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Fuel consumption measurement with agricultural machinery

On a farm, fuel consumption is a major factor in mechanisation costs. Through the expected reduction in fuel subsidy, fuel consumption will in the future be a more important consideration when choosing machinery and implements. In order that the farmer has the necessary information for such a decision there is a requirement for on-farm comparisons. Here, investigations on position-related fuel consumption with on-land ploughing are reported. This work also allowed an evaluation of different implement adjustments and the effects of different field conditions.

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Fuel consumption is dependant upon the implements used as well as tractor stage of development, intensity of use and efficient transmission/engine mode. In order to ease the setting-up of the latter by the driver, some tractor manufacturers equip their machines with gauges showing actual fuel consumption. Others offer automatic motor management which results in reduced consumption.

The farmer has the possibility of influencing the demands on the engine through the arrangement of implement and tractor and, when not working at full load, through adopting a fuel-efficient transmission/engine mode. But business decisions based on consideration of the available parameters are possible only when differences can be monitored from working engine fuel consumption figures from several field areas.

The fuel consumption is also an indication of the power requirements of a tractor and implement. Power requirements can be calculated from the consumption where the engine performance figures and the respective engine/transmission mode is known. For a limited area of the full-load curve the engine performance is proportional to fuel consumption. The power requirement of the complete tractor and implement team is often easier to recognise for the farmer compared with when only the required engine power for the hitched equipment is given.

Investigation method

Aggregate
Chosen for the investigation was a tractor and implement team where it was known that adjusting the implement alone would have different effects on the tractor. The team featured the four-furrow mounted plough Star 120 MCSN 75-38 from Rabe and the 99 kW Case Maxxum MX135. The (onland) plough permitted the choice of driving the tractor in or out of the furrow. The tractor was equipped with a fuel sensor as well as a DGPS with its antennae fixed to the plough [1]. During the investigations the variable draught control was disconnected so that the working depth could be held constant through differing soil conditions. The investigation was carried out on three field areas with differing soils (between S12 and L) and over smooth and broken-up surfaces.

Fuel sensor
Used as fuel measurement equipment was an instrument developed by the Technical University Russe (Bulgaria) [2]. The complete system comprised a microprocessor-controlled calculation unit with an external block „keyboard – indicator“, a measuring wheel with course sensor and flow meters of various sizes. Because a complete recording system (MOPS from the firm Caesar) was required for recording further measurements, the sensor eventually used had a measuring chamber size of 5.53 cm^3. Such small measuring capacity should allow a very precise indication of the fuel consumption to be achieved. For conversion of fuel volume into a standard factor the temperature of the fuel was measured at both the beginning and the end of each passage.

DGPS system
Determination of position data was made via the ten-channel DGPS receiver K202-K from the firm Sercel which took into account the C/A code including the carrier frequency phase when determining position. This positioning system had a stationary accuracy of a few centimetres. The position renewal rate was 0.6 s. Just as with the small volume of the fuel measuring apparatus, the high precision of the positioning equipment enabled exact assessment of fuel consumption and position. The antennae was fixed over the land side of the rear plough share.

Evaluation
Reporting of position data was based on north and east values. The observation of the travelling movements of an aggregate is simplified when one centreline of the coordinate-system lies parallel to the direction of travel so that any alteration in implement working width is reflected by the second centreline. The system of coordinates was turned as required and based on a zero point in the field. At 0.6 s, the renewal rate of the position data is higher than the fuel consumption at a volume of 5.53 cm^3. In order

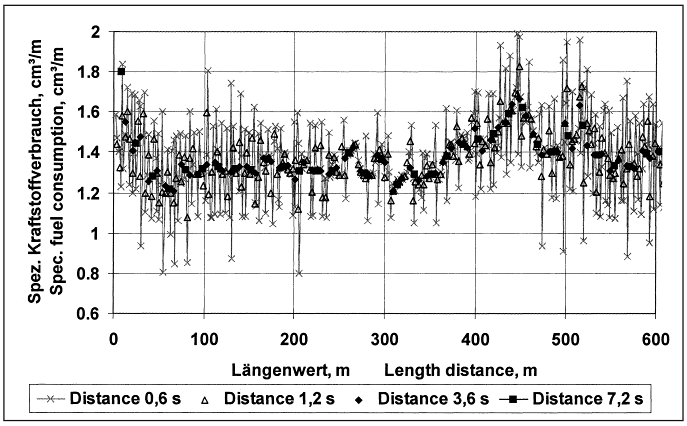

Fig. 1: Averaged way specific fuel consumption along the passage 1 on the site 804 over different time (way) distances

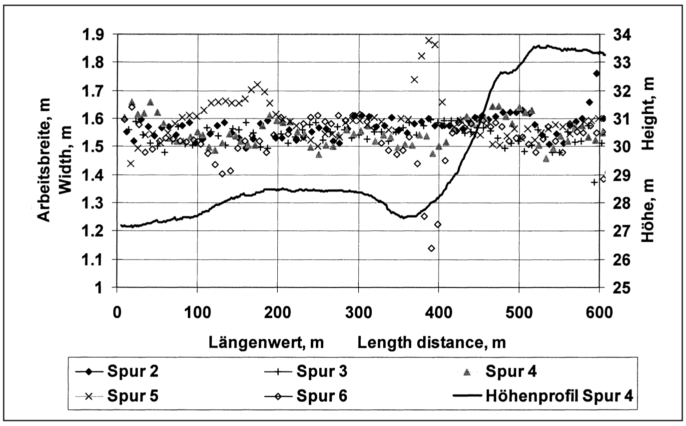

Fig. 2: Working width at ploughing (tractor drives in the furrow) for adjacent passages on the site 804

to be able to attribute a fuel value to every new position value, the fuel value was time-dependently interpolated for conversion to a standard factor under consideration of the fuel temperature.

Results

Route-specific fuel consumption

At a position renewal rate of 0.6 s and an average speed of 2.5 m/s, the fuel consumption was measured over route sections of 1.5 m. As can be expected, the variation between travel section values with this size is still too high (*Fig. 1*). Only when the values from larger travel (and time) sections were gathered together is the variation of values reduced and the changes in fuel consumption along the route visible. The comparison of curve developments resulting from the original data and from enlarging of the route sections by the factors 2, 6 and 12 showed that the value scatter caused by the measurement sys-tem is already resolved by enlarging route sections by the factor 6. In the case of the chosen measuring equipment, calculation of fuel consumption can therefore be achieved over practical 10 m sections.

Working width

The route-specific fuel consumption can be converted into area-specific consumption when a consistent working width can be depended upon. The working width, however, fluctuates according to ground conditions and can, following adjustment of the plough to allow the draught tractor in-furrow or onland, also mean a change in the average values.

The working width can be calculated from the DGPS data which determines a mean width value for the observed route section and from this subtracts the value from the previous passage within the same piece of field (Fig. 2). The actual existing scatter of values reduces the danger of a calculation error.

The area-specific fuel consumption

differed from the route-specific consumption in these measurements because the average plough working width for each investigated variant was taken into account (*Fig. 3*). The figure indicates the measured results from four passages of the particular rig made with the standard variant of the plough followed by five bouts with the onland variant. The height curves of the two innermost and outermost passages were used to document the field surface contours.

With the same adjustment of the plough, i.e. through swinging the plough to the middle position of the lower links in the horizontal plane, there was no noticeable difference in fuel consumption between both plough variants. This result is consolidated through the average value per passage. This means that the larger draught resistance of the plough which can be expected with onland ploughing because of the existing greater lateral force is compensated for, probably because the required power can be applied evenly by both wheels. This result was reached on sandy to loamy soil and on even as well as on broken-up surfaces and applies so long as the onland plough is adjusted according to the instructions.

Independently of the implement setting, fuel consumption differences caused by ground influences can be identified. In the main, these can be traced more to an altered working resistance of soil and less to the countours of the field surface.

Conclusion

The use of a fuel measuring system of the type previously described enabled the fuel consumption to be determined for a complete field area or parts of it. In order that more farmers may Independently carry out their own fuel consumption measurements this approach would require, however, support from the tractor manufacturer. The fuel consumption must be available as a continual reading (in part already achieved) as well as in total values for periods of time or parts of fields.

The DGPS systems which are increasingly used in the agricultural sector allow a stationary precision of less than 2 m. This means that in the case of position-related fuel consumption measurements, the classifiable course sections would be larger in comparison with the introduced measurement results, but just as suitable for presentation. Suitable for this work is a tractor-mounted computer similar to a yield mapping system and which can deliver the position-related fuel consumption of different implement set-ups including the tractor.

The investment in position-related determination of fuel consumption pays only when a sustainable conversion into the parameter „power requirement“ results. The prerequisite for this are values for engine rpm as well as at least the engine performance details. The power requirement is suitable for then demonstrating the differences between aggregates, or adjustments of aggregates, as well as between different parts of a field.

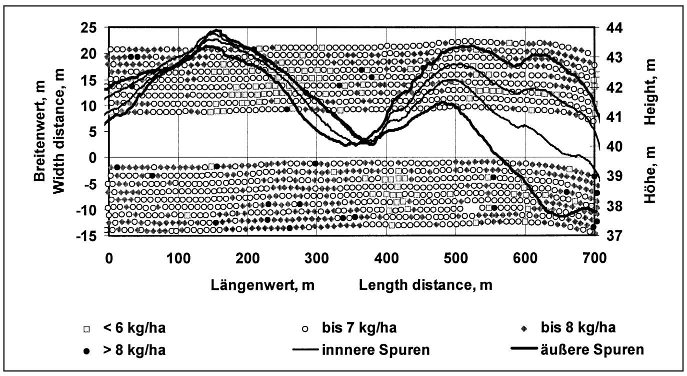

Fig. 3: Area specific fuel consumption for ploughing on the site 803 and the height profile of the innermost and outermost passages