INTERNATIONAL STANDARD

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# Self-propelled agricultural machinery — Assessment of stability —

## Part 2:
## Determination of static stability and test procedures

*Machines agricoles automotrices — Évaluation de la stabilité —*

*Partie 2: Détermination de la stabilité statique et modes opératoires d'essai*



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# Foreword

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The committee responsible for this document is ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 3, *Safety and comfort*.



ISO 16231 consists of the following parts, under the general title *Self-propelled agricultural machinery — Assessment of stability*:

— *Part 1: Principles*

— *Part 2: Determination of static stability and test procedures*

 

# Introduction

Self-propelled agricultural machinery with a ride-on operator (driver) can be exposed to the hazard of rolling or tipping over during the intended operation. A risk assessment is used to determine whether this hazard is to be considered in case of a specific machine and the protective measures to be used in order to avoid or minimize this hazard for the ride-on operator.

The risk assessment considers the operating conditions in which the machine is intended to be used, the physical properties of the machine, and the required skills to operate the machine as well as any other parameter which can have an impact on the risk for roll- or tip-over.

# Self-propelled agricultural machinery — Assessment of stability —

## Part 2:
## Determination of static stability and test procedures

## 1 Scope

This part of ISO 16231 specifies a method to determine the centre of gravity of un-laden self-propelled machines, a method to determine the centre of gravity of laden machines and combinations with attachments, and methods to determine the static overturning angle.

NOTE Requirements related to self-protective structures and ROPS are to be dealt with in a separate International Standard.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.



ISO 789-6, *Agricultural tractors — Test procedures — Part 6: Centre of gravity*

ISO 16231-1, *Self-propelled agricultural machinery — Assessment of stability — Part 1: Principles*



## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16231-1 and the following apply.

**3.1**
**maximum operating slope**
**MOS**
value indicating, for each type of self-propelled machine and each direction, the maximum slope in (%) on which the machine is intended to work according to good agricultural practice

**3.2**
**slope compensation system**
system to improve the functional performance of an agricultural machine working on slopes, without levelling the main body of the machine, such as a levelling of internal components, adjusting the kinematics of separating systems, or adjusting air flow or pattern or both

**3.3**
**body levelling system**
system to improve the function performance, drivers comfort, ability to work on slopes, and stability of an agricultural machine working on slopes, by means of levelling the main body of the machine in a longitudinal or transversal sense or a combination of both

# 4 Determination of the centre of gravity (COG) of a self-propelled machine

## 4.1 Method to determine and to calculate the centre of gravity of the un-laden machine

The centre of gravity of the un-laden machine is determined by means of scales and support stands (see Tables 1 and 2 and Figures 1, 2, and 3).

## 4.2 Remarks and items to observe during this procedure

**4.2.1** Follow the procedure as outlined in ISO 789-6; this method is based on the increasing load on the supporting axle when the other axle is lifted and supported on a certain height; the lifting angle ω and the increased load on the scale allow determination of the height of the COG.

**4.2.2** It is recommended to use steel wheels in order to avoid deviations due to changing wheel radius under changing load conditions. For calculation of the COG with the actual tires, see 4.3.

Any suspension system shall be locked. If locking the suspension system is not possible, then inflate all tires up to the maximum permissible pressure as specified by the tyre manufacturer. The difference in radius of the wheels on the fixed axle between horizontal and raised position shall not be higher than 1,5 % of the wheel radius.

**4.2.3** Ensure that the plane of the scale is horizontal and flush with the ground plane.

**4.2.4** Wheels on the scale shall be free to rotate, in order to exclude tangential forces on the tires. Therefore, the parking brake shall not be applied and the gearbox shall be in neutral or the transmission shall be in the position for towing the vehicle.



**4.2.5** Although not required, lifting the side of the swivelling axle is preferred; in most cases, this is the axle with the smallest diameter wheels.

**4.2.6** Raised wheels shall rest on wheel stands before reading the weight on the scale.

**4.2.7** For easy installation of the wheel stands, it can be necessary to lock the swivelling axle with wedges when lifting the machine.

When resting on the wheel stands, the wedges shall be removed.

**4.2.8** The accuracy of this method depends on the height of wheel stand as a proportion of the wheel base and the accuracy of the scale.

Accuracy of weighing during five consecutive measurements: all values shall fall within a range of 1,0 % of the maximum measured load from the fixed axle in raised position.

**4.2.9** Calculate the COG, using the ± deviation of the accuracy of the scale and determine the deviation of the height of the COG.

This deviation shall not exceed ±4 %. In case the value exceeds ±4 %, the height of the wheel stands shall be increased in order to decrease the deviation.

 

**Table 1 — Input data for calculation of centre of gravity(COG)**

| **Data description** | **Symbol** | **Unit** |
|---|---|---|
| Static load radius wheel fixed axle (see Figure 2) | R | mm |
| Static load radius wheel swivelling axle (raised axle) (see Figure 2) | r | mm |
| Wheel base (see Figure 1 top view) | W | mm |
| Load on left wheel fixed axle in horizontal position (see Figure 1 rear/front view) | $F_{fl}$ | daN |
| Load on right wheel fixed axle in horizontal position (see Figure 1 rear/front view) | $F_{fr}$ | daN |
| Load on swivelling axle in horizontal position (see Figure 1 rear/front view) | $F_{sw}$ | daN |
| Load on fixed axle in raised position (swivelling axle supported on stand) (see Figure 3) | $F_{far}$ | daN |
| Height of stand (see Figure 3) | L | mm |
| Distance between outer edges of tires on fixed axle (see Figure 1 top view) | o | mm |
| Width of tires on the fixed axle (see Figure 1 top view) | p | mm |
| Lateral offset of the swivelling axle pivot point (to the right is positive) (see Figure 1 top view) | a | mm |

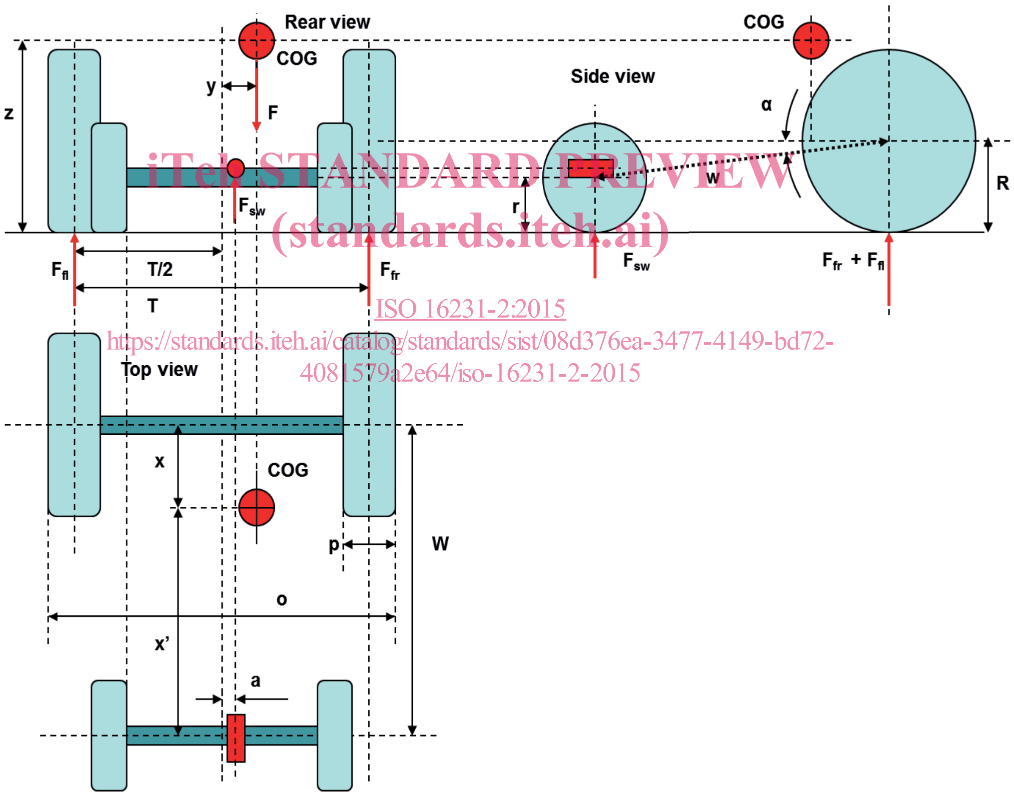




**Figure 1 — Rear, top, and side view of the machine**

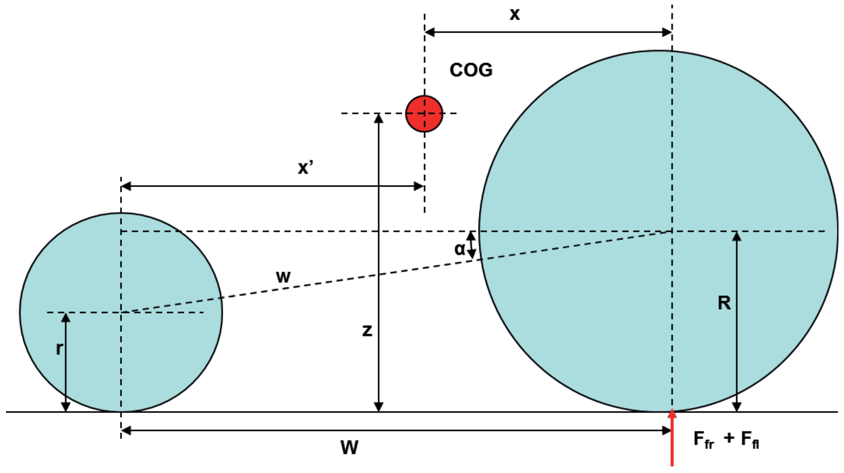


**Figure 2 — Machine in horizontal position — Side view**



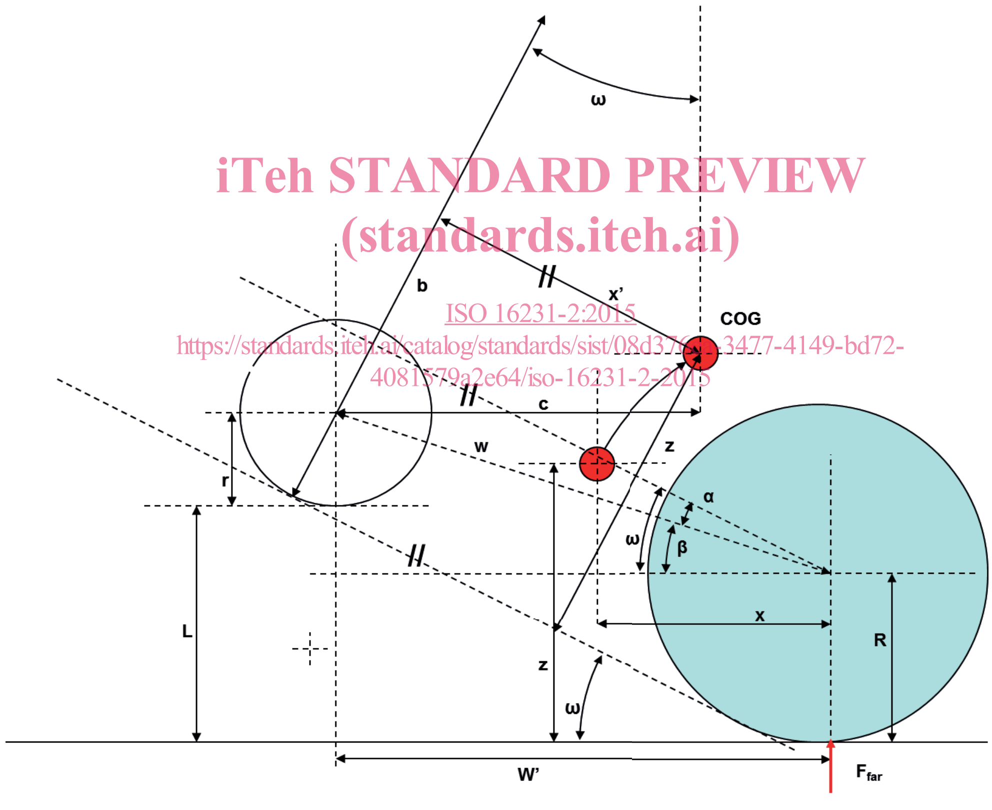


**Figure 3 — Machine in raised position — Side view**

**Table 2 — Calculation of centre of gravity(COG)**

| Data description | Symbol | Unit | Calculation |
|---|---|---|---|
| Wheel track of fixed axle | T | mm | o – p |
| Total weight of the machine | $F_t$ | daN | $F_{fr} + F_{fl} + F_{sw}$ |
| Lateral position of COG (versus centre of fixed axle) (positive number means right from centre of fixed axle in Figure 1) | y | mm | $[(F_{fr} * T) + (T/2 + a) * F_{sw}] / F_t – T/2$ |
| Longitudinal position of COG (versus centre line of swivelling axle) | x’ | mm | $W * (F_{fr} + F_{fl}) / F_t$ |
| Longitudinal position of COG (versus centre line of fixed axle) | x | mm | W - x’ |
| Longitudinal distance between wheel centres | w | mm | $\sqrt{((R – r)^2 + W^2)}$ |
| Vertical projection of wheel base in raised position | W’ | mm | $\sqrt{(w^2 – (L + r – R)^2)}$ |
| Angle formed by the line between wheel centres and horizontal through the centre of the fixed axle wheels | α | ° | $\cos^{-1} (W / w)$ |
| Angle formed by the line between wheel centres and horizontal through the centre of the fixed axle wheels in raised position | β | ° | $\tan^{-1} ((L + r – R) / W’)$ |
| Lifting angle | ω | ° | α + β |
| Vertical projection of longitudinal distance between COG and the swivelling axle in raised position | c | mm | $F_{far} * W’ / F_t$ |
| Auxiliary line for calculation (see Figure 3) | b | mm | r + (c / sin ω) |
| Height of COG | z | mm | b – (x’ / tan ω) |



NOTE An example of calculation of centre of gravity is given in Annex A.

## 4.3 Methods to determine the centre of gravity of a laden machine or a machine with attachments

### 4.3.1 Graphical method

**4.3.1.1** Because weighing a laden machine with attachments under an angle is not practical and can be unsafe, it is advisable to determine the COG of the laden machine by means of a graphical method.

It is assumed that the weight and the COG of the load (e.g. grain) and the attachment(s) are known.

**4.3.1.2** The following example shows a combine harvester with full grain tank and a header in the raised position (worst case field condition).

The COG of the empty machine is known (e.g. by the procedure 4.1) and marked on the scaled drawing of the machine as $cog_a$ (see Figure 4). The COG of the grain in the tank can be defined graphically as $cog_b$. The mass of the grain represents, for instance 50% of the empty weight of the machine. The COG of the combination empty machine and grain load is marked as $cog_d$ and falls on the line between $cog_a$ and $cog_b$ at 1/3 from $cog_a$. The mass of the header is, for instance, 20% of the empty mass of the machine. The COG of the attachment marked as $cog_c$ is known (e.g. by weighing on a hoist under two angles). The COG of the combination empty machine and attachment falls on the line between $cog_a$ and $cog_c$ at 1/6 from $cog_a$. The COG of the combination loaded machine and attachment can be determined in a similar way. The height and the longitudinal position of the new COG can now be measured on the drawing. The same principles apply to determine the new lateral position (y) of the COG.

Example: