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Estimation of tooth bending strength of
cylindrical plastic gears

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Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by Japan Gear Manufacturers Association (JGMA)/Japanese Standards Association (JSA) with a draft being attached, based on the provision of Article 12, paragraph (1) of the Industrial Standardization Act applied mutatis mutandis pursuant to the provision of Article 16 of the said Act. This edition replaces the previous edition (**JIS B 1759:2013**), which has been technically revised.

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Estimation of tooth bending strength of cylindrical plastic gears

1 Scope

This Japanese Industrial Standard stipulates the method for estimating the strength exhibited by plastic materials against bending fatigue breakage at the dedendum when they are used for cylindrical gears (hereafter referred to as the gears) that constitute a paralleled gear pair. No corresponding International Standard has been established at this point. Evaluation is made by obtaining the allowable bending stress of the gear materials based on results of an operation test of an external gear pair.

It also stipulates the safety evaluation methods using the nominal tangential forces assumed for gears made of plastic materials for which the allowable bending stress has already been obtained based on the evaluation method of this Standard. Safety evaluation is performed by comparing the dedendum bending stress obtained from the nominal tangential force and the allowable dedendum stress obtained from the allowable bending stress of the material. Safety evaluation can be applied to not only external gear pair but also to internal gear pair.

This Standard is applicable to plastic gears and steel gears having the specifications given in a) to l), or to external gear pairs and internal gear pairs consisting only of plastic gears.

Items j) to l) are matters requiring special attention.

- a) Normal module : $\geq 0.5 \text{ mm}$ and $\leq 2.0 \text{ mm}$
- b) Reference diameter : $\leq 100 \text{ mm}$
- c) Pressure angle : $\geq 14.5^\circ$ and $\leq 25^\circ$
- d) Helix angle : $\leq 25^\circ$
- e) Transverse contact ratio : > 1.0 and < 2.0
- f) Facewidth : $\leq 25 \text{ mm}$
- g) Gear precision : conforming to the precision class stipulated by **JIS B 1702-3**
- h) Tooth profile : in accordance with the provision in **JIS B 1701-1**; alternatively, other tooth profile [refer to c) above] than given in the said standard as for normal pressure angle or other dedendum fillet shapes than those created by the basic rack.
- i) Others : gear pairs without any contact issues, which consist of gears without natural undercut or sharp tooth tip, and are assembled with a centre distance with no dedendum

interference but appropriate backlash, and machined plastic gear pairs apart from the injection-moulded plastic gears mainly covered by this Standard.

- j) This Standard can be applied to plastic materials in general, but only when damage mode in the operation test is dedendum fatigue failure.
- k) This Standard cannot be applied to cases of extreme friction involving a damage that occurs near the dedendum but may be of a different mode.
- l) This Standard can be applied to gears made of fibre-reinforced plastics, except where the strength of the fibre-reinforced plastics, which is dependent on the particular method of fibre reinforcement and the forming process used, is such that a crack can develop in areas other than the dedendum dangerous section (refer to 7.3.2) ^[1].

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS B 0102-1 *Vocabulary of gear terms — Part 1 : Definitions related to geometry*

JIS B 0121 *International gear notation — Symbols for geometrical data*

JIS B 1701-1 *Cylindrical gears for general and heavy engineering — Part 1 : Standard basic rack tooth profile*

JIS B 1702-1 *Cylindrical gears — ISO system of flank tolerance classification — Part 1 : Definitions and allowable values of deviations relevant to flanks of gear teeth*

JIS B 1702-3 *Cylindrical gears — The accuracy — Part 3 : Definitions and allowable values of deviations relevant to corresponding flanks of the gear teeth and radial composite deviations of injection molding plastic gears*

3 Terms and definitions

For the purpose of this Standard, the terms and definitions given in JIS B 0102-1, and the following apply.

3.1

test torque

load torque on a test gear controlled during an operation test

When using a power-absorption type operation test device, the load torque should be checked at appropriate intervals during the operation test so that it does not exceed the range specified in 5.2. When using a power-circulation type operation test device, the load torque may decrease during the operation test due to friction on the test gear

flanks; it is thus desirable that the operation test automatically stop when the load torque exceeds the range specified in 5.2.

3.2

rotation rate of test gear

rotation rate of a test gear controlled during an operation test

The rotation rate of the test gear should be checked at appropriate intervals during the operation test so that it does not exceed the range specified in 5.2.

3.3

test temperature

ambient temperature around a test gear controlled during an operation test

It is the controlled temperature of lubricant oil in the case of oil bath or drip-feed lubrication, and the controlled ambient temperature around the test gear in the case of lubrication with grease.

4 Symbols and units

For the purpose of this Standard, the symbols and units given in **JIS B 0121** and the following apply.

B_R	: backup ratio
b	: facewidth (mm)
d	: reference diameter (mm)
d_a	: tip diameter (mm)
d_{an}	: tip diameter of equivalent spur gear (mm)
d_{bn}	: base diameter of equivalent spur gear (mm)
d_{en}	: diameter of circle passing through the point on the tooth tip side of single flank mesh area of equivalent spur gear (mm)
d_n	: reference diameter of equivalent spur gear (mm)
d_{Na}	: effective tip diameter (mm)
d_w	: operating pitch circle diameter (mm)
E	: dimension showing the centre position of the radius of basic rack dedendum fillet (mm)
F_{wt}	: nominal tangential force (on operating pitch circle) (N)
G	: auxiliary coefficient to obtain dangerous section tooth thickness
H	: auxiliary angle to obtain dangerous section tooth thickness (rad)
h	: total tooth depth (mm)
h_{Fe}	: arm length of bending moment (mm)

h_{fp}	: dedendum for basic rack (mm)
L	: ratio between the dangerous section tooth thickness and arm length of bending moment
m_n	: normal module (mm)
n	: rotation rate (min^{-1})
P	: transmission power (W)
p_{bn}	: tooth normal pitch (mm)
q_s	: ratio between the dangerous section tooth thickness and rounding radius of dedendum fillet
R_c	: radius of basic rack dedendum fillet (mm)
S_F	: safety factor for bending strength
S_{Fmin}	: minimum safety factor
s_{Fn}	: dedendum dangerous section tooth thickness (mm)
s_R	: rim thickness (mm)
T	: torque (N·m)
v_w	: circumferential velocity on operating pitch circle (m/s)
x	: profile shift coefficient (the coefficient is positive when it results in a greater tooth thickness, for both external or internal gears) ^[2]
x_0	: profile shift coefficient of pinion-type cutter
Y_B	: rim thickness coefficient
Y_f	: dedendum shape coefficient
Y_F	: tooth profile coefficient
Y_L	: lubrication coefficient
Y_M	: mating gear coefficient
Y_{NT}	: life coefficient
Y_S	: stress correction coefficient
Y_β	: helix angle coefficient
$Y_{\Delta\Theta}$	: temperature increase coefficient
Y_Θ	: ambient temperature coefficient
z	: number of teeth (negative for interior gear) ^[2]
z_0	: number of teeth for pinion-type cutter
z_n	: number of teeth for equivalent spur gear
α_{en}	: pressure angle at the point on the tooth tip side of the single flank mesh area

- of equivalent spur gear ($^{\circ}$ for indication and rad for calculation)
- α_{Fen} : operating angle at the point on the tooth tip side of the single flank mesh area of equivalent spur gear ($^{\circ}$ for indication and rad for calculation) (refer to Figures 2 and 3).
- α_n : normal pressure angle ($^{\circ}$ for indication and rad for calculation)
- α_{wt} : transverse contact pressure angle ($^{\circ}$ for indication and rad for calculation)
- β : helix angle ($^{\circ}$ for indication and rad for calculation)
- β_b : base helix angle ($^{\circ}$ for indication and rad for calculation)
- γ_e : angle at the point on the tooth tip side of the single flank mesh area of equivalent spur gear ($^{\circ}$ for indication and rad for calculation)
- ε_{α} : transverse contact ratio
- $\varepsilon_{\alpha n}$: transverse contact ratio of equivalent spur gear
- ε_{β} : overlap ratio
- ε_{γ} : total contact ratio
- θ : test temperature ($^{\circ}\text{C}$)
- θ : generating angle of rack tool or pinion-type cutter at the dangerous section position of dedendum (rad)
- ρ_{fp} : radius of basic rack dedendum fillet (mm)
- ρ_{fpv} : edge radius of rack tool or pinion-type cutter (mm)
- ρ_F : rounding radius of dedendum fillet (mm)
- σ : standard deviation
- σ_F : dedendum bending stress (MPa)
- σ_{Flim} : allowable bending stress of gear material (MPa)
- σ_{FP} : allowable dedendum bending stress of gear (MPa)
- ω : angular velocity (rad/s)

5 Operation test method

5.1 General

The general requirements of operation test are as follows.

- a) The operation test of plastic gears shall be performed by operating the test gear at a constant rotation rate under a constant load until the test gear is damaged or until the number of contacts of the test gear reaches the cutoff value (standard value is 10^6).
- b) A power-absorption type gear operation test device shall normally be used; a power-circulation type device may be used provided the variation in load torque stays