# International Standard ISO 6178

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

## Centrifuges — Construction and safety rules — Method for the calculation of the tangential stress in the shell of a cylindrical centrifuge rotor

*Centrifugeuses — Règles de construction et de sécurité — Méthode pour le calcul des contraintes tangentielles des viroles de rotors cylindriques*



**First edition — 1983-11-01**



**UDC 677.057.123 : 614.8** **Ref. No. ISO 6178-1983 (E)**

**Descriptors** : centrifuges, construction, specifications, verifying, safety requirements.

ISO 6178-1983 (E)

Price based on 6 pages

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been authorized has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 6178 was developed by Technical Committee ISO/TC 72, *Textile machinery and allied machinery and accessories*, and was circulated to the member bodies in April 1982.



It has been approved by the member bodies of the following countries :

| | | |
|---|---|---|
| Australia | India | Spain |
| Belgium | Indonesia | Switzerland |
| Czechoslovakia | Japan | Turkey |
| Egypt, Arab Rep. of | Romania | USSR |
| France | South Africa, Rep. of | |

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Germany, F. R.
Italy
United Kingdom

# Centrifuges — Construction and safety rules — Method for the calculation of the tangential stress in the shell of a cylindrical centrifuge rotor

## 0 Introduction

This International Standard has been established by ISO/TC 72 in response to the requirements of the majority of its members. It is understood that the contents of this International Standard cover fields other than textile machinery and therefore the Central Secretariat of ISO, which is responsible for the co-ordination of technical work, and ISO/TC 72 will ensure that this International Standard is reviewed when necessary in the light of future ISO publications and will be withdrawn should the occasion arise.

## 1 Scope and field of application

This International Standard gives

— regulations relating to the construction and safety of certain centrifuges;

— a method of calculation of the tangential stress of cylindrical centrifuge rotors.

## 2 Field of application

**2.1** These construction and safety rules do not apply to the following centrifuges, which are expressly excluded from the field of application of this International Standard :

— centrifuges in which the kinetic energy of the loaded rotor is less than 750 J;

— centrifuges considered to be electric motor-driven domestic machines;

— centrifuges with a circumferential speed greater than 300 m/s;

— centrifuges used exclusively for the processing of atomic energy products.

**2.2** The method of calculation of tangential stress of cylindrical centrifuge rotors described in clause 5 is applicable to centrifuges having a cylindrical rotor of constant wall thickness, perforated or unperforated, having either a horizontal or a vertical axis of rotation, lined or unlined, with or without filter.

The method is applicable only to rotors constructed from ductile metallic materials, it having been assumed that in selection of the material due account has been taken of the possible effects of operating temperature on the properties of the material; it does not hold good for centrifuge rotors with a ratio of wall thickness to radius :

$$\frac{\delta}{r_2} > 0,1$$



It can be applied in an analogous manner to centrifuge rotors with holes which are not circular.

## 3 Definition

For the purpose of this International Standard, the following definition applies.

**3.1 centrifuge** : A machine designed for the separation of two liquid phases, or of one solid phase held in suspension in one or more liquids, or for the drying of solid products, by means of centrifugal force produced by the rotation of a rotor.

This rotor is commonly called a "basket" when its wall is perforated and a "bowl" when it is not perforated.

## 4 Construction and safety rules

### 4.1 Choice of materials of construction

**4.1.1** The choice of materials of construction will be guided by consideration of the mechanical stresses and fatigue properties.

**4.1.2** The materials used shall have appropriate properties for the intended application and shall take corrosion and abrasion into account.

**4.1.3** All parts of a centrifuge shall be constructed and assembled carefully in accordance with good engineering practice.

## 4.2 Casing

**4.2.1** All centrifuges shall be equipped with a fixed casing mounted either on the machine frame or on the machine foundations.

**4.2.2** The dimensions of the casing and the materials for the construction shall be chosen so as to reduce the risk of injury in the event of fracture of the rotor.

If the casing is constructed from several component parts, the method of construction shall be such as to require the use of a tool for their dismantling.

### 4.2.3 Protection against risks of contact of the operator with the moving rotor under normal working conditions

**4.2.3.1** All openings in the casing shall be designed or protected in such a way that access to the rotor is impossible while it is turning under normal working conditions of the centrifuge.

Openings are classified into three types :

a) Those which by design are closed or protected during normal working, such as inlet and outlet pipes, inspection windows, access points in the casing for maintenance or cleaning purposes. These openings shall be considered as giving efficient protection if a tool is necessary to open them or if their design makes access to the rotor impossible while it is turning under normal working conditions of the centrifuge.

b) Those (covers) which must be opened for cleaning the centrifuge, for example peelers, decanters, etc. Such casing covers shall be arranged so as to prevent the starting of the centrifuge while the cover is open.

c) Those (covers) which may be opened during normal operation for loading and discharging the centrifuge. These will be referred to as "opening devices" and the requirements of 4.2.3.2 and 4.2.3.3 will apply to them.

**4.2.3.2** When protection is obtained by means of "opening devices" as defined in 4.2.3.1 c), each "opening device" shall comply with the following conditions :

a) it shall be equipped with a locking system arranged to prevent any starting of the centrifuge until the "opening device" has been closed and it shall not be possible to open the "opening device" whilst the rotor is in motion;

b) it shall be strong enough to prevent the ejection from the centrifuge of process products for which it has been designed.

**4.2.3.3** The locking system of the "opening devices" of the casing shall be designed and constructed to prevent access to the moving rotor in the event of failure or loss of electric power or pneumatic pressure.

## 4.3 Rotor

**4.3.1** If the basket or bowl has a cover (or lid), a safety system shall be provided which will prevent the centrifuge being started until the cover has been locked.

**4.3.2** If necessary, an efficient system shall be provided which will prevent excessive swinging of the rotor.

Provision shall be made for the installation of a device to detect vibration or swinging.

**4.3.3** The rim of the rotor shall be so constructed that personnel are not exposed to risk of injury by manual turning of the rotor.

**4.3.4** Calculation, construction and assembly of the rotor shall be such as to withstand all stresses which may result from the normal use of the centrifuge for the purpose intended by the manufacturer. Calculation of rotor stresses shall be made in accordance with the method specified in clause 5 whenever this method is applicable.

## 4.4 Devices for isolating the power supply — Braking system

**4.4.1** In cases when the centrifuge is delivered with its power supply equipment, means for isolating the power supply shall be provided.



When the centrifuge is installed it shall be possible to lock the isolating device in such a position that the machine cannot be operated.



**4.4.2** When a centrifuge is equipped with a braking device, it shall be designed and constructed so that its action does not give rise to excessive stresses in the moving parts of the centrifuge.

## 4.5 Speed

In cases when the centrifuge is equipped with a motor capable of driving the rotor beyond the permissible speed, it shall be equipped with a governing device which will prevent the permissible speed being exceeded.

## 4.6 Drive

**4.6.1** All moving parts of the drive and transmission shall be fitted with guards to prevent access while the rotor is turning under the normal working conditions of the centrifuge.

**4.6.2** The starting device shall be designed or protected to prevent the inadvertent starting of the centrifuge in case of accidental contact or shock.

## 4.7 Electrical equipment

All electrical equipment and circuits shall conform to the standards in force and take account of any specific risks which may be present (for example dampness, explosion risk, fire risk, etc.).

Equipment and circuits shall also comply with legislation in force relating to the protection and safety of workers.

### 4.8 Special safety measures

**4.8.1** Where the plough is designed to be used at a speed below the permissible speed of the rotor, an interlock shall be incorporated to prevent the use of the plough if the rotor speed exceeds the designed ploughing speed.

**4.8.2** The design of centrifuges intended for use under specified conditions of pressure, temperature or with dangerous atmospheres shall incorporate appropriate devices for control and ventilation.

**4.8.3** The design of centrifuges intended for use in places where risks of explosion exist or for processing of explosive substances or substances which might produce explosive mixtures shall incorporate the following safety measures :

a) to avoid the generation of sparks of mechanical or electrical origin (including electrostatic sparks) and to prevent impact and dangerous friction;

b) to ensure that, under normal working conditions as defined by the purchaser, no parts of the centrifuge will reach dangerous temperatures, as stated by the purchaser.



### 4.9 Nameplates

**4.9.1** Each centrifuge shall be fitted by the manufacturer with a nameplate bearing at least the following clearly legible information :



a) name of manufacturer;

b) identification number of machine;

c) year of manufacture;

d) maximum rotational frequency, in revolutions per minute (r/min);

e) maximum load, in kilograms, or maximum density of product, in kilograms per cubic decimetre (kg/dm$^3$).

**4.9.2** The direction of rotation of the rotor shall be clearly indicated on the centrifuge by means of an arrow.

**4.9.3** Each rotor should be marked preferably with an identification number for technical verification purposes.

### 4.10 Instruction manual

A manual shall be supplied with each machine giving precise instructions for the operation, installation, maintenance and use of the centrifuge and its protective devices.

The manufacturer shall supply drawings and sketches necessary for the maintenance and technical verification of the centrifuge, and all its ancillary parts, supplied by him.

### 4.11 Exclusions

**4.11.1** Notwithstanding the provisions of 4.2.3.2, in cases where the process requires visual examination of the centrifuged product whilst the centrifuge is in motion without interposition of a window, a direct opening may be used.

Such opening shall nevertheless give adequate protection; in particular, the operator shall not be able to gain access to the moving part with his hands.

**4.11.2** Compliance with 4.2.3.3 is not required for centrifuges dealing with explosive products or when/and if the process requires it, providing that other measures are taken to maintain an equivalent degree of safety.

## 5 Method for the calculation and the verification of the tangential stress in the shell of a cylindrical centrifuge rotor

### 5.1 Symbols used

| Symbols | Designation | Units |
|---|---|---|
| $b_1$, $b_2$ | Centre distances between adjacent perforations | mm |
| $d$ | Diameter of holes (perforations) | mm |
| $G$ | Maximum permissible mass of contents at maximum speed of rotation | kg |
| $h$ | Internal height of rotor | mm |
| $k_1$, $k_2$ | Coefficients for welded joints | |
| $k_3$, $k_4$, $k_5$ | Coefficients for shell perforations | |
| $n$ | Number of rows of holes in the axial direction | |
| $q$ | Coefficient of reduction of the apparent density of the rotor due to perforations | |
| $r_1$ | Internal radius of rotor | mm |
| $r_2$ | Mean radius of shell | mm |
| $r_3$ | Internal radius of load | mm |
| $\delta$ | Wall thickness of shell | mm |
| $z$ | Coefficient to allow for reinforcing rings (hoops) | |
| $\alpha$ | Angle between lines connecting staggered holes | degrees |
| $\varrho_1$ | Density of shell | kg/dm$^3$ |
| $\varrho_2$ | Density of contents or of wet cake (maximum value) | kg/dm$^3$ |
| $\sigma_1$ | Tangential stress in shell due to rotation of the empty rotor | N/mm$^2$ |
| $\sigma_2$ | Tangential stress in shell due to centrifugal force of homogeneous contents | N/mm$^2$ |
| $\sigma_3$ | Tangential stress in shell due to centrifugal force of non-homogeneous contents | N/mm$^2$ |
| $\sigma_R$ | Ultimate tensile strength | N/mm$^2$ |
| $R_e$ | Yield point for steel with marked yield points | N/mm$^2$ |
| $R_{0,002}$ | 0,2 % proof stress for steel without marked points | N/mm$^2$ |
| $R_{0,01}$ | 1,0 % proof stress for austenitic steel | N/mm$^2$ |
| $\sigma_t$ | Sum of tangential stresses in the rotor shell | N/mm$^2$ |
| $\omega$ | Permissible angular velocity | rad/s |



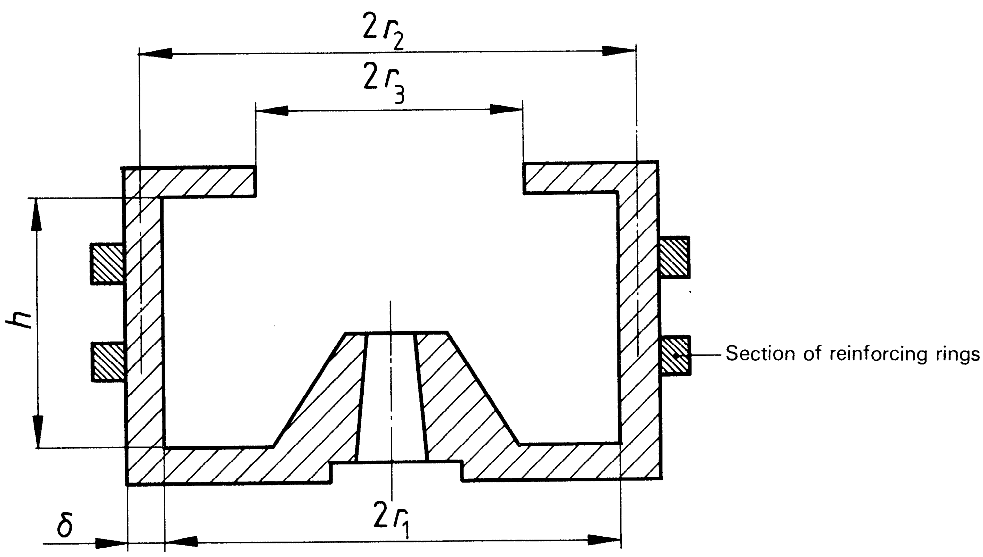


Figure 1

### 5.2 Tangential stresses in the shell of the rotating rotor

#### 5.2.1 Tangential stresses in the shell of the empty drum

$$\sigma_1 = 10^{-9}\, q \varrho_1 \omega^2 r_2^2$$

In order to allow for the reduced density of the shell due to the perforation, the coefficient $q$ (see 5.3.2.3) may be inserted.

#### 5.2.2 Tangential stress due to centrifugal force of the load

**5.2.2.1** In the case of lined rotors, the load shall be increased by the mass of the lining. Allowance shall also be made for filters, etc.

**5.2.2.2** On loading with material with homogeneous mass distribution (for example liquids), the stress in the rotor shell is as follows :

$$\sigma_2 = 10^{-9} \varrho_2 \omega^2 \left( \frac{r_1^2 - r_3^2}{2} \right) \frac{r_1}{\delta}$$

**5.2.2.3** On loading with material having heterogeneous mass distribution (e.g. textiles, furs), the stress in the rotor shell is as follows :

$$\sigma_3 = 10^{-3} \frac{\omega^2 G}{\pi} \cdot \frac{1}{3h\delta} \left( \frac{r_1^3 - r_3^3}{r_1^2 - r_3^2} \right)$$



### 5.3 Coefficients

#### 5.3.1 Coefficient to allow for reinforcing rings

Reinforcing rings may be used. If reinforcing rings are used, their effect on the strength of the rotor shall be taken into account in calculation of the tangential stress according to generally recognized technical rules. A coefficient ($z$) can then be defined.

#### 5.3.2 Coefficients to allow for welded joints and perforations

**5.3.2.1** The smallest of the following five coefficients $k$ must be used in the calculations.

**5.3.2.2** Coefficients to allow for welded joints

On the assumption that the mechanical properties of the welded joints correspond to those of the material used for the main construction, the following coefficients can be introduced to allow for the effect of the welded joints :

a) Coefficient for untested welded joints :

$$k_1 = 0{,}8$$

b) Coefficient for welded joints, subjected to 100 % radiographic inspection or other test method recognized as equivalent :

$$k_2 = 0{,}95$$

The results of non-destructive tests of welded joints shall give no cause for objections.

If a higher welding coefficient is used, an appropriate test procedure shall be established.

**5.3.2.3** Coefficient to allow for perforations

**5.3.2.3.1** In the coefficients to allow for weakening due to perforations, no allowance has been made for the stress concentration at the edges of the holes.

No perforations shall be made in the region of the welded joint.

If this cannot be avoided, then the smallest of the coefficients $k_3$, $k_4$, $k_5$ shall be multiplied by the coefficient for welded joints.

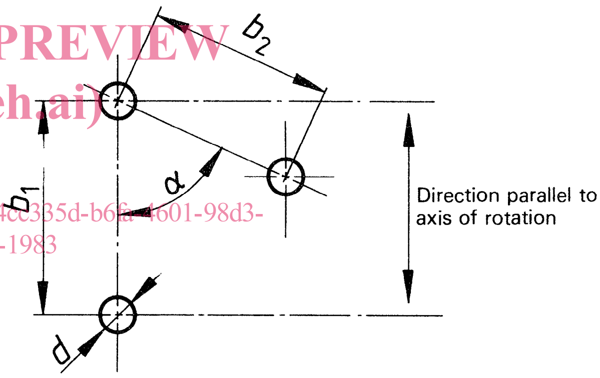


Figure 2

**5.3.2.3.2** In the case of uniformly distributed perforations of the shell the smaller of the following values of $k$ shall be used (see figure 2)

$$k_3 = \frac{b_1 - d}{b_1}$$

or

$$k_4 = \frac{b_2 - d}{b_2} \nu$$

The value

$\nu = \dfrac{1 + \mathrm{tg}^2 \alpha}{\sqrt{1 + 3\,\mathrm{tg}^2 \alpha}}$ may be obtained as a function of the angle $\alpha$ by the curve in figure 3.

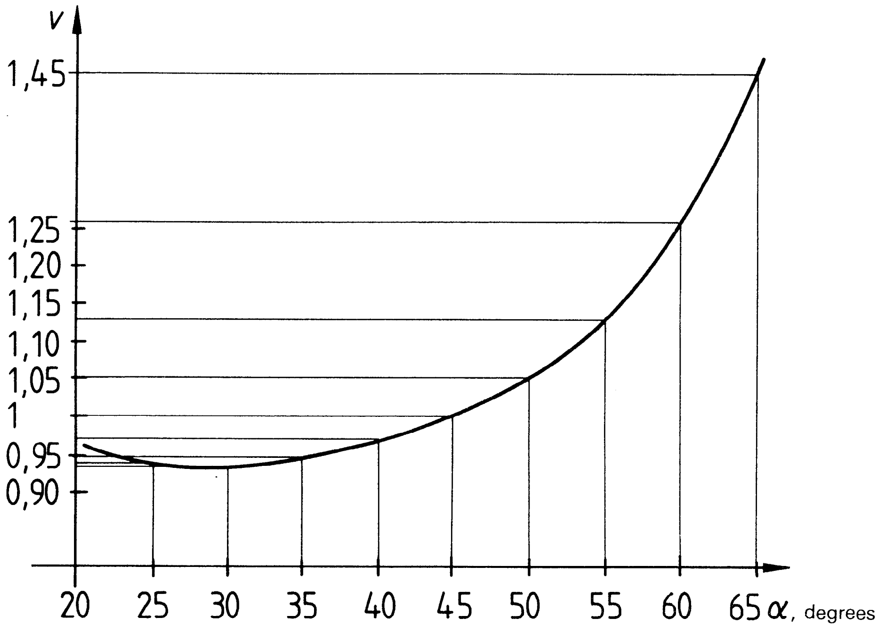


Figure 3



**5.3.2.3.3** From a single row of perforations and for a row close to the bottom of the rotor and/or to the lip ring, the following coefficient shall be determined :

$$k_5 = \frac{h - nd}{h}$$

### 5.3.3 Coefficient of reduction of the apparent density of the shell due to perforations

$$q = 1 - \frac{\pi d^2}{4 b_1 b_2 \sin \alpha}$$

## 5.4 Determination of strength of the rotor

### 5.4.1 Summation of tangential stresses

**5.4.1.1** On filling with a load having homogeneous mass distribution (such as liquids) :

$$\sigma_t = (\sigma_1 + \sigma_2) \frac{1}{k}$$

that is, using the density of the load

$$\sigma_t = \frac{\omega^2}{10^9 k} \left[ q \varrho_1 r_2^2 + \varrho_2 \left( \frac{r_1^2 - r_3^2}{2} \right) \frac{r_1}{z\delta} \right]$$

or using the mass of the load

$$\sigma_t = \frac{\omega^2}{10^9 k} \left( q \varrho_1 r_2^2 + \frac{10^6 G}{2 \pi h} \cdot \frac{r_1}{z\delta} \right)$$

**5.4.1.2** On filling with a load of heterogeneous material (for example textiles, furs) :

$$\sigma_t = (\sigma_1 + \sigma_3) \frac{1}{k}$$

that is, using the mass of the load

$$\sigma_t = \frac{\omega^2}{10^9 k} \left[ q \varrho_1 r_2^2 + \frac{10^6 G}{3 \pi h} \left( \frac{r_1^3 - r_3^3}{r_1^2 - r_3^2} \right) \frac{1}{z\delta} \right]$$

### 5.4.2 Comparison with the permitted tangential stress

Due to factors which have not been considered in this International Standard, in particular stress concentrations which can exist in the areas joining shell and base and top, the calculated tangential stress shall not exceed the lesser of the two following values for permissible tangential stress :

$$\sigma_t \leqslant 0{,}5 R_e \text{ and } \sigma_t \leqslant 0{,}33 \sigma_R$$

If this condition is met, the strength of the rotor shell satisfies the requirements of this International Standard.