Karl Theodor Renius, München

Agricultural tractors 2006

More than 50% of the turnover in the German agricultural machinery industry is related to tractors. 54,590 units were produced in Germany in 2005, worth € 2.35 milliards and 44,601 (82%) were exported. For the globally active agricultural machinery companies [1] the tractor is also their most important agricultural machine. The following paper highlights global market complexity, the structure of modular design concepts, the role of technology levels and the latest development trends with two noteworthy examples.

While the Fordson tractor of the 1920s dominated the world market with only one model, the range of market demands and thus the diversity of models are tremendously wide today and even still increasing.

Modular design concepts and technology levels

A classical principle of first cost saving is the well known strategy of forming modular tractor families [2, 3], today for western standard tractor markets at least four (*Table 1*). Each family has an uniform number of engine cylinders (length). Here and there, family 2 is widened by 6-cylinder-engines from family 3. A displacement of about 0.9 to 1.1 l is common for each cylinder, considerably more for family 4.

A graduation of requested specifications is necessary meeting worldwide market needs, e.g. by 5 technology levels [3] (*Table 2*). The lowest level represents low engine power, only rear wheel drive, moderate comfort, no cab and very simple components – typically for a first tractor generation in a developing country. Level 2 offers already more, at present for example typical for Indian tractors. The levels III, IV and V are again more sophisticated, meeting the market demands in the highly developed industrial nations.

Not listed in table 2, but also graded in the same sense are the requirements by regulations, which increased in the recent years very strongly, mainly within the EEC and the USA. Level V thus represents not only the highest technology level but also the highest level meeting the regulations for public traffic, health & safety and environmental protection.

All companies try to cover several technology levels with only one modular component structure in order to specify as many models as possible economically by a limited number of parts [3]. This requires high-quality product planning.

Technical trends

Some typical technical trends are listed for family 4 and 5 completing the specifications of table 2 from a Western Europe view.

Vehicle, chassis, brakes, steering
4WD, front axle suspension, disproportionately large tires ("model law") and „exploding" cooler systems for engine, charging air, exhaust gas recirculation, fuel, transmission oil, hydraulic oil and air condition influence at present the general vehicle concepts [4].

Table 1: Family pattern for standard tractors (model)

Family	**1**	**2**	**3**	**4**
Power, kW ECE R24	30 - 55	60 - 90	90 - 130	135 - 240
rated speed, rpm		2100 ... **2200** ... 2300		
Diesel engine	3 cylinder	4 cylinder	6 cylinder	6 cyl./large
vol. tractor function	moderate	very large		large
comfort level	moderate	high		very high

Table 2: Basic specifications of standard tractors by technology levels [3]

Technologiestufe / *tech. level*	Leistung *Power*			Fahrwerk *Chassis*			Dieselmotor *Diesel engine*					Schaltgetriebe *Gear box*				Zapfwelle *PTO*			Hydraulik *Hydraulics*				Kabine *Cab*			Elektronik *Electronics*		
	klein / *low*	mittel / *medium*	groß / *high*	kein Allradantr. / *only 2WD*	Allradantr. opt. / *4WD opt.*	Allradantr. std. / *4WD std.*	1 Zyl. / *1 cyl.*	2 Zyl. / *2 cyl.*	3 Zyl. / *3 cyl.*	4 Zyl. / *4 cyl.*	6 Zyl. / *6 cyl.*	sehr einfach / *very simple*	einfach / *simple*	Teillastschaltg. / *partial p.s.*	Vollastschaltung / *full p.s*	stufenlos / *infinite*	540/min	540 + 1000/min	3, 4 Drehz. / *3, 4 speeds*	Heck-Kraftheber / *rear hitch*	Remote Control	Heck- u. Front-Kraftheber *rear and front 3-point hith*	Load Sensing	keine Kabine / *no cab*	Einfachk. / *simple cab*	Komfortk. / *comfort cab*	nicht vorhanden / *no*	etwas vorh. / *little*	bedeutend / *important*
I	X			X			X	X		X		X					X			X				X			X		
II	X	X			X			X	X	X	X		X					X		X	X			X	(X)		X	(X)	
III		X	(X)		(X)	X			X	X	X			X				(X)	X	X	X	X			X	(X)		X	(X)
IV		X	X			X			(X)	X	X			X	X				X	X	X	X	X			X			X
V		X	X			X				X	X					X			X	X	X	X	X			X			X

Prof. Dr.-Ing. Dr. h.c. Karl Theodor Renius was head of the Institute of Agricultural Machinery of the TU München (Munich) and retired 30. 9. 2003.
He conducts since then the section of Mobile Machinery at the Institute of Automotive Engineering of the TU München, Boltzmannstr. 15, 85748 Garching; e-mail: *renius@ftm.mw.tum.de*

Keywords

Tractors, development trends, product planning, modular systems, technology levels, engines, emissions, transmissions

Fig. 1: Winner of the Agritechnica 2005 Gold Medals: Fendt Vario 936 (243 kW nominal ECE R24, 2006) and John Deere series 8030 (158 to 236 kW nominal ECE R24, 2006)

Wet disc brakes are more and more equipped at all wheels, power steering systems are getting equipped with electro-hydraulic interfaces for automatic navigation.

Diesel engines
The new directive 2005/13/EG (content identical with 2004/26/EG for mobile machinery) requires a graded reduction of Diesel engine emissions. (currently EG-step IIIA). Similar regulations exist in the US (Tier 3). The just introduced 4-valve-engines with electronic injection control must again be improved, in order to reduce the emissions without loosing their high level of fuel economy. Rated engine speeds are now often as low as 2100 or 2200/min. The power levels are still increasing, some engines offer booster power automatically for PTO works and/or fast transport operations.

Transmissions
Further infinitely variable power split transmissions with automatic control have been introduced by John Deere, Claas (ZF) und Fendt (max. 40, 50 or Fendt even 60 km/h). Automatic control strategies are also introduced more and more for power shift transmissions.

Driver work place and automatic tractor functions
The low noise cabs (70 to 75 dBA/OECD) are now often soft suspended with the first active seat suspensions. All connections to the chassis are soft to exclude structure-born noise („drive by wire“). A terminal for the system tractor-implement(s) based on ISO 11783 communication supports the process control with various programmable automatic functions such as optimised tractor-implement operation, head land management, drive line management, auto navigation (GPS) etc. Output mapping simplifies planning of following field missions for the farmer.

Hydraulics and mounted implements
Load sensing-hydraulics with variable displacement pumps are further improved - mainly by electro-hydraulic valves (remote control, front end loader) and power beyond-interfaces (ISO 17567, 2005) for implements with own LS control systems.

Most modern technology by two examples

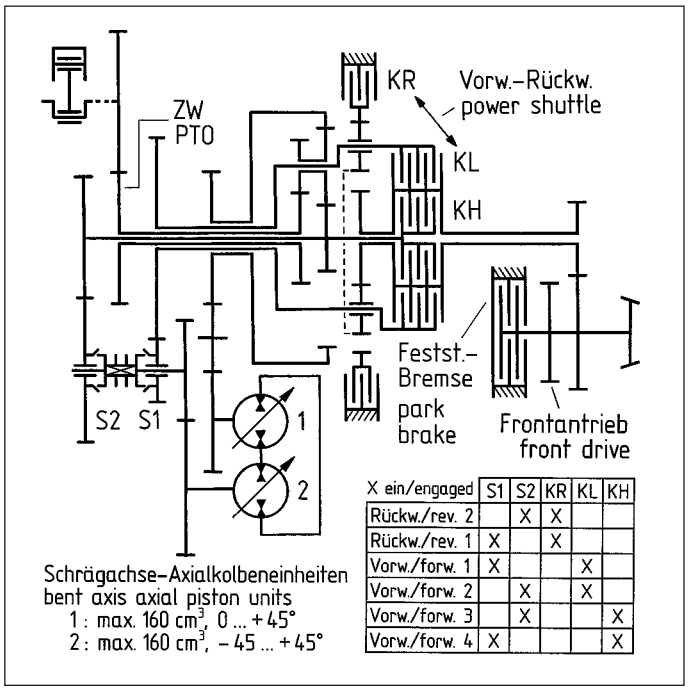
Figure 1 shows two new tractors, which both received a Gold Medal at Agritechnica 2005 and which represent the most updated technology level in tractor design.

The new tractor series John Deere 8030 (production since early 2006) with front axle single wheel-suspension has new own 9.0 l-engines with a new cooling concept as well as a new own hydrostatic power split drive transmission “AutoPowr” (40 or 50 km/h) optional to the automatic 16/5-power shift transmission. John Deere states that the engines have a better fuel economy than the previous series – in spite of meeting EG IIIA/Tier3. This is the result of 4-valve technology, electronic CommonRail-injection and cooled external exhaust gas recirculation, supported by a lowered rated speed of 2100 rpm, the first tractor application of a turbo charger with variable turbine geometry (VTG) and the infinitely variable fan drive.

The transmission (*Fig. 2*) incorporates 4 ranges, between which the shift is done automatically in synchronous points (own design, axial piston units from Sauer-Danfoss). The reverser concept is the same as for the 7020 AutoPowr.

Fendt announced for autumn 2006 the availability of the Agritechnica 2005 novelty „936 Vario“, the worldwide first standard tractor with 60 km/h top speed, developed for a series production. The front axle single wheel-suspension features a vehicle roll control depending on the velocity. The new Deutz engine (Euro IIIA/Tier 3) works with electronic CommonRail injection, 4-valve technology and cooled external exhaust gas recirculation and achieves also a very favourable fuel economy according to Fendt specifications.

Future emission reductions are requested within the EC and the US and they will again require drastic development actions.



X ein/engaged	S1	S2	KR	KL	KH
Rückw./rev. 2		X	X		
Rückw./rev. 1	X		X		
Vorw./forw. 1	X			X	
Vorw./forw. 2		X		X	
Vorw./forw. 3		X			X
Vorw./forw. 4	X				X

Fig. 2: Infinitely variable automatic power split transmission John Deere “AutoPowr” for the new 8030 tractors (Fig. 1)

Literature

[1] *Kutschenreiter, W.*: The Big 8. Eilbote 54 (2006), H. 19, S. 12-14

[2] *Welschof, G.*: Entwicklungslinien im Schlepperbau. Kriterien für die heutige und zukünftige Entwicklung. Grundlagen der Landtechnik 24 (1974), H. 1, S. 6-13

[3] *Renius, K.Th.*: Global tractor development: Product families and technology levels. 30. Symposium “Actual Tasks on Agricultural Engineering”; Opatija, Kroatien, 12-15. 3. 2002. Proceedings, pp. 87-95

[4] *Knechtges, J.*: Trends bei Traktoren und Transportfahrzeugen. Landtechnik 60 (2005), H. 6, S. 324-326