Reckleben, Yves; Schäfer, Niels and Weißbach, Michael

Increase in efficiency of road transport on the example of different types of tires of tractors

The tractor as central draught machine on the farm has an increasing amount of road transport work to accomplish, although the classic fieldwork has still to be carried out efficiently with avoidance of soil structure damage. The diversity of agricultural requirements, as well as the narrow time windows for cultivations and harvest, needs tractors that can be used specifically for transport out on the field and on the road. The main distinguishing features of tyres are, in addition to their rolling resistance, their vibration damping and noise reduction abilities, ground contact area and effects on traction performance and fuel consumption.

Keywords

Tire comparison, industrial tires, AG tires, efficiency, abrasion

Abstract

Landtechnik 68(3), 2013, pp. 196–201, 4 figures, 5 tables, 6 references

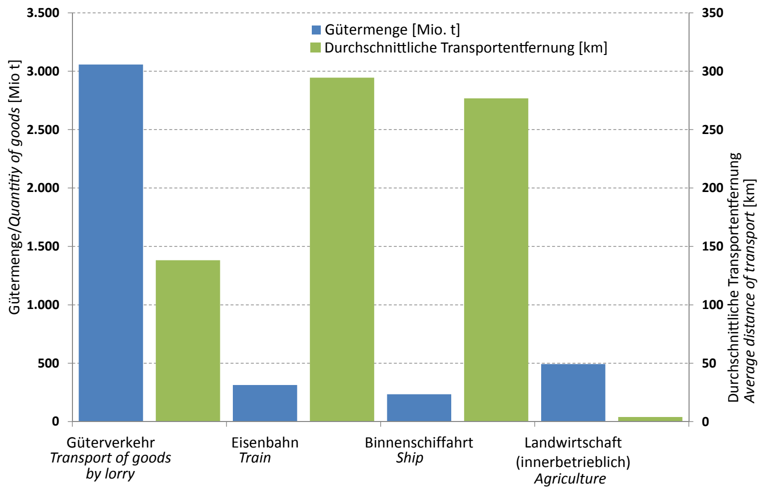
The proportion of transport tasks in agricultural operations has continually increased in recent years. Alongside the use of tractors in this respect, lorries also show a steadily increasing application in farming. Desirable in this respect with regard to soil structure protection is a general separation of field and road work with soil protecting vehicles featuring large soil surface contact areas on the fields and trucks with energy-efficient high pressure tires for road transport. In each case this approach would reduce damaging effects, wear and fuel consumption. Disadvantages hereby would be the higher organisational input required and the increased vehicle fleet. In the following study the factors determining or influencing the tyre variants in each case are described [1].

Transport loads and distances

On average in Germany each year approx. 500 million tonnes of material are transported by farmers over an average farmyard-field distance of four kilometres.

Figure 1 shows that the amount of agricultural goods farm-transported clearly exceeds that moved by railways and inland waterways craft. The transport distance for agriculture of an

Fig. 1



Quantity of goods and transport services in Germany [2]

Fig. 2

Fendt Vario 828 with industrial tires (Nokian TRI2)

Fig. 3

Comparison of AG tires (left) and industrial tires (right)
(Foto: Reckleben)

annual 1900 billion km, on the other hand, tends to be relatively small. Transported agricultural products differ regarding their physical characteristics and the actual amounts involved. Additionally, the transport distances depend on where the material is to be used. The products used within agriculture are as a rule produced and processed in the same region whereby the average transport distance is mostly under 10 km. Material that is to be further processed in external production sites, e. g. sugar beet, milk and meat, have markedly higher transport distances.

For road transport, agricultural vehicles require higher tyre pressures (>1.6 bar) to reduce wear and increase stability when braking. However, field tractor tires (AS profile) are not optimal for road transport because the lugs scrub over the road surface. In this context more, and less prominent, lugs – as applied in industrial tyre design – are better.

For trial comparison purposes three identical models of a tractor were used, each fitted with one set of tires. The tractors used had a power output of 191 kW and a net weight of 9 450 kg. The tractors were approx. 1 year old (1 800 operating hours) and already fitted with SCR exhaust technology. Following weighing of the tractors on a weighbridge, weight distribution (unballasted) of 40 % on the front axle and 60 % on rear axle was calculated.

With regard to the difference between the tires, the conventional AS profile differs markedly from an industrial profile (type: Nokian TRI2) (**Figure 2**). The AS tires were from Trelleborg model TM900-High Power. The industrial tires had a hybrid profile between lorry and tractor, or AS, tires. **Figure 3** shows a comparison of both types' profile.

Both types differ in lug structure as well as in usable lug height. Thus the usable lug height with new AS tires lies between 40 and 60 mm. This value is only approx. 23 mm with the industrial tires. Through the closer positioning of the lugs, the contact area of industrial tires on a hard surface is markedly greater. The manufacturer has developed these tires so that, through their block profile, they can be used efficiently in a wider range of conditions. This means these tractor tires should be suitable not only for industrial use, but also for transport and draught work in agriculture.

Additionally, the relatively high proportion of lug area on the tires permits a less damaging effect on surfaces, especially

Table 1

Overview of used tractors and tires

Schleppertyp *Tractor*	**Vorderachsbereifung** *Front tires*	**Hinterachsbereifung** *Rear tires*	**Kurzzeichen** *ID*
Fendt-Vario 828 (Jogi 231)	600/70/R30	710/70/R42	AS-Bereifung *AS-tires*
	Luftdruck/*Pressure*: 1.4–1.8	Luftdruck/*Pressure*:1.2-2.2	
	Vorlauf/*Forerun*: 3.43 %		
Fendt-Vario 828 (Jogi 224)	540/65/R30	650/65/R42	Industr. A *Industrial tires A*
	Luftdruck/*Pressure*: 1.4–2.0	Luftdruck/*Pressure* 1.4-2.2	
	Vorlauf/*Forerun*: 1.0 %		
Fendt-Vario 828 (Jogi 237)	440/80/R34	620/80/R42	Industr. B *Industrial tires B*
	Luftdruck/*Pressure*: 1.4-2.0	Luftdruck/*Pressure*: 1.4-2.2	
	Vorlauf/*Forerun*: 0.6 %		

Table 2

Calculating usable lug height

		Stollenhöhe *Lug height* [mm]	Mindestprofiltiefe *Minimum profile depth* [mm]	Nutzbare Stollenhöhe *Usable lug height* [mm]
AS-Bereifung *AS-tires*	Vorderreifen *Front tires*	55	1.6	**53.4**
	Hinterreifen *Rear tires*	62	1.6	**60.4**
Industr. A *Industrial tires A*	Vorderreifen *Front tires*	25	1.6	**23.4**
	Hinterreifen *Rear tires*	28	1.6	**26.4**
Industr. B *Industrial tires B*	Vorderreifen *Front tires*	23	1.6	**21.4**
	Hinterreifen *Rear tires*	30	1.6	**28.4**

grassland. During road journeys the tyre-caused noise level is similar to that of a lorry. Through the relatively high tyre pressure certified as suitable by the manufacturer, (**Table 1**) high load carrying capacities with limited rolling resistance are possible. Additionally, the industrial tires are fitted with a wear indicator, the cross section of which in the lugs shortens as the lug height wears down.

The tractors available for the test described here were fitted with different tyre sizes (**Table 1**). Both industrial types differed only in their measurements. The tyre type with the code description "Industr. A" is rather broad with reduced diameter. The type coded "Industr. B" is slightly narrower and has a larger diameter. The given required tyre pressure range varied depending on speed range and load. All three tractors indicated an advancement of between 0 and 4 % and were therefore within the tyre manufacturers' approved range [3].

Wear results

Rate of wear with the different types of tires was determined through observing the rate of reduction in lug height. Four measurements were carried out at a monthly interval. In order to measure the respective tires at exactly the same point every time with the digital vernier calliper the measurement point was clearly marked in colour. The first measurements were carried out at the beginning of the trial on new, unused tires; and from these were calculated the usable lug height (**Table 2**).

In combination with the recorded profile reduction at each measurement date, the usable lug heights were used to calculate the expected maximum usable lifetime (**Table 3**).

Combined results from front and rear tires gave highest possible usable lifetime per set of tires. The AS tires (AS-Ber.) indicated a theoretical combined lifetime if 2864 operation hours. The industrial tires (Industr. A) indicated a lifetime of

Table 3

Comparison of the three types of tires and decrease of the measured profile

	AS-Bereifung *AS-tires*		Industriebereifung A *Industrial tires A*		Industriebereifung B *Industrial tires B*	
	Vorderreifen *Front tires*	Hinterreifen *Rear tires*	Vorderreifen *Front tires*	Hinterreifen *Rear tires*	Vorderreifen *Front tires*	Hinterreifen *Rear tires*
Nutzbare Stollenhöhe *Usable lug height* [mm]	53.4	60.4	23.4	26.4	21.4	28.4
Profilabnahme/1 000 Bh *Profile decrease/1 000 operating hours* [mm]	22.9	17.8	2.8	2.8	2.7	2.7
Max. Nutzungsdauer ***Useful life* [h]**	**2334**	**3394**	**8341**	**9411**	**7855**	**10424**
kombinierte Nutzungsdauer ***Combined useful life* [h]**	***2 864***		***8 876***		***9 140***	

Table 4

Indication of the value ranges for the plausibility check

Parameter	Minimum	Maximum
Geschwindigkeit *Speed* [km/h]	2	54
Motordrehzahl *Motor rpm* [1/min]	750	2 300
Momentanverbrauch *Fuel consumption* [l/h]	3	60

8 876 operation hours with best performance in this context achieved by the narrower industrial tyre (Industr. B) with 9 140 operation hours.

Fuel consumption

The momentary fuel consumption of the individual tractors was recorded and documented using CAN-Bus systems. Via a mobile radio modem the recorded data was transmitted to the farm's telemetry server and subsequently imported in Excel. The database covered May, June, July and August for all three trial tractors individually. A dataset contained all the CAN-Bus delivered data (fuel, rpm, speed, etc.) for a certain point in time with noted GPS position.

All datasets were tested for plausibility and any measurement errors filtered out.

All recorded datasets that did not lie within the range given in **Table 4** were regarded as defective and omitted from the subsequent evaluations. Speeds between 0 and 2 km/h were, for example, regarded as stillstand because of the predetermined measurement tolerances of the system manufacturer.

Figure 4 shows that the highest consumption independently of whether from field or road operations was with tractors fitted with AS tires. These were followed by the industrial tyre (Industr. A) tractors and then the identical tyre type (Industr. B).

More precise information regarding fuel consumption is possible through detailed observation of individual activities in the measurement period:

- Grass tedding
- Grass silage carriage
- Straw baling
- General transport

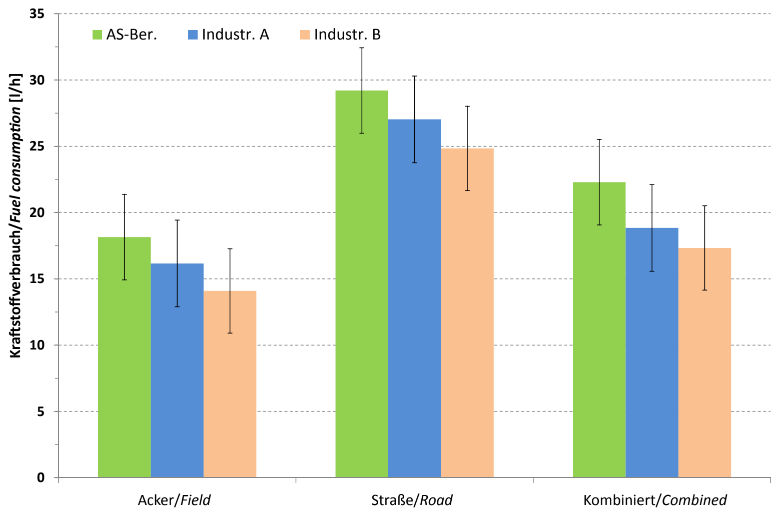
Table 5 shows evaluation of field-road ratios for tractors in the individual activity areas.

It is clear that the different activities show different field/road ratios. The field ratios reach a maximum of around 80 % for grass tedding and up to 41 % for general transport. This trend is confirmed in other recordings [4] which at the same time highlight the potential of good machinery utilisation.

Results

To exploit the saving potentials of industrial tires while at the same time not limiting the activity area of the tractors, each tractor in this trial was fitted with the most economically practical tires according to its activity area. Industrial tires were used most because of this saving effect in comparison to AS tires. The AS tires were used in activity areas where high draught power had to be supported under wet conditions, such as during forage maize harvesting. This flexible approach allowed tractors to more fully express performance capacities while also exploiting the savings potential of the industrial tires. The approach also meant additional costs for a second set of wheels. These were calculated under the industrial tyre costs. This trial was able to show that there were in some aspects clear differ-

Fig. 4



Fuel consumption with the different tires

Table 5

Field-road ratio in relation to the different activities

Bereifungsart *Tires*	**Tätigkeiten** *Activity*	**Gras schwaden** *Grass swathed*	**Grassiloabfuhr** *Grass silage carriage*	**Stroh pressen** *Straw baling*	**Allgemeine Transporte** *General transport*
AS-Bereifung *AS-tires*	Acker/*Field*	81.0 %	58.3 %	73.1 %	35.3 %
	Straße/*Road*	19.0 %	41.7 %	26.9 %	64.7 %
Industr. A *Industrial tires A*	Acker/*Field*	90.1 %	66.0 %	75.5 %	31.5 %
	Straße/*Road*	9.9 %	34.0 %	24.5 %	68.5 %
Industr. B *Industrial tires B*	Acker/*Field*	78.3 %	48.6 %	79.4 %	46.3 %
	Straße/*Road*	21.7 %	51.4 %	20.6 %	53.7 %
Gesamtbetrachtung *Overall consideration*	Acker/*Field*	80.4 %	60.0 %	75.0 %	41.3 %
	Straße/*Road*	19.6 %	40.0 %	25.0 %	58.7 %

ences between the different tires with regard to the parameters investigated.

Within the trial period of four months clear tendencies developed with regard to tyre wear, fuel consumption, noise level effects and quality-based driver opinions. With a ratio of 31 % road and 69 % field work there emerged the following picture: the tyre wear showed a profile reduction with AS tires of between 30 and 40 % wear per 1 000 operation hours, the alternative industrial tires between 10 and 13 % wear per 1 000 operation hours. Through this clear advantage for industrial tires the prognosis for usable lifetime was approx. 9 000 operation hours and thus around 6 000 operational hours more than that for the conventional farm tractor tires.

The field-road ratio is very important when making a fundamental statement on fuel consumption. Taking the two ground surface characteristics separately and a speed of 15 km/h gave a field:road ratio of 2 : 1. Observing the entire activity area the field tractor tires lay, with a calculated consumption of 22 l/h, around three litres more than the industrial tires (Industr. A). The industrial tires (Industr. B) returned, with 17 l/h, the lowest consumption. Further investigation of fuel consumption in the individual activity areas gave precise consumption information whereby activities such as “grass tedding” or “straw baling” clearly indicated no marked fuel saving effect with industrial tires. With activities such as “grass silage carting” or “general transport” where the proportion of road travel was substantially higher the industrial tires could confirm their suitability for roadwork through clearly reduced fuel consumption.

Regarding noise level, the results showed no significant difference between operating without load or with load. With recorded noise levels between 68 and 70 dB as well as occasional peaks of 77 dB the results lay between the average noise level range in a family car of 70 to 80 dB [5]. Basically, noise level with all the tires tested rose directly in line with speed increase.

On questioning, the test driver indicated a clear preference for industrial tires. With a total mark of 2.3, these tires are therefore assessed as “good”. However, the driver noted deficits in traction efficiency under wet conditions with these tires. Positive impressions were related regarding driving comfort on the road, as well as robustness and rate of wear.

Looking at economic comparisons, the information gathered from two tractors with industrial tires indicated an annual saving of approx. 8000 € under the assumption that the tires were retained for all operation, i. e. also for field cultivations. Farms in the position to secure year-round use of a tractor with industrial tyre must, on the one hand, have a high proportion of road-based activities. On the other hand, there must be some reason why, on such a farm, the purchase of a lorry with low running costs is not attractive within the farm structure. An alternative to this can be fitting a tractor with AS or industrial tires to suit operations, where working time is at least 800 hours per year. This assumes four tyre change-overs during the year with a usage of 50 % for the AS ones.

Conclusions

The results of this study create the possibility of new ideas for consideration. For instance, fitting a tractor with industrial tires on the front wheels and AS tires on the rear wheels. Thus fuel savings could be influenced by the front tires while the rear tires offered soil-structure protection and draught effectiveness on the fields. At the same time the disadvantages of a fundamentally shorter working lifetime for front tires could be balanced through the fitting of the longer-lasting industrial tires on the front axle.

The following tyre combinations could also be practical: as narrow as possible industrial trials on the rear axle to create optimal road performance and then additional dual tires with AS profile and slightly less diameter , with the assembly chosen to keep the tractor still within the maximum permitted width on public roads. During road journeys the twin AS tires would have no surface contact because of their smaller diameter which in turn means no rolling resistance is created by them. Through the installed tyre air pump for the industrial tires it would then be possible in the field – among other things because of the lower speeds in this environment – to minimise tyre pressure to such an extent that the twin tires can then rest of the field surface and exert traction grip there. Thus this tyre combination permits fast alteration from the optimum for roadwork to soil-structure protecting and traction-strong field tires.

As alternative to this twin tyre concept, tyre manufacturers are challenged to develop a tyre that has the same characteristics as this idea. First thoughts on this envisage an AS tyre with narrow band of industrial profile in the middle of the tread surface. Where the industrial profile has a slightly larger diameter at road pressures, this would allow economical driving operations on the road and, through reducing tyre pressure in the field, full use of the AS tread areas with their advantages of increased soil contact area and traction capabilities.

References

[1] Brunotte, J.; Demmel, M.; Fröba, N.; Uppenkamp, N.; Weißbach, M. (2011): Boden schonen Kosten senken. KTBL-Schrift Nr. 89, Darmstadt

[2] Engelhardt, D.; Bernhardt, H. (2007): Frachtraum wird knapp. DLG-Mitteilungen 122(6), S.24–25

[3] Weißbach, M. (2011): Wie lassen sich >200 kW effizient in Zugleistung umsetzen? Landtechnik 66(4), S. 294–296

[4] Reckleben, Y. (2010): Richtige Reifenwahl für den landwirtschaftlichen Transport. Bauernblatt Schleswig-Holstein, 9.1.2010, S. 27–28.

[5] Reckleben, B. (2011): Ist Belastung durch landwirtschaftlichen Verkehr messbar? Bauernblatt Schleswig-Holstein, 24.12.2011, S. 50–51

[6] Koehne, P. (2012): Produktinformation Traktorbereifung TRI2. http://www.nokianheavytyres.com/, Zugriff am 1.3.2013

Authors

Prof. Dr. Yves Reckleben is lecturer and **M. Sc. Niels Schäfer** student in the Faculty of Agriculture within the Kiel University of Applied Sciences, Grüner Kamp 11, 24783 Osterrönfeld, E-Mail: yves.reckleben@fh-kiel.de

Dr. Michael Weißbach is managing director with Grasdorf Wennekamp GmbH, Ziegeleistraße 29, 31188 Holle.