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TU Munich's single axle roller test rig

Test rig trials enable controlled and replicative test conditions almost impossible to achieve in the field. However the expense involved in a test rig for investigating a complete vehicle – e.g. tractor – is large. This is now possible with the new single axle roller test rig at the TU Munich, used together by the Chair for Agricultural Machinery (Prof. Renius) and the Chair for Vehicle Technology (Prof. Heißing).

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The TU Munich roller test rig (manufacturer: Renk AG, Augsburg; with major input from TUM, Chair for Agricultural Machinery, in planning, construction and initial operation) can be applied for testing transmissions, developing or testing driving strategies, measurement of performance and consumption characteristics or for the determination of noise emissions. Through two transmission stages and moment measurement shafts the maximum possible roller circumferential forces (60 or 14.5 kN) and speeds (65 or 250 km/h) can be adjusted for the vehicle being tested or the trial. At the roller circumference the test rig offers a maximum power of 280 kW in draught work as well as 220 kW in pushing force. The torque at the roller unit (diameter 2 m) is recorded by measurement shaft. This is corrected to draught force at the roller circumference through forces from friction and acceleration processes in the test rig determined during a „loss-run".

The types of test rig drive enable the regulating of roller circumferential speed, the draught force at the roller and a „drive-mass" simulation. In the drive type „drive-mass" simulation, the test rig loads the test vehicle with drive resistances to which parameters can be applied (rolling resistance, slopes, wind resistance and acceleration force). There also exists the possibility of simulating work applications through an additional force, or the coupling of vehicle and test rig through measurement values to automate trials.

Testing tractors

For testing tractors or mobile working machinery on the single axle test rig (*fig. 1*) first of all knowledge is required of rolling resistances and rolling radii of the tyres used with the test vehicle. Additionally effects caused by using the drive from only one axle on the test rig have to be taken account of when applying test forces. In order to avoid overheating, e.g. one of the four-wheel-drive clutches or inter-axle transmission differential, the drive shaft of the non-driven axle must be disconnected or the second axle driven on a freewheeling roller. In both cases the different power flows in the transmission for field or road application have also to be considered just as the front axle tractive capacity and rolling resistance of the complete vehicle in comparison to the rolling resistance of the axle driven by the test rig. Fundamental to all investigations is the consideration of the not unimportant influences of engine working temperatures, transmission and tyres.

With knowledge of front wheel resistance on the rollers, the freewheel loss of the front axle can be determined on the roller test rig. Alternatively, results from Brenninger [1] on the efficiency degree losses of driven axle can be used. The tractive capacity equals, e.g. with the tractor being tested, with a front tyre 14.9 R 28, ~ 100 Nm at the wheel circumference for a front axle without brakes.

Fig. 1: Research tractor Valmet 8050E at the single axle roller test rig

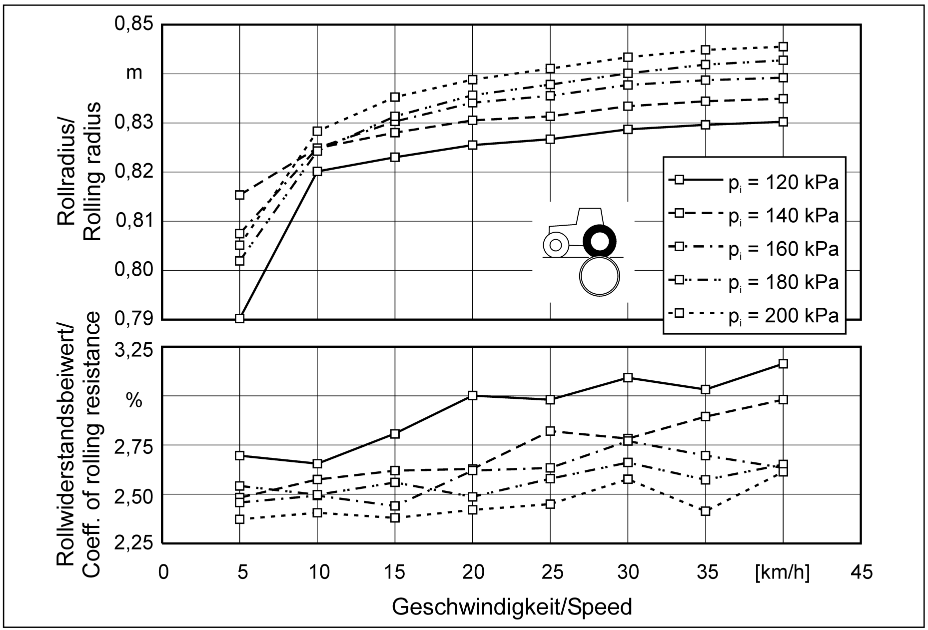

Fig.2: Coefficients of rolling resistance (at ~ 1% slip) as well rolling radii of a standard tyre Goodyear 18.4 R 38 on the roller test rig as a function of tyre pressure and speed. Static axle load: 24.6 kN

If this should be equipped with wet disc brakes the tractive capacity at working temperatures is increased to ~ 150 Nm.

Rolling radii and rolling resistance on the roller test rig

Rolling resistance and rolling radii depend on different parameters such as tyre size, tyre pressure, wheel loading, driving surface and speed. As repeatedly mentioned [2] in other places, these parameters are dependent on the definition of the zero wheelslip condition. Regarding the results presented here, the zero wheelslip (linearly determined) between the two driving conditions „Drive moment zero“ and „Draught force zero“. While additionally, however, as occurred with the presented measurements, the torque at the wheel has to be measured from the tractor side. This is seldom possible and so representative rated values are very helpful.

For the typical drive wheel tyres 18.4 R 38, representative rolling resistance and rolling radius could, with road travel-typical tyre pressures (120 to 200 kPa) and speeds (5 to 40 km/h), be determined on the roller test rig.

The rolling resistance on the roller is substantially different from that on a firm even road. In comparison with the flat road the roller is sharply rounded ($r_{Rolle}/r_{Reifen} \approx 1.2$). There occurs greater local tyre deformations and with that a rise in inner friction. The energy thus converted into heat makes itself apparent as rolling resistance which lies, with the tyre pressure and speed set here, in the area of 2.3 to 3.2 % (*fig. 2*). The values are given with free-running wheel (draught force zero) and an axle load of 24.6 kN. The influence of non-round points on the circumference of the wheel and vibrations are eliminated through arithmetical averaging over 5000 values.

Investigations by Kiesing [3] also indicated linear rolling resistance dependency on speeds. However, the rolling resistance coefficients determined on the flat belt test rig under comparable conditions lay by around 0.8 to 2%. This agrees well with the investigations by Steiner [4] which gave an empirical approximation for the calculation of the rolling resistance coefficient. The values calculated according to this for the tyres used lie between 1.5% by 120 kPa tyre pressure and 1.3% by 200 kPa. In [4] however, the speed was not taken account of.

The rolling radii changes with speed and tyre pressure (fig. 2). Here, in comparison to other investigations [3] a substantially larger influence of speed and tyre pressure is shown than on the flat belt test rig. This is due to the very different rolling conditions on the roller. Especially with lower speeds very „unround“ running characteristics can develop. The short distance of the tyre footprint means that the tyres do not roll on several lugs at the same time but instead that the rolling motion is influence by positive and negative lug sectors having different influences within the ground contact area which in turn causes vertical vibrations.

While on the flat belt test rig the dynamic rolling radius increases by up to 10 mm, the difference produced on the roller are up to 35 mm. This also represents the relationships regarding rolling resistance. Here, however, consideration must be given to the fact that Kiesing determined the dynamic rolling radius with free rolling wheel as the vertical distance between wheel axle wheel contact level.

Application possibilities for the test rig

- Determining engine characteristics (required is a torque sensor in the vicinity of the flywheel): here the test rig serves as brake or drive (drive characteristics or traction loss characteristics). The universal fuel consumption measuring equipment enables the determination of consumption performance.
- Investigations of drives: efficiency degrees and drive strategies can be investigated with a high degree of reliability. Possible also are vibration, comfort and acoustic investigations on the entire vehicle.
- Combined application with pto loading unit and vertical loading: the combination of the roller test rig and hydropulse unit (extension planned) and pto shaft brakes under simultaneous loading of the vehicle on-board hydraulics enables investigation of complex combined loading profiles as they appear, e.g., during trailer work or pto operations. Alongside this, the powerful test room cooling and fresh air supply as well as a drive wind fan enables realistic and reproducible operating conditions.

With the single-axle roller test rig presented here, research and industry are offered a universal and powerful large-capacity test rig.

Literature

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