TECHNICAL REPORT

ISO TR 10064-3

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Cylindrical gears — Code of inspection practice —

Part 3:
Recommendations relative to gear blanks, shaft centre distance and parallelism of axes

Engrenages cylindriques — Code pratique de réception —

Partie 3: Recommandations relatives aux roues brutes, à l'entraxe et au parallélisme des axes

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Contents

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established 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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

– type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

– type 2, when the subject is still under technical development or where for any other reason there is a future but not immediate possibility of an agreement on an International Standard;

– type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 10064-3, which is a Technical Report of type 3, was prepared by Technical Committee ISO/TC 60, *Gears*.

ISO 10064 consists of the following parts, under the general title *Cylindrical gears - Code of inspection practice*:

- *Part 1: Inspection of corresponding flanks of gear teeth*
- *Part 2: Inspection related to radial composite deviations, runout, tooth thickness and backlash*
- *Part 3: Recommendations relative to gear blanks, shaft centre distance and parallelism of axes*
- *Part 4: Recommendations relative to surface roughness and tooth contact pattern checking.*

Annex A of this part of ISO 10064 is for information only.

Introduction

In the course of revising ISO 1328:1975, it was agreed that the descriptions and numerical values relative to the inspection of gear blanks, shaft centre distance and parallelism of axes should be published under separate cover as a Technical Report, type 3. For the general replacement of ISO 1328:1975, a system of documents as listed in clause 2 (References) and annex A (Bibliography), together with this Technical Report, has been established.

Cylindrical gears - Code of inspection practice

Part 3: Recommendations relative to gear blanks, shaft centre distance and parallelism of axes

1 Scope

This technical report provides recommended values for dimensional deviations on blanks, centre distance and parallelism of axes of gears.

Numerical values given in this document are not to be regarded as strict ISO quality criteria, but may serve as a guide for mutual agreements, for steel or iron components.

2 References

The following standards contain provisions which are referenced in the text of this International Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent editions of the standards indicated.

ISO 53: 1974 *Cylindrical gears for general and heavy engineering - Basic rack.*

ISO 54: 1996 *Cylindrical gears for general engineering and for heavy engineering - Modules.*

ISO 286-1:1988 *ISO system of limits and fits - Part 1: Bases of tolerances, deviations and fits.*

ISO 1328-1:1995 *Cylindrical gears - ISO System of accuracy - Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth.*

ISO 1328-2:1996 *Cylindrical gears - ISO System of accuracy - Definitions and allowable values of deviations relevant to radial composite deviations and runout information.*

3 Symbols and definitions

3.1 Symbols

Symbols used for deviations of individual element measurements are composed of lower case letters, such as "*f* ", with subscripts, whereas symbols used for "total" deviations, which may represent combinations of several individual element deviations are composed of capital letters, such as "*F* ", also with subscripts, see table 1.

Table 1 - Symbols and terms

a	centre distance	mm
b	face width	mm
D_d	diameter of datum surface	mm
D_f	diameter of mounting face	mm
$f_{\Sigma\delta}$	shaft parallelism in-plane deviation	µm
$f_{\Sigma\beta}$	shaft parallelism out-of-plane deviation	µm
F_β	total helix deviation of gear teeth	µm
F_p	total cumulative pitch deviation of gear teeth	µm
L	larger shaft bearing span distance	mm
n	the number of links in a tolerance chain	

3.2 Definitions

3.2.1 Fuctional mounting surfaces are the surfaces which are to be used to mount the gear.

3.2.2 The **functional axis** of the gear is the axis about which the gear rotates in service and is defined by the centres of the functional mounting surfaces. The functional axis is one which is only meaningful when a complete assembly is being considered.

3.2.3 The **datum surfaces** are those used to define the datum axis.

3.2.4 The **datum axis** of the gear is defined by the centres of the datum surfaces. It is the axis to which the gear details, and in particular the pitch, profile, and helix tolerances are defined.

3.2.5 The **manufacturing mounting surfaces** are surfaces which are to be used to mount the gear during manufacture or inspection.

4 Accuracy of gear blanks

This clause is concerned with the selection and adequate specification of the datum axis, the datum surfaces which define it, and other associated datum surfaces.

The numerical values of the parameters associated with gear tooth accuracy (profile deviation, adjacent pitch deviation, etc.) are only meaningful relative to a particular axis of rotation. If the axis about which the gear is rotated during measurement is changed, then the measured value of these parameters will change. It follows that the gear drawing must define an axis which is to act as the datum axis for the specified tooth tolerances, and, in fact, for the gear geometry as a whole.

Gear blank dimensional deviations and gear housing dimensional deviations can have a strong effect on the contact conditions and operation of the gear pair. Since it is usually more economical to manufacture blanks and housings to tight tolerances than to manufacture gear teeth to high accuracy, consideration should be given to holding gear blank and housing tolerances to minimum values, consistent with the manufacturing facilities available. This practice allows the gears to be made to less exact tolerances and usually produces the most economical overall design.

4.1 Relationship between datum and functional axes

The datum axis is the one which will be used by the manufacturer (and inspector) to define the geometry of the gear teeth on an individual component. It is the responsibility of the designer to ensure that the datum axis is defined with sufficient clarity and precision to ensure that the requirements of the gear in relation to the functional axis are met.

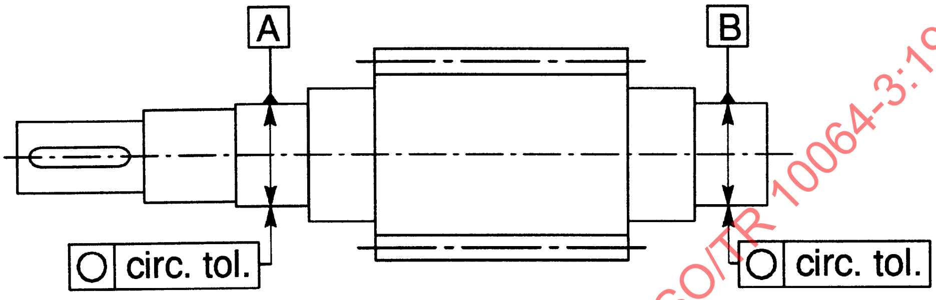
Very often this can be conveniently achieved by defining the datum axis in such a way that it coincides with the functional axis by using the mounting surfaces as the datum surfaces.

In general, however, it will be necessary to define a datum axis and then to relate all other axes (including the functional axis and possibly some manufacturing axes) to it by appropriate tolerances. In this case, due consideration must be given to the effect of the additional link in the tolerance chain.

4.2 Methods of defining datum axes

The datum axis of a component is defined by means of datum surfaces. There are three basic methods of doing this:

4.2.1 Method 1 Two points on the axis are defined as the centres of specified circles on two 'short' cylindrical or conical datum surfaces, as in figure 1.



Note – A and B are intended as bearing mounting surfaces

Figure 1 - Datum axis defined by two "short" datum surfaces

4.2.2 Method 2 The position and direction of the axis are both defined by one 'long' cylindrical or conical surface, as in figure 2. The axis of the bore can be adequately represented by the axis of a mating work arbor, properly fitted.

4.2.3 Method 3 The axis position is defined by the centre of a circle on a short cylindrical datum and its direction by a datum end face perpendicular to the axis, as in figure 3.

If Method 1 or 3 is used, the cylindrical or conical datum surfaces must be axially short so that they do not themselves each define a *separate* axis. For Method 3, the diameter of the datum end face should be as large as possible.

A shaft with an integral pinion will often have a section on which a gear wheel will be mounted. The tolerances of the mounting surface should be selected appropriate to the quality requirements of the gear wheel.

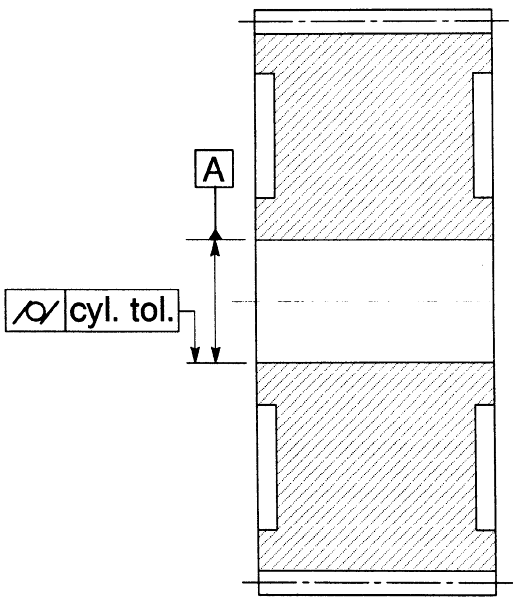


Figure 2 - Datum axis defined by one "long" datum surface

4.3 Use of centre holes

A common (and satisfactory) method of dealing with gears which are integral with a shaft is to mount the component between centres during manufacture and inspection. In this case the centre holes define the datum axis. Both the gear tolerances and the mounting (bearing) surface tolerances need to be specified relative to this axis (see figure 4) and clearly there needs to be a tight tolerance on the runout of the mounting surfaces relative to the centre holes; see 4.6.

Proper care should be given in alignment of the contacting angles, i.e. 60° inclusive.

4.4 Datum surface form tolerances

The required accuracy of the datum surfaces depends on:

- the specified gear accuracy; these surfaces should be defined to limits significantly tighter than those of the individual gear teeth;

- the relative positions of the surfaces; in general, the greater the distance spanned, in proportion to the reference diameter of the teeth, the more relaxed can be the tolerance.

The accuracy of the surfaces must be specified on the component drawings.

The form tolerances on all datum surfaces should not exceed the values specified in table 2. The tolerance should be reduced to the minimum.

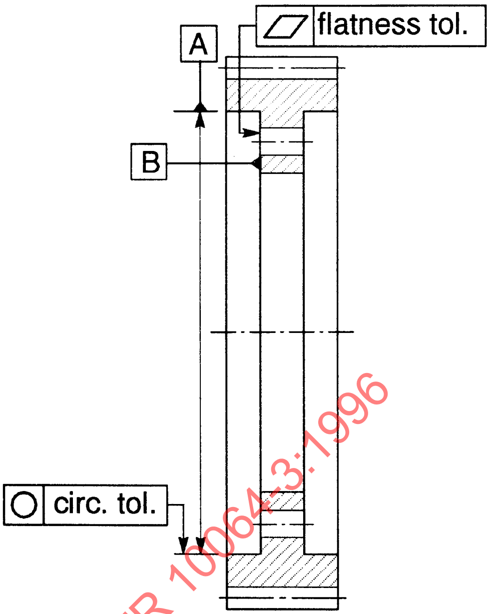


Figure 3 - Datum axis defined by one cylindrical surface and one end-face

4.5 Form tolerances of functional and manufacturing mounting surfaces

The form tolerances of the functional mounting surfaces should not exceed the values specified in table 2. When separate manufacturing mounting surfaces are used, similar limits will need to be applied.

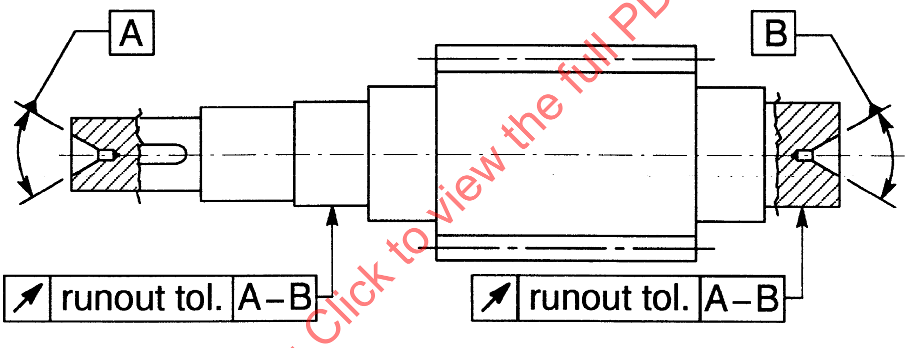


Figure 4 - Datum axis defined by centre holes

4.6 Runout tolerances of functional axis

This clause is not relevant if the functional mounting surfaces have been chosen as the datum surfaces. When the datum axis does not coincide with the functional axis then the runout(s) of the functional mounting surface(s) relative to the datum axis must be controlled on the drawing. The runout tolerances should not exceed the values specified in table 3.

4.7 Mounting surfaces used during gear cutting and inspection

To manufacture the teeth to the tolerances specified and measure their resulting deviations with sufficient accuracy, it is essential to mount the gear for both manufacture and inspection so that its actual axis of rotation during both processes corresponds as closely as possible to the datum axis defined on the gear drawing.

Unless the surfaces which are to be used to mount the gear during manufacture or inspection are those used as datums for the datum axis, then these too must be controlled relative to the datum axis. The values shown in table 3 are appropriate for use as tolerances for these surfaces. For maximum precision, a "highspot" giving the position and amount of the high point of runout can be marked near to datum surfaces and duplicated as appropriate at each step in the manufacture of high quality gears.

When strict process control during manufacturing of the gear blank, accurate expanding mandrels for centering the blank, a fixture for supporting the blank with appropriately limited runout and a high quality gear cutting machine are used, the position of the gear blank on the gear cutting machine has to be checked only for the first gear of a series. This procedure is typically used in mass production of gears on gear cutting machines.

For high quality gears, special datum surfaces have to be provided (see figure 5). For very high quality gears, the gear has to be mounted on the shaft, in which case the shaft journals can be used as datum surfaces.

Table 2 - Form tolerances for datum and mounting surfaces

Axis defined by	Tolerance feature		
	Circularity	**Cylindricity**	**Flatness**
Two 'short' cylindrical or conical datum surfaces	0,04 $(L/b)\ F_\beta$ or 0,1 F_p whichever is least		
One long cylindrical or conical datum surface		0,04 $(L/b)\ F_\beta$ or 0,1 F_p whichever is least	
One short cylindrical and one end-face	0,06 F_p		0,06 $(D_d /b)\ F_\beta$
Note: The gear blank tolerances should be reduced to the minimum which can be economically manufactured.			

Table 3 - Tolerances on runout of mounting surfaces

Axis defined by	Runout (total indicated range)	
	Radial	**Axial**
Cylindrical or conical datum surface only	0,15 $(L/b)\ F_\beta$ or 0,3 F_p (whichever is greater)	-
One cylindrical datum surface and one end datum face	0,3 F_p	0,2 $(D_d /b)\ F_\beta$
Note: The gear blank tolerances should be reduced to the minimum which can be economically manufactured.		

4.8 Tip cylinder

The tolerance on the tip diameter should be chosen by the designer to ensure that the minimum design contact ratio is achieved together with adequate bottom clearance. If the tip cylinder of the blank is to be used as a datum surface, however, whilst the above value may still be applied as a size tolerance, the form tolerance should not exceed the appropriate value from table 2.

4.9 Tolerance build up

The tolerances of table 3 are applicable when the functional axis coincides with the datum axis or can be toleranced directly from it. When this is not the case, then a tolerance chain exists between the two. It will then be necessary to reduce the individual tolerances to values smaller than those given in the tables 2 and 3. The degree of reduction will depend on the specific arrangement, but in general will be approximately proportional to the square root of n, where n is the number of links in the chain.

For gears of the highest accuracy (for example, ISO 1328, Part 1, accuracy grade 4 or better), it will normally be necessary to assemble the gears on their shafts before finishing the teeth. However, where this is not possible, the use of runout measurements on datum surfaces after assembly may be used to demonstrate that the required overall gear accuracy is actually being achieved. This measurement detects errors caused not only by the combined runout of all the functional gear mounting surfaces, but also those caused by runout of any bearing rings fitted to the shaft.

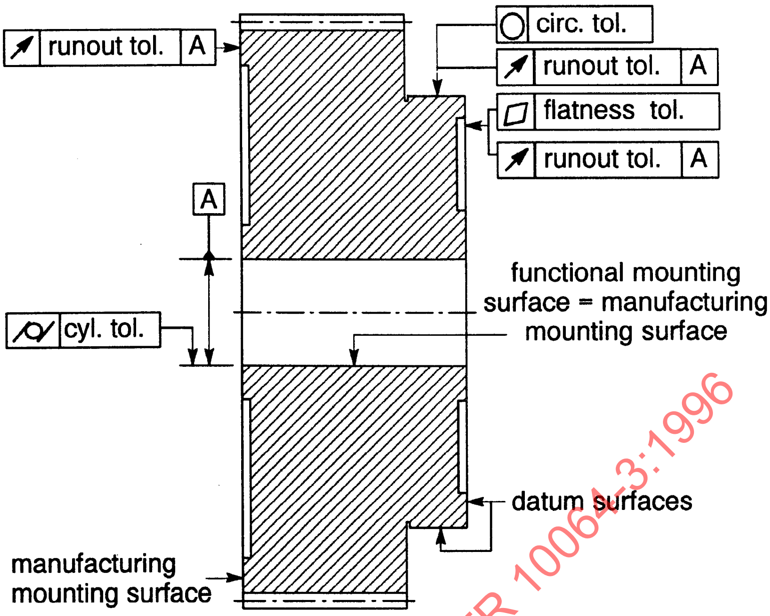


Figure 5 - High quality gear with datum surfaces

4.10 Mounting surfaces for other gears

A shaft with an integral pinion will often have a section on which a gear wheel is to be mounted. The tolerances of the mounting surface should be selected by proper consideration of the quality requirements of the teeth of the wheel to be mounted on it. It will usually be appropriate to specify allowable runouts relative to the already defined datum axis.

4.11 Datum surfaces

Datum surfaces are reference bands (axial and radial) that are machined true with the actual bore, journals and shoulders of gear blanks (see figure 5).

These can be checked while mounted on the machine that finishes the teeth, while mounted on the inspection machine or while mounted in the final application. For even more accurate work, the datum surfaces are checked and marked for the amount and location of the high point of runout. This high point and amount are duplicated at every step in the process to control very high quality gears.

Many gear applications are, however, produced in small quantities. In this case the position of the gear on the gear cutting machine has to be checked before machining. Whether every blank or some portion has to be checked depends upon the experience of the gear manufacturer. For medium accuracy grade gears part of the tip cylinder can be used as a radial datum surface, while the axial position can be checked using the mounting face for gear cutting.

5 Centre distance and parallelism of axes

The gear designer has to select the proper tolerances for deviations in both the centre distance, *a*, and the parallelism of axes. Tolerances should be chosen so as to ensure that backlash and alignment of the meshing gear teeth are in accordance with the application requirements. Provision for the assembly adjustment of bearing position may offer what is probably the most effective technical solution to the demands of high accuracy. However, the costs may in many instances be unacceptably high.

5.1 Centre distance allowances

The centre distance tolerance is the allowable deviation specified by the designer. The nominal centre distance is determined by considerations of minimum backlash and interference between the tips of the teeth of each gear member with the non-involute profile at the root of its mate.

In the case where the gears carry load in only one direction, with infrequent reversals, the control of maximum backlash is not a critical consideration and the allowance in centre distance can be governed by consideration of contact ratio.

When backlash must be closely controlled, as in motion control gears, or when the load on the teeth reverses, the tolerance for centre distance must be carefully studied, taking into account the effect of:

- deflections of shafts, housings and bearings;
- misalignment of gear axes due to housing deviations and bearing clearances;
- skew of gear axes due to housing deviations and bearing clearances;
- mounting errors;
- bearing runouts;
- temperature effects (a function of temperature difference between housing and gear elements, centre distance and material difference);
- centrifugal growth of rotating elements;
- other factors, such as allowance for contamination of lubricant and swelling of non-metallic gear materials.

The recommendations in ISO TR 10064-2 with regard to tooth thickness tolerances and backlash should be followed when deciding on the tolerance for all dimensions which affect the deviation in backlash.

The selection of centre distance tolerance for high speed drives involves other considerations which are beyond the scope of this report.

In the case of gear transmissions in which one gear drives several other gear pairs (or vice versa); e.g., in the case of epicyclic gear transmissions with several planet gears, or in the case of transfer gear boxes or power take-off gears, it may be necessary to restrict the shaft centre distance allowances in order to achieve proper load sharing and correct operating conditions in all of the meshes. These conditions require detailed study of operating and manufacturing restraints which are beyond the scope of this report.

5.2 Shaft parallelism tolerances

Since the effect of a shaft parallelism deviation depends on its vectorial direction, different specifications have been established for the "in-plane deviation" $f_{\Sigma\delta}$ and for the "out-of-plane deviation" $f_{\Sigma\beta}$ (see figure 6).

The "in-plane deviation" $f_{\Sigma\delta}$ is measured in the common plane of axes, defined by using the longer of the two bearing spans L and one of the bearings on the other shaft. If the bearing spans are the same, use the pinion shaft and a wheel bearing. The "out-of-plane deviation" $f_{\Sigma\beta}$ is measured in the "skew plane" which is perpendicular to the common plane of axes.

Each of these parallelism deviations is expressed as a length referred to the distance L between the bearings of the relevant axis ("bearing centre distance" L). See figure 6.

Shaft in-plane deviation relates to helical misalignment as a function of the sine of the operating pressure angle, and shaft out-of-plane deviation as a function of the cosine of the operating pressure angle. Thus mesh misalignment due to a given amount of out-of-plane deviation will be from two to three times as large as the mesh misalignment due to a similar amount of in-plane deviation. Therefore different recommended maximum values have been established for the two deviation elements.

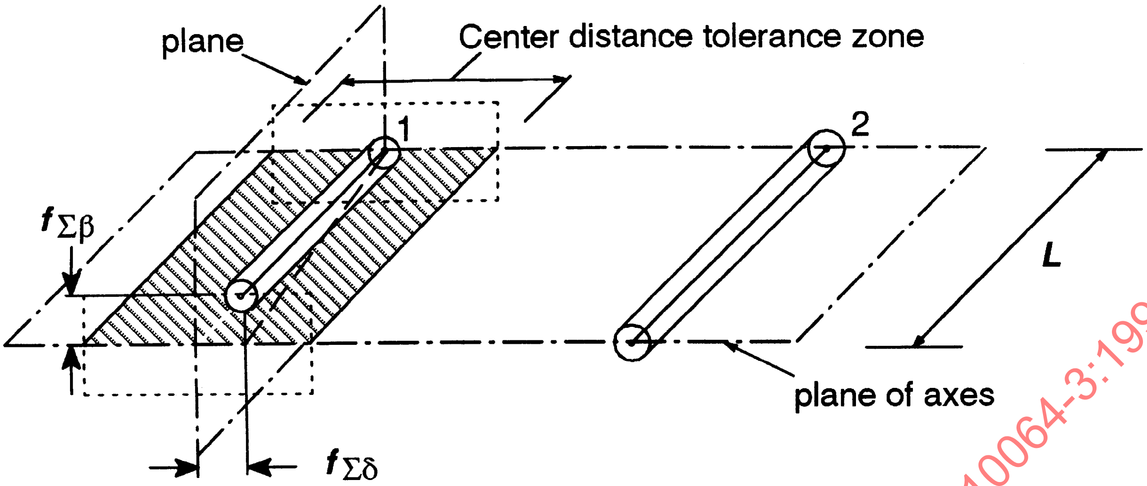


Figure 6 - Shaft parallelism deviations

5.3 Recommended maximum values for shaft deviation

a) Recommended maximum value for shaft out-of-plane deviation $f_{\Sigma\beta}$ is:

$$f_{\Sigma\beta} = 0,5\left(\frac{L}{b}\right) F_\beta \quad \text{...(1)}$$

a) Recommended maximum value for shaft in-plane deviation $f_{\Sigma\delta}$ is:

$$f_{\Sigma\delta} = 2 f_{\Sigma\beta} \quad \text{...(2)}$$