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Gears are some of the most important elements used in machinery. There are few mechanical devices that do not have the need to transmit power and motion between rotating shafts. Gears not only do this most satisfactorily, but can do so with uniform motion and reliability. In addition, they span the entire range of applications from large to small. To summarize:

1. Gears offer positive transmission of power.
2. Gears range in size from small miniature instrument installations, that measure in only several millimeters in diameter, to huge powerful gears in turbine drives that are several meters in diameter.
3. Gears can provide position transmission with very high angular or linear accuracy; such as used in servomechanisms and military equipment.
4. Gears can couple power and motion between shafts whose axes are parallel, intersecting or skew.
5. Gear designs are standardized in accordance with size and shape which provides for widespread interchangeability.

This technical manual is written as an aid for the designer who is a beginner or only superficially knowledgeable about gearing. It provides fundamental theoretical and practical information. Admittedly, it is not intended for experts.

Those who wish to obtain further information and special details should refer to the reference list at the end of this text and other literature on mechanical machinery and components.

SECTION 1 INTRODUCTION TO METRIC GEARS

This technical section is dedicated to details of metric gearing because of its increasing importance. Currently, much gearing in the United States is still based upon the inch system. However, with most of the world metricated, the use of metric gearing in the United States is definitely on the increase, and inevitably at some future date it will be the exclusive system.

It should be appreciated that in the United States there is a growing amount of metric gearing due to increasing machinery and other equipment imports. This is particularly true of manufacturing equipment, such as printing presses, paper machines and machine tools. Automobiles are another major example, and one that impacts tens of millions of individuals. Further spread of metric gearing is inevitable since the world that surrounds the United States is rapidly approaching complete conformance. England and Canada, once bastions of the inch system, are well down the road of metrication, leaving the United States as the only significant exception.

Thus, it becomes prudent for engineers and designers to not only become familiar with metric gears, but also to incorporate them in their designs. Certainly, for export products it is imperative; and for domestic products it is a serious consideration. The U.S. Government, and in particular the military, is increasingly insisting upon metric based equipment designs.

Recognizing that most engineers and designers have been reared in an environment of heavy use of the inch system and that the amount of literature about metric gears is limited, we are offering this technical gear section as an aid to understanding and use of metric gears. In the following pages, metric gear standards are introduced along with information about interchangeability and noninterchangeability. Although gear theory is the same for both the inch and metric systems, the formulae for metric gearing take on a different set of symbols. These equations are fully defined in the metric system. The coverage is thorough and complete with the intention that this be a source for all information about gearing with definition in a metric format.

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1.1 Comparison Of Metric Gears With American Inch Gears

1.1.1 Comparison of Basic Racks

In all modern gear systems, the rack is the basis for tooth design and manufacturing tooling. Thus, the similarities and differences between the two systems can be put into proper perspective with comparison of the metric and inch basic racks.

In both systems, the basic rack is normalized for a unit size. For the metric rack it is 1 module, and for the inch rack it is 1 diametral pitch.

1.1.2 Metric ISO Basic Rack

The standard ISO metric rack is detailed in **Figure 1-1**. It is now the accepted standard for the international community, it having eliminated a number of minor differences that existed between the earlier versions of Japanese, German and Russian modules. For comparison, the standard inch rack is detailed in **Figure 1-2**. Note that there are many similarities. The principal factors are the same for both racks. Both are normalized for unity; that is, the metric rack is specified in terms of 1 module, and the inch rack in terms of 1 diametral pitch.

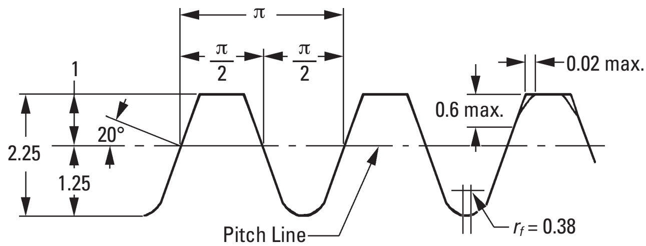

Fig. 1-1 The Basic Metric Rack From ISO 53 Normalized For Module 1

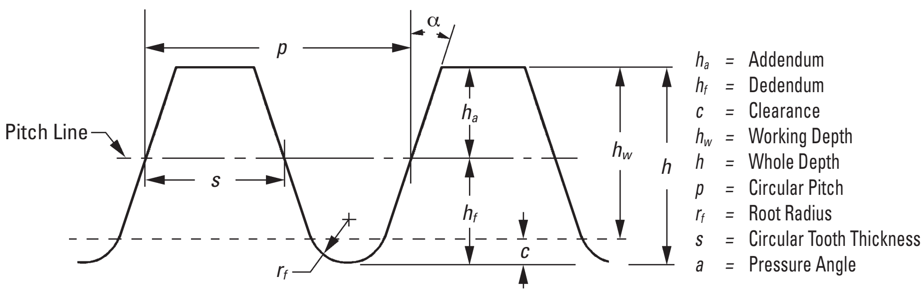

Fig. 1-2 The Basic Inch Diametral Pitch Rack Normalized For 1 Diametral Pitch

From the normalized metric rack, corresponding dimensions for any module are obtained by multiplying each rack dimension by the value of the specific module *m*. The major tooth parameters are defined by the standard, as:

Tooth Form: Straight-sided full depth, forming the basis of a family of full depth interchangeable gears.

Pressure Angle: A 20° pressure angle, which conforms to worldwide acceptance of this as the most versatile pressure angle.

Addendum: This is equal to the module *m*, which is similar to the inch value that becomes 1/*p*.

Dedendum: This is 1.25 *m*; again similar to the inch rack value.

Root Radius: The metric rack value is slightly greater than the American inch rack value.

Tip Radius: A maximum value is specified. This is a deviation from the American inch rack which does not specify a rounding.

1.1.3 Comparison of Gear Calculation Equations

Most gear equations that are used for diametral pitch inch gears are equally applicable to metric gears if the module *m* is substituted for diametral pitch. However, there are exceptions when it is necessary to use dedicated metric equations. Thus, to avoid confusion and errors, it is most effective to work entirely with and within the metric system.

1.2 Metric Standards Worldwide

1.2.1 ISO Standards

Metric standards have been coordinated and standardized by the International Standards Organization (ISO). A listing of the most pertinent standards is given in **Table 1-1**.

1.2.2 Foreign Metric Standards

Most major industrialized countries have been using metric gears for a long time and consequently had developed their own standards prior to the establishment of ISO and SI units. In general, they are very similar to the ISO standards. The key foreign metric standards are listed in **Table 1-2** for reference.

1.3 Japanese Metric Standards In This Text

1.3.1 Application of JIS Standards

Japanese Industrial Standards (JIS) define numerous engineering subjects including gearing. The originals are generated in Japanese, but they are translated and published in English by the Japanese Standards Association.

Considering that many metric gears are produced in Japan, the JIS standards may apply. These essentially conform to all aspects of the ISO standards.

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Table 1-1 ISO Metric Gearing Standards

ISO 53:1974	Cylindrical gears for general and heavy engineering – Basic rack
ISO 54:1977	Cylindrical gears for general and heavy engineering – Modules and diametral pitches
ISO 677:1976	Straight bevel gears for general and heavy engineering – Basic rack
ISO 678:1976	Straight bevel gears for general and heavy engineering – Modules and diametral pitches
ISO 701:1976	International gear notation – symbols for geometrical data
ISO 1122-1:1983	Glossary of gear terms – Part 1: Geometrical definitions
ISO 1328:1975	Parallel involute gears – ISO system of accuracy
ISO 1340:1976	Cylindrical gears – Information to be given to the manufacturer by the purchaser in order to obtain the gear required
ISO 1341:1976	Straight bevel gears – Information to be given to the manufacturer by the purchaser in order to obtain the gear required
ISO 2203:1973	Technical drawings – Conventional representation of gears
ISO 2490:1975	Single-start solid (monobloc) gear hobs with axial keyway, 1 to 20 module and 1 to 20 diametral pitch – Nominal dimensions
ISO/TR 4467:1982	Addendum modification of the teeth of cylindrical gears for speed-reducing and speed-increasing gear pairs
ISO 4468:1982	Gear hobs – Single-start – Accuracy requirements
ISO 8579-1:1993	Acceptance code for gears – Part 1: Determination of airborne sound power levels emitted by gear units
ISO 8579-2:1993	Acceptance code for gears – Part 2: Determination of mechanical vibrations of gear units during acceptance testing
ISO/TR 10064-1:1992	Cylindrical gears – Code of inspection practice – Part 1: Inspection of corresponding flanks of gear teeth

Table 1-1 FOREIGN Metric Gearing Standards

AUSTRALIA		
AS B 62	1965	Bevel gears
AS B 66	1969	Worm gears (inch series)
AS B 214	1966	Geometrical dimensions for worm gears – Units
AS B 217	1966	Glossary for gearing
AS 1637		International gear notation symbols for geometric data (similar to ISO 701)

FRANCE		
NF E 23-001	1972	Glossary of gears (similar to ISO 1122)
NF E 23-002	1972	Glossary of worm gears
NF E 23-005	1965	Gearing – Symbols (similar to ISO 701)
NF E 23-006	1967	Tolerances for spur gears with involute teeth (similar to ISO 1328)
NF E 23-011	1972	Cylindrical gears for general and heavy engineering – Basic rack and modules (similar to ISO 467 and ISO 53)
NF E 23-012	1972	Cylindrical gears – Information to be given to the manufacturer by the purchaser
NF L 32-611	1955	Calculating spur gears to NF L 32-610

Continued on the next page

Table 1-2 (Cont.) Foreign Metric Gearing Standards

GERMANY – DIN (Deutsches Institut für Normung)		
DIN 37	12.61	Conventional and simplified representation of gears and gear pairs [4]
DIN 780 Pt 1	05.77	Series of modules for gears – Modules for spur gears [4]
DIN 780 Pt 2	05.77	Series of modules for gears – Modules for cylindrical worm gear transmissions [4]
DIN 867	02.86	Basic rack tooth profiles for involute teeth of cylindrical gears for general and heavy engineering [5]
DIN 868	12.76	General definitions and specification factors for gears, gear pairs and gear trains [11]
DIN 3961	08.78	Tolerances for cylindrical gear teeth – Bases [8]
DIN 3962 Pt 1	08.78	Tolerances for cylindrical gear teeth – Tolerances for deviations of individual parameters [11]
DIN 3962 Pt 2	08.78	Tolerances for cylindrical gear teeth – Tolerances for tooth trace deviations [4]
DIN 3962 Pt 3	08.78	Tolerances for cylindrical gear teeth – Tolerances for pitch-span deviations [4]
DIN 3963	08.78	Tolerances for cylindrical gear teeth – Tolerances for working deviations [11]
DIN 3964	11.80	Deviations of shaft center distances and shaft position tolerances of casings for cylindrical gears [4]
DIN 3965 Pt 1	08.86	Tolerancing of bevel gears – Basic concepts [5]
DIN 3965 Pt 2	08.86	Tolerancing of bevel gears – Tolerances for individual parameters [11]
DIN 3965 Pt 3	08.86	Tolerancing of bevel gears – Tolerances for tangential composite errors [11]
DIN 3965 Pt 4	08.86	Tolerancing of bevel gears – Tolerances for shaft angle errors and axes intersection point deviations [5]
DIN 3966 Pt 1	08.78	Information on gear teeth in drawings – Information on involute teeth for cylindrical gears [7]
DIN 3966 Pt 2	08.78	Information on gear teeth in drawings – Information on straight bevel gear teeth [6]
DIN 3967	08.78	System of gear fits – Backlash, tooth thickness allowances, tooth thickness tolerances – Principles [12]
DIN 3970 Pt 1	11.74	Master gears for checking spur gears – Gear blank and tooth system [8]
DIN 3970 Pt 2	11.74	Master gears for checking spur gears – Receiving arbors [4]
DIN 3971	07.80	Definitions and parameters for bevel gears and bevel gear pairs [12]
DIN 3972	02.52	Reference profiles of gear-cutting tools for involute tooth systems according to DIN 867 [4]
DIN 3975	10.76	Terms and definitions for cylindrical worm gears with shaft angle 90° [9]
DIN 3976	11.80	Cylindrical worms – Dimensions, correlation of shaft center distances and gear ratios of worm gear drives [6]
DIN 3977	02.81	Measuring element diameters for the radial or diametral dimension for testing tooth thickness of cylindrical gears [8]
DIN 3978	08.76	Helix angles for cylindrical gear teeth [5]
DIN 3979	07.79	Tooth damage on gear trains – Designation, characteristics, causes [11]
DIN 3993 Pt 1	08.81	Geometrical design of cylindrical internal involute gear pairs – Basic rules [17]
DIN 3993 Pt 2	08.81	Geometrical design of cylindrical internal involute gear pairs – Diagrams for geometrical limits of internal gear-pinion matings [15]
DIN 3993 Pt 3	08.81	Geometrical design of cylindrical internal involute gear pairs – Diagrams for the determination of addendum modification coefficients [15]
DIN 3993 Pt 4	08.81	Geometrical design of cylindrical internal involute gear pairs – Diagrams for limits of internal gear-pinion type cutter matings [10]
DIN 3998 Suppl 1	09.76	Denominations on gear and gear pairs – Alphabetical index of equivalent terms [10]
DIN 3998 Pt 1	09.76	Denominations on gears and gear pairs – General definitions [11]
DIN 3998 Pt 2	09.76	Denominations on gears and gear pairs – Cylindrical gears and gear pairs [11]
DIN 3998 Pt 3	09.76	Denominations on gears and gear pairs – Bevel and hypoid gears and gear pairs [9]
DIN 3998 Pt 4	09.76	Denominations on gears and gear pairs – Worm gear pairs [8]
DIN 58405 Pt 1	05.72	Spur gear drives for fine mechanics –Scope, definitions, principal design data, classification [7]
DIN 58405 Pt 2	05.72	Spur gear drives for fine mechanics – Gear fit selection, tolerances, allowances [9]
DIN 58405 Pt 3	05.72	Spur gear drives for fine mechanics – Indication in drawings, examples for calculation [12]
DIN 58405 Pt 4	05.72	Spur gear drives for fine mechanics – Tables [15]
DIN ISO 2203	06.76	Technical Drawings – Conventional representation of gears

NOTES:

1. Standards available in English from: ANSI, 1430 Broadway, New York, NY 10018; or Beuth Verlag GmbH, Burggrafenstrasse 6, D-10772 Berlin, Germany; or Global Engineering Documents, Inverness Way East, Englewood, CO 80112-5704
2. Above data was taken from: DIN Catalogue of Technical Rules 1994, Supplement, Volume 3, Translations

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Table 1-2 (Cont.) Foreign Metric Gearing Standards

ITALY		
UNI 3521	1954	Gearing – Module series
UNI 3522	1954	Gearing – Basic rack
UNI 4430	1960	Spur gear – Order information for straight and bevel gear
UNI 4760	1961	Gearing – Glossary and geometrical definitions
UNI 6586	1969	Modules and diametral pitches of cylindrical and straight bevel gears for general and heavy engineering (corresponds to ISO 54 and 678)
UNI 6587	1969	Basic rack of cylindrical gears for standard engineering (corresponds to ISO 53)
UNI 6588	1969	Basic rack of straight bevel gears for general and heavy engineering (corresponds to ISO 677)
UNI 6773	1970	International gear notation – Symbols for geometrical data (corresponds to ISO 701)

JAPAN – JIS (Japanese Industrial Standards)		
B 0003	1989	Drawing office practice for gears
B 0102	1988	Glossary of gear terms
B 1701	1973	Involute gear tooth profile and dimensions
B 1702	1976	Accuracy for spur and helical gears
B 1703	1976	Backlash for spur and helical gears
B 1704	1978	Accuracy for bevel gears
B 1705	1973	Backlash for bevel gears
B 1721	1973	Shapes and dimensions of spur gears for general engineering
B 1722	1974	Shape and dimensions of helical gears for general use
B 1723	1977	Dimensions of cylindrical worm gears
B 1741	1977	Tooth contact marking of gears
B 1751	1976	Master cylindrical gears
B 1752	1989	Methods of measurement of spur and helical gears
B 1753	1976	Measuring method of noise of gears
B 4350	1991	Gear cutter tooth profile and dimensions
B 4351	1985	Straight bevel gear generating cutters
B 4354	1988	Single thread hobs
B 4355	1988	Single thread fine pitch hobs
B 4356	1985	Pinion type cutters
B 4357	1988	Rotary gear shaving cutters
B 4358	1991	Rack type cutters

NOTE:
Standards available in English from: ANSI, 1430 Broadway, New York, NY 10018; or International Standardization Cooperation Center, Japanese Standards Association, 4-1-24 Akasaka, Minato-ku, Tokyo 107

Continued on the next page

Table 1-2 (Cont.) Foreign Metric Gearing Standards

UNITED KINGDOM – BSI (British Standards Institute)		
BS 235	1972	Specification of gears for electric traction
BS 436 Pt 1	1987	Spur and helical gears – Basic rack form, pitches and accuracy (diametral pitch series)
BS 436 Pt 2	1984	Spur and helical gears – Basic rack form, modules and accuracy (1 to 50 metric module) (Parts 1 & 2 related but not equivalent with ISO 53, 54, 1328, 1340 & 1341)
BS 436 Pt 3	1986	Spur gear and helical gears – Method for calculation of contact and root bending stresses, limitations for metallic involute gears (Related but not equivalent with ISO / DIS 6336 / 1, 2 & 3)
BS 721 Pt 1	1984	Specification for worm gearing – Imperial units
BS 721 Pt 2	1983	Specification for worm gearing – Metric units
BS 978 Pt 1	1984	Specification for fine pitch gears – Involute spur and helical gears
BS 978 Pt 2	1984	Specification for fine pitch gears – Cycloidal type gears
BS 978 Pt 3	1984	Specification for fine pitch gears – Bevel gears
BS 978 Pt 4	1965	Specification for fine pitch gears – Hobs and cutters
BS 1807	1981	Specification for marine propulsion gears and similar drives: metric module
BS 2007	1983	Specification for circular gear shaving cutters, 1 to 8 metric module, accuracy requirements
BS 2062 Pt 1	1985	Specification for gear hobs – Hobs for general purpose: 1 to 20 d.p., inclusive
BS 2062 Pt 2	1985	Specification for gear hobs – Hobs for gears for turbine reduction and similar drives
BS 2518 Pt 1	1983	Specification for rotary form relieved gear cutters – Diametral pitch
BS 2518 Pt 2	1983	Specification for rotary relieved gear cutters – Metric module
BS 2519 Pt 1	1976	Glossary for gears – Geometrical definitions
BS 2519 Pt 2	1976	Glossary for gears – Notation (symbols for geometrical data for use in gear rotation)
BS 2697	1976	Specification for rack type gear cutters
BS 3027	1968	Specification for dimensions of worm gear units
BS 3696 Pt 1	1984	Specification for master gears – Spur and helical gears (metric module)
BS 4517	1984	Dimensions of spur and helical geared motor units (metric series)
BS 4582 Pt 1	1984	Fine pitch gears (metric module) – Involute spur and helical gears
BS 4582 Pt 2	1986	Fine pitch gears (metric module) – Hobs and cutters
BS 5221	1987	Specifications for general purpose, metric module gear hobs
BS 5246	1984	Specifications for pinion type cutters for spur gears – 1 to 8 metric module
BS 6168	1987	Specification for nonmetallic spur gears

NOTE:
Standards available from: ANSI, 1430 Broadway, New York, NY 10018; or BSI, Linford Wood, Milton Keynes MK146LE, United Kingdom

1.3.2 Symbols

Gear parameters are defined by a set of standardized symbols that are defined in JIS B 0121 (1983). These are reproduced in **Table 1-3**.

The JIS symbols are consistent with the equations given in this text and are consistent with JIS standards. Most differ from typical American symbols, which can be confusing to the first time metric user. To assist, **Table 1-4** is offered as a cross list.

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Table 1-3A The Linear Dimensions and Circular Dimensions

Terms	Symbols
Center Distance	a
Circular Pitch (General)	p
Standard Circular Pitch	p
Radial Circular Pitch	p_t
Circular Pitch Perpendicular to Tooth	p_n
Axial Pitch	p_x
Normal Pitch	p_b
Radial Normal Pitch	p_{bt}
Normal Pitch Perpendicular to Tooth	p_{bn}
Whole Depth	h
Addendum	h_a
Dedendum	h_f
Caliper Tooth Height	$\bar{h}$
Working Depth	h' h_w
Tooth Thickness (General)	s
Circular Tooth Thickness	s
Base Circle Circular Tooth Thickness	s_b
Chordal Tooth Thickness	$\bar{s}$
Span Measurement	W
Root Width	e
Top Clearance	c
Circular Backlash	j_t
Normal Backlash	j_n
Blank Width	b
Working Face Width	b' b_w

Terms	Symbols
Lead	p_z
Contact Length	g_a
Contact Length of Approach	g_f
Contact Length of Recess	g_a
Contact Length of Overlap	g_b
Diameter (General)	d
Standard Pitch Diameter	d
Working Pitch Diameter	d' d_w
Outside Diameter	d_a
Base Diameter	d_b
Root Diameter	d_f
Radius (General)	r
Standard Pitch Radius	r
Working Pitch Radius	r' r_w
Outside Radius	r_a
Base Radius	r_b
Root Radius	r_f
Radius of Curvature	ρ
Cone Distance (General)	R
Cone Distance	R_e
Mean Cone Distance	R_m
Inner Cone Distance	R_i
Back Cone Distance	R_v
Mounting Distance	*A
Offset Distance	*E

* These terms and symbols are specific to JIS Standard

Table 1-3B Angular Dimensions

Terms	Symbols
Pressure Angle (General)	α
Standard Pressure Angle	α
Working Pressure Angle	α' or α_w
Cutter Pressure Angle	α_0
Radial Pressure Angle	α_t
Pressure Angle Normal to Tooth	α_n
Axial Pressure Angle	α_x
Helix Angle (General)	β
Standard Pitch Cylinder Helix Angle	β
Outside Cylinder Helix Angle	β_a
Base Cylinder Helix Angle	β_b
Lead Angle (General)	γ
Standard Pitch Cylinder Lead Angle	γ
Outside Cylinder Lead Angle	γ_a
Base Cylinder Lead Angle	γ_b

Terms	Symbols
Shaft Angle	Σ
Cone Angle (General)	δ
Pitch Cone Angle	δ
Outside Cone Angle	δ_a
Root Cone Angle	δ_f
Addendum Angle	θ_a
Dedendum Angle	θ_f
Radial Contact Angle	ϕ_a
Overlap Contact Angle	ϕ_β
Overall Contact Angle	ϕ_r
Angular Pitch of Crown Gear	τ
Involute Function	inv α

Continued on the next page

Table 1-3C Size Number, Ratios & Speed Terms

Terms	Symbols
Number of Teeth	z
Equivalent Spur Gear Number of Teeth	z_v
Number of Threads in Worm	z_w
Number of Teeth in Pinion	z_l
Number of Teeth Ratio	u
Speed Ratio	i
Module	m
Radial Module	m_t
Normal Module	m_n
Axial Module	m_x

Terms	Symbols
Contact Ratio	ε
Radial Contact Ratio	ε_α
Overlap Contact Ratio	ε_β
Total Contact Ratio	ε_γ
Specific Slide	*σ
Angular Speed	ω
Linear or Tangential Speed	v
Revolutions per Minute	n
Coefficient of Profile Shift	x
Coefficient of Center Distance Increase	y

NOTE: The term "Radial" is used to denote parameters in the plane of rotation perpendicular to the axis.

Table 1-3D Accuracy / Error Terms

Terms	Symbols
Single Pitch Error	f_{pt}
Pitch Variation	*f_u or f_{pu}
Partial Accumulating Error (Over Integral k teeth)	F_{pk}
Total Accumulated Pitch Error	F_p

Terms	Symbols
Normal Pitch Error	f_{pb}
Involute Profile Error	f_f
Runout Error	F_r
Lead Error	F_b

*These terms and symbols are specific to JIS Standards

Table 1-4 Equivalence Of American And Japanese Symbols

American Symbol	Japanese Symbol	Nomenclature
B	j	backlash, linear measure along pitch circle
B_{LA}	j_t	backlash, linear measure along line-of-action
B_a	j_n	backlash in arc minutes
C	a	center distance
ΔC	Δa	change in center distance
C_o	a_w	operating center distance
C_{std}		standard center distance
D	d	pitch diameter
D_b	d_b	base circle diameter
D_o	d_a	outside diameter
D_R	d_f	root diameter
F	b	face width
K	K	factor, general
L	L	length, general; also lead of worm
M		measurement over-pins
N	z	number of teeth, usually gear
N_c	z_c	critical number of teeth for no undercutting

American Symbol	Japanese Symbol	Nomenclature
N_v	z_v	virtual number of teeth for helical gear
P_d	p	diametral pitch
P_{dn}	p_n	normal diametral pitch
P_t		horsepower, transmitted
R	r	pitch radius, gear or general use
R_b	r_b	base circle radius, gear
R_o	r_a	outside radius, gear
R_T		testing radius
T	s	tooth thickness, gear
W_b		beam tooth strength
Y		Lewis factor, diametral pitch
Z	i	mesh velocity ratio
a	h_a	addendum
b	h_f	dedendum
c	c	clearance
d	d	pitch diameter, pinion
d_w	d_p	pin diameter, for over-pins measurement
e		eccentricity
h_k	h_w	working depth

Continued on the next page

Table 1-4 (Cont.) Equivalence of American and Japanese Symbols

American Symbol	Japanese Symbol	Nomenclature
h_t	h	whole depth
m_p	e	contact ratio
n	z_1	number of teeth, pinion
n_w	z_w	number of threads in worm
p_a	p_x	axial pitch
p_b	p_b	base pitch
p_c	p	circular pitch
p_{cn}	p_n	normal circular pitch
r	r	pitch radius, pinion
r_b	r_b	base circle radius, pinion
r_f	r_f	fillet radius
r_o	r_a	outside radius, pinion
t	s	tooth thickness, and for general use, for tolerance

American Symbol	Japanese Symbol	Nomenclature
y_c		Lewis factor, circular pitch
γ	δ	pitch angle, bevel gear
θ		rotation angle, general
λ	γ	lead angle, worm gearing
μ		mean value
ν		gear stage velocity ratio
ϕ	α	pressure angle
ϕ_o	α_w	operating pressure angle
Ψ	β	helix angle (b_b=base helix angle; b_w= operating helix angle)
ω		angular velocity
inv ϕ	inv α	involute function

1.3.3 Terminology

Terms used in metric gearing are identical or are parallel to those used for inch gearing. The one major exception is that metric gears are based upon the module, which for reference may be considered as the inversion of a metric unit diametral pitch.

Terminology will be appropriately introduced and defined throughout the text.

There are some terminology difficulties with a few of the descriptive words used by the Japanese JIS standards when translated into English. One particular example is the Japanese use of the term "radial" to describe measures such as what Americans term circular pitch. This also crops up with contact ratio. What Americans refer to as contact ratio in the plane of rotation, the Japanese equivalent is called "radial contact ratio". This can be both confusing and annoying. Therefore, since this technical section is being used outside Japan, and the American term is more realistically descriptive, in this text we will use the American term "circular" where it is meaningful. However, the applicable Japanese symbol will be used. Other examples of giving preference to the American terminology will be identified where it occurs.

1.3.4 Conversion

For those wishing to ease themselves into working with metric gears by looking at them in terms of familiar inch gearing relationships and mathematics, **Table 1-5** is offered as a means to make a quick comparison.

Table 1-5 Spur Gear Design Formulas

To Obtain	From Known	Use This Formula*
Pitch Diameter	Module	$D = mN$
Circular Pitch	Module	$p_c = m\pi = \frac{D}{N}\pi$
Module	Diametral Pitch	$m = \frac{25.4}{P_d}$
Number of Teeth	Module and Pitch Diameter	$N = \frac{D}{m}$
Addendum	Module	$a = m$

* All linear dimensions in millimeters
Symbols per **Table 1-4**

Continued on the next page