High-clearance tractors

Stability on slopes and protection in event of overturning
High-Clearance Tractors are tractors designed to be used with high crops planted in parallel rows such as vine. HCT are made up of raised chassis so that they could circulated over and parallel to one or more crop rows. HCT are designed to carry or power rear or front implements and also implements mounted on a platform or between their two axles. In their working positions, HCT have a ground clearance generally higher than 1000 mm.
Main differences

- HCT are intended and then designed to be used on very important slopes,
- HCT are manufactured in very small series,
- HCT are fitted with very specific implements,

It has been decided in France, to develop a specific standard dealing with the stability on slopes and the protection in event of overturning of HCT.
Main features: the diversity

Large

Narrow
Main features: the diversity

3 wheels

3 wheels
Main features: the diversity

- Non conventional 4 wheels
- Non conventional dual wheels on the rear
Main features: the diversity
A long tradition
Contents of the standard

✓ Typology of HCT,
✓ Categories of fields,
✓ Categories of implements,
✓ Combinations of implements,
✓ Implements main features,
✓ Risk assessment,
✓ ROPS test method.
Types of HCT

- HCT “two rows of crop”
- HCT “three rows of crop” with lowered engine
- HCT “three rows of crop”
- Rows of crop
Categories of fields

We consider three types of field profiles where HCT are intended to be used:

- Plain
- Hill
- Rough hill.

For each type of field we consider two working situations (two different ways to circulate on the field) to which maximum travelling speeds are associated:

- **Along the slope:** HCT moves up or down along the line of the slope. This is the value of the slope that is used for stability calculations and rear rollover;
- **Crossing the slope:** HCT operates perpendicular to the line of the slope in an area of lower slope specially equipped. This value of the slope which is used for the calculation of stability and lateral rollover.
## Categories of fields

<table>
<thead>
<tr>
<th>Travelling way/Category of field</th>
<th>Plain</th>
<th>Hill</th>
<th>Rough Hill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perpendicular to the slope</td>
<td>10 %</td>
<td>15 %</td>
<td>15 %</td>
</tr>
<tr>
<td>Parallel to the slope</td>
<td>15 %</td>
<td>35 %</td>
<td>50 %</td>
</tr>
<tr>
<td>Maximum travelling speed</td>
<td>2 m/s</td>
<td>1,5 m/s</td>
<td>1 m/s</td>
</tr>
</tbody>
</table>
## Categories of implements

- List of 22 types of implements

<table>
<thead>
<tr>
<th>Implement</th>
<th>Type of HCT</th>
<th>Position of the implement</th>
</tr>
</thead>
</table>
| 1 : Vine shoot tipping machine (200 kg) | * Two rows  
* Three rows  
* Three rows with lowered engine | Front mounted             |
| 7 : Manure spreader (5 T)           | * Three rows with lowered engine                      | On the platform           |
| 16 : Sprayer (1,5 T)                | * Three rows  
* Three rows with lowered engine                      | Rear mounted              |
Combination of implements

List of 12 combinations of implements:

<table>
<thead>
<tr>
<th>Combinaison of implements</th>
<th>Type of HCT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7 : Sprayer (500 kg)</strong> + 2 lateral tanks (400 kg each tank)</td>
<td>* Two rows</td>
</tr>
<tr>
<td></td>
<td>* Three rows</td>
</tr>
<tr>
<td></td>
<td>* Three rows with lowered engine</td>
</tr>
<tr>
<td><strong>10 : Sprayer (500 kg)</strong> + 1 tank (1200 kg) + 2 Vine shoot tipping machines (200 kg each)</td>
<td>* Three rows with lowered engine</td>
</tr>
</tbody>
</table>
Implements main features

For each implement the following characteristics have been defined:

- Mass (kg),
- Position of its centre of gravity (mm) according to the tractor reference frame,
- Tensor of inertia (m².kg) at its centre of gravity.

Example of implement n° 1:
Mass : 200 kg
Position of the centre of gravity (mm):
  \[ X_g = E + Rav + 77 \]
  \[ Y_g = 0 \]
  \[ Z_g = 150^* + 934 = 1084 \]
  \[ 150^* : \text{height above the ground} \]
Tensor of inertia (m².kg):

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>137</td>
<td>0</td>
<td>-9</td>
</tr>
<tr>
<td>0</td>
<td>47</td>
<td>0</td>
</tr>
<tr>
<td>-9</td>
<td>0</td>
<td>112</td>
</tr>
</tbody>
</table>
Stability on slopes

We consider 5 hazardous situations (3 statics and 2 dynamics).

**Static stability:**
- \(\alpha_1\) : Parking
- \(\alpha_2\) : Hanged man
- \(\alpha_3\) : Stationary rear roll-over

**Dynamic stability:**
- \(\alpha_4\) : Turn
- \(\alpha_5\) : Rear roll-over (in motion)

For each of them the limit of stability angle is calculated and compared to reference slope.

If the calculated angle is greater than the reference angle the HTC is deemed to be stable for the considered risk and category of field.
Stability on slopes

**Static stability:** Stationary rear roll-over

The tractor stays on a slope (parallel to the slope). The rear wheels are supposed to be locked on the ground.

The maximum available torque is supposed to be applied to the rear axle.

\( \alpha_3 \)
Stability on slopes

Dynamic stability: Turn

The tractor travels with a constant speed (parallel to the slope). It is supposed to turn with a constant radius. The centrifugal force is calculated when the tractor is perpendicular to the slope.

\[ \alpha 4 \]
But it was not possible to use the usual formulas for calculating energy to be applied:
- used on very high slopes,
- impossible to estimate the energy from a set of simple parameters,
- avoid the risk to oversize the ROPS and then increase the risk of rollover.
Roll-over protection

- Lateral roll-over

- Loading from the side

- Vertical crushing
Roll-over protection

- Rear roll-over

- Vertical crushing

- Longitudinal loading
Non-continuous rolling

Lateral and rear non-continuous rolling
Summary

There are three types of HCT
- two rows of crop;
- three rows of crop;
- three rows of crop with lowered engine.

There are three types of field profiles
- Plain;
- Hill;
- Rough hill.

There are five cases of stability calculation (considered risks)
  Static stability:
  \( \alpha_1 \): Parking
  \( \alpha_2 \): Hanged man
  \( \alpha_3 \): Stationary rear roll-over
  Dynamic stability:
  \( \alpha_4 \): Turn
  \( \alpha_5 \): Rear roll-over (in motion)
Summary

For each type of tractor, the desired type of field is chosen. The stability of the tractor alone and then successively with each type of equipment and each type combination of equipment is calculated for the five cases of stability by using the slope values corresponding to those of the selected field.

If for a given configuration (tractor alone and with equipment and combination of equipment) the calculated angles $\alpha_1$, $\alpha_2$ and $\alpha_4$ are greater than the slope angle of the selected field when travelling parallel to the slope and $\alpha_3$ and $\alpha_5$ are greater than the slope angle of the selected type of field when travelling perpendicular to the slope, the tractor is deemed stable in this configuration and for the type of field profile selected.

All clearance tractor deemed stable on rough hill, is stable on hill. All clearance tractor deemed stable on hill is stable on plain.