Heinz Weiss and Stephan Nagelschmitz, Mannheim

Advanced Engineering

Production innovation under changing market conditions and new technologies

Agricultural technology and advanced engineering began when man turned from nomadism to organised cropping and engineering joined agriculture as influences permanently influencing human existence.
Changes in farming production have occurred in every age and these include the first harnessing of draught animals or the discovery of the plough, processes that would now be described as paradigmatic changes.

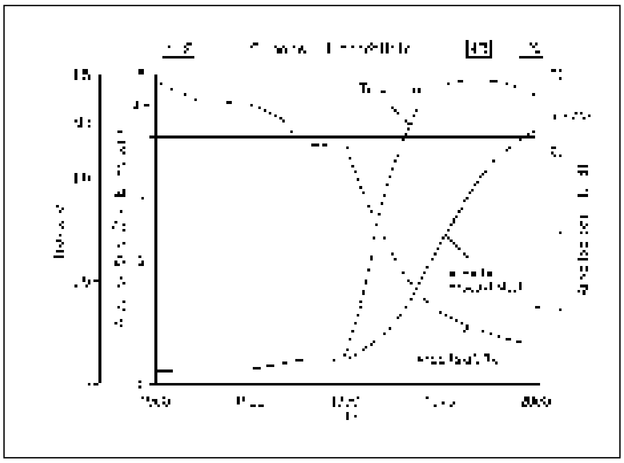

Fig. 1: Agritechnical research and development – quo vaditis?

Dipl.-Ing. Heinz Weiss was until retiral in August 2001 Manager, Advanced Agricultural Tractors, John Deere Werken, Mannheim. Dipl.-Wirtsch.-Ing. Stephan Nagelschmitz is a member of the Marketing Department staff, John Deere Werke Mannheim. He prepared his diploma work as student oat the TU Dresden in the Advanced Engineering Dept.

Keywords

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In the middle of the last century tractors experienced a surge in development. It is important to realise what caused this and why it flattened off again after 25 years. Only when this pattern is understood can one appreciate the challenges involved (*fig. 1*).

Machines are applied as production factors in farming and thus every function improvement or introduction of a new component must increase customer utility. One can see what happens when this principle is not followed by looking at the experiences in eastern Germany.

A customer-oriented basic approach requires permanent adjustment of company organisation to keep the economic process running. Short term, this means meeting customer requirement with acceptable products. Long term, it means anticipating such requirements so that the product solutions are ready at the right time: Product Innovation (*fig. 2*).

Here, the concept must be rejected that product ideas can be reached through asking the customers what they might want because it infers that the harnessing of draught animals or invention of the plough could have been anticipated. Customer surveys have another role: they deliver information on what the customer thinks about products in comparison with the competition: Competitive Assessment.

The large number of machines nowadays and their complexity represent big challenges to the farmer. He or she can be unable to cope with the matching of requirement specifications and new technologies. All this means is that it is the manufacturers who decide what has to be done today to stay competitive tomorrow: Assessments of Markets and Technologies.

To this can be added the Conceptional Design & Feasibility phase. With the setting of a priority the project can be established within the Strategic Business Plan. This can be said to be the link between advanced engineering and serial development. Such an adjustment process often needs much time and even more patience. Vide „Transrapid“.

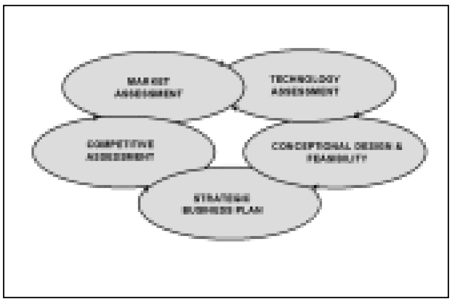

Fig. 2: Tasks of Advanced Engineering

What is advanced engineering?

It has already been made clear that comparative investigations and customer surveys cannot deliver basically new product ideas and because the competition is hardly likely to reveal marketing strategies and latest technological achievements, each company is left to make these decisions on their own. Advanced engineering can be compared with shooting at a running boar: aim a little too far ahead and you miss, wait to long and your bullet is also wasted.

There are risks both ways because when you're assessing the market the application requirements are often not yet clarified. At this stage the real role of advanced engineering can be appreciated: the formulation of product suggestions against calculable risks so that these suggestions can be further checked-out in context.

With the organisation of advanced engineering as a progressive decision-making process, the reconnection with marketing or

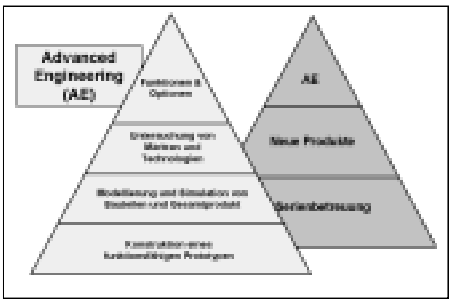

Fig. 3: Phases of product development

work preparation must not be forgotten. Fixed procedural rules must be followed for these adjustment processes (*fig. 3*).

Processing of future perspectives

Examples for changing market
Because even in 1975 there was a flattening out of tractor numbers, manufacturers were already then seeking solutions.

Tractors have no productivity of their own and are thus dependent on their interaction with implements, a reason why self-propelled machinery such as combine harvesters, beet or potato harvesters or self-propelled sprayers must be regarded as competition for tractors (*fig. 4*).

All these developments tend towards tractor number reductions, a situation which need not be alarming for a „full liner" where a large tractor and a combine can be instead of two smaller tractors.

Agricultural change and mechanisation adjustment
The following data were processed in a diploma paper [2] and relate to a 150 ha farm in the Kölner Bucht which is almost fully ring-fenced and has three tractors of differing power. All other data for the system comparison regarding tractor numbers was from KTBL models and calculated with AVORW simulation software.

Total costs for variant 1 were 310 000 DM. So that the results here could be better compared with the average 300 ha farm in eastern Germany, input costs were raised to 620 000 DM (*fig. 5*).

A ring-fenced area of 300 ha was taken for variant 2 with the power for the biggest tractor raised from 111 to 149 kW. For this power figures for associated implements were once again taken from the KTBL databank. Here the cost saving was 60000 DM compared with variant 1. This is not a real cost saving, however, because the extra 150 ha was not available as self-enclosed land. Because of this, the results from variant 3 recognised the additional 150 ha as outwith a ring fence with an average distance of 10 km from the farm and leading to extra costs of 100000 DM compared with variant 2.

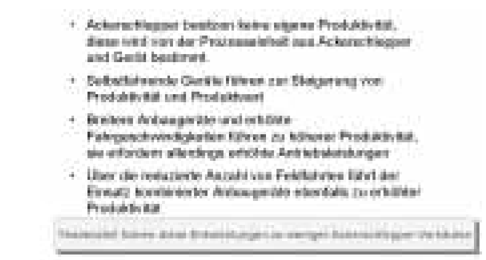

Fig. 4: Conclusions on the trends of agricultural machinery

- Getreideanbauender Betrieb
  - Größe: 150 [ha] erweitert auf 300 [ha]
  - durchschnittliche Schlaggröße: 10 [ha]

Quelle: AVORWin KTBL

	150 ha zusammenhängende Schläge (Schlepper kW 111, 92, 60)	300 ha zusammenhängende Schläge (Schlepper kW 149, 92, 60)	150 ha zusammenhängende & 150 ha verteilte* Schläge (Schlepper kW 149, 92, 60)
Arbeitsstunden	2400 h	3600 h	4900 h
Schlepperstunden	1200 h	1200 h	2500 h
Kraftstoffkosten	18.000 DM	18.000 DM	32.000 DM
Gesamtaufwand	310.000 DM	560.000 DM	660.000 DM
Gewinn	basic: 620.000 DM	+ 60.000 DM	-100.000 DM

* Entfernung von Hof zum Einsatzort 10 km / von Schlag zu Schlag 5 km

Fig. 5: Comparing economics of agricultural enterprises

As this was attributable to the extra transport requirements it can be assumed that there's additional tractor sales potential in farm transport work.

Further tractor development targets
Farming customer requirements can be roughly aligned to three basic wishes (*fig. 6*).

• Increasing productivity
Because the tractor alone gives no productivity, this increase can only be achieved in association with implements and while there are such a lot of those the focus should be on the tractor/implement interface – a point where, after 75 years, the Ferguson three-point hitch has found a worthy successor in the hexapod hitch, a development aimed at, and still worked upon, within the project „Development of new structural concepts for tractors" through cooperation of John Deere Werke Mannheim and the Chair of Agricultural Machinery, TU Dresden.

The hexapod hitch fulfils all the above basic requirements and allows a simplified operation through to automatic hitching and detaching of implements. Efficiency improvements and productivity increases are achievable through adjusting draught point and this ability to adjust the draught point means axle loads can be influenced thus allowing soil compaction risk reduction through ballast reduction with utilising mounted tyre pressure regulation.

• Increasing comfort
Because of the expected increase in work hours per day and year the driver wants more comfort and a reduction in physical stress.

The multiple possibilities through electronics currently go as far as self-driving farm machinery. Two innovations from Agritechnica 2001 can be mentioned.

On the Same stand a self-levelling cab was shown. Unlike cabs with conventional suspension, this allowed the driver platform to be kept largely level on up and down and lateral slopes. As backache can be regarded as a professional disease with farmers the improved seating comfort is eagerly accepted by customers.

Also at Agritechnica, John Deere presented the stepless „AutoPowr" transmission, or rather a seamlessly-changing hydro-mechanical transmission. The transmission is a cooperative development of John Deere Werke Mannheim and ZF Friedrichshafen whereby the preselect gear change was developed in Mannheim. ZF also delivers the Ecom transmission to Deutz.

• Protecting the environment
The automatic adjustment of optimum tyre pressure when moving from street to field or vice versa, the reduction of tractor ballast through regulating the hexapod hitch control of axle loads and implement steering all show that „environmental protection" is no empty phrase.

Preparing for the new conception of a product

Structuring the tractor in modular component groups
The organisation of a tractor with a multiplicity of functions and controlling of a large number of variants and options represents a great challenge for the manufacturer (*fig. 7*). For those who have not yet been able to visit the transmission and tractor assembly in Mannheim the ground principle can be summarised as follows:

• Construction of tractor via preliminary assembly of basic parts, then assembling

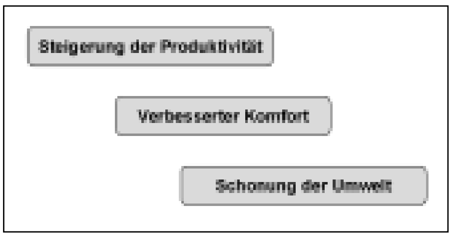

Fig. 6: Basic requirements for agricultural tractors

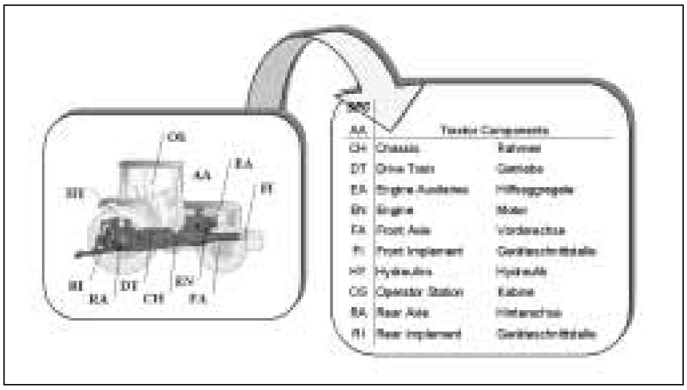

Fig. 7: SFC basic structure of tractors

	Funktionalität	Funktionalität & Aufwand
- 4WD Elektro - Einzelradantrieb	8,7	8,8
- E - Achsantrieb	7,2	7,0
- E - Zentralantrieb & Differentiale	4,1	3,8
- E - Zentralantrieb mit zuschaltbarem MFWD	2,1	3,6

Fig. 10: Value Analysis on electric drive systems

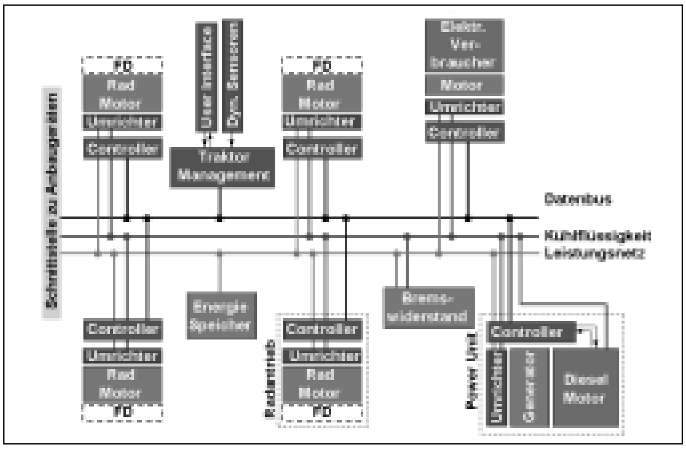

Fig. 11: Modular structure of electric single wheel drives

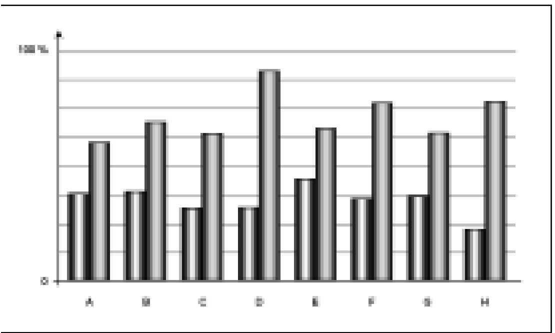

Fig. 8: Value Analysis on infinitely variable transmissions

these to more complex components,
- Arrival of these components and their preparation on the tractor assembly belt,
- Assembly of different models in mixed models and for pre-series and pilot models.

The assembly of parts into components represents the organisation principle which can be carried through from the manufacture to the repair of a tractor. With presentation of the cost list of a comparative tractor this advantage also serves the pre-development stages. The SFC (Structured Functional Codes) represents a measuring rod for the adjustment of function and costs.

All non-altered components can be ignored for the moment and first orienteering data is already present for those that have to be newly conceived or altered.

Where a change takes place from three-point to hexapod hitch or from shift transmission to stepless, certain adjustments have to be made to SFC structure.

Gradual filtering out of the best technical variant in each case

From the information so far, following specifications for a future transmission can be roughly deduced.
- maximum speed 50 km/h and higher
- stepless speed setting from 0 km/h to maximum
- in forward and reverse
- speed adjustment as with „AutoPowr“
- all-wheel differential

With this information it is possible to establish detailed comparative criteria for all transmission variants weighted through cost-benefit analyses and evaluated per individual criterion and variant. Totalling the points gives the required system comparison (*fig. 8*).

Because electro-transmissions achieved the highest points total, their suitability for tractors must be further investigated. Here, the first question is differentiating between electro-drives (*fig. 9*).

If one simplifies the analysis by considering combustion engine and generator as a central power unit, in that this can be the same for all variants, one can differentiate between three electric drives: central drive with one motor; front and rear axle drive with respective motors; and four motors for individual wheel drive. For these variants a further cost/benefit analysis with following result would be conducted (*fig. 10*).

Investigations for military vehicles led to the same result: that the individual drive of wheels and adjacent aggregates including guns was the best solution. The transmission in such cases is extended to the vehicle differentials and axle drive and situated between combustion engine and wheels.

Through rpm selection and monitoring for every wheel, all working conditions can be regulated including these of the differential. Cost-benefit analyses were conducted on

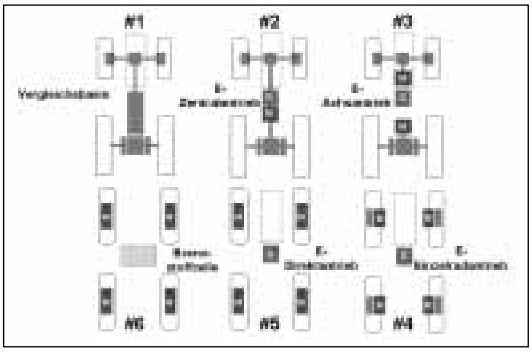

Fig. 9: Possible alternatives for electric vehicles

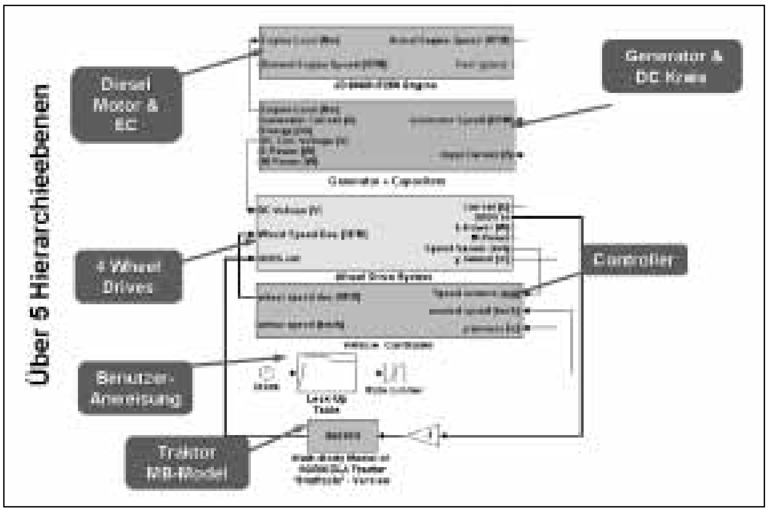

Fig. 12: Drive train control

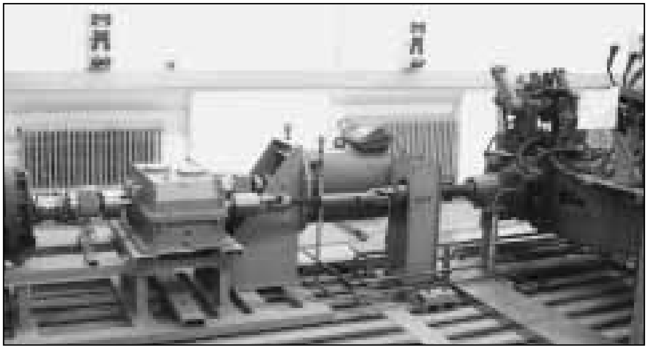

Fig. 13: Transmission test bench of the TU Dresden

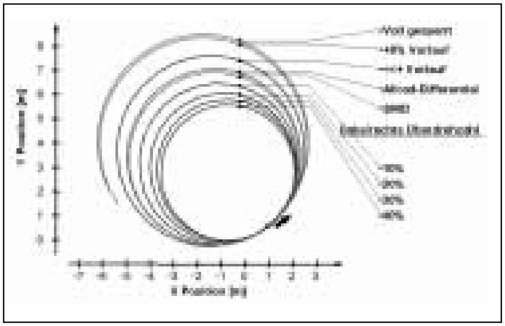

Fig. 14: Trajectories of the geometric tractor center

five levels for comparative evaluation of transmission variants.

Every wheel drive consisted of a controller, a frequency converter, the wheel motor and possible a final drive. This drive unit represents a self-supporting function unit being controlled through the communication bus from vehicle management (*fig. 11*). Additionally every unit is supplied with electricity over a central power network and is connected to the coolant circulation and other servicing facilities.

Modelling of complete tractor concept

To gain information on function capabilities of a tractor, it is modelled as a multibody entity and all individual functions programmed and simulated via Matlab/Simulink (*fig. 12*). The simulation results were verified on a test stand at the TU Dresden (*fig. 13*).

The individual results of the simulation are represented as follows using the example of the turning circles (*fig. 14*).

Summary and outlook

Vehicle demands must be extended in multiple aspects for a high-speed tractor or be redefined in order to offer the farmer a suitable transport system in the future.

In that the standard tractor with front loader is already threatened through the telescopic loader, a further platform extension in the direction of a high-speed „Trac" tractor represents only a logical step.

Indications that the system tractor has been unable to achieve sustainable economic success so far were taken seriously, critically checked, but in the end classified as unsupportable because no „new version of the MB-Trac" was suggested but instead a further development on the basis of new technologies. Here one can speak about a paradigmatic change because the functionality of the tractor is changed regarding many aspects at the same time.

In conclusion another nostalgic look back (*fig. 15*). The illustrated car with electrical front wheel drive was exhibited by Ferdinand Porsche 100 years ago at the World Exhibition in Paris and 300 examples produced.

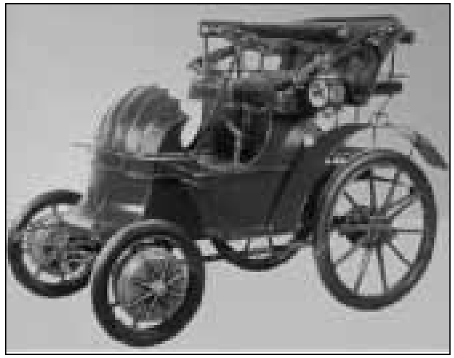

Fig. 15: Electromobile, Paris, Expo 1900

Literature

[1] *Sommer, C. und H. Schön*: Agrartechnische Forschung – quo vadis? VDI Berichte 1356, VDI-Verlag, Düsseldorf, 1997, S. 3

[2] *Nagelschmitz, St.*: Marktbedürfnisse und Technologiepotentiale als Bestimmungsfaktoren der Konzeptneuentwicklung eines Traktors – Eine Analyse auf Basis von Expertenstudien. Diplomarbeit, TU Dresden, 2000