



Automated assistance functions for more harvesting efficiency

Controlled Harvesting

A new assistance system for CLAAS combine harvesters permanently monitors the harvesting process and automatically adjusts the machine settings to the current conditions – faster and more exactly than an operator ever could. This automated optimization is based on a distributed control system. dSPACE's production code generator, TargetLink, supports the developers in this complex project.



The annual harvest season has just a very small time slot. Wheat, rye, barley, and corn have to be harvested at just the right point of maturity. Once this harvest maturity has been reached, the combine harvesters work the fields day and night. But running a combine is a highly complex task. Up to 50 parameters from the reel to the chopper influence the harvest yield. The operator has to continuously monitor and evaluate around a dozen of these parameters. Hardly any operator is capable of keeping an eye on everything and tapping the machine's full potential.

Less Complexity on the Field

The high number of settings and parameter dependencies is the result of many different environmental factors, such as climate and terrain, and basic objectives concerning throughput, fuel consumption, and threshing quality. This makes optimizing the harvesting process very

complex. Operators can barely master the challenge of choosing settings and checking the displayed values time and time again. To take off some of their burden so they only have to enter the most important settings, some functions can be partially automated. The new assistance system CEMOS AUTOMATIC (CLAAS Electronic Machine Optimization System) tackles the challenge of optimizing the crop yield. CEMOS monitors the harvesting process, regulates the process parameters and continuously adjusts the machine to the harvesting conditions. Its key to success is on-line modeling: The assistance system permanently computes the machine and environment model, analyzes the parameters, and determines the optimal parameter set. It then passes these parameters to the machine.

Automated Harvesting

Before the combine is on the field, the driver enters the harvest objectives via a graphical dialog-based user in-

terface. CEMOS AUTOMATIC analyzes the objectives, sensor data, and machine settings and very quickly determines the optimal combination of parameters. The harvesting conditions change throughout the day, so the system checks these optimal settings time after time and adjusts them continuously. This means that CEMOS AUTOMATIC makes permanent readjustments to an extent that operators could never perform on their own. These automated parameter adjustments yield optimal results, such as maximum throughput with the highest grain quality, grain cleanliness, and minimum fuel consumption. In combination with other assistance systems, such as the CRUISE PILOT for controlling driving speed and the LASER PILOT for steering, a combine becomes fully automated.

ECU System for Optimal Harvesting

Optimal harvests are reached when all of the combine's systems interact in coordination. This is done by an automatic mechanism that works on a level above the ECUs of the individual systems. The ECU network consists of control units for basic control tasks and superordinate ECUs. A fully equipped LEXION 780 combine harvester includes 35 ECUs that are connected via CAN bus. For the systems directly involved in the harvesting process, CLAAS develops the ECUs itself. Purchased systems, such as the combustion engine, are equipped with ECUs from their suppliers. Depending on the task, ECUs with processors based on fixed-point or floating-point arithmetic are inserted. The ECU of CEMOS AUTOMATIC is designed for a 32-bit PowerPC.

Model-Based ECU Software Development

ECU software development is model-based. All of the large control units are developed with MATLAB®/Simulink® and dSPACE TargetLink®. The neces-

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CEMOS AUTOMATIC with the subsystems AUTO SEPARATION, AUTO CLEANING, and CRUISE PILOT.



Assistance Functions Developed with TargetLink

DYNAMIC COOLING:

Automatically sets the combine's cooling system (for diesel motor and the hydraulics system), depending on the required cooling power

CEMOS AUTO SEPARATION:

Automatically adjusts the residual grain separation

CLAAS LASER PILOT:

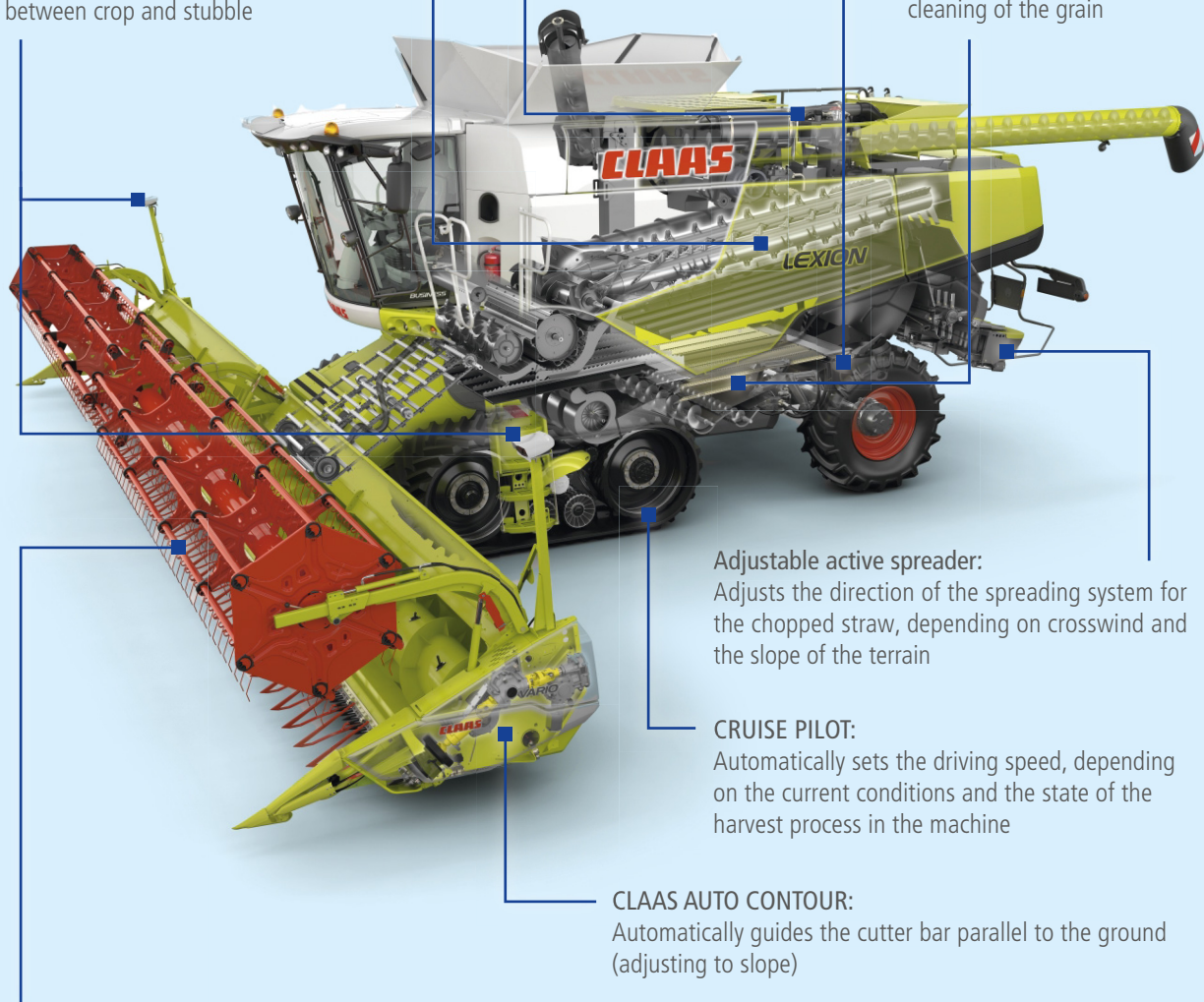
Uses a laser scanner to automatically steer the machine along the edge between crop and stubble

MONTANA:

Automatic chassis that swings the axle portals to compensate cross tilt up to 17% and longitudinal tilt up to 6% for operation on steep terrain

CEMOS AUTO CLEANING:

Automatically adjusts the cleaning of the grain



Adjustable active spreader:

Adjusts the direction of the spreading system for the chopped straw, depending on crosswind and the slope of the terrain

CRUISE PILOT:

Automatically sets the driving speed, depending on the current conditions and the state of the harvest process in the machine

CLAAS AUTO CONTOUR:

Automatically guides the cutter bar parallel to the ground (adjusting to slope)

Automatic reel speed control:

Synchronizes the reel's circumferential speed with the machine's driving speed (2001: pilot project for TargetLink, 5 days of development time from the available hydraulics components to integrating the first prototype into the ECU)

Basic features:

- Various speed settings
- Various position settings



The graphical user interface makes entering objectives easy.

>> sary machine functions are designed according to the principle of a distributed automation represented by one overall model. This complex model has a size of 50 megabytes. Task control and the communication between the system functions are based on the OSEK (Open Systems and the Corresponding Interfaces for Automotive Electronics) operating system. The OSEK module for TargetLink is used to define interfaces and tasks. The developed assistance function therefore only has to be connected to the existing environment.

Code Generation and Offline Testing

After the model-based development of new functions, the code can be generated for the controllers either incrementally or completely. It is possible to generate code only for individual functions (incremental code genera-

tion) or for the overall controller function (complete code generation). TargetLink supports different simulation modes so the new functions can be tested as soon as possible. This validation phase before the harvest is extremely important. When harvest season is underway, the development team does not have any time to look for implementation errors while on the field. The harvesting needs to start with well-tested software. The validation phase includes integration tests and also intensive functional validation, which uses complex plant models. The offline test scenarios use the large amount of data that is collected on the field during each harvesting phase.

Virtual ECUs

With the CLAAS online simulator, the behavior of the combine can be tested prior to the harvest and under different conditions. The operators can

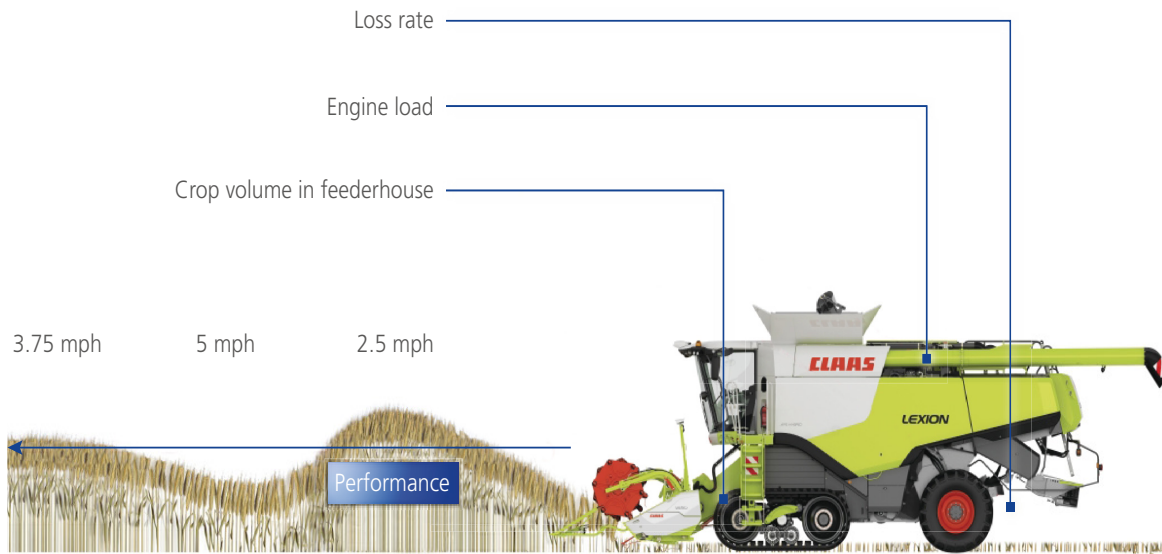
even use the simulation scenarios to get used to the combine or to polish up and improve how they handle it. PC-based simulation makes this possible. The online simulator uses the virtual representation of the different machine components and the process model that contains the data from many years of harvesting experience. Real-time-capable virtual ECUs run in the background, with software that matches the real ECUs. These possibilities for simulation before the harvest is another important way to minimize the risk of machine damage and operating errors during the harvest.

TargetLink Evaluated

For years, CLAAS has successfully developed basic functions with TargetLink. These functions include an automatic reel speed control – the first pilot project using TargetLink. Even back then, the short development time of only 5 days for going from the available hydraulics components to integrating the first prototype function into the ECU was astonishing (TargetLink Goes to the Fields, dSPACE NEWS 2001/2). Because the ECU systems of combines are becoming increasingly complex, their development no longer focuses only on easy handling and a steep learning curve but also on other aspects. This made it easy to integrate the functions for CEMOS AUTOMATIC into the model and the complex ECU network. It is still important that the software can be tested in the laboratory with TargetLink's own instruments. This way, functions can be validated very early on. Even special functions, such as defining multi-rate tasks or background tasks, can be described

“New assistance functions make our combine harvesters much more efficient. For their development we rely on dSPACE's production code generator, TargetLink.”

Andreas Wilken, CLAAS



Harvesting process with environmental influences, driving behavior, and machine parameters.

and implemented precisely with TargetLink. For CLAAS, the combination of TargetLink and the OSEK module means that developers can concentrate on the essential development tasks. Despite the complexity of the model, efficient code can be generated quickly with TargetLink, both for individual functions (incremental code generation) and for the entire ECU network.

CEMOS AUTOMATIC Assistance System

The CEMOS AUTOMATIC assistance system is a shining example of how important software is in the commercial vehicle sector. The system first went into series production as an optional feature for the LEXION 740-780 series of combine harvesters. Implementing and testing the new function became

easy with model-based development and production code generation. The generated code is reliable and error-free and lets the developers focus on the most important task during their short and valuable time on the machine: the final function test on the fields. ■

Andreas Wilken, CLAAS

Conclusion and Outlook

There is a steady increase in the demands on modern combine harvesters regarding efficiency and the economical use of fuel. Assistance systems such as CEMOS AUTOMATIC (CLAAS Electronic Machine Optimization System) are a tried-and-tested solution and are becoming more and more important. The production code generator TargetLink is a firmly established part of the development process for such assistance systems. TargetLink's easy-to-handle functions

support the development of complex control systems and make it possible to generate reliable production code. For learning purposes, the TargetLink models are also used on virtual ECUs on a PC so the operators can become familiar with the combine before the harvest. Tools like TargetLink are the ideal basis for spurring innovation. In the future, new standards such as AUTOSAR will lay the groundwork for developing distributed controllers and easily reusing software.

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