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Active suspended rubber belt track with automatic footprint adjustment

Self-propelled machinery in agriculture still increases in size and weight. The legislative limitation for driving on public streets and the technical limits are reached. New undercarriage systems are needed for carrying the high load safety on roads and with maximum of soil protection on fields. The Harain crawler track concept is an option to connect the advantages of track technology and rubber wheeled undercarriages. The hydraulic system gives the track unit a smooth ride on roads and fields while following the surface contours. The possibility for pressing over during steering on head lands gives e. g. combine harvesters high steer ability. First experiences show that the features are functional. Investigations and documentation of the track unit and of some important components were planned and are still in process for the harvest season 2010. The results are needful for improving and showing the benefits of the new undercarriage system.

Keywords
Suspension, hydraulic-mechanic, rubber belt, self-propelled harvesting machines

Abstract
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The boost of capacity of self-propelled harvesting machines is often connected with an increase of total weight and therefore of wheel loads. Wheel load of > 130 kN in loaded state are no curiosity. This range of loads exceeded the maximum adequate carrying capacity of the biggest pneumatic tires available at market (1050/50R32) which is indicated with about 12,750 kg at 10 km/h cyclic load and 2.8 bar inside pressure of tires [1].

Next to the technical barriers of crawler tracks there are legislative limitations in regard of driving on public streets. The maximum axle load of 120 kN for two-axle machines for driving on public streets is partly reached or exceeded of the powerful machines. Auxiliary axes for driving on public streets afforded the fulfilment of the legal condition, but were no option for soil protection on the field. The more problematic limitation for self-propelled harvesting machines is the compliance with maximum broadness of carriage by 3.5 m [2]. For this reason the use of twin tires or tires with high volume on constantly bigger self-propelled machines, for example used in corporate operation, is uninteresting or rather limited.

Apart from the technical and legal limitations the prevented soil protection, most notably the avoidance of compaction, shouldn't be neglected. Recommendations of acting and chances for this are described in VDI-guideline 6101, which was introduced in November 2007. Among other things maximum inside pressure of tires for different operating conditions, which indirect were up to limitations of wheel loads, were defined in the guideline [3].

Requirements to modern undercarriage

To apply modern running gear technology soil-conserving and economical, you have to attend to the following points:

- The available space of the machine has to be used optimal to accomplish the biggest footprint for a soil-conserving support of high loads at compliance with maximum allowed broadness of carriage and maximum carrying capacity concurrently.
- At the same time the universal use, especially in corporate operation, asks for a high stability under load, fuel-efficient power transmission as well as maximum driving comfort at high speed on street and field.

State of the art

Today mainly air-tired wheeled machines are in use. Until a few years ago machines with crawler tracks were especially found in special areas of application like trashing of rice or soil cultivation on industrialized farms. This technic achieved increasingly in self-propelled harvesting machines. This is due to still bigger machines as well as to aforesaid legal limitations for driving on public streets.

Modern crawler tracks in agriculture are predominantly fitted up with rubber belts. These enable, compared to crawler chains, higher speed on the street (up to 40 km/h) with soil-conserving power transmission on field at the same time. The rubber belts are built up like tire carcase. The carcase exists of steel wire ropes, enclosed with rubber and arranged in longitudinal direction, as well as an inclined to that running casing of cord. According to manufacturer the tread coordinated to operation purpose will be vulcanised in different procedures. Suspension systems are used increasingly to advance the driving comfort at fast transport- and field rides.

Crawler tracks can be divided into two categories in regard to their drive mechanism. The so called positive drive means a driving of the rubber belt by a driving gear in which a vulcanized bar on the inside of the belt grips.

In this way the rubber belt will be activated positive. The initial load of the belt conduces paramountly the guide of the belt and should avoid a transition of the driving bar, hobbed with the driving gear, at high power transmission (acceleration/deceleration).

At friction drive the rubber belt is clamped so heavy by a high clamping of the belt (>160 kN) [4] that the friction activates the rubber belt. In this case the bars on the inside of the belt are only for the guide of the rubber belt.

Advantages and disadvantages of crawler tracks compared to air-tired running gears are shown in **table 1**.

Harain-concept of rubber belt tracks

At the development of the new rubber belt track of Harain Company, the known advantages of rubber belt tracks were combined with new solutions to achieve maximum soil protection and highest driving comfort in a rootedly new developed spring mounted and tracking force optimized rubber belt track. The, from the DLG already at the Agritechnica 2005 with a silver medal awarded, rubber belt track was since then advanced and improved.

Functional description

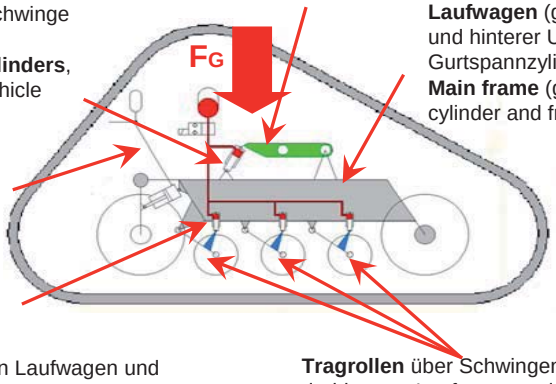
The 2005 introduced symmetric triangle rubber belt track was changed into an asymmetric design (**figure 1**). At this configuration all components are allowed to store in the shadow of the belt space serving, because of advancing the angle of enlacement. For the hydraulic control system of the mid roller-axes the positive drive with an overhead driving gear has been chosen. Thereby a low clamping of the belt of about 50 kN sufficed to guide the belt, so that the belt is allowed to adapt on floor unevenness's, too. Because of the lower clamping the roll resis-

Table 1

Advantages and disadvantages of crawler track usage

Vorteile *Advantages*	Nachteile *Disadvantages*
Große Bodenkontaktfläche für mehr Bodenschutz *Bigger foodprint for more soil protection*	Eingeschränkte Lenkbarkeit unter Last *Limited manoeuvrability under load*
Geringerer Schlupf (Kraftstoffeffizienz) *Less slip (fuel efficiency)*	Komforteinbußen durch Vibrationen auf harter Fahrbahn *Comfort losses by vibrations on hard surface*
Verringerte Einsinktiefe im Feld (Kraftstoffeffizienz) *Less sinkage on muddy fields (fuel efficiency)*	Dammbildung bei engen Kurven auf weichem Boden am Vorgewende *Dam creation on headlands by close curves and muddy soil*
Bessere Ausnutzung des Bauraums *Better usage of available space*	Beschädigung und Abscheren der Feldfrüchte am Vorgewende *Field fruits can be damaged and sheared off while steering on headlands*
Kein Aufschaukeln im Feld wie bei großvolumigen Reifen *No power hopping like high volume tyres*	Höherer Verschleiß der Gummigurtbänder bei schneller Fahrt auf der Straße *Higher abrasion of rubber tracks by high speed ride on streets*
Höhere Laufruhe bei Unebenheiten im Feld *Smooth ride on rough fields*	Höhere Kosten für die Anschaffung und die Wartung *Higher costs for purchase and service*
Leichteres Einhalten der technischen und gesetzlichen Grenzen von zulässigen Achslasten und Transportbreiten *Easier confirmation of technical and legislative limitations*	Höherer Rollwiderstand auf Straßen und harter Fahrbahn *Higher roll resistance on streets and hard surface*
Keine Anpassung und Kontrolle von Reifeninnendrücke *No inflation pressure adjustment and control necessary*	Kein Federungsvermögen wie beim Luftreifen durch die Reifenflanken *No suspension like tyre walls of tyres filled with air*
Geringerer Ballastierungsaufwand (Traktoreinsatz) *Less ballasting work (tractor application)*	Nicht für Grünland geeignet *Not practical for gras land*

Fig. 1



Schwinge (grün) Verbindungselement zwischen einem Fahrzeugrahmen und dem Laufwagen /
Swing (green) Connection between vehicle frame and undercarriage frame

Ein oder mehrere **Federungszylinder**, stützen die mit der Last FG beaufschlagte Schwinge gegen den Laufwagen ab /
One or more **Suspension cylinders**, carry the Load FG from the vehicle

Laufwagen (grau) mit vorderer und hinterer Umlenkrolle, sowie Gurtspannzylinder /
Main frame (grey) with tension cylinder and front and rear idler

Hydraulische Verbindung (rot) Federungszylinder und Belastungszylinder mit zuschaltbarem Blasspeicher /
Hydraulic connection (red) suspension cylinder and mid roller cylinder with bladder accumulator

Belastungszylinder zwischen Laufwagen und Tragrollenschwingen, beaufschlagen die Tragrollen, den lastabhängigen Systemdruck und der geeigneten Auslegung aller Hebellängen und Zylinderflächen entsprechend immer gleichmäßig /
Mid roller cylinder between main frame and mid roller swing for equal load distribution and footprint reduction during steering

Tragrollen über Schwingen (blau) drehbar am Laufwagen gelagert /
Mid roller moveable with swings (blue) on main frame mounted

Function asymmetric track design

tance of the crawler track is lesser. Furthermore the positive drive avoids the danger of slipping trough at muddy conditions and high traction force – transfer. The rubber belt track comes with an integrated final drive gear box furthermore, whose speed increaser can be fitted that way that the same speed as wheeled machines can be achieved. According to the position of the gear and the available constructed space of the machines to retool, the long or the short side of the crawler track can be arranged to the front or the back by the asymmetric design.

The main frame is elastically hanged up with a suspension swing hydro-pneumatically against an individual aligned axe-connection, which is connected close to the machine. On the inside the crawler track is controlled by an anchor in a hinge support at the frame of the machine. On the outside the suspension swing is connected with the axe-connection extending into the crawler track by a base per anchor and hinge support.

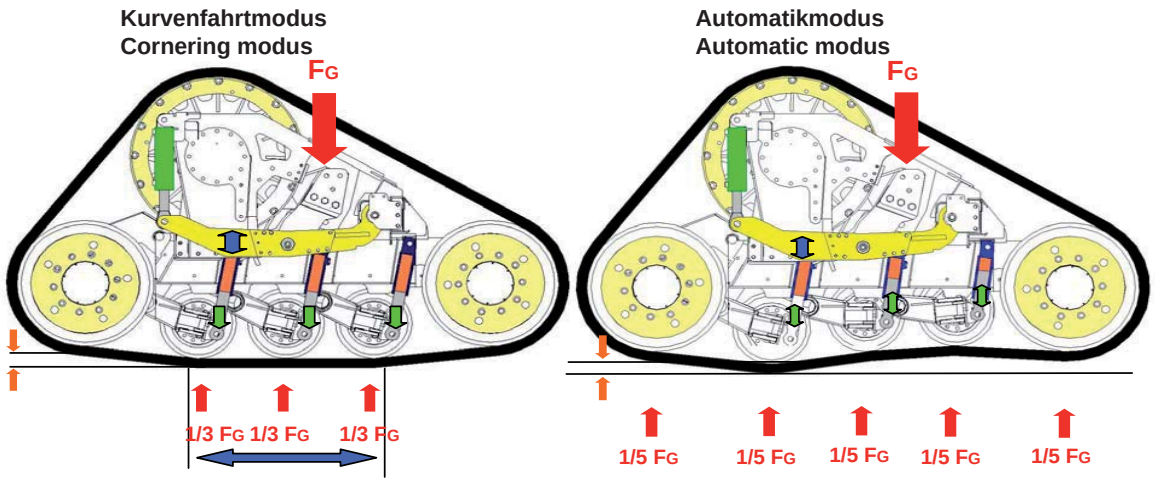
On the outer fixation is the possibility of trace and camber alignments of the whole main frame. Since the abrasion of the rubber belt is an important criterion for the use of rubber belt tracks, possibilities were established in addition to adapt the track within the main frame. For this the grip head can be shift to the left or the right by set screws, according to requirements. The mid roller-axes were designed oscillating for a better surface alignment at vaulted streets and can that way oscillate horizontally up to 8° to the left or right. The oscillation radius of the whole main frame is 10° to the front and back and is bordered softly by polyurethane coated arresters, what avoided wheel spin by 360°, e.g. at the stucking of the whole main frame, in contrast to crawler tracks that are only flange-mounted on existing final drive.

The suspension cylinders of the mid roller-axes generate an optimal weight distribution within the main frame and guarantied an optimal alignment to the surface. Furthermore these cylinders reduce the food print by automatic over-pushing of the three mid roller-axes in cornering (**figure 2**). This enables easier steer ability (better manoeuvrability) of for example harvesters at the headland and lead to reduced dam creation.

By the ISOBUS-ready crawler track terminal the lock angle can be adjusted individually for this function. Furthermore three driving modes can be pre-selected by the terminal: food print always long, always short and preset automatic modus, at which the over-pushing takes place automatically depending on the lock angle.

The Harain rubber belt track concept is presently available in four configurations. The dimensioning is depending on the available space and the tonnage to carry. The configurations with 234” × 26 “ (660 mm) respectively 234” × 30” (762 mm) broad rubber belts and an allowed bearing load of maximum 180 kN per track (= 360 kN/axe on filed) present the norm for harvesters currently. The major alternative is constructed for 250 kN bearing load per track (= 500 kN/axe on field) and can be prepared with 252” × 30” (762 mm) and 252” × 36” (914 mm) rubber belts. This option has applications on sugar beet harvesters (KRB 6) and self propelled potato harvesters so far.

Fig. 2



Model of function for suspension, automatic surface alignment and food print reduction. F_G = load

Conclusions

The practical experience since 2005 attested the functionality of the Harain rubber belt track concept. At the so far retooled harvesters high transport speed and driving comfort were brought in a line with soil protection as well as an increase in harvest effort. At the same time legal limits of maximum 3.5 m for transport on public streets can be hold. The good steer ability by reduction of food print at the headland advanced the manoeuvrability and led to a smaller earthwork, e.g. on wet cornfields. No noteworthy stramineous losses at the headland appeared, despite increased swath-deposition of straw.

The Harain concept combined widely the known advantages of rubber belt track technology with the positive qualities of air-tired running gears.

From operating experiences of the crawler track kits, being on the market since 2005, as well as a scientifically oriented research program since 2008, experiences were and are still integrated for improvement of specifics of several components; this enabled further improvement and maturity phase of the system.

Literature

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