

[1] involute  $\Sigma$  iii(spur and helical gear design system)

Option : ISO 6336(2006): INTERNATIONAL STANDARD

Calculation of load capacity of spur and helical gears

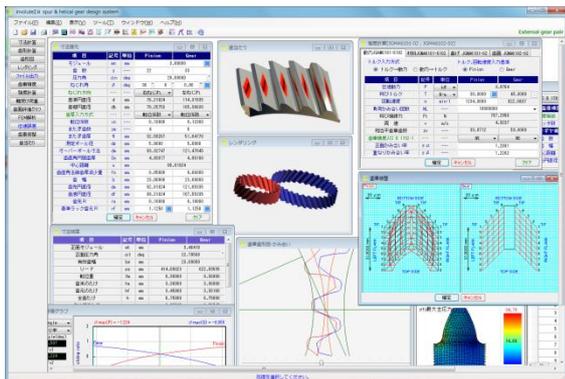


図 1.1 involute  $\Sigma$  iii(spur and helical)

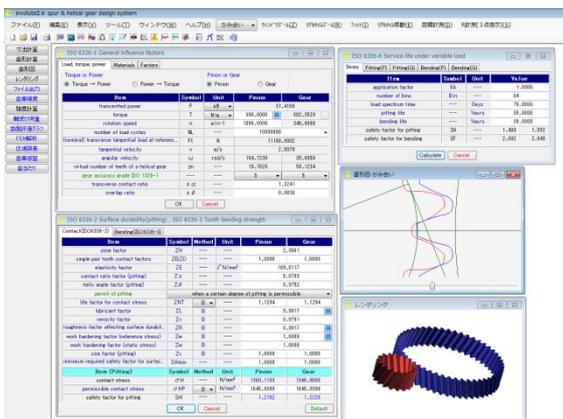


図 1.21.0 ISO 6336 強度結果

1.1 概要

involute  $\Sigma$  iii(spur and helical)に ISO 6336(2006)をオプションとして追加しました。 involute  $\Sigma$  iii(spur and helical)の構成は別途カタログをご覧ください。

1.2 プロパティ (基準ラック, 精度, 強度)

図 1.2~1.5 に設定画面を示します。

- ・ 歯車の組み合わせ : 外歯車×外歯車, 外歯車×内歯車
- ・ 基準ラック : 並歯, 低歯, 特殊
- ・ 歯先円決定の方式 : 標準方式, 等クリアランス方式
- ・ 鋼歯車の強度計算規格は, 図 100.3 に示すように

- ・ JGMA 401-02:1974, 402-02:1975
- ・ JGMA 6101-02:2007, 6102-02:2009
- ・ ISO 6336:2006

の 3 種類があり, プラスチック歯車の強度計算規格は, JIS B 1759(2013)に対応しています。



図 1.3 強度, ISO 6336 設定を追加

1.21 ISO 6336 規格

ISO 6336 の規格に基づいた計算例を以下に示します。

項目	記号	単位	Pinion	Gear
モジュール	m	mm	3.00000	
歯数	z	---	17	50
圧力角	$\alpha_n$	deg	20.00000	
ねじれ角	$\beta$	deg	18 ° 0' 0.00 "	
ねじれ方向	---	---	右ねじれ	左ねじれ
基準円直径	d	mm	51.00000	157.50000
基礎円直径	db	mm	50.08231	147.30093
歯厚入力方式	---	---	転位係数	転位係数
転位係数	xn	---	0.30000	-0.25000
またぎ歯数	zm	---	3	6
またぎ歯厚	w	mm	23.58072	50.62097
測定ボール径	dp	mm	5.8169	4.9348
オーバボール寸法	dm	mm	63.30911	162.87024
歯角円弧歯厚	Sn	mm	5.36754	4.16643
中心距離	a	mm	106.10000	
歯角法線歯厚減少量	fn	mm	0.30000	0.15000
歯幅	b	mm	30.00000	30.00000
歯先円直径	da	mm	61.40000	162.20000
歯底円直径	df	mm	47.95000	148.60000
歯先 R	ra	mm	0.50000	0.30000
基準ラック歯元 R	rf	mm	1.1000	1.3500

図 1.21.4 諸元設定 (外歯車×外歯車)

Item	Symbol	Unit	Pinion	Gear
transmitted power	P	kW		31.4169
torque	T	N·m	300.0000	882.3529
rotation speed	n	min <sup>-1</sup>	1000.0000	340.0000
number of load cycles (nominal) transverse tangential load at referenc...	NL	---	10000000	
tangential velocity	v	m/s		2.8079
angular velocity	$\omega$	rad/s	104.7230	35.6058
virtual number of teeth of a helical gear	zn	---	19.7620	58.1234
gear accuracy grade ISO 1328-1	---	---	5	5
transverse contact ratio	$\epsilon_\alpha$	---		1.2922
overlap ratio	$\epsilon_\beta$	---		0.9836

図 1.21.5 トルク, 回転速度の設定, 6336-1

Item	Symbol	Unit	Pinion	Gear
nominal stress number (bending)	$\sigma_{Flim}$	N/mm <sup>2</sup>	312.0	312.0
allowable stress number(contact)	$\sigma_{Hlim}$	N/mm <sup>2</sup>	1300.0	1300.0
hardness(bending)	HV	---	700.0	700.0
hardness(contact)	HV	---	700.0	700.0
modules of elasticity	E	N/mm <sup>2</sup>	206000.0	206000.0
Poisson's ratio	$\nu$	---	0.30	0.30

図 1.21.6 材料の設定

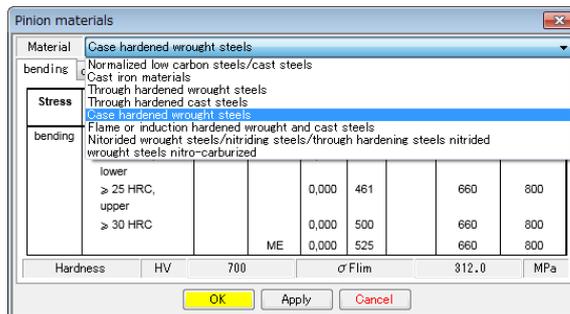


図 1.21.7 材料選択 1

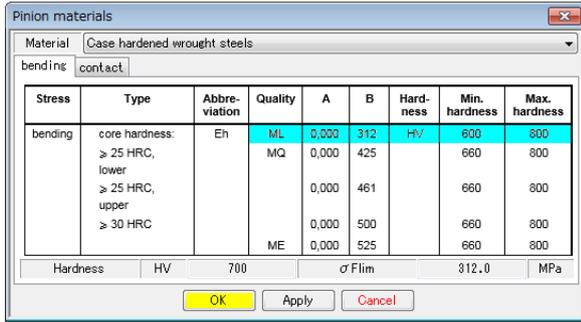


図 1.21.7a 材料選択 2 (曲げ)

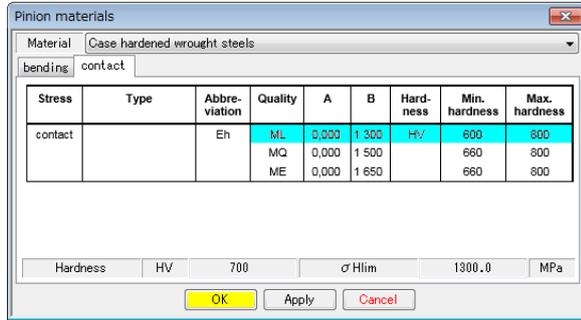


図 1.21.7b 材料選択 2 (歯面)

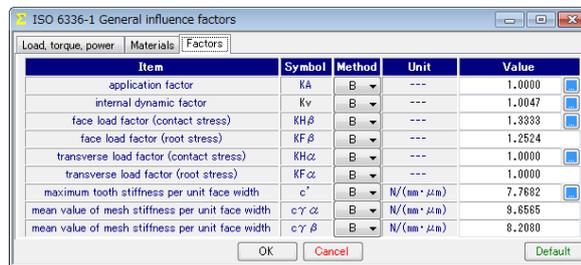


図 1.21.8 係数, 6336-1

A, B, C 法を で選択することができます。



図 1.21.8a 係数 KA, 6336-1

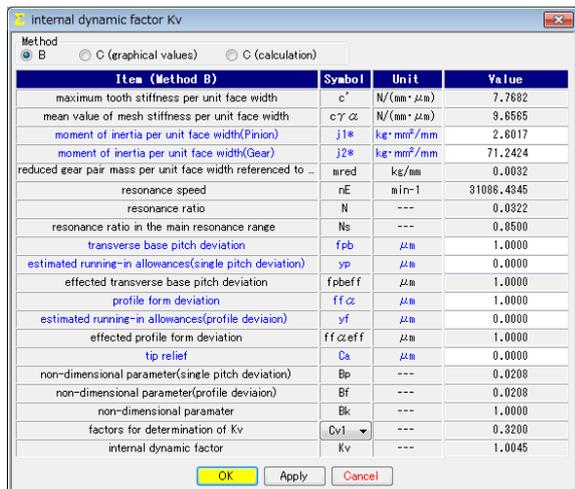


図 1.21.8b 係数 Kv, 6336-1

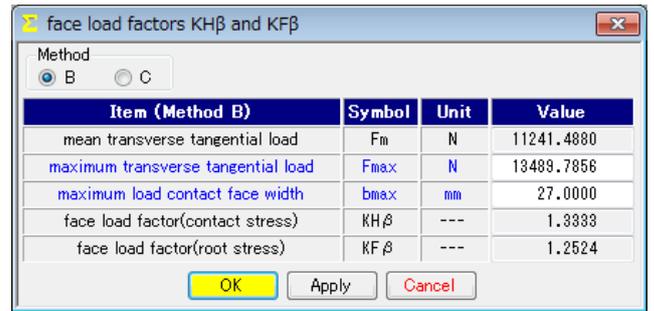


図 1.21.8c 係数 KHβ, 6336-1



図 1.21.8d 係数 KHα, 6336-1

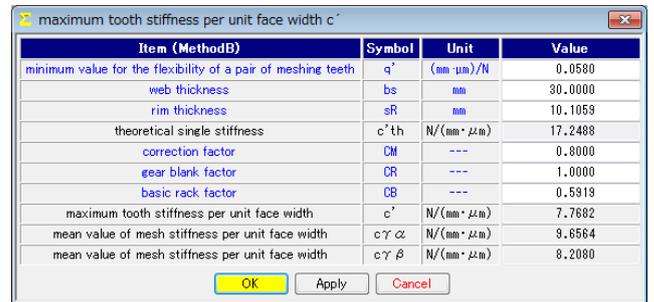


図 1.21.8e 係数 c', 6336-1

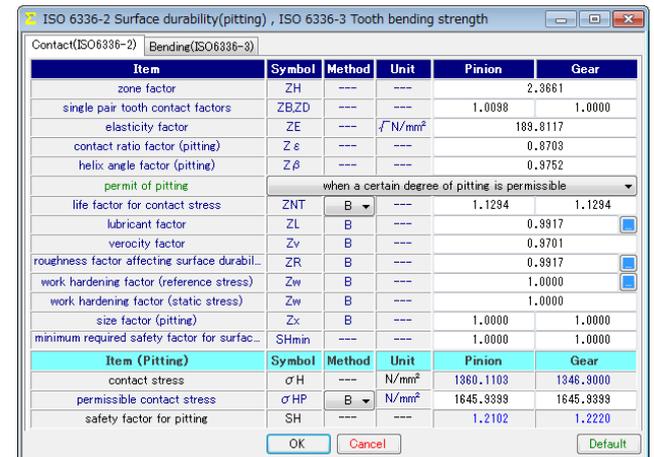


図 1.21.9 歯面強さ, 6336-2

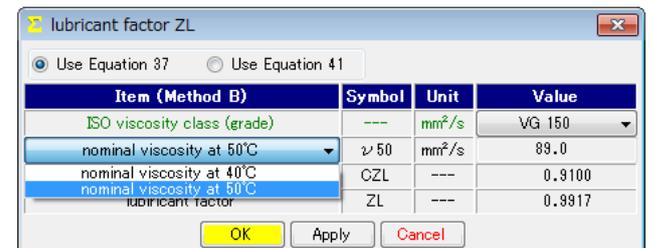


図 1.21.9a 歯面強さ, ZL

roughness factor affecting surface durability ZR

Item (Method B)	Symbol	Unit	Pinion	Gear
mean peak-to-valley roughness	Rz	μm	3.0000	3.0000
radius of relative curvature	ρ red	mm	7.3237	
mean relative peak-to-valley roughness for...	Rz10	μm	3.3282	
factor for determining lubricant film factors	CZR	---	0.0800	
roughness factor affecting surface durability	ZR	---	0.9917	

OK Apply Cancel

図 1.21.9b 歯面強さ, ZR

rim thickness factor YB (Pinion)

Item (Method B)	Symbol	Unit	Value
rim thickness	sR	mm	10.1059
tooth height	ht	mm	6.7373
rim thickness factor	YB	---	1.0000

OK Apply Cancel

図 1.21.10c 曲げ強さ, YB

work hardening factor Zw

Surface-hardened pinion with through-hardened gear  
 Through-hardened pinion and gear

Item (Method B)	Symbol	Unit	Value
mean peak-to-valley roughness	Rz	μm	3.0000 3.0000
ISO viscosity class (grade)	---	---	VG 150
nominal viscosity at 40°C	ν40	mm²/s	150.0
radius of relative curvature	ρ red	mm	7.3237
The equivalent roughness	RZH	μm	5.0559
pitch line velocity	v	m/s	2.8079
Brinell hardness	HB	---	622.1
work hardening factor(reference)	Zw	---	1.0000
work hardening factor(static)	Zw	---	1.0000

OK Apply Cancel

図 1.21.9c 歯面強さ, Zw

relative notch sensitivity factor YδrelT (Pinion)

Item (Method B)	Symbol	Unit	Value
Material	Eh,IF(root);for all hardness		
residual fillet undercut	Spr	mm	0.0000
relative notch sensitivity factor	yδrelT	---	0.9977
define for St			
stress correction factor	YS	---	2.0437
YδrelT for static stress	yδrelT	---	1.0192

OK Apply Cancel

図 1.21.10d 曲げ強さ, YδrelT

relative surface factor YRrelT (Pinion)

Item (Method B)	Symbol	Unit	Pinion	Gear
mean peak-to-valley roughness	Rz	μm	3.0000	3.0000
relative surface factor	YRrelT	---	1.0663	

OK Apply Cancel

図 1.21.10e 曲げ強さ, YRrelT

ISO 6336-2 Surface durability (pitting), ISO 6336-3 Tooth bending strength

Item	Symbol	Method	Unit	Pinion	Gear
tooth form factor	YF	B	---	1.4316	1.7889
stress correction factor	YS	---	---	2.0437	1.7070
stress correction factor, relevant to the di...	YST	---	---	2.0000	
helix angle factor (tooth root)	Yβ	---	---	0.9525	
rim thickness factor	YB	---	---	1.0000	1.0000
deep tooth factor	YDT	---	---	1.0000	1.0000
life factor for tooth root stress	YNT	B	---	0.9762	0.9762
relative notch sensitivity factor	YδrelT	B	---	0.9977	0.9913
relative notch sensitivity factor for static ...	YδrelT	B	---	1.0192	0.8711
relative surface factor	YRrelT	B	---	1.0663	1.0663
size factor (tooth root)	Yx	B	---	1.0000	1.0000
minimum required safety factor for tooth r...	SFmin	---	---	1.0000	1.0000
Item (Bending)	Symbol	Method	Unit	Pinion	Gear
tooth root stress	σF	B	N/mm²	390.1564	407.2120
permissible tooth root stress	σFP	B	N/mm²	663.8790	659.5739
safety factor for tooth breakage	SF	---	---	1.7016	1.6197

OK Cancel Default

図 1.21.10 曲げ強さ 6336-3

ISO 6336-6 Service life under variable load

Items: Pitting(P) Pitting(G) Bending(P) Bending(G)

Item	Symbol	Unit	Value
application factor	KA	---	1.0000
number of bins	Bin	---	64
load spectrum time	---	Days	70.0000
pitting life	---	Years	30.0000
bending life	---	Years	30.0000
safety factor for pitting	SH	---	1.409 1.552
safety factor for bending	SF	---	2.002 2.045

Calculate Cancel

図 1.21.11 寿命, 6336-6

tooth form factor YF (Pinion)

Item (Method B)	Symbol	Unit	Value
residual fillet undercut	Spr	mm	0.0000
root fillet radius of basic rack for cylindrical gears	ρFPv	mm	1.1000
tip diameter (tip form diameter)	da(dNa)	mm	60.9880
tooth root chord at the critical section	SFn	mm	6.3141
bending moment arm for tooth root stress releva...	hFe	mm	3.2481
load direction angle, relevant to direction of appl...	αFen	deg	23.4596
Theta	θ	deg	47.6447
tooth form factor	YF	---	1.4316

OK Apply Cancel

図 1.21.10a 曲げ強さ, YF

stress correction factor YS (Pinion)

Item (Method B)	Symbol	Unit	Value
tooth root radius at the critical section	ρF	mm	1.3949
factor L	L	---	1.9439
notch parameter	qs	---	2.2693
stress correction factor	YS	---	2.0437

OK Cancel

図 1.21.10b 曲げ強さ, YS

ISO 6336-6 Service life under variable load

Items: Pitting(P) Pitting(G) Bending(P) Bending(G)

Calculation of pitting safety factor from load spectrum safety factor = 1.409

Bin No.	Pinion torque T1 [N·m]	Time over 70 days [s]	Pinion speed n1 [r/min]	Stress cycles in 30 years	Face load factor β	Contact stress σH [N/mm²]	Life factor ZNT	Cycles to failure Nf	Damage parts Uf (N/Nf)
1	309.677	0.000E+00	1000.000	0.000E+00					0.000E+00
2	304.839	0.000E+00	1000.000	0.000E+00					0.000E+00
3	300.000	1.656E+01	1000.000	4.320E+04	1.333	1916.412	1.545	1.793E+06	2.409E-02
4	295.161	2.484E+01	1000.000	6.481E+04	1.333	1900.900	1.533	1.973E+06	3.284E-02
5	290.323	3.318E+01	1000.000	8.649E+04	1.333	1885.263	1.520	2.175E+06	3.974E-02
6	285.484	4.141E+01	1000.000	1.080E+05	1.333	1869.492	1.507	2.401E+06	4.500E-02
7	280.645	4.969E+01	1000.000	1.296E+05	1.333	1853.587	1.494	2.655E+06	4.883E-02
8	275.806	5.797E+01	1000.000	1.512E+05	1.333	1837.545	1.482	2.941E+06	5.143E-02
9	270.968	6.625E+01	1000.000	1.728E+05	1.333	1821.364	1.469	3.269E+06	5.297E-02
10	266.129	7.453E+01	1000.000	1.944E+05	1.333	1805.035	1.455	3.639E+06	5.360E-02
11	261.290	8.281E+01	1000.000	2.160E+05	1.333	1788.557	1.442	4.041E+06	5.346E-02
12	256.452	9.110E+01	1000.000	2.377E+05	1.333	1771.929	1.429	4.511E+06	5.269E-02
13	251.613	9.938E+01	1000.000	2.593E+05	1.333	1755.140	1.415	5.045E+06	5.139E-02
14	246.774	1.077E+02	1000.000	2.810E+05	1.333	1738.189	1.401	5.655E+06	4.965E-02
15	241.935	1.159E+02	1000.000	3.024E+05	1.333	1721.071	1.388	6.354E+06	4.759E-02

Calculate Cancel

図 1.21.11a 寿命, Pinion(Pitting)

Bin No.	Pinion torque T1 (N·m)	Time over 70 days (s)	Pinion speed n1 (r/min)	Stress cycles in 30 years N	Face load factor K <sub>F</sub>	Bending stress σ <sub>H</sub> (N/mm <sup>2</sup> )	Life factor YNT	Cycles to failure N <sub>H</sub>	Damage parts U <sub>H</sub> (N/mm <sup>2</sup> )
1	309.677	0.000E+00	1000.000	0.000E+00					0.000E+00
2	304.939	0.000E+00	1000.000	0.000E+00					0.000E+00
3	300.000	1.655E-01	1000.000	4.202E+04	1.253	761.400	1.177	6.724E+05	6.435E-02
4	295.161	2.484E-01	1000.000	6.410E+04	1.253	769.890	1.159	7.696E+05	6.306E-02
5	290.323	3.313E-01	1000.000	8.649E+04	1.253	756.282	1.139	9.081E+05	6.151E-02
6	285.484	4.141E-01	1000.000	1.089E+05	1.253	743.682	1.120	1.059E+06	6.020E-02
7	280.645	4.969E-01	1000.000	1.286E+05	1.253	731.082	1.101	1.239E+06	5.904E-02
8	275.806	5.797E-01	1000.000	1.512E+05	1.253	718.482	1.082	1.453E+06	5.801E-02
9	270.968	6.625E-01	1000.000	1.729E+05	1.253	705.884	1.063	1.709E+06	5.710E-02
10	266.129	7.453E-01	1000.000	1.944E+05	1.253	693.284	1.044	2.015E+06	5.630E-02
11	261.290	8.281E-01	1000.000	2.160E+05	1.253	680.684	1.025	2.384E+06	5.561E-02
12	256.452	9.110E-01	1000.000	2.377E+05	1.253	668.086	1.006	2.830E+06	5.502E-02
13	251.613	9.938E-01	1000.000	2.593E+05	1.253	655.486	0.987	3.352E+06	5.452E-02
14	246.774	1.077E+02	1000.000	2.810E+05	1.253	642.886	0.968	3.959E+07	5.416E-02
15	241.935	1.159E+02	1000.000	3.024E+05	1.253	630.286	0.949	4.636E+07	5.390E-02

図 1.21.11a 寿命, Pinion(Bending)

Item	Symbol	Unit	Pinion	Gear
transmitted power	P	kW		31.4189
torque	T	N·m	300.0000	750.0000
rotation speed	n	min-1	1000.0000	400.0000
number of load cycles	NL	---		10000000
(nominal) transverse tangential load at reference...	FT	N	7872.9582	
tangential velocity	v	m/s		3.3905
angular velocity	ω	rad/s	104.7230	41.8892
virtual number of teeth of a helical gear	zn	---	33.8712	84.6780
gear accuracy grade ISO 1328-1	---	---	3	3
transverse contact ratio	ε <sub>α</sub>	---		1.9539
overlap ratio	ε <sub>β</sub>	---		1.5915

図 1.21.14 トルク, 回転速度の設定, 6336-1

Item	Symbol	Method	Unit	Pinion	Gear
transmitted power	P	kW		300.0000	31.4189
torque	T	N·m		300.0000	832.3519
rotation speed	n	min-1		1000.0000	340.0000
number of load cycles	NL	---			10000000
(nominal) transverse tangential load	FT	N		11188.9002	
tangential velocity	v	m/s		104.7230	35.6058
angular velocity	ω	rad/s		104.7230	35.6058
virtual number of teeth of a helical gear	zn	---		33.8712	84.6780
gear accuracy grade ISO 1328-1	---	---		3	3
transverse contact ratio	ε <sub>α</sub>	---			1.9541
overlap ratio	ε <sub>β</sub>	---			0.9838

図 1.21.12 印刷例

項目	記号	単位	Pinion	Gear
モジュール	m	mm		3.00000
歯数	z	---	22	55
圧力角	α <sub>n</sub>	deg		20.00000
ねじれ角	β	deg	30	0
ねじれ方向	---	---	右ねじれ	右ねじれ
基準円直径	d	mm	76.21024	190.52559
基準円歯距	db	mm	70.25753	175.64383
歯厚入力方式	---	---	転位係数	転位係数
転位係数	xn	---	0.20000	0.30000
またぎ歯数	zm	---	4	10
またぎ歯厚	W	mm	32.79788	88.22658
測定ボール径	dp	mm	5.1046	4.9818
オーバーボール寸法	dm	mm	84.21039	185.64691
歯直角円弧歯厚	Sn	mm	5.14915	4.05724
中心距離	a	mm		57.40000
歯直角法線歯厚減少量	f <sub>n</sub>	mm	0.20000	0.10000
歯幅	b	mm	30.00000	30.00000
歯先円直径	da	mm	83.41024	186.32559
歯底円直径	df	mm	69.91024	189.82559
歯先 R	ra	mm	0.20000	0.20000
基準ラック歯元 R	rf	mm	1.1250	1.1250

図 1.21.13 諸元設定 (外歯車×内歯車)

Item	Symbol	Method	Unit	Pinion	Gear
zone factor	ZH	---	---		2.1928
single pair tooth contact factors	ZB,ZD	---	---	1.0000	1.0000
elasticity factor	ZE	---	√N/mm <sup>2</sup>		189.8117
contact ratio factor (pitting)	Zε	---	---		0.8594
helix angle factor (pitting)	Zβ	---	---		0.9306
life factor for contact stress	ZNT	B	---	1.1294	1.1294
lubricant factor	ZL	B	---		0.9917
velocity factor	Zv	B	---		0.9771
roughness factor affecting surface durability	ZR	B	---		1.0251
work hardening factor (reference stress)	Zw	B	---		1.0000
work hardening factor (static stress)	Zs	B	---		1.0000
size factor (pitting)	Zx	B	---	1.0000	1.0000
minimum required safety factor for surface durability	SHmin	---	---	1.0000	1.0000
contact stress	σ <sub>H</sub>	---	N/mm <sup>2</sup>	553.7022	553.7022
permissible contact stress	σ <sub>HP</sub>	B	N/mm <sup>2</sup>	1481.0010	1481.0010
safety factor for pitting	SH	---	---	2.6386	2.6386

図 1.21.15 歯面強さ, 6336-2

Item	Symbol	Method	Unit	Pinion	Gear
tooth form factor	YF	B	---	1.1648	0.9122
stress correction factor	YS	---	---	2.1890	2.3355
stress correction factor, relevant to the di...	YST	---	---		2.0000
helix angle factor (tooth root)	Yβ	---	---		0.7500
rim thickness factor	YB	---	---	1.0000	1.0382
deep tooth factor	YDT	---	---	1.0000	1.0000
life factor for tooth root stress	YNT	B	---	0.9762	0.9762
relative notch sensitivity factor	YδreIT	B	---	0.9370	1.0009
relative notch sensitivity factor for static ...	YδreIT	B	---	1.0832	1.1476
relative surface factor	YReIT	B	---	1.0663	1.0663
size factor (tooth root)	Yx	B	---	1.0000	1.0000
minimum required safety factor for tooth r...	SFmin	---	---	1.0000	1.0000
tooth root stress	σ <sub>F</sub>	B	N/mm <sup>2</sup>	210.5094	182.5903
permissible tooth root stress	σ <sub>FP</sub>	B	N/mm <sup>2</sup>	663.3908	665.9743
safety factor for tooth breakage	SF	---	---	3.1514	3.8474

図 1.21.16 曲げ強さ 6336-3

- (1) ISO6336 は, involute Σ iii (spur and helical) のオプションです。
- (2) 強度規格の比較については付録をご覧ください。対象規格は

- JGMA 401-02:1974, 402-02:1975
- JGMA 6101-02:2007, 6102-02:2009
- ISO 6336:2006
- ANSI/AGMA2001-C95:1995

の 4 種類と [45]CT-FEM Opera iii の応力解析結果を比較しています。ご希望される方はお申込みください。別途お送りさせていただきます。