

ISO 21771-2:2025-12 (E)

Cylindrical involute gears and gear pairs - Part 2: Calculation and measurement of tooth thickness and backlash

Contents		Page
Foreword		vii
Introduction		viii
1	Scope	1
2	Normative references	1
3	Terms, definition and symbols	1
3.1	Terms and definitions	1
3.2	Symbols and definitions	6
3.3	Units and conventions	13
3.3.1	Units	13
3.3.2	Conventions	13
4	Application	13
4.1	General	13
4.2	Datum surfaces and the datum axis	14
4.3	Gear tooth thickness specification systems	14
4.3.1	Types of tooth thickness specification systems	14
4.3.2	Non-datum related tooth thickness	15
4.3.3	Axis related tooth thickness	15
4.3.4	Relationship between the measurement methods and specification systems	15
4.3.5	Mean tooth thickness	15
4.4	Gear tooth thickness measurement methods	16
4.5	Reporting of gear tooth thickness	17
4.6	Measurement diameter versus contact diameter	17
4.7	Gear geometry calculations	17
4.7.1	Use of radians or degrees	17
4.7.2	Reference diameter	18
4.7.3	Transverse pressure angle	18
4.7.4	Lead angle	18
4.7.5	Normal tooth thickness from manufacturing profile shift coefficient	18
4.7.6	Base diameter	19
4.7.7	Base helix angle	19
4.7.8	Normal pitch at the reference diameter	19
4.7.9	Normal pitch at calculation diameter d_y	19
4.7.10	Normal base pitch	19
4.7.11	Lead of a helical gear	19
4.7.12	Axial pitch	20
4.7.13	The involute function	20
4.7.14	Helix angle at calculation diameter d_y	20
4.7.15	Transverse pressure angle at calculation diameter d_y	20
4.7.16	Tooth thickness calculations	20
4.7.17	Space width calculations	22
5	Measurement by pitch (index)	24
5.1	Principle of measurement	24
5.2	Underlying assumptions and limitations	24
5.3	Advantages and disadvantages of measurement by pitch	24
5.4	Selection of measurement diameter	25

6	Measurement with a master gear on a double flank tester	25
6.1	Principle of measurement	25
6.1.1	Main principles	25
6.1.2	Tight mesh centre distance	28
6.1.3	Product gear test radius	29
6.1.4	Total radial composite deviation	29
6.2	Underlying assumptions and limitations	29
6.3	Advantages and disadvantages of double flank radial composite measurement	30
6.4	Master gear design considerations	30
6.4.1	Criteria for proper meshing	30
6.4.2	Additional recommendations	31
6.5	Skew angle for double flank testing	32
6.5.1	General	32
6.5.2	Skew angle for parallel axis gear pairs	32
6.5.3	Skew angle for crossed axis gear pairs	32
6.6	Calculation of tight mesh centre distance limits for crossed axis gears	34
6.6.1	Preliminary calculations	34
6.6.2	Tight mesh centre distance limits for crossed axis gears	34
6.7	Tight mesh centre distance limits for parallel axis gears:	35
6.7.1	General	35
6.7.2	For the non-datum related system:	36
6.7.3	For the axis related system:	36
6.7.4	Differences between axis related and non-datum related systems	36
6.8	Product gear test radius limits from tight mesh centre distance limits	37
6.8.1	General	37
6.8.2	Master gear test radius	37
6.8.3	Product gear test radius limits	38
6.9	Axis related normal tooth thickness from double flank test results	38
6.9.1	General	38
6.9.2	Crossed axis external gear axis related tooth thickness from test results	38
6.9.3	Parallel axis gear axis related tooth thickness	38
7	Measurement with a master gear on a single flank tester	39
7.1	Principle of measurement	39
7.2	Underlying assumptions and limitations	39
7.3	Advantages and disadvantages of single flank composite measurement	39
7.4	Master gear design considerations	40
7.5	Axis related tooth thickness from single flank test results	40
8	Span measurement	40
8.1	Principle of measurement	40
8.2	Underlying assumptions and limitations	42
8.3	Advantages and disadvantages of span measurement	42
8.4	Span measurement limits	43
8.5	Number of teeth spanned	43
8.5.1	Limitations	43
8.5.2	Maximum and minimum number of teeth spanned	43
8.6	Angle of rock	45
8.7	Tooth thickness from span measurement	47
8.8	Measurement diameter	47
9	Measurement using three ball span device	47
9.1	Principle of measurement	47
9.2	Underlying assumptions and limitations	48
9.3	Advantages and disadvantages of three ball span device measurement	48
9.4	Number of teeth spanned	49
9.5	Selection of the ball diameter	49
9.6	Calculations with specified ball diameter	49
9.7	Normal tooth thickness from a measurement using a three ball span device	51

10	Measurement over or between balls or pins	51
10.1	Principle of measurement	51
10.2	Underlying assumptions and limitations	54
10.3	Advantages and disadvantages of over balls or pins measurement	54
10.4	Selection of the ball or pin diameter	55
10.4.1	General	55
10.4.2	Transverse base space width half angles	55
10.4.3	Maximum ball or pin diameter	55
10.4.4	Ball or pin diameter for contact at the root involute limit diameter	56
10.4.5	Ball or pin diameter that will be tangent to the tip diameter	56
10.4.6	Ball or pin diameter that will be tangent to the root diameter	57
10.4.7	Minimum usable ball diameter	57
10.4.8	Selection of ball or pin diameter to specify	57
10.4.9	Calculation for racks	58
10.5	Calculations with specified ball or pin diameter (symmetric pressure angles)	60
10.6	Gears with asymmetric pressure angles	61
10.6.1	General	61
10.6.2	Calculations with specified ball or pin diameter	61
10.7	Measurement over one ball or pin	62
10.7.1	General	62
10.7.2	Basic inspection limits for measurement over one ball or pin	63
10.7.3	Axis related normal tooth thickness from one ball or pin measurement	64
10.7.4	Contact diameter from the measurement over one ball or pin	64
10.8	Measurement over two balls or pins	64
10.8.1	General	64
10.8.2	Basic inspection limits for measurement over two balls or pins	65
10.8.3	Normal tooth thickness from a measurement over two balls or pins	66
10.8.4	Contact diameter from the measurement over two balls or pins	66
10.9	Two pin transverse measurement on helical gear, odd number of teeth	66
10.9.1	General	66
10.9.2	Transverse measurement with two free floating pins	66
10.9.3	Measurement with two pins rotating around the micrometer axis	68
10.9.4	Basic inspection limits for the two-pin transverse method	70
10.9.5	Normal tooth thickness from a two-pin transverse method measurement	70
10.10	Free pin measurement over two pins, helical gear, odd number of teeth	70
10.10.1	General	70
10.10.2	Basic inspection limits for the free pin method	71
10.10.3	Non-datum related normal tooth thickness from free pin measurement	72
10.11	Transverse plane measurement method over three balls or pins	72
10.11.1	General	72
10.11.2	Factors for gears with even or odd numbers of teeth	74
10.11.3	Measurement limits using the transverse plane method for three balls or pins	74
10.11.4	Normal tooth thickness from a transverse plane method measurement	74
10.11.5	Contact diameter from the transverse plane method	74
10.12	Axial plane three pin method	74
10.12.1	General	74
10.12.2	Measurement limits using the axial plane three pin method	75
10.12.3	Normal tooth thickness from axial plane method measurement	76
10.12.4	Contact diameter from the axial plane three pin method	76
11	Measurement with measuring blocks	76
11.1	Principle of measurement	76
11.2	Underlying assumptions and limitations	76
11.3	Advantages and disadvantages of using blocks	77
11.4	Measuring block sets	77
11.5	Measurement limits for blocks	78
11.6	Tooth thickness from block measurements	79
12	Chordal measurement	79
12.1	General	79
12.2	Measurements with a gear tooth calliper (in the normal plane)	80

12.2.1	Principle of measurement	80
12.2.2	Underlying assumptions and limitations	81
12.2.3	Advantages and disadvantages of chordal measurement	81
12.2.4	Method for calculation	82
12.2.5	Preliminary calculations for chordal measurements	82
12.2.6	Chordal addendum	83
12.2.7	Minimum contact diameter	83
12.2.8	Minimum normal tooth thickness at diameter $d_{y \min}$	83
12.2.9	Normal chordal tooth thickness measurement limits	83
12.2.10	Adjustment of chordal addendum at time of measurement	84
12.2.11	Normal tooth thickness from a chordal measurement	84
12.3	Chordal measurement with an optical device (in the transverse plane)	84
12.3.1	Principle of measurement	84
12.3.2	Underlying assumptions and limitations	85
12.3.3	Advantages and disadvantages of chordal measurement with optical device	85
12.3.4	Method for calculation	85
12.3.5	Transverse pressure angle at the desired contact diameter	86
12.3.6	Maximum transverse tooth thickness	86
12.3.7	Chordal radius	86
12.3.8	Minimum contact diameter	86
12.3.9	Minimum transverse tooth thickness at diameter, $d_{yt \min}$	86
12.3.10	Transverse chordal tooth thickness measurement limits	86
12.3.11	Conversion of chordal radius to chordal addendum	87
12.3.12	Normal tooth thickness from a chordal measurement	87
12.4	Chordal measurement with a coordinate measurement machine	88
13	Backlash in parallel axis and crossed axis gear pairs	88
13.1	General	88
13.2	Factors that influence backlash	89
13.3	Backlash for parallel axis gears in the axis related system	90
13.4	Backlash for parallel axis gears in the non-datum related system	91
13.5	Backlash in crossed axis gears	93
13.6	Other potential influences on backlash	95
13.7	Ways to express backlash	96
13.7.1	Circumferential backlash	96
13.7.2	Transverse backlash	96
13.7.3	Normal backlash	96
13.7.4	Axial backlash	97
13.7.5	Radial backlash	97
13.7.6	Angular backlash	97
13.8	Variations in backlash	97
Annex A (informative)	Tooth thickness measurement using analytical machines	99
Annex B (informative)	Establishing tooth thickness specifications in the non-datum related system	100
Annex C (informative)	Establishing tooth thickness specifications in the axis related system	102
Annex D (informative)	Calculation method for the inverse involute function	103
Annex E (informative)	Example calculations	104
Bibliography	140