BS ISO 6015:2006

BSI Standards Publication

Earth-moving machinery — Hydraulic excavators and backhoe loaders — Methods of determining tool forces

bsi.

National foreword

This British Standard is the UK implementation of ISO 6015:2006. It supersedes BS 6911-3:1990 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/513/1, Earth moving machinery (International).

A list of organizations represented on this committee can be obtained on request to its secretary.

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Earth-moving machinery — Hydraulic excavators and backhoe loaders — Methods of determining tool forces

Engins de terrassement — Pelles hydrauliques et chargeuses-pelleteuses — Méthodes de détermination des forces de l'outil

Reference number
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Foreword

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Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 6015 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 1, *Test methods relating to machine performance*.

This second edition cancels and replaces the first edition (ISO 6015:1989), which has been technically revised.

Earth-moving machinery — Hydraulic excavators and backhoe loaders — Methods of determining tool forces

1 Scope

This International Standard specifies methods for measuring and calculating the tool forces of earth-moving attachments fitted to hydraulic excavators and the hoe equipment of backhoe loaders. It is applicable to hydraulic excavators and backhoe loaders as defined in ISO 6165.

2 Normative references

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

ISO 6016:1998, *Earth-moving machinery — Methods of measuring the masses of whole machines, their equipment and components*

ISO 6165, *Earth-moving machinery — Basic types — Identification and terms and definitions*

ISO 6746-1:2003, *Earth-moving machinery — Definitions of dimensions and codes — Part 1: Base machine*

ISO 7135:1993, *Earth-moving machinery — Hydraulic excavators — Terminology and commercial specifications*

ISO 7451:1997, *Earth-moving machinery — Volumetric ratings for hydraulic excavator buckets and backhoe loader buckets*

ISO 7546:1983, *Earth-moving machinery — Loader and front loading excavator buckets — Volumetric ratings*

ISO 9248:1992, *Earth-moving machinery — Units for dimensions, performance and capacities, and their measurement accuracies*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
tool force
force generated at the bucket lip or cutting edge, but not at the tips of the teeth, when operating the bucket or arm cylinders independently

3.2
arm cylinder tool force
force generated at the bucket lip with the arm cylinder positioned to provide a rotating moment around the arm pivot

NOTE The bucket lip moves towards the base machine when hoe equipment is used.

3.3
arm cylinder tool force at level crowd
⟨shovel equipment⟩ horizontal arm cylinder tool force generated by the arm cylinder at the bucket lip when the bucket's attitude is level and maintained parallel to the ground line and the lip is at the ground line

3.4
bucket cylinder tool force
tool force generated at the bucket lip with the bucket cylinder(s) positioned to provide a rotating moment to the bucket around its pivot

NOTE The bucket lip moves towards the base machine when hoe equipment is used and away from it when shovel equipment is used.

3.5
crowd tool force
⟨hydraulic excavators with telescoping boom⟩ tool force generated at the bucket lip when the telescoping boom is retracted

3.6
rated tool force
tool force, measured or calculated, that the manufacturer publishes

3.7
actual tool force
measured tool force generated at the bucket without tipping or sliding occurring

3.8
maximum [arm cylinder] [bucket cylinder] [crowd] tool force
largest measured or calculated tool force

3.9
grab [clamshell] closing force
force generated between the grab [clamshell] cutting edges or teeth tips when closing

3.10
maximum grab [clamshell] closing force
largest measured or calculated grab [clamshell] closing force

3.11
arm force radius
A
radius of the arc that passes through the bucket lip and whose centre is located at the arm pivot

See Figure 5.

3.12
bucket force radius
B
radius of the arc that passes through the bucket lip and whose centre is located at the bucket pivot

See Figure 6.

3.13
grab [clamshell] force radius
C
radius of the arc that passes through the grab or clamshell lip and whose centre is located at the grab or clamshell pivot

See Figure 7.

3.14
operating mass
OM
mass of the base machine with equipment and empty attachment as specified by the manufacturer, and with the operator (75 kg), full fuel tank and all fluid systems at the levels specified by the manufacturer

[ISO 6016:1998, definition 3.2.1]

3.15
working circuit hydraulic pressure
normal operating pressure applied to the specific circuit by the pump(s)

3.16
maximum relief circuit hydraulic pressure
maximum static pressure in a specific circuit limited by a relief valve at a flow no greater than 10 % of the rated circuit flow

3.17
hydraulic limit
condition when the tool forces are limited by maximum relief circuit pressure

3.18
tipping limit
condition when the tool forces are limited by the onset of tipping of the machine

3.19
slipping limit
condition when the tool forces are limited by the machine slipping on the test surface

4 Measurement methods

4.1 Test site and general

The test site shall consist of a level, hard surface, with anchor points and space for using the measuring devices specified in 4.2.1 to 4.2.3. For measurements made below the ground plane, a space below that plane is required for acceptance of the machine tool and the measurement devices, the anchorage and any auxiliary equipment.

All measurements shall be accurate to within $\pm$ 2 % or shall accord with an International Standard relative to test equipment accuracy.

In the preferred method, the force to be measured is applied directly to the force measuring device (4.2.1). If the force is applied via a pulley, its friction should be taken into account. The wire rope (4.2.4) should be as short as possible to minimize the affect on accuracy.

4.2 Test apparatus

4.2.1 Force measuring device, of accuracy according to ISO 9248.

4.2.2 Hydraulic oil pressure measuring device, of accuracy according to ISO 9248.

4.2.3 Instrument(s) for measuring linear dimensions, of accuracy according to ISO 9248.

4.2.4 Wire ropes and shackles, **pulley**, **safety chains and adjustable supporting frames**.

4.3 Preparation for testing

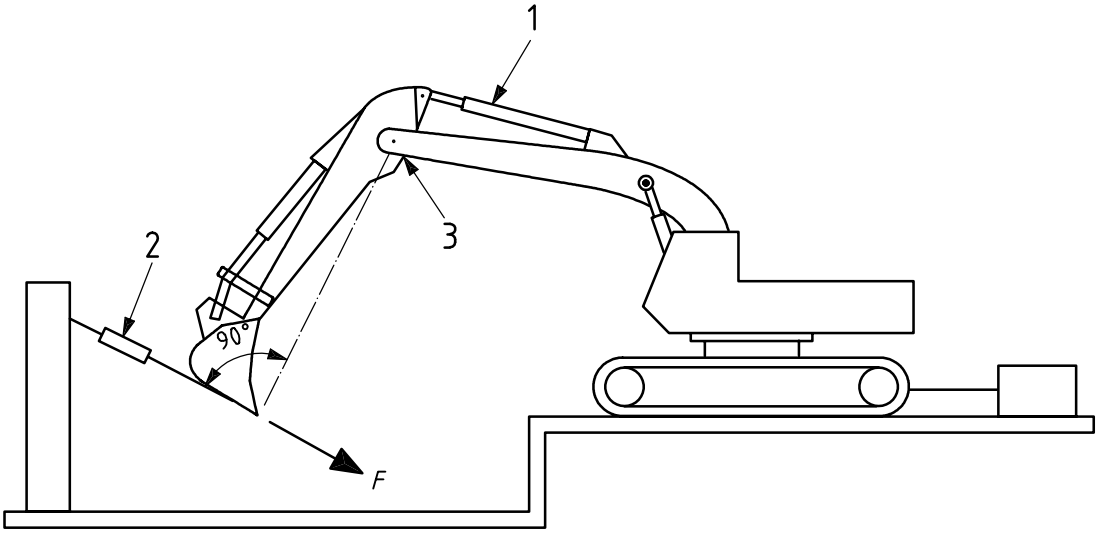
The machine shall be equipped according to ISO 6016.

The machine shall be fitted with the bucket, grab or clamshell and appropriate counterweights, and shall have the tyre pressure, and tyre ballast or track tension as specified by the manufacturer.

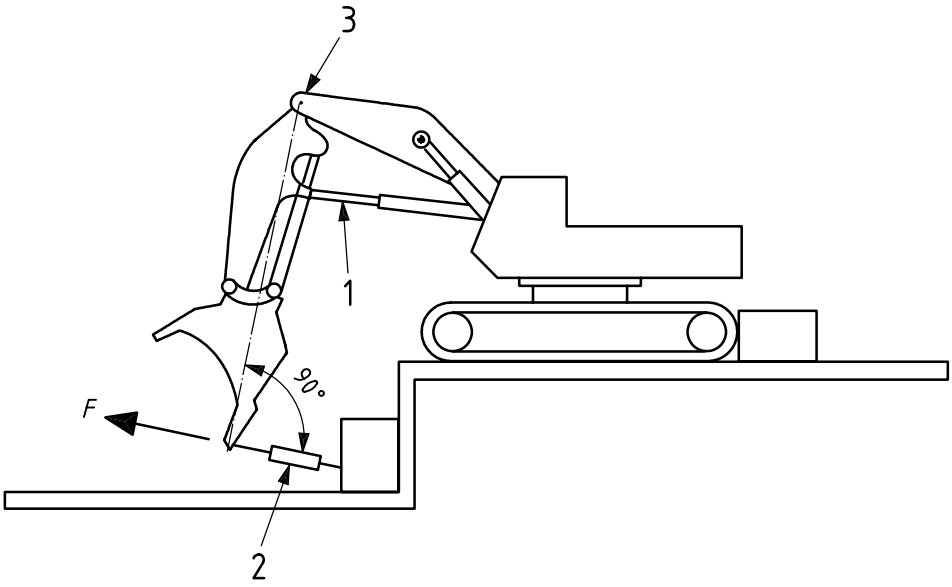
The hoe, shovel, grab or clamshell equipment for each test shall be as specified by the manufacturer.

Prior to testing, the engine and hydraulic system shall attain the normal operating temperature. The working circuit hydraulic pressure and maximum relief circuit hydraulic pressure shall then be checked for compliance with the manufacturer's ratings using the measuring device specified in 4.2.2.

The machine shall be positioned on the test site. The bucket or attachment shall be connected to a force measuring device (4.2.1), as shown in Figures 1, 2, 3, and 4.



a) Hydraulic excavator fitted with hoe

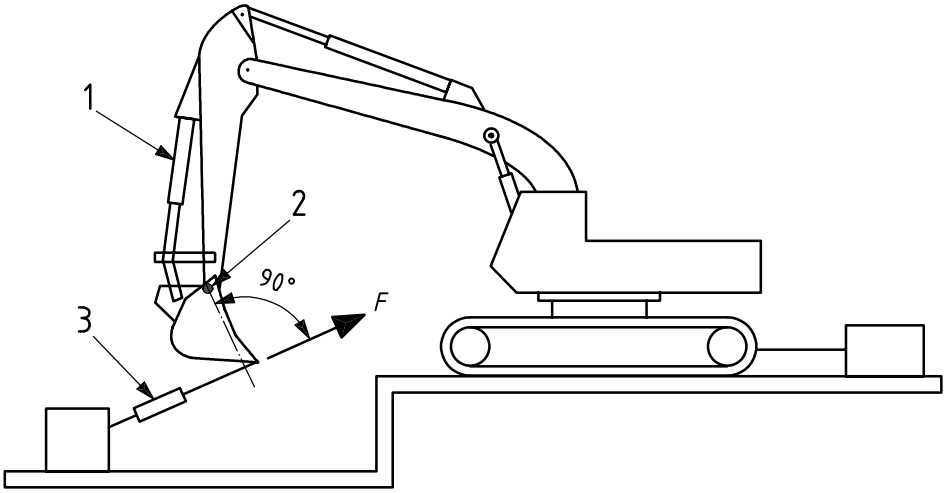


b) Hydraulic excavator fitted with shovel

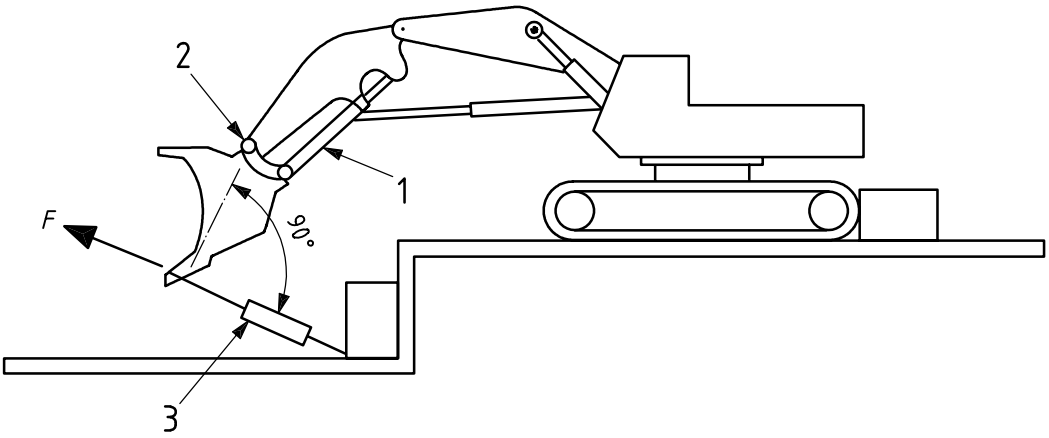
Key

F tool force
1 arm cylinder
2 force measuring device (load cell)
3 arm pivot

Figure 1 — Typical arrangements for measuring maximum arm cylinder tool force (see 4.8.2)



a) Hydraulic excavator fitted with hoe

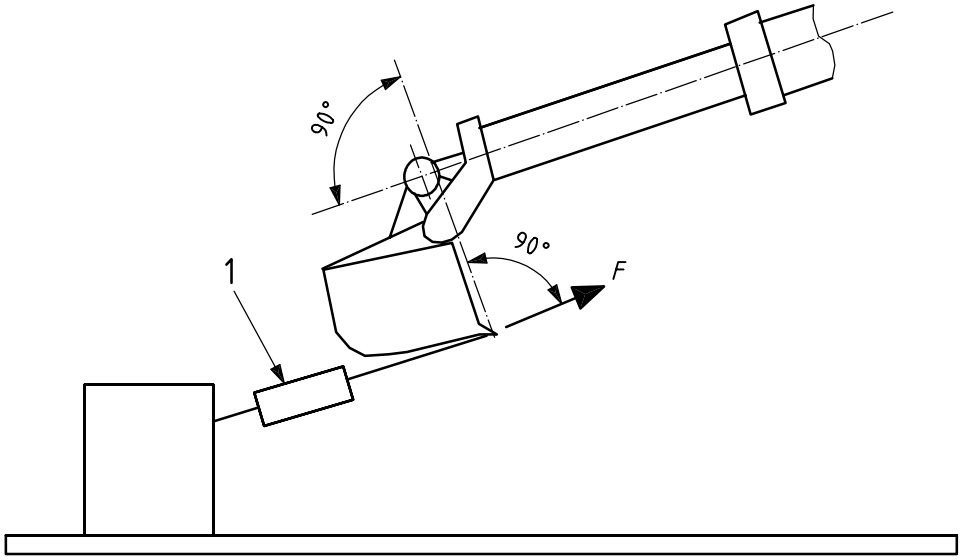


b) Hydraulic excavator fitted with shovel

Key

F	tool force
1	bucket cylinder
2	bucket pivot
3	force measuring device (load cell)

Figure 2 — Typical arrangements for measuring maximum bucket cylinder tool force (see 4.8.3)

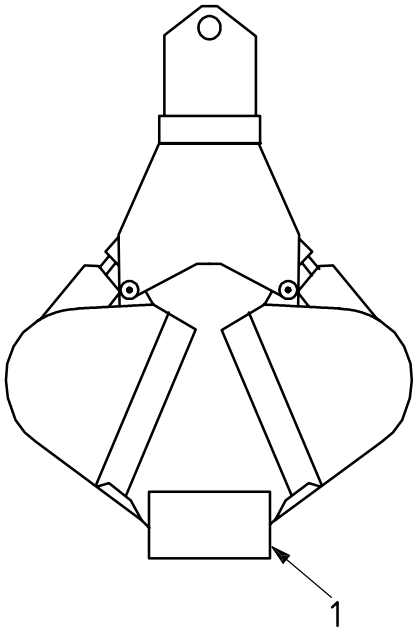


Key

F tool force

1 force measuring device (load cell)

Figure 3 — Hydraulic excavator fitted with telescoping boom — Typical arrangement for measuring maximum crowd tool force (see 4.8.4)



Key

1 force measuring device (load cell)

Figure 4 — Grab or clamshell attachment — Typical test arrangement for measuring grab/clamshell closing force (see 4.8.5)

4.4 Requirement during testing

The tests shall be conducted with the machine running in accordance with the manufacturer's operating instructions and observing all safety rules.

Tie-down and blocking devices (4.2.4) shall be applied to the machine to limit slippage and tipping. Safety chains shall be loose so that the machine can attain the tipping condition and yet be prevented from overturning.

Components may be mounted on a test bed simulating a complete machine.

The required cylinder(s) shall be operated independently and the force at the bucket lip or attachment recorded with the engine running at the manufacturer's rated speed.

A series of preliminary tests shall be conducted with the equipment boom arm and bucket at different angles in relation to each other (i.e. by varying the cylinder stroke), in order to obtain the optimum position giving the maximum force. The position (angle) of the boom, arm and bucket at the optimum position shall be recorded.

4.5 Limit conditions

The limit condition for each test shall be noted.

If the hydraulic limit condition is reached, the report should note the system or circuit in which the maximum relief circuit hydraulic pressure was exceeded.

If the tipping limit condition is reached, the tool force shall be measured after the onset of tipping.

If the slipping limit condition is reached, the machine shall be anchored and the reported results should indicate that the maximum tool force was obtained by anchoring the machine.

4.6 Pivot positions

When alternative pivot positions for the boom, arm, attachment and cylinders and/or a telescopically adjustable boom are available, the relative pin positions of boom, arm and bucket fixing and/or the telescopic boom position as tested shall be recorded.

4.7 Outriggers

For machines fitted with outriggers, the tests shall be conducted with the outriggers raised or lowered as specified by the manufacturer.

4.8 Measurement procedure

4.8.1 General

Each test shall be conducted three times, and the maximum tool force for each test shall be noted; the arithmetic mean of these three values shall be recorded in the test results.

The tool forces shall be measured in accordance with the specified requirements.

For buckets with a curved or pointed cutting edge, the tool forces shall be measured at the centre of the bucket width.

The direction of the tool forces to be measured shall be tangential to the arc described by the bucket lip.

For each machine equipped with hoe, shovel, or telescoping boom equipment, bucket and arm tool forces are required to properly determine the tool forces. For each machine equipped with either grab or clamshell equipment, only the grab/clamshell closing force is required for proper determination.

Where both arm and bucket cylinder tool forces are required, both shall be either actual tool forces or both shall be rated tool forces.

The actual tool force is determined from measurements and considers variables such as the weight of the arm, bucket, clamshell, links, pins, cylinders and attaching hardware, as well as friction.

4.8.2 Arm cylinder tool force

4.8.2.1 Hoe equipment

Measure this tool force tangential to the arc described by the bucket lip about the arm pivot. Position the load cell (4.2.1) such that it is placed in tension, as shown in Figure 1 a).

For the maximum tool force, the working circuit hydraulic pressure shall be at maximum and the bucket positioned for maximum bucket cylinder tool force so as to produce the maximum rotating moment about the arm pivot.

4.8.2.2 Shovel equipment

Measure this tool force tangential to the arc described by the bucket lip about the arm pivot. Position the load measurement device such that it is placed in tension as shown in Figure 1 b).

The bucket lip shall move away from the base machine. See Figure 1 b).

Position the bucket for maximum bucket cylinder tool force so as to have a minimum distance between the bucket lip and the arm pivot.

No part of the bucket shall be outside of the arc described by the bucket lip about the arm pivot.

For the maximum tool force, the working circuit hydraulic pressure shall be at maximum and the bucket positioned for maximum bucket cylinder tool force so as to produce the maximum rotating moment about the arm pivot.

4.8.3 Bucket cylinder tool force

4.8.3.1 Hoe and telescoping boom equipment

Measure this tool force tangential to the arc described by the bucket lip about the bucket pivot. Position the load measurement device such that it is placed in tension as shown in Figure 2 a) or Figure 3, as applicable.

Position the bucket for maximum bucket cylinder tool force. No part of the bucket shall be outside the arc described by the bucket lip about the arm pivot.

For the maximum bucket cylinder tool force, the working circuit hydraulic pressure shall be at maximum and the bucket positioned so as to produce the maximum rotating moment about the bucket pivot.

Adjustable and telescoping boom equipment shall be in the minimum extension position, unless otherwise noted. If the arm can be articulated horizontally, it shall be in the straight position.

4.8.3.2 Shovel equipment

Measure this tool force tangential to the arc described by the bucket lip about the bucket pivot. Position the load measurement device such that it is placed in tension as shown in Figure 2 b).

For the maximum bucket cylinder tool force, the working circuit hydraulic pressure shall be at maximum and the bucket positioned so as to produce the maximum curling moment about the bucket pivot.

4.8.4 Crowd tool force

The crowd tool force shall be measured parallel to the line of action of the retracting boom. The load measurement device shall be positioned such that it is placed in tension.

The bucket lip shall move toward the base machine.

The bucket shall be positioned so that the line of action of the crowd force is parallel to the line of action of the telescoping boom.

For the maximum crowd tool force, the working circuit hydraulic pressure shall be at maximum. See Figure 3.

4.8.5 Grab/clamshell closing force

A force measuring device (4.2.1) shall be placed between the cutting edges or teeth tips of the grab or clamshell, which shall be in the position of maximum closing force, applied by the hydraulic closing cylinders or other means.

The distance between the cutting edges shall be recorded, see Figure 4. In order to minimize measurement errors, the force measuring device (4.2.1) should be as small as possible in order to approach measuring the load tangential to the cutting edges or teeth lips.

The maximum grab or clamshell closing force is obtained when the working circuit hydraulic pressure is at a maximum and the clamshell or grab is positioned for maximum closing moment.

The direction of the closing forces to be determined shall be tangential to the arc described by the clamshell grab cutting edges or teeth lips.

4.9 Test report

The following information shall be reported.

a) **Machine**:

   1) type;

   2) model;

   3) manufacturer;

   4) operating mass of machine as tested, in kilograms;

   5) working circuit hydraulic pressure or maximum relief circuit hydraulic pressure settings, in kilopascals.

b) **Type of undercarriage** (i.e. crawler or wheeled machine, in accordance with ISO 6746-1):

1) Crawler machine

i) type of track shoe;

ii) maximum width (over tracks), $W1$, in metres;

iii) track gauge, $W2$, in metres;

iv) track shoe width, $W4$, in metres;

v) crawler base (distance between vertical centrelines of front and rear idlers or sprockets), $L2$, in metres.

2) Wheeled machine

i) tread, $W3$, in metres (specifying front and rear if different);

ii) wheel-base, $L3$, in metres;

iii) tyre size(s);

iv) tyre pressure, in kilopascals;

v) ballast (if specified), in kilograms.

c) **Equipment fitted** (in accordance with ISO 7135):

1) boom length (at available pin or telescoped positions), in metres;

2) arm length (at available pin or telescoped positions), in metres;

3) bucket type, rated volume (in accordance with ISO 7451 or ISO 7546) and operating mass, in kilograms;

4) attachments (specify) and operating mass, in kilograms;

5) counterweights, in kilograms;

6) outriggers — width between pad centres, outriggers extended, $W6$, in metres.

The tool forces shall be recorded in accordance with Table 1. Under “limit condition”, the manufacturer shall indicate if blocking, tie-downs, safety chains or other devices were necessary to limit movement of the machine during the test.

Table 1 — Test results — Maximum (actual) tool and closing forces

Maximum tool force		**Pin position and arm length** m	**Force F** N	**Limit condition**
Hoe	Arm cylinder tool force			
	Bucket cylinder tool force			
Shovel	Arm cylinder tool force			
	Bucket cylinder tool force			
Maximum grab/clamshell closing force		**Distance between teeth/ cutting edges**		

5 Calculation methods

5.1 General

The tool forces and grab/clamshell closing forces shall be calculated excluding the weight of all components and the effect of friction.

5.2 Rated tool forces and closing force

5.2.1 Arm cylinder tool force

Calculate the tangential arm cylinder tool force as being the force generated by the arm cylinder and tangent to the arc of radius A as shown in Figure 5 a) for hoe equipment and b) for shovel equipment.

5.2.2 Bucket cylinder tool force

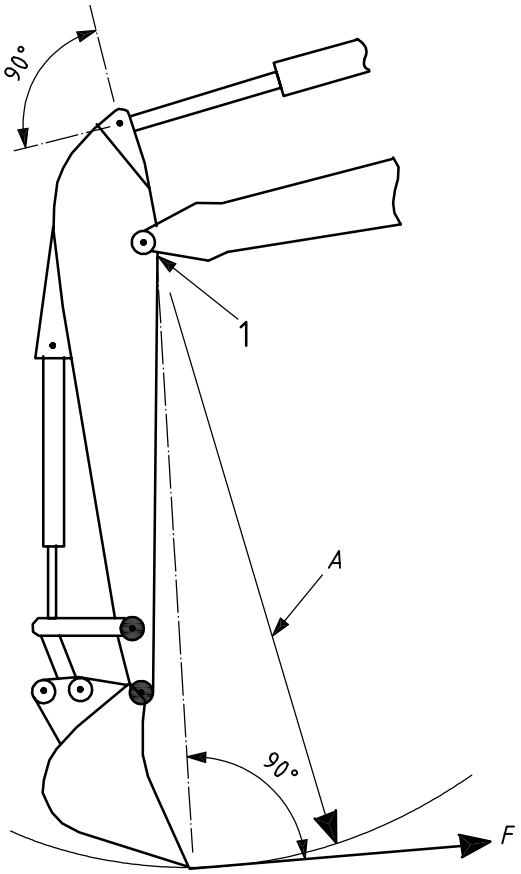
Calculate the bucket cylinder tangential tool force as being the force generated by the bucket cylinder and tangent to the arc of radius B as shown in Figure 6 a), b) and c) for hoe, shovel and telescoping boom equipment, respectively.

5.2.3 Crowd tool force

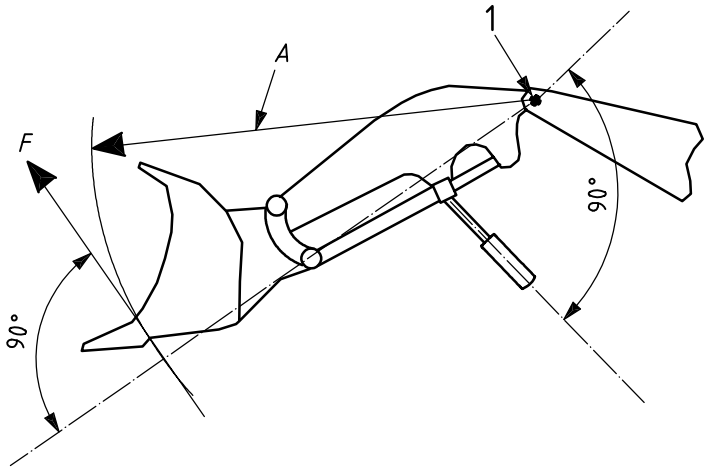
Calculate the crowd tool force of a telescoping boom as being the force generated by retracting the boom, parallel to its line of action, as shown in Figure 3.

5.2.4 Grab/clamshell closing force

Calculate the grab/clamshell closing force as being the force generated by the closing cylinder or other means, tangent to the arc of radius C, as shown in Figure 7.



a) Hoe attachment

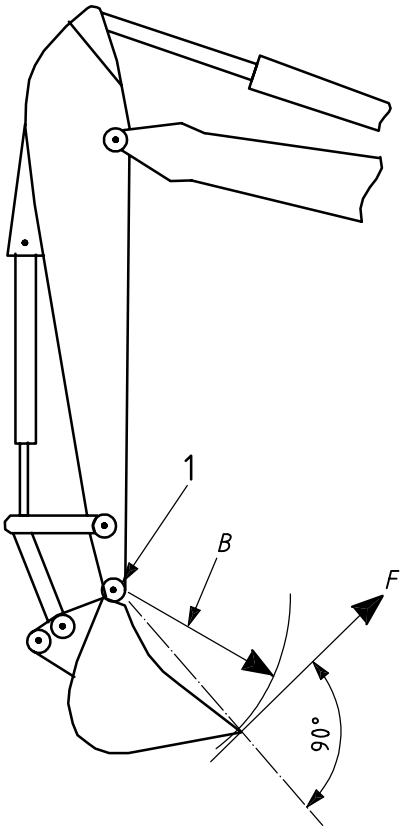


b) Shovel attachment

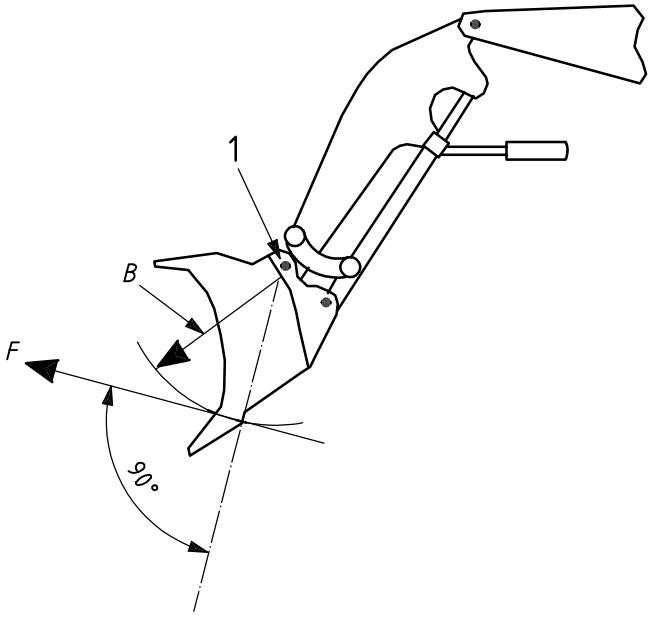
Key

A	arm force radius
F	tool force
1	arm pivot

Figure 5 — Calculated arm cylinder tool force (see 5.2.1)

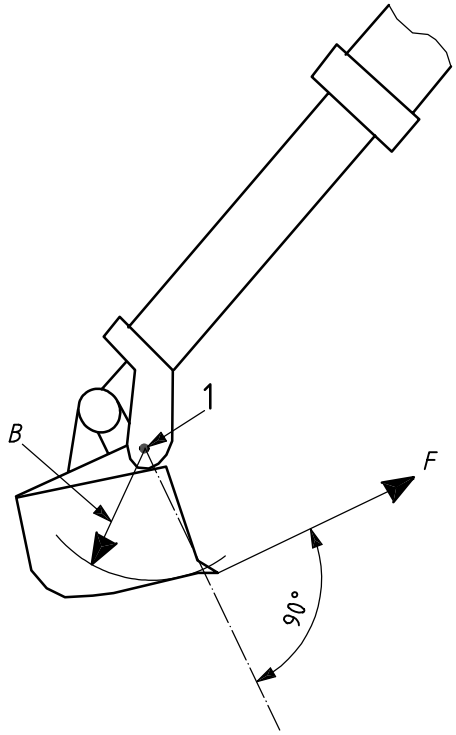


a) Hoe attachment



b) Shovel attachment

Figure 6 — Calculated bucket cylinder tool force (see 5.2.2)

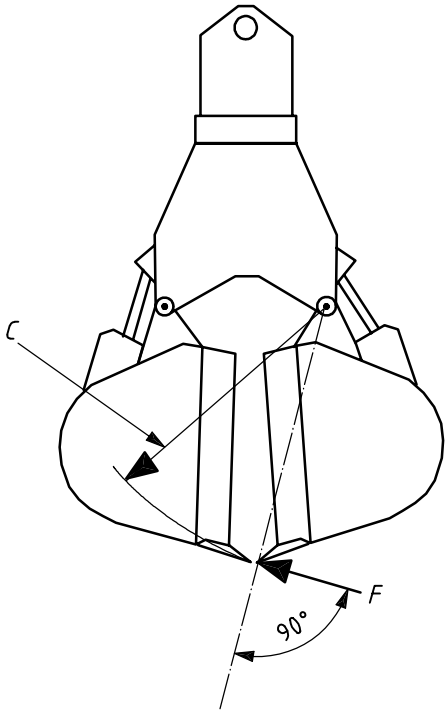


c) Telescoping boom attachment

Key

B bucket force radius
F tool force
1 bucket pivot

Figure 6 — Calculated bucket cylinder tool force (see 5.2.2) (*Continued*)



Key

C grab/clamshell force radius

F closing force

Figure 7 — Grab/clamshell attachment — Calculation of grab/clamshell closing force (see 5.2.4)

6 Verification of rated tool and closing forces

Rated tool and closing forces based on calculations may be published, but these shall have been correlated (verified) by actual measurement.

For verification purposes, the rated tool force shall be no more than 95 % of the actual tool force measured. If the tool force has been calculated, then the manufacturer shall state this.

The manufacturer shall specify the arm or boom position used when a published tool force value has been obtained using a multi-position boom and/or arm.

The specified guide linkage and bucket linkage shall be used for the published values of tool forces for machines fitted with hoe or shovel equipment.

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