineering. In the frame of the project the Product Design Suite 2012 (Autodesk) was purchased to allow concurrent engineering. Not only detailed design of the parts and the assemblies, but also the simulation and analysis become possible using the digital model. A simulation-ready model was created in form of the assembly of all the designed parts and the virtual model by defining the relations between parts and their motion constrains. Up until very recently the prototype testing was possible only if the physical prototype had been built previously. However, within the project, kinematical simulation, stress and force analysis were used for evaluating the functionality of the newly designed elements before any of the parts were available. The most important advantages of digital prototyping included savings in labour and materials, straightaway feedback from prototype testing and increased possibility to create design variants. Due to the fact that the automated feeding of the hop picking machine is an innovative and unique system, theoretically its development would entail a lot of trials to eliminate errors in order to achieve the first prototype ready for manufacturing. The developed digital prototype allowed the processing of the data through the entire process chain, from preliminary design to the assembling of the prototype. Based on this repeatedly approved method, the errors in design were minimised and the development time was considerably reduced. The final design was verified with collision analysis. A screenshot of the digital prototype is presented in the figure 2. Based on the digital model the first physical prototype was built.

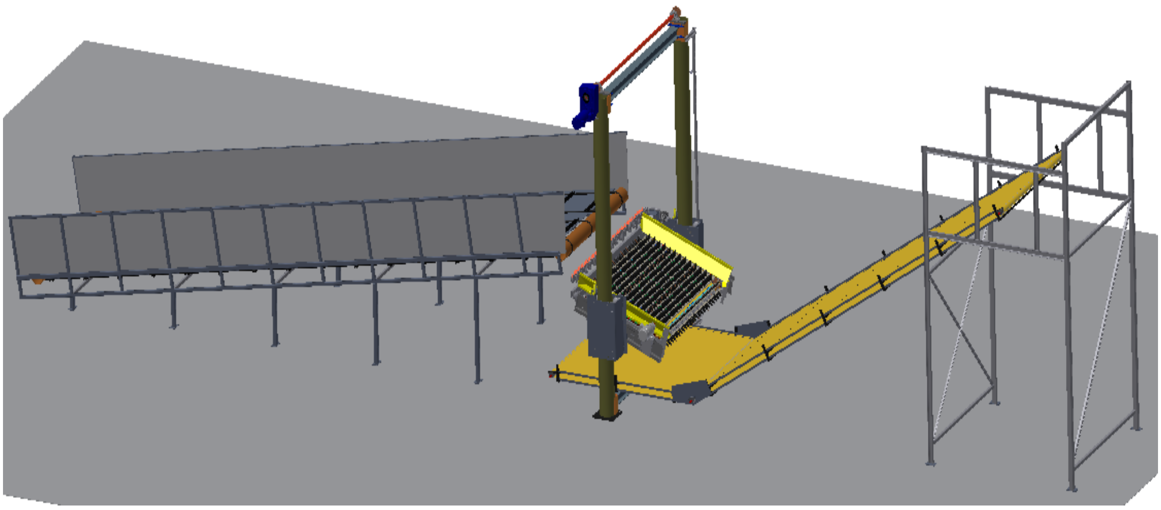

Figure 2. Digital prototype of the automated hop picking machine feeding system

2.1 First physical Prototype

The first prototype of the system consists of a conveyer, a cutting subsystem including a pre-picking unit and a transport conveyer with a pre-separator for cones for transporting the cut hop vines into the picking machine for the further processing.
Exactly like in the concept the bulk of hop vines needs to be unloaded from the trailer onto a conveyor (1) which transports the hops to the mechanism for cutting (2) the hop vines into pieces. The pre-picking unit (3) is mounted on the same carrier together with

the cutter bar and has the task to pick as much cones as possible already in this phase before the processing of the hop vines takes place inside of the picking machine. The cutting length is a parameter which can be adjusted in the control software and needs to be defined depending on the variety of hop and yield quantity, providing undisturbed cutting of the bulk of hop vines without significant damaging of the cones. The second conveyor (4) transports the hop vines pieces longitudinally and spread them over the entire width of the mechanism providing continuous feeding of the picking machine. An important element of the final picking machine will be the picking unit, a product of the private limited company Fuss. The complete system is controlled by a PLC mounted within the electrical cabinet (5).

The control software allows three operation modes: off, manual and automatic. The speed of all electric motors, including the speed of both conveyers, the vertical speed (up and downwards separately) of the cutting mechanism with the cutter bar and pre-picking unit and the speed of the pre-picking unit can be adjusted in the manual mode. By changing a time constant, which is a PLC parameter, the length of the hop vine segments can be defined. In the automatic mode all operation repeats cyclically and controlled by sensors and in such a way a whole hop bulk can be processed without manual intervention. The first prototype of the system is shown in the figure 3.

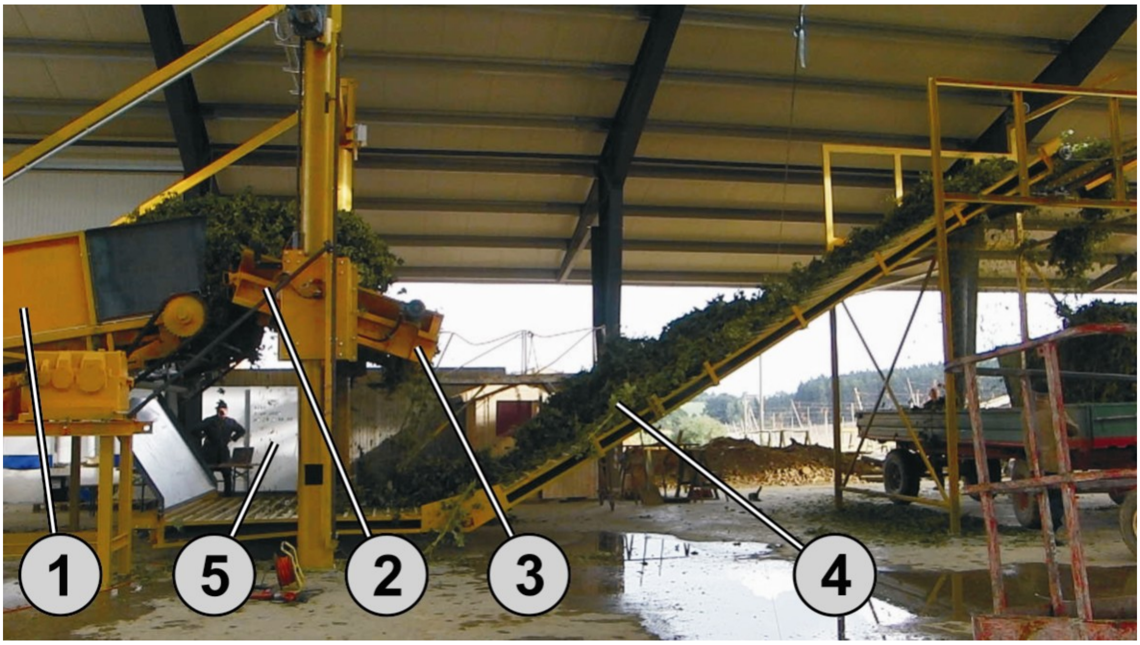

Figure 3 Prototype of the system for automated feeding of the picking machine. Legend: (1) – conveyor; (2) – mechanism for cutting; (3) – pre-picking unit; (4)– feeding mechanism; (5) – electrical cabinet with the PLC

3. TESTING OF THE SYSTEM

During tests videos of the cutting unit were captured with a high speed camera. Tests under different working conditions, considering different cutting speeds and directions, different hop varieties and modification of the position of the assembly of the pre-picking unit were carried out. During the analysis two important factors were observed, the continuity of the material stream and the quality of the picked cones. The results from the analysis were integrated into the digital prototype.

The first tests of the physical prototype were carried out in 2012. The main task of the testing was to prove the simulation results, to check the stability and reliability of the system and to gain new insights. Selected parameters of the frequency inverter which controls the electric motor of the lifting system were acquired and analysed considering efficiency.

The collected information is currently used for the optimization of the developed system and its integration with the stationary picking machine. The improvements regarding to stability, accuracy, reliability and capacity are striven for.

4. CONCLUSIONS AND OUTLOOK

Based on contemporary design and analysis tools such as digital prototyping, simulation, real-time acquisition of the relevant parameters and capturing of high-speed videos during the testing, a new prototype of a system for automated feeding of a hop picking machine was developed without high expenditures.

In the next step during the harvest in 2013 the yield losses, damaging and quality of the cones need to be analysed and compared with the results during the processing on a conventional picking machine. Also the operational capabilities and energy consumption will be analysed, through acquisition of all relevant parameters using compact modular data logging system and adequate software solutions. Using the automated data analysis the behaviour of the prototype in series of tests will be evaluated , allowing to detect the possibilities for the improvement of the entire system.

The safety aspects of the machine need to be incorporated in the final design and related problems have to be solved according to the new machinery directive 2006/42/EC [7].

ACKNOWLEDGEMENTS

The project “Development and optimisation of an automatic hop picking machine” is funded by the German Federal Agency for Agriculture and Food (BLE) as a part of the innovation support program of the German Federal Ministry of Food, Agriculture, and Consumer Protection (BMELV). The authors would like to thank the employees of the Institute for Agricultural Engineering and Animal Husbandry and the Institute for Crop Science and Plant Breeding of the Bavarian State Research Center for Agriculture and the private limited company Fuß Fahrzeug- und Maschinenbau GmbH & Co. KG

(Pfeffenhausen, Germany) which were involved in the project for successful cooperation.

5. REFERENCES

Blackmore, S., Stout, B., Wang, M. and Runov, B. 2005. Robotic Agriculture - the future of agricultural mechanization? In J.V. Stafford (Ed.), Precision Agriculture '05. Wageningen Academic Publishers. pp. 621-628

Fraser, I. (general editor). 2010. Guide to application of the Machinery Directive 2006/42/EC. 2nd ed. Available at: ec.europa.eu/enterprise/sectors/mechanical/files/machinery/guide-appl-2006-42-ec-2nd-201006_en.pdf. Accessed 21 June 2013