Nienhaus, Clemens

Overload clutches in agricultural machinery

Overload clutches are used in the main driveline between tractor and implement, and also in the implement itself, serving to protect individual units with different power requirements. In accordance with international regulations, clutches in the main driveline must always be installed on the implement side. The available space is often limited, resulting in restrictions on the diameter and length of the overall volume available. Functional features and their applications will be described in detail.

Keywords
Overload clutches, functional characteristics, applications

Abstract
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Development over the years led to the emergence of the clutch types and functional features presented in the diagram (**Figure 1**).
The necessary functions are largely fulfilled by similar features and designs across all makes.

Constant-torque clutches

All types of friction clutches are considered to be constant-torque clutches. (**Figure 2**) They convert the drive power entirely into heat during the slipping phase.

Since only a small mass can usually be accommodated in the limited installation space, they heat up very quickly. The stored heat has to be dissipated via the surface. Consequently, cooling takes a very long time (**Figure 3**). The disengaging frequency and the slipping time are very limited, because overheating would otherwise destroy the clutch. Therefore, friction clutches should specifically be used in applications where large masses have to be accelerated. Overloading leading to blocking should preferably be avoided.

The friction linings used are generally made of organic materials and specifically designed to suit the respective requirements. The ban on asbestos in the 1980s posed a major challenge when developing suitable alternative materials. They needed to offer good retention of the coefficient of friction, together with high temperature resistance, a high specific surface pressure and good wearing properties. Owing to the numerous influencing variables, the coefficients of friction were subject to major fluctuations and corresponding deviations in torque transmission.

Sintered materials were also examined intensively as alternatives. These linings are characterised by a higher coefficient of friction and are also less temperature-sensitive, but they tend to display stick-slip effects in the slipping phase and to develop a harmful increase in the coefficient of friction. These properties are usually undesirable, since they can have a destructive effect. Consequently, dry clutches with sintered-metal linings did not find widespread use.

Sintered-metal linings are, however, suitable for use on rotary cultivators, where blocking usually only occurs for short periods when rolling over obstacles. As a result, sintered-metal linings are almost exclusively used on rotary cultivators.

To already achieve the machine-specific design torque during first-time operation, all clutches are subjected to a separate running-in process to adapt the sliding surfaces.

Friction clutches are used with preference on mowing attachments, cutters, balers and muck spreaders.

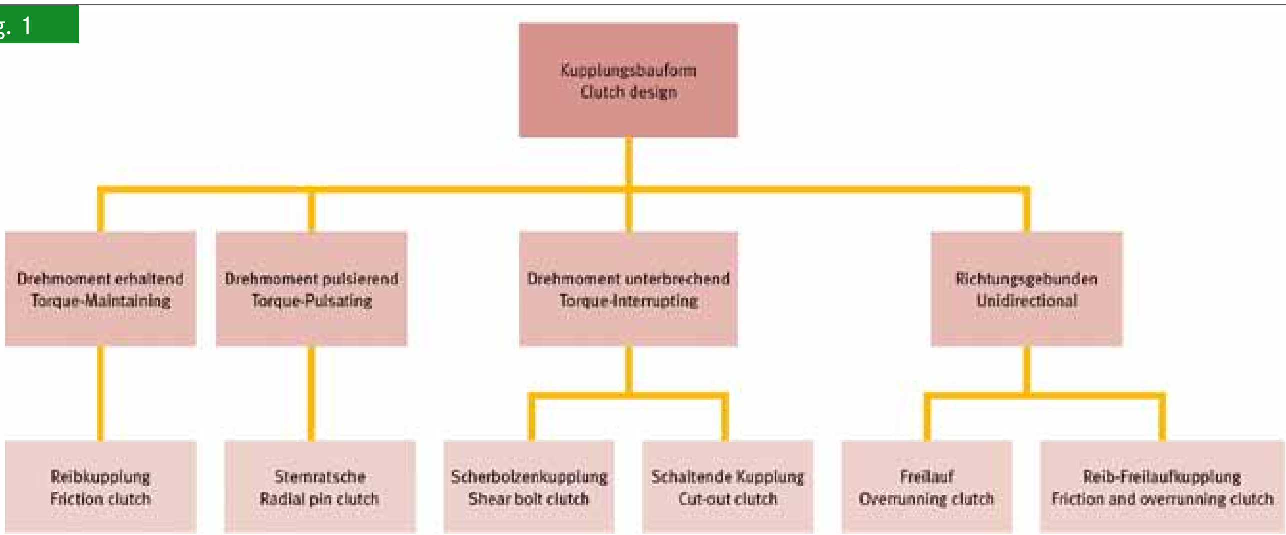
General notes on ratchet clutches

All ratchet clutches generate a pulsating torque. This pulsating torque is frequently desirable, since it is suitable for clearing congestions and overfeeding. The noise generated upon disengaging also draws the driver's attention to the overload.

The lubricant plays a decisive role in all ratchet clutches. In these clutch principles, the locking elements are pressed against the springs as a result of vectorial force resolution, until the positive connection to the opposite surface is eliminated and the slipping phase begins.

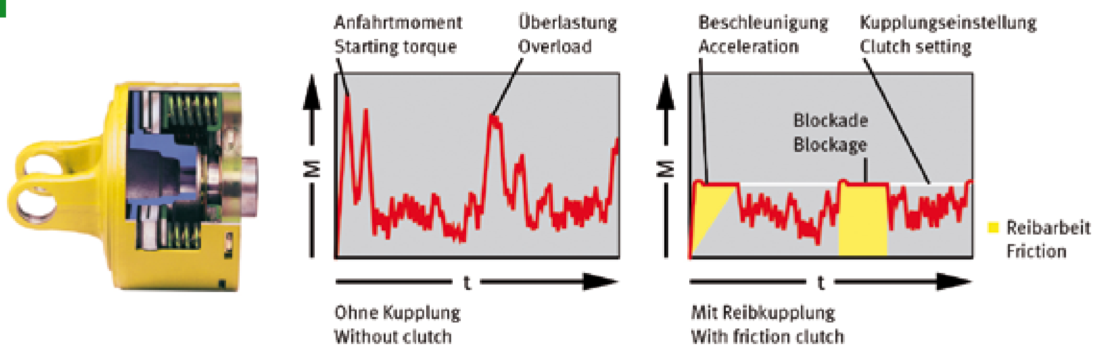
Owing to transmission of the torque, and also due to other vibrations, the locking elements perform micro-movements under high specific surface pressure on their opposite surfaces and in the guides on the hub. This effect destroys the lubricant film of a normal lithium-saponified general-purpose grease. Metal-to-metal contact results, this inducing frictional corrosion (fretting corrosion). This corrosion leads to an uncon-

Fig. 1



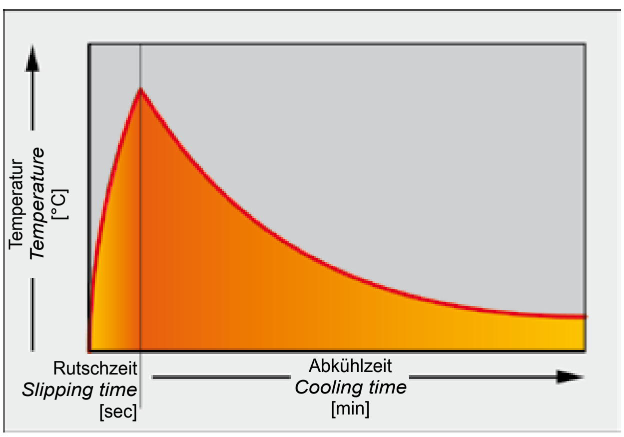
Overview of different clutch functions and design

Fig. 2



Design of a friction clutch and its operating characteristics

Fig. 3



Schematic diagram of temperature behaviour of friction clutches (logarithmic time scale)

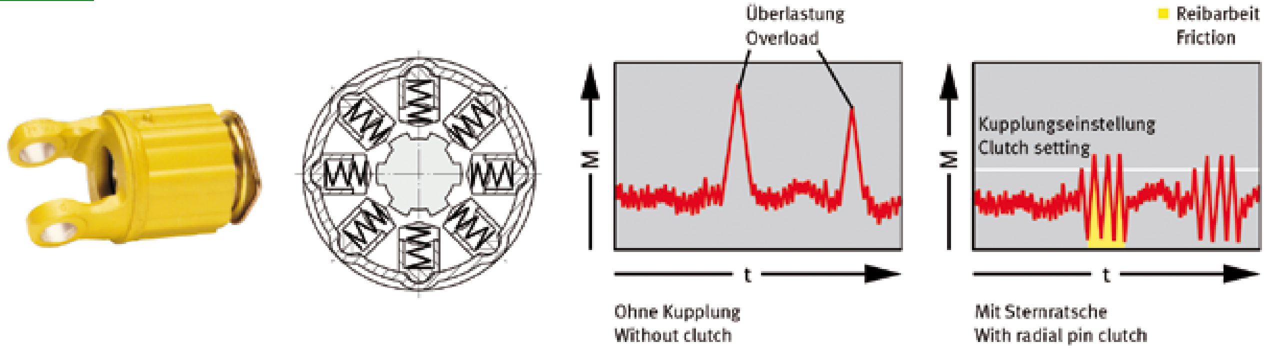
trolled increase in the coefficient of friction, all the way to the point of blocking, and thus to failure of the clutch.

This relationship was already recognised in the 1960s, from the Walterscheid Company and a special-purpose grease with high solids content was developed in extensive test series in collaboration with the Molykote Company, later Gleitmo. During the running-in procedure, the solid particles combine with the surface – "hard facing" – and thus lastingly prevent metal-to-metal contact.

Every overload clutch is run in on a test bench by means of a special procedure. "Hard facing" and settling of the springs take place during this procedure, thus guaranteeing faultless functioning of the clutch. A commercially available, lithium-saponified general-purpose grease can later be used again when servicing the clutch. The "hard facing" is also preserved in the event of cleaning during repairs.

Ratchet clutches have good response characteristics with only slight deviations over the entire life cycle and are thus widely used.

Fig. 4



Design of a radial pin clutch and its operating characteristics

Star ratchet clutches (radial pin clutches)

Star ratchet clutches are still the most commonly used type of overload clutch today. At Walterscheid alone, star ratchet clutches account for more than 8 million of the roughly 14 million overload and overrunning clutches produced in total.

This special position is attributable to their simple, and thus inexpensive structure. The basic concept from the 1950s has essentially been retained. However, the material, surface treatment, hardening process and lubricant have repeatedly been improved since that time.

Owing to the combination of frictional connection/positive locking, approx. 30 % of the power is converted into heat during the slipping phase. The pulsation generates vibrations that have to be absorbed and tolerated by the entire driveline (**Figure 4**). Sympathetic vibrations can occur if the elasticities are not matched, this significantly impairing the service life of the machine.

The speed is limited to 540 rpm, and the torque usually to 900 Nm.

The main applications are machines for gathering green crops and haymaking, the protection of individual units in corn pickers, cotton pickers and pick-up drives.

In the USA, the term “ratchet clutch” has negative connotations because of the axial ratchet clutches in the telescope with high axial forces and vibrations of the PTO drive shaft. Consequently, the designation “radial pin clutch” is particularly used in the USA to successfully market this clutch type, especially for power take-offs.

Disengageable clutches

Increasing engine powers call for overload clutches that convert only a small portion of the power into heat during the slipping phase. Moreover, they should enable the clearing of congestions, or even blockages, such as is not possible with shear bolt clutches.

If congestion or blocking occurs, it can be cleared or eliminated by vibrations of the pulsating torque (**Figure 5**). This effect is provided by the automatically re-engaging cam-type cut-out clutch and key-type cut-out clutch.

These clutches are widely used in high-power machines, such as rotary harrows, self-loading trailers, muck spreaders and big balers.

In contrast, shear bolt clutches interrupt the driveline completely, without any residual torque. Consequently, they are predominantly used in power take-offs, e. g. to protect mowing disks on disk mowers.

The low-maintenance “oil filled cam-type cut-out clutch” is particularly suitable for high torques and long slipping times, e. g. for protecting packer and rotor drives on big balers.

Cam-type and key-type cut-out clutches replace the ball-type ratchets (year of construction: 1954) that were originally used with preference on gripper-ditchers and draining machines. The pulsating torque smashes or exposes hardly accessible obstacles in the ground, such as stones. Disengageable clutches are far more gentle on the implement in realising this function.

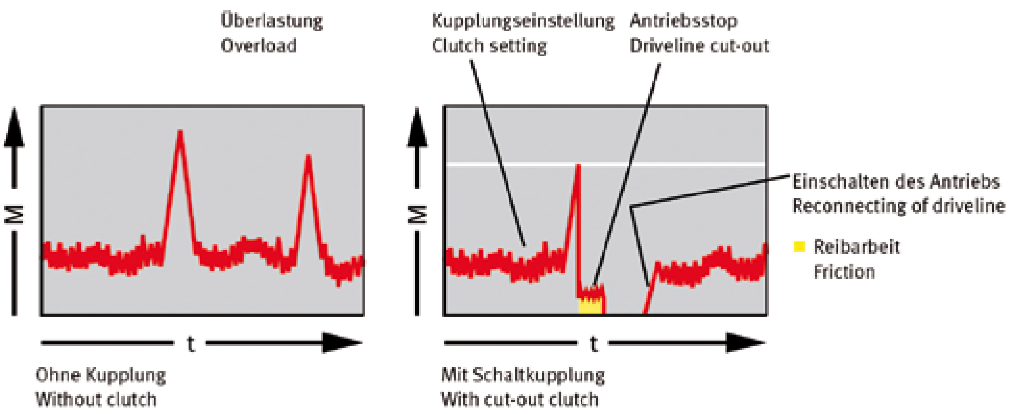
The ball-type cut-out clutch holds a special position as a disengageable clutch, since it acts in both directions of rotation. It is primarily used in snowploughs and corn headers.

In a special version, the switching plate can be controlled from the outside to permit disengaging without the torque limit being exceeded (**Figure 6**). Because of this quick-stop function, this clutch has proven its worth in forage harvesters in combination with metal detectors. When the switching plate is actuated by a pawl, the drive comes to a halt after a maximum of a quarter-turn, i. e. after just 0.025 seconds at a speed of 600 rpm.

Overrunning clutches

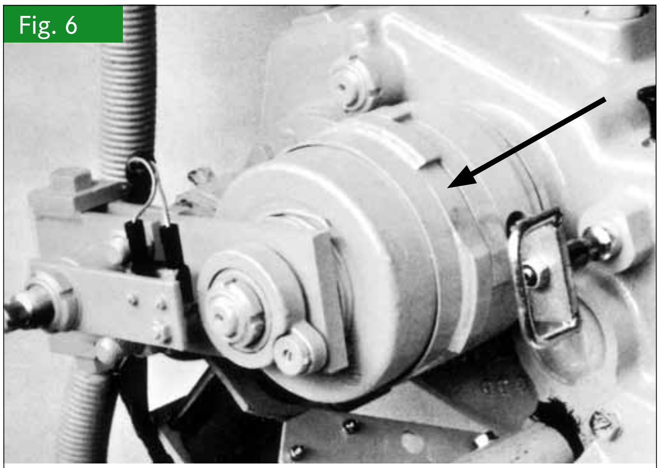
Overrunning clutches transmit torques in one direction only. In the event of rotation in the other direction, they freewheel (**Figure 7**). Key-type overrunning clutches are the predominant form used in agritechnical engineering. While having the same size, they have a considerably higher capacity than pressure-type overrunning clutches, which operate solely on

Fig. 5



Operating characteristics of reengaging clutches

Fig. 6



Ball-type cut-out clutch as quick-stop device, switching plate with locking cam (Photo: GKN Walterscheid)

the basis of a frictional connection. The restriction to a fixed pitch is often desirable in this context.

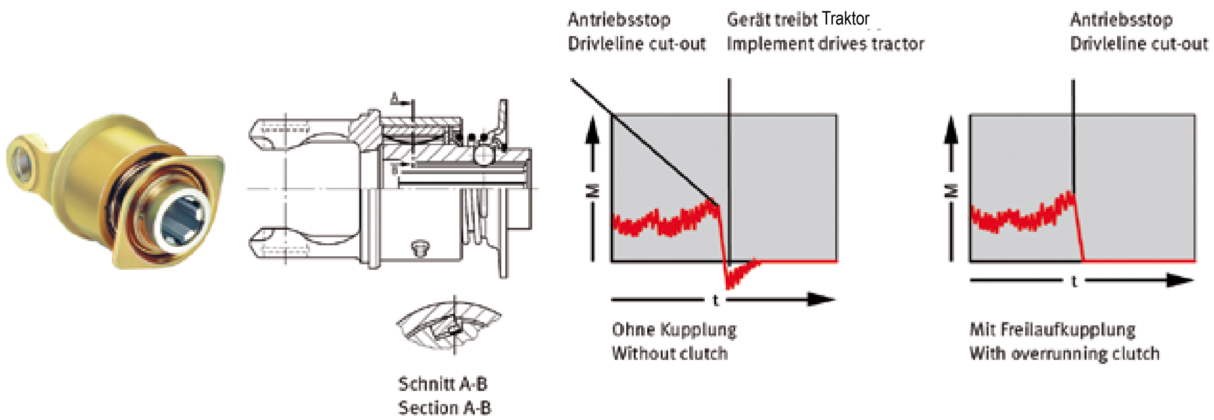
The preferred applications include rotary mowers, cutters and machines with large rotating masses, such as flywheel drives, often in combined form as a friction and overrunning clutch.

Field measurements and design notes

In order to protect mechanical driveline systems against unusual loads by means of overload clutches, close attention has to be paid to the operating conditions and the machine function (**Figure 8**). This is done by means of field measurements, during which the mean torque and also recurrent torque peaks are recorded.

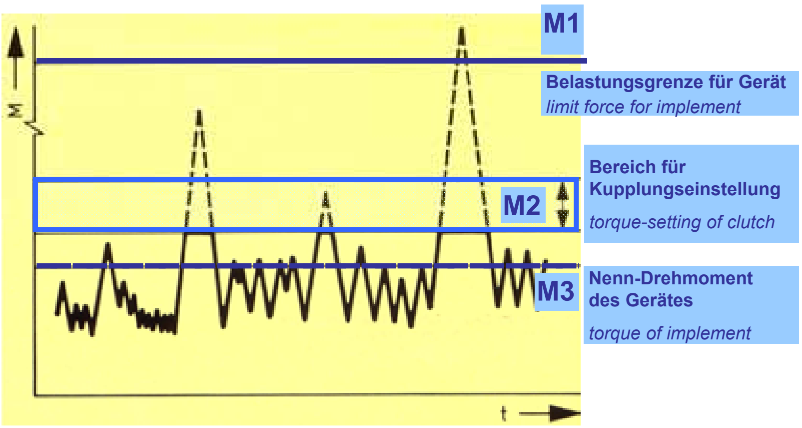
Field measurements have been performed since the mid-1950s – Walterscheid alone has carried out more than 7 000

Fig. 7



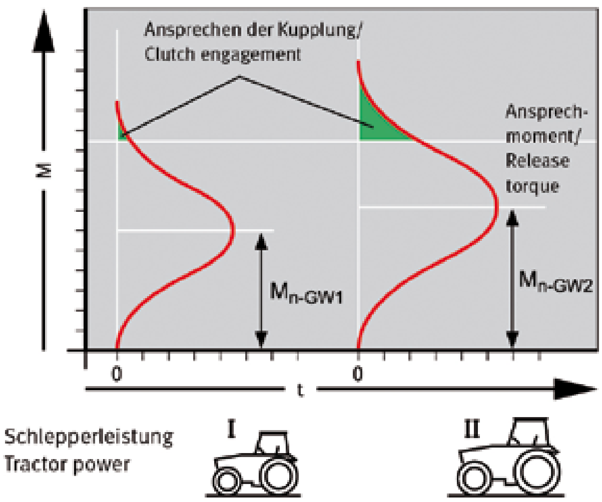
Design of an overrunning clutch and its operating characteristics

Fig. 8



Preventing peak torques by means of overload clutches

Fig. 9



Implement load as a function of the tractor power

such measurements in that time. Computer-assisted procedures employing modern evaluation and documentation methods are used for this purpose today. The measurement data are used to dimension and design the entire driveline. At the same time, these data form the basis for test-bench and laboratory tests. The data are available to manufacturers for optimising their machines.

The disengaging torque of the overload clutch must be significantly higher than the recurrent working torques. Excessively frequent disengaging impedes the workflow and is not accepted by users. The clutches should only disengage in the event of torque peaks that threaten the durability of the machine. Moreover, excessively frequent disengaging also entails a risk of overheating and premature wear of the overload clutch.

However, not even overload clutches can reliably protect inadequately dimensioned machines against premature failure. Thus, even given the same disengaging torque of the clutch, the machine with the higher tractor output is exposed to substantially higher loads on average (**Figure 9**). The mean machine torques thus become significantly higher ($M_{n-GW2} > M_{n-GW1}$). The same applies to the overload clutch, since more frequent disengaging subjects it to greater stresses (green field in graphic). Consequently, the disengaging properties and disengaging torque of the clutch must be designed to match the load limit and torque characteristic of the machine.

(**Figure 10**) shows modern measuring equipment and its application. The measuring equipment is designed as a compact unit for mobile use (**Figure 11**).

Torques and rpm speeds are measured in field measurements, then being used to calculate the output power (**Figure 12**). The load spectrum for designing the overall machine driveline is determined from the measured data by computer (**Figure 13**).

In addition to the measurements on the main driveline, supplementary measurements are also carried out on power take-offs, as well as on other driveline components and various machinery components.

Conclusions

The development of overload clutches will have to continue to follow further increases in output power, as well as new implement concepts and their diverse applications in the future. This applies both to the main driveline and to the units within the implement. Changing types of drive, such as hydraulic drives and also the electric drives to be expected, will have a major influence on the development of mechanical overload clutches.

Author

Dipl.-Ing. Clemens Nienhaus is member of the VDI-MEG Fachausschuss Geschichte der Agrartechnik, Höfferscheid 23, 53819 Neunkirchen-Seelscheid, e-Mail: clemnienhaus@freenet.de

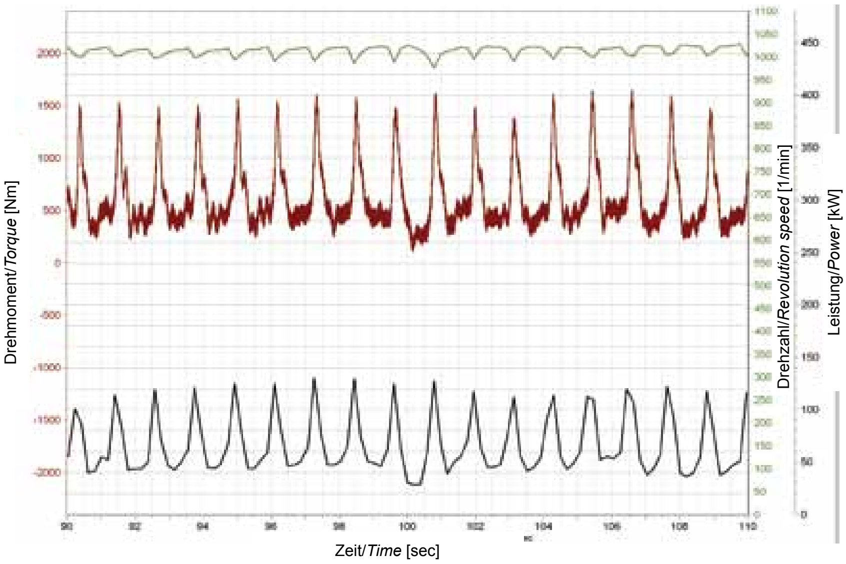
Fig. 10

Measuring hubs, amplifier and recording equipment (left), computer-aided evaluation unit (right) (Photo: GKN Walterscheid)

Fig. 11

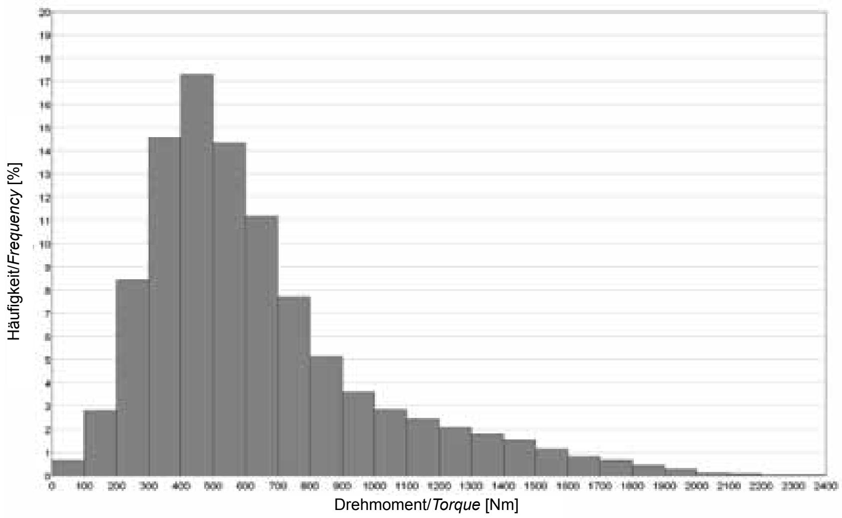
Field measurement; arrangement of the measuring hub for torque and speed and wiring to the tractor (Photo: GKN Walterscheid)

Fig. 12



Field measurement big baler: torque, revolution speed and power of main driveline

Fig. 13



Load cycle diagramm of a big baler