



American
Gear Manufacturers
Association

ANSI/AGMA 6013-B16
(Revision of ANSI/AGMA 6013-A06)

American National Standard

Standard for Industrial Enclosed Gear Drives

ANSI/AGMA 6013-B16

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Standard*****Standard for Industrial Enclosed Gear Drives***

ANSI/AGMA 6013-B16

[Revision of ANSI/AGMA 6013-A06]

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ABSTRACT

This standard includes design, rating, lubrication, testing, and selection information for enclosed gear drives, including foot mounted, shaft mounted, screw conveyor drives, and gearmotors. These drives may include spur, helical, herringbone, double helical, or bevel gearing in single or multistage arrangements as either parallel, concentric, or right angle configurations.

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Contents

Foreword	vi
1 Scope	1
1.1 Limitations	1
1.2 Exceptions	1
2 Normative references	1
3 Symbols and terms	2
3.1 Symbols	2
3.2 Terms	3
3.2.1 Gearmotors	3
3.2.2 Shaft mounted drives	3
3.2.3 Foot mounted drives	3
3.2.4 Flange or face mounted drives	3
3.2.5 PAO synthetic lubricant	3
3.2.6 PAG synthetic lubricant	3
4 Application and design considerations	3
4.1 Momentary load	3
4.2 Rating factors	4
4.3 System analysis	4
4.4 Considerations for cold temperature operation	4
4.5 Inertia effects	4
4.5.1 Large motor inertia – small driven inertia	4
4.5.2 Small motor inertia – large driven inertia	4
4.5.3 Other inertia considerations	4
4.6 Additional application and design considerations	5
5 Unit rating	5
5.1 External loading	5
5.2 Efficiency	5
5.2.1 Electric motor	6
5.3 Application power	6
5.4 Momentary overloads	6
6 Gear rating criteria	6
6.1 Pitting resistance power rating, P_{ac}	7
6.1.1 Pitting resistance for spur and helical gearing	7
6.1.2 Pitting resistance for bevel gears	8
6.2 Bending strength power rating, P_{at}	8
6.2.1 Bending strength for spur and helical gearing	8
6.2.2 Bending strength for bevel gears	9
6.3 Allowable stress numbers for pitting resistance and bending strength	9
6.4 Load spectrum analysis	9
7 Thermal power rating	9
8 Component design	10
8.1 Housing	10
8.2 Threaded fasteners	10
8.3 Bearings	10
8.4 Shafting	10
8.5 Balancing	10
8.6 Keys	10

8.6.1	External keyways	10
8.6.2	Interference fit of hubs and shafts	10
8.7	Torque arms	11
8.8	Backstops	12
8.8.1	Backstop types	12
8.8.2	Selection and application	12
8.8.3	Installation	12
8.8.4	Lubrication	13
8.9	Couplings	13
8.10	Shrink discs	13
8.11	Shaft bushings	13
8.11.1	Bushing types	13
8.11.2	Design considerations	14
8.11.3	Installation criteria	15
8.12	Electric motors	15
8.12.1	Motor types	15
8.12.2	Selection criteria	16
8.13	Other components	16
9	Service factors and application classification	17
9.1	Selection of recommended factors	17
9.2	Service factors	17
9.3	Application classification numbers	17
9.4	Determining service factor or application class number	18
9.4.1	Operational characteristics	18
9.4.2	System conditions	18
9.4.3	Special considerations	19
10	Overhung load	19
11	Lubrication and lubricants	20
11.1	Lubrication	20
11.1.1	Ambient temperature	20
11.1.2	Other considerations	20
11.1.3	Oil sump temperature	20
11.1.4	Food and drug	21
11.1.5	Mounting position	21
11.1.6	Corrosion	21
11.2	Lubricant viscosity	21
11.3	Lubricant recommendation	21
11.3.1	External cooling	22
11.3.2	Lubricant viscosity considerations	22
11.4	Cold temperature conditions	22
11.4.1	Cold temperature gear lubricants	22
11.4.2	Sump heaters	23
11.5	Lubricant types	23
11.5.1	Rust and oxidation inhibited gear lubricants	23
11.5.2	Antiscuff lubricants	23
11.5.3	Synthetic gear lubricants	23
11.5.4	Synthetic lubricant selection	23
11.6	Lubricant maintenance	24
11.6.1	Initial lubricant maintenance	24
11.6.2	Subsequent lubricant maintenance	24
11.6.3	Abnormal operating conditions	24
11.6.4	Cleaning and flushing	24

11.6.5	Cleaning with solvents	25
11.6.6	Inspection	25
11.6.7	Lubricant disposal	25
12	Sound and vibration	25
13	Assembly and shaft rotation	25
14	Ratios and output speeds	28
15	Sizes, designations and ratios for AGMA standard size shaft mounted gear drives	29
15.1	AGMA standard sizes	29
15.2	Standard designations	29
15.3	Ratios	30
16	Screw conveyor drive dimensions	30
17	Marking and identification	30
18	Storage	30
18.1	Normal storage	31
18.2	Adverse conditions or long term storage	31
18.3	Removal from storage	31
19	Installation	31

Annexes

Annex A (informative)	Service factors and application classification numbers	32
Annex B (informative)	Keys and keyways for shaft extensions	46
Annex C (informative)	Test and inspection procedures	53
Annex D (informative)	Owner responsibilities	55
Annex E (informative)	Screw conveyor drive dimensions	57
Annex F (informative)	Illustrative examples	59
Annex G (informative)	Recommended bore sizes for AGMA standard size shaft mounted drives	68
Annex H (informative)	Installation	69
Annex I (informative)	Wormgearing	73
Annex J	Bibliography	77

Figures

Figure 1	– Threaded rod torque arm	11
Figure 2	– Torque link	11
Figure 3	– Single point torque arm	12
Figure 4	– Shaft rotation	25
Figure 5	– Parallel shaft spur, helical and herringbone gear drives, single or multiple stages	26
Figure 6	– Horizontal bevel gear drives, single stage; horizontal bevel - helical drives, multiple stage	27
Figure 7	– Vertical bevel gear drives, single stage; vertical bevel - helical drives, multiple stage	27
Figure 8	– Standard designations	30
Figure B.1	– Diagrams for metric keys	46
Figure B.2	– Diagrams for metric keyways	48
Figure B.3	– Diagrams for inch keys with fillet radius and key chamfer	50
Figure B.4	– Diagrams for inch keyways	51
Figure E.1	– Drive shaft dimensions	57
Figure E.2	– Screw conveyor drive mounting dimensions	58

Tables

Table 1	– Symbols	2
Table 2	– Shaft diameter tolerances for supporting shafts	15
Table 3	– Service factor, K_{SF}	18
Table 4	– Overhung load factor, K_{Oh}	20
Table 5	– Viscosity grade requirements	21
Table 6	– Viscosity grade guidelines	22

Table 7 – Output speeds for preferred ratios	28
Table 8 – Standard sizes and maximum bores	29
Table 9 – Nominal ratios	30
Table A.1 – Conversion table for single or multi-cylinder engines	33
Table A.2 – Service factors for enclosed gear drives	33
Table A.3 – Application classification	39
Table A.4 – Industrial duty overhead electric crane service factors	44
Table A.5 – Service factors for industrial duty overhead electric cranes	44
Table A.6 – Mill duty overhead electric crane service factors	44
Table B.1 – Metric dimensions and tolerances of keys, millimeters	47
Table B.2 – Metric dimensions and tolerances of keyways, millimeters	49
Table B.3 – Inch dimensions and tolerances of keys, inches	50
Table B.4 – Inch dimensions and tolerances of keyways, inches	52
Table E.1 – Screw conveyor drive shaft dimensions, inches	57
Table E.2 – Screw conveyor drive mounting dimensions, inches	58
Table G.1 – Recommended output bore diameters for inch shafts	68

Foreword

[The foreword, footnotes and annexes, if any, in this document are provided for informational purposes only and are not to be construed as a part of AGMA Standard 6013-B16, *Standard for Industrial Enclosed Gear Drives*.]

This standard revises, combines and supersedes two previous independent standards, ANSI/AGMA 6009-A00, *Standard for Gearmotors, Shaft Mounted and Screw Conveyor Drives*, and ANSI/AGMA 6010-F97, *Standard for Spur, Helical, Herringbone and Bevel Enclosed Drives*. The history of these standards have their roots in:

- AGMA 420.04, *Practice for Enclosed Speed Reducers or Increasers Using Spur, Helical, Herringbone and Spiral Bevel Gears*
- AGMA 460.05, *Practice for Gearmotors Using Spur, Helical, Herringbone and Spiral Bevel Gears*
- AGMA 480.06, *Practice for Spur, Helical and Herringbone Gear Shaft-Mounted Speed Reducers*

ANSI/AGMA 6013-A06 presents general guidelines and practices for design, rating and lubrication of parallel, concentric, and right angle shaft drives. It includes foot mounted, shaft mounted, screw conveyor drives, and gearmotors. It includes the available data, gear technology, and operational experience.

The comprehensive thermal rating procedure has been removed but is included by reference to AGMA ISO 14179-1.

This standard reflects the consolidation of “Enclosed Drives”, to include gearmotors, shaft mounted, and screw conveyor drives, into a single document.

The allowable stress numbers used in this standard are derived from ANSI/AGMA 2001-D04, *Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth* and ANSI/AGMA 2003-C10, *Rating the Pitting Resistance & Bending Strength of Generated Straight Bevel, Zerol Bevel, and Spiral Bevel Gear Teeth*, and, along with other rating factors, provide a rating basis for enclosed gear reducers and increasers. The rating formulas are based on many years of experience in the design and application of enclosed gear drives for industrial use. Provisions are included in this standard for using stress cycle factors other than 1.0 to adjust the rating for extended or reduced life. Using a stress cycle adjustment factor does not guarantee a certain number of life hours or stress cycles, but is a method of approximating gear life under different load and speed conditions.

In addition to a general update to match current industry practices, substantial changes in the new ANSI/AGMA 6013-B16 include:

- moved wormgearing related text to Annex I;
- expanded crane service factor recommendations;
- revised and updated lubrication clause.

The competence to design enclosed gear drives, especially the knowledge and judgment required to properly evaluate the various rating factors, comes primarily from years of experience in designing, testing, manufacturing, and operating similar gear drives. The proper application of the general rating formulas for enclosed gear drives is best accomplished by those experienced in the field.

The first draft of ANSI/AGMA 6013-A06 was created in November 2000. It was approved by the AGMA membership in March 2006. It was approved as an American National Standard on April 25, 2006.

The first draft of ANSI/AGMA 6013-B16 was created in November 2011. It was approved by the AGMA membership in October 2015. It was approved as an American National Standard on April 5, 2016.

Suggestions for improvement of this standard will be welcome. They may be submitted to tech@agma.org.

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American National Standard—

Standard for Industrial Enclosed Gear Drives

1 Scope

This standard is applicable to enclosed gear drives including configurations of parallel, concentric, and right angle shafts. It includes foot mounted, shaft mounted, screw conveyor drives, and gearmotors. These enclosed drives utilize spur, helical, herringbone, double helical, or bevel gearing in single or multiple stages. Bevel gear drives may include shaft angles other than 90 degrees.

1.1 Limitations

This standard is applicable to gear drives having single or multiple stage gearing with pitch line velocities not exceeding 7000 ft/min for spur, helical and spiral bevel gearing and 6000 ft/min for straight bevel, and shaft speeds not exceeding 4500 rpm for helical, spur, straight bevel, and spiral bevel gearing.

1.2 Exceptions

This standard does not cover epicyclic or crossed-helical gear drives. This standard does not cover the rating of spur, helical, or bevel gears due to wear or scuffing. The design and rating of the electric motor is beyond the scope of this standard. This standard does not apply to gear drives that are covered by other specific AGMA application standards.

For gear drives using wormgears, the design parameters shall be in accordance with the methods and procedures of ANSI/AGMA 6035-A02 for double enveloping wormgears and ANSI/AGMA 6034-B92 for cylindrical wormgears. Refer to Annex I for more details.

2 Normative references

The following documents contain provisions which, through reference in this text, constitute provisions of this American National Standard. At the time of publication, the editions shown were valid. All standards are subject to revision, and the users of this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

AGMA 908-B89, *Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth*

AGMA ISO 14179-1, *Gear Reducers – Thermal Capacity Based on ISO/TR 14179-1*

ANSI/AGMA 1010-F14, *Appearance of Gear Teeth – Terminology of Wear and Failure*

ANSI/AGMA 1012-G05, *Gear Nomenclature, Definitions of Terms with Symbols*

ANSI/AGMA 2001-D04, *Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth*

ANSI/AGMA 2003-C10, *Rating the Pitting Resistance and Bending Strength of Generated Straight Bevel, Zerol Bevel, and Spiral Bevel Gear Teeth*

ANSI/AGMA 6000-B96, *Specification for Measurement of Linear Vibration on Gear Units*

ANSI/AGMA 6001-E08, *Design and Selection of Components for Enclosed Gear Drives*

ANSI/AGMA 6025-D98, *Sound for Enclosed Helical, Herringbone, and Spiral Bevel Gear Drives*

ANSI/AGMA 6034-B92, *Practice for Enclosed Cylindrical Wormgear Speed Reducers and Gearmotors*

ANSI/AGMA 6035-A02, *Design, Rating and Application of Industrial Globoidal Wormgearing*

ANSI/AGMA ISO 6336-6-A08, *Calculation of Load Capacity of Spur and Helical Gears – Part 6: Calculation of Service Life Under Variable Load*

ANSI/AGMA 9002-C14, *Bores and Keyways for Flexible Couplings (Inch Series)*

ANSI/AGMA 9005-F16, *Industrial Gear Lubrication*

ANSI B17.1 – 1967, *Keys and Keyseats*

3 Symbols and terms

3.1 Symbols

The symbols used in this standard are shown in Table 1.

NOTE: The symbols and terms contained in this document may vary from those used in other AGMA standards. Users of this standard should assure themselves that they are using these symbols and terms in the manner indicated herein.

Table 1 – Symbols

Symbol	Term	Units	Where first used
C_f	Surface condition factor	--	6.1.1
C_L	Stress cycle factor for pitting, bevel gears	--	6.1.2
C_{ma}	Mesh alignment factor	--	6.1.1.2
C_R	Reliability factor		6.1.2
d_p	Pitch diameter of element on shaft	in	10
K_L	Stress cycle factor for bending strength, bevel gears	--	6.2.2
K_m	Load distribution factor	--	6.1.1
K_o	Overload factor	--	6.1.1
K_{oh}	Overhung load factor	--	10
K_R	Reliability factor	--	6.1.1
K_{SF}	Service factor	--	4.1
K_T	Temperature factor	--	6.1.1
K_v	Dynamic factor	--	6.1.1
P_A	Application power	HP	5.3
P_{ac}	Allowable transmitted power for pitting resistance	HP	6.1
P_{at}	Allowable transmitted power for bending strength	HP	6.2
P_{mc}	Minimum component power rating	HP	5.3
P_T	Thermal power rating	HP	5.3
Q_v	Transmission accuracy level number	--	6.1.2.2
S_F	Safety factor for bending strength	--	6.2.1
S_H	Safety factor for pitting resistance	--	6.1.1
T	Transmitted shaft torque	lb in	10
W_{oc}	Effective overhung load	lb	10
Y_N	Stress cycle factor for bending strength, spur and helical gears	--	6.1.1.3
Z_N	Stress cycle factor for pitting, spur and helical gears	--	6.1.1
S_{ay}	Allowable yield stress number	lb/in ²	5.4

3.2 Terms

The terms used, wherever applicable, conform to ANSI/AGMA 1012, *Gear Nomenclature, Definitions of Terms with Symbols*.

3.2.1 Gearmotors

A gearmotor is defined as an enclosed gear drive in combination with an electric motor of 1/8 HP or larger, the frame of one supporting the other, with the motor shaft common or directly coupled to the input shaft and parallel, concentric, or at an angle to the output shaft. The output shaft may be either solid or hollow.

3.2.2 Shaft mounted drives

A shaft mounted drive is defined as an enclosed gear drive that is supported by the driven shaft and a torque reaction member. A specific type of hollow shaft mount drive is further defined in Clause 15. Other shaft mounted drives exist and are also covered by this standard.

3.2.3 Foot mounted drives

A foot mounted drive is defined as an enclosed drive supported by mounting feet or lugs incorporated into the housing.

3.2.4 Flange or face mounted drives

A flange or a face mounted drive is defined as an enclosed drive supported by a rigid structural connection that provides location and connection features to the driving, or driven, equipment.

3.2.5 PAO synthetic lubricant

Polyalphaolefin, or PAO, based synthetic lubricant.

3.2.6 PAG synthetic lubricant

Polyalkylene glycol, or PAG, based synthetic lubricant.

4 Application and design considerations

The knowledge and judgment required to evaluate the various rating factors comes from years of accumulated experience in designing, manufacturing, and operating gear units. Empirical factors given in this standard are general in nature. This standard is intended for use by the experienced gear designer, capable of selecting reasonable values for the factors. It is not intended for use by the engineering public at large.

Unit rating is based on the mechanical rating of all gear drive components determined with a unity service factor. In some applications, it may be necessary to select or design the drive to account for unusual application requirements that may include:

- reduced or increased reliability;
- extended or shortened life;
- intermittent operation;
- increased thermal capacity;
- increased external load capacity.

4.1 Momentary load

Gear drives designed and selected in accordance with this standard permit the following peak load conditions:

- each peak shall not exceed 200% of the unit rating (at a service factor or application classification I, $K_{SF} = 1.0$);
- a limited number of peak stress cycles, typically less than 10^4 .

For applications exceeding these conditions an appropriate service factor, or application classification, should be selected.

WARNING: For momentary torques in excess of 200%, stall conditions, and low number of stress cycles the gear drive should be evaluated to confirm that these conditions do not exceed the yield strength of any component.

Some applications may require selecting a gear drive with increased unit rating in order to accommodate adverse effects of environmental conditions, thermal capacity of the unit, external loading, or any combination of these factors.

4.2 Rating factors

For calculating pitting resistance and bending strength rating for gears, specific values or procedures for rating factors are given in Clause 6. Material properties, manufacturing considerations, or experience may indicate that more, or less, conservative rating factors may be used.

4.3 System analysis

This standard assumes that within the operating speed range, the system of connected rotating parts is compatible and free from critical speeds and torsional, or other types, of vibration, no matter how induced. The gear drive designer or manufacturer is not responsible for the system analysis.

4.4 Considerations for cold temperature operation

If units are to be operated in cold temperatures, generally below 32°F, care should be taken to select materials and components that have adequate properties at the operating temperature. Consideration should be given to:

- low temperature impact strength of materials;
- fracture appearance transition or nil ductility temperature specification for impact testing;
- reducing carbon content of load carrying component to less than 0.4%;
- use of higher nickel alloy steels;
- seal material selection;
- lubricant type and viscosity, see 11.4.

4.5 Inertia effects

Normally, in designing a gear drive that may be used in a variety of applications, a manufacturer cannot anticipate what magnitude of inertias will be incorporated into the final system application. When sizing a gear drive for an application, the prime mover, gear drive, and driven equipment inertias during both acceleration and deceleration should be considered to ensure adequate performance of the gear drive.

4.5.1 Large motor inertia – small driven inertia

At startup, most of the torque generated by the motor is used to accelerate the motor rotor, which results in relatively low loads on the gear drive.

Sudden stops of the driven inertia result in high loads on the gear drive due to the rapid deceleration of the large motor inertia.

4.5.2 Small motor inertia – large driven inertia

At startup, most of the torque generated by a motor with high starting torque characteristics passes through the gear drive to accelerate the driven equipment, resulting in high loads on the gear drive.

Sudden stops of the driven inertia result in high loads on the driven equipment. There is a lesser effect passed through the gear drive due to the relatively low motor inertia.

4.5.3 Other inertia considerations

The gear drive contributes significantly to the dynamics of the system and should be taken into account when designing the system. The inertial effects transferred across the gear drive are a function of the square of the ratio.

When designing a system, if these effects are considered in the early stages, it may be possible to design the system to accommodate likely operating conditions. For example, if a system is to be started frequently, it may be possible to select a motor with high inertia, or if a system is expected to encounter frequent jams, a small motor inertia may be preferred. Other considerations may include a torque limiting coupling, soft braking controls, a flywheel in the system, increased service factor, or torsionally softening the system.

4.6 Additional application and design considerations

For additional application and design considerations, such as metallurgy, residual stress, and manufacturing tolerances, refer to ANSI/AGMA 2001-D04 and ANSI/AGMA 2003-C10.

5 Unit rating

Throughout this standard the term “unit rating” is defined as the maximum power that can be transmitted without exceeding the lowest individual rating of the following:

- gearing;
- housing;
- shafting;
- keys;
- bearings;
- threaded fasteners;
- motor connection for gearmotors;
- other components of the basic gear drive and auxiliary systems.

The effects of both torque and external loads at the peak load conditions shall be considered. Pitting resistance and bending strength ratings for all gearing are to be in accordance with the appropriate reference standard.

5.1 External loading

External loads shall be considered as acting in directions and rotations producing the most unfavorable conditions of stress and life, unless more specific information is available. The allowable external loads, overhung load and thrust load shall be based upon the weakest of shafts, bearings, housings, bearing retainers, bolts, or other related components. These components shall allow for momentary peak loads of 200% of the unit rating.

The manufacturer should be consulted when overhung and thrust loads occur simultaneously.

The allowable overhung load values shall be accompanied by stipulation of the load center location at which the value is applicable. The load center is usually designated as one shaft diameter measured outward from the face of the housing or housing component, or at the center of the shaft keyway.

5.2 Efficiency

Gear drive efficiency is dependent upon such variables as:

- operating speed;
- oil viscosity, level, and type;
- pitch line velocity;
- bearing type;
- applied loads;
- gear design;
- internal space constraints;
- oil seal style and quantity;
- number of gear meshes;
- shaft driven accessories, such as fans and pumps.

Specific values for gear drive efficiency should be obtained from the gear drive manufacturer.

Efficiency estimates can be determined by using the method in AGMA ISO 14179-1.

5.2.1 Electric motor

Electric motor efficiency is dependent upon such variables as:

- voltage variation;
- power factor;
- motor design;
- motor material electrical characteristics;
- percentage of full load torque;
- other electrical and mechanical parameters.

Specific values for electric motor efficiency should be obtained from the electric motor manufacturer.

The total efficiency of a gearmotor is the product of the individual efficiencies of the electric motor and the gear drive.

5.3 Application power

The application of the enclosed drive requires that its capacity as defined by its unit rating, for example, its minimum rated component power, P_{mc} , and its thermal rating, P_T , be related to the actual service conditions.

$$P_A \leq \frac{P_{mc}}{K_{SF}} \text{ and } P_A \leq P_T \quad (1)$$

where

P_A is application power of enclosed drive, HP;

P_{mc} is minimum component power rating, HP;

P_T is thermal power rating, HP, see Clause 7;

K_{SF} is the service factor, or application classification. Refer to Clause 9.

For cases where the gear mesh has been determined to be the minimum rated component, the lesser of P_{ac} or P_{at} , as defined in this standard, becomes P_{mc} in Equation 1. See 6.1 and 6.2.

5.4 Momentary overloads

When the enclosed drive is subjected to infrequent momentary overloads, stall conditions and low-cycle fatigue (less than 100 cycles), the conditions should be evaluated to assure that the yield strength of any component is not exceeded. See 9.4.1.

With respect to the gear bending strength for momentary overloads, the maximum allowable stress is determined by the allowable yield properties rather than the bending fatigue strength of the material. This stress for spur and helical gearing is designated as s_{ay} ; its determination is shown in ANSI/AGMA 2001. Shaft, bearing, and housing deflections have a significant effect on gear mesh alignment during momentary overloads. The enclosed drive shall be evaluated to assure that the reactions to momentary overloads do not result in excessive misalignment causing localized high stress concentrations, or permanent deformation, or both. In addition, the effects of external loads such as overhung, transverse and thrust loads shall be evaluated.

6 Gear rating criteria

The pitting resistance power rating and the bending strength power rating for each mesh in the gear drive shall be calculated.

The lowest value obtained shall be used as the power rating of the gear set. It is permissible to use more conservative values.

6.1 Pitting resistance power rating, P_{ac}

The pitting resistance of gear teeth is considered to be a Hertzian contact fatigue phenomenon. Initial pitting and destructive pitting are illustrated and discussed in ANSI/AGMA 1010.

The intent of the AGMA pitting resistance rating formula is to determine the power level which can be transmitted for the design life of the teeth without causing destructive pitting. The ratings for pitting resistance are based on the formulas developed by Hertz for contact pressure between two surfaces, modified for the effect of load sharing between adjacent teeth.

6.1.1 Pitting resistance for spur and helical gearing

The pitting resistance power rating for involute spur and helical teeth shall be determined by the rating methods and procedures of ANSI/AGMA 2001 using specific values or procedures for the following factors:

- K_T = 1.0, temperature factor;
- C_f = 1.0, surface condition factor;
- K_R = 1.0, reliability factor;
- S_H = 1.0, safety factor;
- K_o = 1.0, overload factor;
- K_v is dynamic factor (see 6.1.1.1);
- K_m is load distribution factor (see 6.1.1.2);
- Z_N is stress cycle factor (see 6.1.1.3).

6.1.1.1 Dynamic factor, K_v

The dynamic factor shall be determined from ANSI/AGMA 2001-D04, Clause 8, with the exception that values of K_v shall not be based on a transmission accuracy number less than $A_v = 6$.

Transmission accuracy number, A_v , shall be based upon the quality level of the gearing produced. In the absence of a known specific quality level, the curve for $A_v = 11$ shall be used.

Figure 1 of ANSI/AGMA 2001-D04 limits values for the dynamic factor as a function of pitch line velocity. These curves shall not be extrapolated to obtain values beyond the limits given.

6.1.1.2 Load distribution factor, K_m

To calculate the load distribution factor, the empirical method of ANSI/AGMA 2001-D04 Clause 15 shall be used.

In the absence of specific knowledge, Curve 2 of Figure 7 in ANSI/AGMA 2001-D04 for mesh alignment factor, C_{ma} , shall be used for general design and manufacturing practice. When justified by a detailed analysis of design and manufacturing along with proper installation, Curve 3 for C_{ma} may be used. Curve 4 shall not be used.

6.1.1.3 Stress cycle factor, Z_N and Y_N

This factor adjusts the rating of individual gear elements based on the relative number of subjected stress cycles. However, use of this factor does not in any way imply a fixed life. It adjusts each gear element rating based on the relative number of cycles.

The number of cycles corresponding to 10 000 hours should be used to determine the stress cycle factor for all enclosed drives except gearmotors and AGMA standard sized shaft mounted, screw conveyor, and flange mounted drives, which should use 5000 hours.

Two curves are presented in Figures 17 and 18 of ANSI/AGMA 2001-D04 for stress cycle factors above 107 cycles for pitting and 3×10^6 cycles for bending, respectively. In both figures, the upper portion should be used for general design.

Where specific experience and satisfactory performance has been demonstrated by successful use of service factors, values of Z_N and Y_N of 1.0 may be appropriate.

6.1.2 Pitting resistance for bevel gears

The pitting resistance power rating for bevel gears shall be determined by the rating procedures and formulas of ANSI/AGMA 2003, using specific values or procedures for the following factors:

- K_o = 1.0, overload factor;
- S_H = 1.0, contact safety factor;
- K_T = 1.0, temperature factor;
- C_R = 1.0, reliability factor;
- C_L is stress cycle factor (see 6.1.2.1);
- K_v is dynamic factor (see 6.1.2.2).

6.1.2.1 Stress cycle factor, C_L

This factor adjusts the rating of individual gear elements based on the relative number of load cycles. The number of cycles corresponding to 10 000 hours should be used to determine the stress cycle factor for all enclosed drives except gearmotors and AGMA standard sized shaft mounted, screw conveyor, and flange mounted drives, which should use 5000 hours. See Figure 5 in ANSI/AGMA 2003-C10.

Where specific experience and satisfactory performance has been demonstrated by successful use of service factors, a value of C_L of 1.0 may be appropriate.

6.1.2.2 Dynamic factor, K_v

This factor is to be determined by Clause 10 in ANSI/AGMA 2003-C10. In the absence of a known quality level, the curve for $Q_v = 6$ shall be used.

6.2 Bending strength power rating, P_{at}

The bending strength of gear teeth is a measure of the resistance to fatigue cracking at the tooth root fillet. Typical cracks and fractures are illustrated in ANSI/AGMA 1010.

The intent of the AGMA bending strength rating formula is to determine the power that can be transmitted for the design life of the teeth without causing root fillet cracking or failure.

Occasionally, manufacturing tool marks, wear, surface fatigue, or plastic flow may limit bending strength due to stress concentration around large sharp cornered pits, or wear steps on the tooth surface.

6.2.1 Bending strength for spur and helical gearing

The bending strength power rating for involute spur and helical gear teeth shall be determined by the rating methods and procedures of ANSI/AGMA 2001 using specific values or procedures for the following factors:

- K_T = 1.0, temperature factor;
- K_R = 1.0, reliability factor;
- S_F = 1.0, safety factor;
- K_o = 1.0, overload factor;
- K_v is dynamic factor (see 6.1.1.1);
- K_m is load distribution factor (see 6.1.1.2);
- Y_N is stress cycle factor (see 6.1.1.3).

6.2.2 Bending strength for bevel gears

The bending strength rating for bevel gears shall be determined by the rating methods and procedures of ANSI/AGMA 2003 using specific values or procedures for the following factors:

- K_o = 1.0, overload factor;
- K_T = 1.0, temperature factor;
- K_R = 1.0, reliability factor;
- S_F = 1.0, safety factor;
- K_v is dynamic factor (see 6.1.2.2);
- K_L is stress cycle factor (see 6.2.2.1).

6.2.2.1 Stress cycle factor, K_L

This factor adjusts the rating of individual gear elements based on the relative number of load cycles. The number of cycles corresponding to 10 000 hours should be used to determine the stress cycle factor for all enclosed drives except gearmotors and AGMA standard sized shaft mounted, screw conveyor, and flange mounted drives, which should use 5000 hours. See Figure 6 in ANSI/AGMA 2003-C10.

Two curves are presented for load cycles above 3×10^6 cycles. The upper curve should be chosen for general design.

Where specific experience and satisfactory performance has been demonstrated by successful use of service factors, a value of K_L of 1.0 may be appropriate.

6.3 Allowable stress numbers for pitting resistance and bending strength

As defined in ANSI/AGMA 2001 and ANSI/AGMA 2003, the allowable stress numbers for gear materials vary with composition, cleanliness, quality, heat treatment, and processing practices. It is recommended that only material Grades 1 and 2 be used to determine stress numbers for industrial gear drives.

6.4 Load spectrum analysis

To determine the effects of variable loading on gear life, it is recommended that the cumulative fatigue damage analysis criteria proposed by Miner (Miner's Rule) be used. Refer to ANSI/AGMA ISO 6336-6 for information on the use of Miner's Rule in conducting a load spectrum analysis.

Since the accuracy of the results is determined by the quality of the analysis, when an accurate life is required, a thorough analysis is necessary. This more detailed analysis would include:

- a load spectrum broken into a significant number of increments;
- a detailed S-N curve for the specific material and load levels.

7 Thermal power rating

Maintaining an acceptable temperature in the oil sump of a gear drive is critical to its life. Therefore, the selection of a gear drive shall consider not only the mechanical rating but also the thermal rating. If the application is less than 60 minutes per hour, continuous thermal rating can be less than continuous service power. See AGMA ISO 14179-1 for more information.

Thermal rating is defined as the maximum power that can be continuously transmitted through a gear drive without exceeding a specified oil sump temperature. The thermal rating shall equal or exceed the actual service transmitted power for continuous duty. Service factors are not used when determining thermal requirements. The magnitude of the thermal rating depends upon the specifics of the drive, operating conditions, and the maximum allowable sump temperature, as well as the type of cooling employed.

The primary thermal rating criterion is the maximum allowable oil sump temperature. Unacceptably high oil sump temperatures influence gear drive operation by increasing the oxidation rate of the oil and decreasing its viscosity. Reduced viscosity translates into reduced oil film thickness on the gear teeth and

bearing contacting surfaces, which may result in reducing the life of these elements. To achieve the required life and performance of a gear drive, the operating oil sump temperatures shall be evaluated and limited.

Thermal ratings of gear drives rated by this standard are limited to a maximum allowable oil sump temperature of 200°F. However, based on the gear manufacturer's experience or application requirements, selection can be made for maximum oil sump temperatures above or below 200°F. See 11.1.3 for additional considerations regarding oil sump temperatures specifically and Clause 11 regarding lubricants generally.

Thermal rating may be determined by the methods and procedures of AGMA ISO 14179-1.

8 Component design

The components of a gear drive shall be designed with consideration for all loads encountered during operation. These include the loads imposed on the components through the gearing and the external loads such as overhung loads, external thrust loads and dynamic loads. Components shall also be designed to withstand any assembly forces that might exceed the operating loads. During the design process, the operating loads shall be considered to occur in the worst possible direction and loading combinations.

All components shall allow for momentary peak loads as defined in 4.1. User requirements or specifications dictating different design criteria shall be by contractual agreement.

8.1 Housing

Refer to Clause 8 of ANSI/AGMA 6001.

8.2 Threaded fasteners

Refer to Clause 9 of ANSI/AGMA 6001.

8.3 Bearings

Shafts should be mounted in bearings, of a size, type, and capacity to carry the maximum operating radial and thrust loads. For additional information, consult Clause 7 of ANSI/AGMA 6001.

8.4 Shafting

Shafting should be designed in accordance with Clause 5 of ANSI/AGMA 6001.

8.5 Balancing

The purpose of balancing is to minimize or eliminate vibration in a rotating element due to unbalance. The importance of proper balancing increases directly in proportion to the pitch line velocity of the rotating part. Excessive unbalance can result in premature bearing, gear, or other component failure.

It is the responsibility of the manufacturer of the drive components to determine the need for balancing and assure that it is done without affecting the structural integrity of the rotating mass.

8.6 Keys

Refer to Clause 6 of ANSI/AGMA 6001.

8.6.1 External keyways

Keyways in external shaft extensions on the gear drive should conform to Annex B.

8.6.2 Interference fit of hubs and shafts

Refer to Clause 6 of ANSI/AGMA 6001.

8.7 Torque arms

Torque arms are required on shaft mounted gear drive systems to prevent rotational movement of the gear drive and to accommodate radial and slight axial movement. Torque arms tether the gear drive system to an anchor point and shall be designed to support the live loads, dead loads, and shock loads. Loads may include the mass of other components within the drive system such as motors, couplings, brakes, swing bases, and other accessories. Location and retention of the gear drive system on the driven shaft is typically accomplished by other means.

Torque arms are of varying designs such as threaded rod and solid linkages that are pinned at the anchor points, and solid members that are connected to the gear drive system. All torque arms shall include provisions for freedom of movement while providing torque reaction.

Dual point torque arms are illustrated in Figures 1 and 2. The length of the threaded rod torque arm is typically adjusted by a turnbuckle or similar means, allowing for more flexibility in the location of the anchor points, see Figure 1.

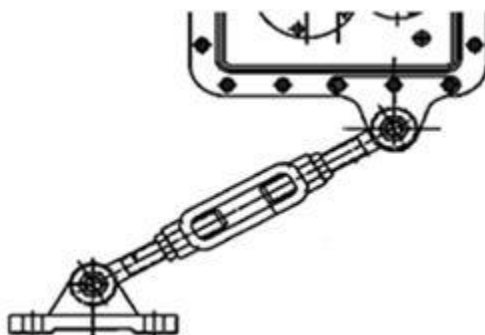


Figure 1 – Threaded rod torque arm

Torque links are typically fixed length and pinned at each end, see Figure 2.

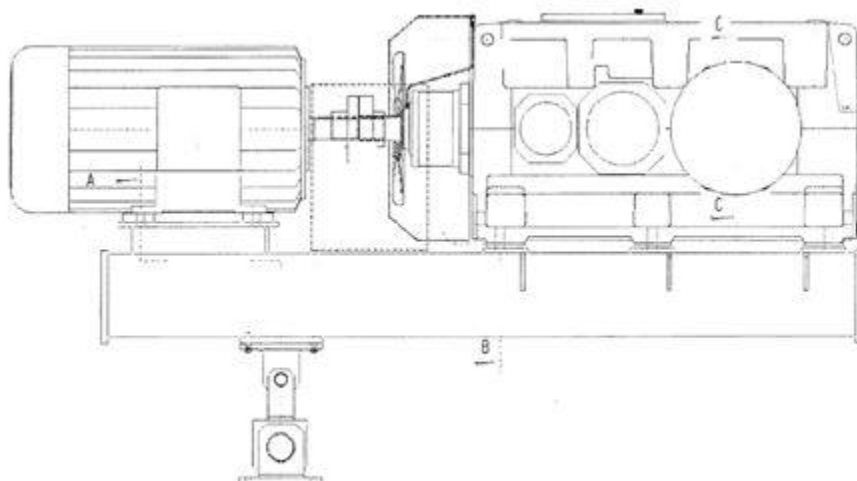


Figure 2 – Torque link

Single point torque arms are fixed to the gear housing and often include integrated rubber bushings in the anchor point at the end of the torque arm. Single point torque arms generally require more planning to precisely locate the anchor point, see Figure 3. The use of elastomeric bushings should be considered.

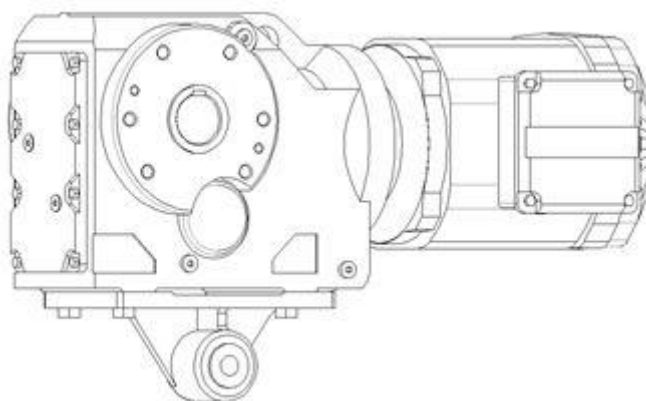


Figure 3 – Single point torque arm

8.8 Backstops

Backstops prevent reverse rotation of driven equipment that is intended for unidirectional rotation only. They allow free, unimpeded rotation in one direction while preventing rotation in the opposite direction.

8.8.1 Backstop types

Backstops are a type of clutch. This standard is limited to cam or “sprag” type clutches. However, other types may be used. Cam clutches are generally used for three distinct operational modes: overrunning, indexing, and backstopping. This standard is further limited to the backstopping mode of operation.

8.8.2 Selection and application

Backstops are designed to prevent reverse rotation up to a specified torque limit and rotational speed. These limits will vary depending on the backstop size and manufacturer.

Backstop selection is based upon the number of backstopping cycles, the applied torque and the maximum operating speed.

The maximum allowable overrunning backstop speed shall be equal to or greater than the maximum shaft speed attainable in all conditions.

Backstopping torque will pass through all components between the load and the backstop. This may render the backstop function ineffective in instances of component failure between the backstop and the driven load.

8.8.3 Installation

A backstop is installed with the outer race of the backstop anchored to a stationary member while the inner member can overrun freely in one direction of rotation. A backstop with a separate inner race shall have that race secured to the rotating shaft.

8.8.3.1 Installation of built in types

A backstop can be built into the gear drive and the inner race eliminated by having the cams engaging directly on the shaft. In this case, the inner race surface shall be capable of sustaining a Hertzian contact stress as required by the backstop design.

The following items, concerning the shaft, shall also be addressed:

- surface hardness;
- case depth;
- taper in the cam contact area;
- surface finish in the cam contact area;
- concentricity with the backstop outer race.

The shaft that the backstop engages shall be supported by bearings. The backstop is not intended to withstand reaction loads imposed by gears or other sources.

8.8.3.2 Initial installation

Backstops can be mounted externally to the gear drive or incorporated internally. In either case, special care shall be taken to verify the proper direction of rotation. Manufacturers usually identify the backstop housing with a marking to indicate the appropriate shaft rotation to prevent damage to the backstop. Before the drive is connected and energized, the added precaution of ensuring the proper rotation of all components is advised.

8.8.4 Lubrication

The backstop, much like other elements of the gear drive, shall have proper lubrication free of contaminants. The lubricant shall be drained, flushed, and changed on a regular maintenance schedule as recommended by the gear drive manufacturer.

The backstop may be lubricated by grease or oil that is appropriately selected for the application considering the environment in which it will operate.

WARNING: Do not use lubricants that include friction modifiers based on sulphur, chlorine, lead, and phosphorous derivatives, as well as graphite and molybdenum disulfide in gear drives equipped with an internal backstop unless approved by the gear drive manufacturer or the backstop manufacturer.

8.9 Couplings

Refer to the appropriate ANSI/AGMA coupling standards for detailed information.

8.10 Shrink discs

Shrink discs are one option to connect a hollow shaft gear drive to the drive shaft without using a key. One type of shrink disc is an external locking device installed over a hollow shaft projection. By tightening the locking screws, the locking collars exert radial forces on the tapered inner ring and the hub. After bridging the fit clearances, radial clamping pressure is generated between the drive shaft and the hollow shaft establishing a solid, keyless, frictional connection.

During the selection process, the following items should be considered:

- hollow shaft and drive shaft yield point of material;
- diameter changes when the shrink disc is applied;
- coefficient of friction between the hollow shaft and the drive shaft;
- tolerances and fits of the mating surfaces;
- surface finishes of the hollow shaft and drive shaft;
- axial forces applied to the assembly;
- starting and peak loads transmitted through the drive system;
- a shrink disk is a keyless connection, and therefore, there is no mechanical backup to the connection.

The shrink disc should be selected and applied according to the manufacturer's recommendations.

8.11 Shaft bushings

Bushings are commonly used to adapt standard gear drives with hollow output shafts to various sizes of driven shafts. Used in this sense, bushings provide an economical means of designing around standard products.

8.11.1 Bushing types

The two most common types of bushings are straight sleeve and tapered sleeve.

Straight sleeve bushings fit between the driven shaft and the gear drive and contact the driven shaft over the entire bushing length. Set screws are generally used to maintain axial position of the gear drive and bushing assembly to the driven shaft.

Tapered bushings mate with gear drive hollow shafts that have tapered bores. The wedging action secures the gear drive to the driven shaft. During removal, the gear drive only has to move a short distance along the taper to disconnect the gear drive from the driven shaft. This type of bushing system generally lends itself to easier removal of the gear drive from the driven shaft than straight bushings.

Tapered bushings come in many varieties. Some of these are:

- single taper or twin taper;
- sleeves with threaded collars or sleeves with integral flanges;
- keyed or frictional grip.

Single tapered bushings have a taper that usually protrudes at least 50% of the gear drive width or is supported on the opposite end by a stabilizing bushing. Twin tapered bushings have shorter tapers and are installed in each end of the gear drive output shaft.

Tapered bushings can be drawn tight against the driven shaft in one of two ways: using fasteners that extend through the flanged end of the bushing, or using a threaded collar with a thread on the outside diameter of the extended end of the bushing.

Usually straight sleeve and tapered sleeve bushings contain a key which transmits the torque from the gear drive output shaft to the driven shaft.

8.11.2 Design considerations

In selecting an appropriate bushing, some elements of the design such as materials, fits, shafting, and keys should be considered.

8.11.2.1 Materials

The material selection depends upon the stress level the bushing will experience, the flexibility or ductility required to function properly, the probability that fretting corrosion will exist, and the bushing's ability to withstand these criteria as well as other applicable environmental considerations. The use of dissimilar metals in corrosive environments can lead to galvanic corrosion.

8.11.2.2 Fits

Any bushing, whether straight or tapered, should have a close fit avoiding excessive gaps that collect moisture and foreign materials resulting in crevice corrosion. Rust or other unfavorable conditions can make the removal of the bushing more difficult.

Another condition resulting from excessive gap and poor fit is fretting corrosion. Surfaces working against each other can generate heat, oxidize, and lead to local welding of one part to another.

Special consideration should be given to the type of bushing fit for vertical applications or those applications where axial loading is applied to the gear drive. The contact pressure shall be sufficient to resist the axial forces generated by the gear drive external loads and equipment weight unless otherwise supported.

8.11.2.3 Shafting

The responsibility for the design and construction of the supporting shaft is beyond the scope of this standard. However, the shaft shall be adequate to withstand normal operating loads and peak loads without damage to itself or any of the system components, and to maintain alignment of the components under such loads.

In the absence of a specific recommendation from the manufacturer, tolerances given in Table 2 may be used for cold drawn or turned and polished round bars.

The hollow shaft of the gear drive shall have sufficient torque capacity and wall thickness to allow the use of a bushing in the design.

Table 2 – Shaft diameter tolerances for supporting shafts

Shaft diameter, in	Maximum undersize variation, in ¹⁾
To 1.50	0.004
Over 1.50 to 2.50	0.005
Over 2.50 to 4.00	0.006
Over 4.00 to 6.00	0.007
Over 6.00 to 6.50	0.008
NOTE: ¹⁾ Keys and keyways in supporting shaft should be in accordance with ANSI B17.1 for size, depth, offset, lead and parallelism.	

8.11.2.4 Bushing keys

Most bushings are torsionally connected to the gear drive output shaft and driven shaft by a key. With thin wall bushings, a single key (square, rectangular, or stepped) is usually all that is necessary. Frequently with thick wall bushings, two keys are required, one that connects the bushing to the gear drive output shaft and a second one to connect the bushing to the driven shaft. The key arrangement is generally specified by the gear drive manufacturer. See ANSI/AGMA 6001 for key design and selection.

8.11.3 Installation criteria

When installing a gear drive on a driven shaft using a bushing, the distance between the bearing support and the gear drive should be minimized. As a guideline, the gear drive should be no more than one shaft diameter away from the bearing support. With some bushing types, there needs to be clearance to access the bushing flange from the bearing support side.

Manufacturers usually include tightening procedures with their installation, maintenance, and lubrication instructions. With single taper bushings, the procedure is fairly simple. For twin taper bushings, care needs to be taken to assure each bushing is tightened properly. The installer shall follow the manufactures' instructions during installation and mounting.

8.12 Electric motors

This clause provides guidance about the effect of electric motor selection on gearmotor performance and describes typical motors used. It is not intended to define electric motor ratings or specific motor characteristics. For more detailed information, see NEMA Standard Publication MG1-2011 [1] or IEC 60072-1 [2].

8.12.1 Motor types

Both alternating current, AC, and direct current, DC, motors can be used on gearmotors. The AC motor is the most common type.

8.12.1.1 Alternating current motors

Standard gearmotors typically use an induction type, asynchronous AC motor of a NEMA Design B or IEC Design N torque characteristic. The design of the motor determines the locked rotor current and subsequent starting torque characteristics when started across the line, or with very short acceleration times in applications with a variable frequency drive. Class II and Class III gear drive selections should be considered when NEMA Design Types C and D or IEC Design H motors are used when high starting torques are required.

CAUTION: Occasionally a motor manufacturer may apply a NEMA Design B nameplate to a design type C or D motor, which can lead to higher than expected starting torques.

In across the line operation, full motor starting torque is developed each time the motor is started. Full motor starting torque can be 200–300% of rated motor torque resulting in rapid acceleration causing high torque loads that can exceed design peak loads.

The use of a variable frequency drive to reduce the rate of acceleration or the use of a higher inertia motor can reduce such peak loads. Often the current limitation and other protective functions of a variable frequency drive can also reduce or control peak loads.

8.12.1.2 Direct current motors

DC motors historically have been used where applications require speed variation. These motors are capable of delivering constant torque or constant power over a given speed range.

Considering these motors are capable of developing starting torques over three times their nameplate rating and stall torques over five times their nameplate rating, these motors should be selected upon agreement with the gearmotor manufacturer to ensure the overload capability of the gear drive is sufficient.

8.12.2 Selection criteria

When selecting an electric motor for a gearmotor application, consideration should be given to:

- normal running load;
- loading on the motor shaft from gear drive with integral pinion designs;
- starting characteristics;
- current type AC, DC;
- phase, voltage and frequency;
- motor service factor;
- motor efficiency;
- rotor inertia;
- speed and speed variation;
- ambient temperature and insulation class;
- environmental protection and method of cooling;
- duty cycle, including braking operations;
- run time.

Special motor features or different motor types may affect the motor frame size.

8.13 Other components

See ANSI/AGMA 6001 for additional information on the following components:

- shims;
- gaskets;
- oil seals;
- breathers;
- expansion chambers;
- oil level indicators;
- bearing retainers;
- grease retainers;
- dowels and pins;
- spacers;
- seal retainers;
- locking devices for fasteners;
- tolerance and fits of mating surfaces.

NOTE: It is recognized that gear drives applied in certain industries and under certain atmospheric conditions should be equipped with special seals and breathers designed for those conditions. Examples are units installed in the dusty or corrosive atmospheres of chemical plants, cement mills, and taconite processing plants. It is also recommended when gear drives are exposed to severe moisture and vapor laden atmospheres that they be

equipped with moisture barrier seals and breathers. Some applications in wet locations subject to direct or indirect wash down may preclude the use of breathers, such as in the paper and food industries. In these cases, expansion chambers may be used.

9 Service factors and application classification

When selecting an enclosed gear drive for a specific industrial application, the effects of the various loads inherent to the application need to be accounted for. Some of these loads may include; peak loads, overloads, starting loads, deceleration or braking loads, the frequency of these various load types, as well as external influences such as type of prime mover or system vibrations.

In industry, these load variations are commonly accounted for by the use of service factors for enclosed gear drives, or by the use of application classification numbers for gear motors, shaft mount drives, and screw conveyor drives. The use of these service factors and application classification numbers has served industry and users well when the application has been identified by knowledgeable and experienced gear design engineers.

9.1 Selection of recommended factors

The tables of Annex A for service factor and application classification number have been developed from the experience of manufacturers and users of gear drives for use in common applications and have been found to be generally satisfactory for the listed industries when gears are rated using AGMA standards. This standard is based on the premise that the user is defining a catalog rating. It is suggested that selection of factors for special applications, such as crane drives, be agreed upon by the user and the gear manufacturer when variations of the tabulated value may be necessary.

Service factors, and the application class number with related service factor, include the combined effects of varying duty cycles, reliability, overload factors, expected performance, plus magnitude and frequency of peak load occurrences in an empirically determined single factor. The mathematical contribution of each of these factors has not been established. For additional information refer to ANSI/AGMA 2001-D04, Clause 10 and Annex C. In the absence of more specific load data, a service factor as shown in Table A.2 or an application classification number shown in Table A.3 may be used.

9.2 Service factors

Before an enclosed gear drive is selected, a service factor shall be determined based upon the application it will be used in. An equivalent power rating will then be determined by multiplying the specified transmitted power by the service factor. Since service factors represent the normal relationship between unit rating and the maximum potential transmitted power, it is suggested that the service factor be applied to the nameplate rating of the driven machine or prime mover, as applicable.

Manufacturer and user shall agree upon which power, prime mover rating, or driven machine requirements, should dictate the selection of the gear drive. It is necessary that the gear drive selected have a unit rating equal to or in excess of this equivalent power rating.

9.3 Application classification numbers

Before a gear motor, shaft mount drive, or screw conveyor drive is selected, an application class number shall be determined based upon the application it will be used in. An equivalent power rating will then be determined by multiplying the specified transmitted power by the service factor, K_{SF} . Since application classification represents the normal relationship between unit rating and the maximum potential transmitted power, it is suggested that the application class number be applied to the nameplate rating of the electric motor.

Manufacturer and user shall agree upon which power, electric motor rating, or driven machine requirements, should dictate the selection of the gear drive. It is necessary that the gear drive selected have a unit rating equal to, or in excess of, this equivalent power rating.

The application class numbers are I, II, and III. Their relationship to service factor is shown in Table 3.

Table 3 – Service factor, K_{SF}

Class numbers	K_{SF}
I	1.0
II	1.4
III	2.0

9.4 Determining service factor or application class number

Service factors and application class numbers may be selected from Annex A or may be determined analytically. Listed below are some of the factors to be considered.

9.4.1 Operational characteristics

Some of the operational characteristics that could affect an increase or decrease in service factors are:

- **Type of prime mover.** Different types of prime movers are electric motors, hydraulic motors, steam or gas turbines, and internal combustion engines having single or multiple cylinders.
- **Starting conditions.** Starting conditions where momentary peak loads exceed those defined in 4.1.

When a soft start coupling is used between the prime mover and the gear drive, the selection of service factors can be based on the gear drive manufacturer's analysis for the application.

- **Overloads.** Loads which are in excess of the unit rating divided by service factor should be considered overloads. Overloads can be of momentary duration, periodic, quasi-steady state, or vibratory in nature. The magnitude and the number of stress cycles require special analysis to prevent low cycle fatigue or yield stress failure.

Applications such as high torque motors, extreme repetitive shock, or where high energy loads need to be absorbed, as when stalling, require special consideration.

- **Overspeeds.** Overspeeds contributing to external transmitted loads and dynamic loads require special analysis.
- **Brake equipped applications.** When a gear drive is equipped with a “working” brake that is used to decelerate the motion of the system, select the drive based on the brake rating or the transmitted power, whichever is greater. If the brake is used for holding only, and is applied after the motion of the system has come to rest, the brake rating should be less than 200% of the unit rating. If the brake rating is greater than 200% of the unit rating, special analysis is required.
- **Reliability and life requirement.** Applications requiring a high degree of dependability or unusually long life should be given careful consideration by the user and the gear manufacturer before assigning a service factor.
- **Thermal performance.** High service factors may affect the thermal rating of the drive in that the proportion of the load and non-load losses will change with lighter loads affecting thermal performance.

9.4.2 System conditions

Analysis of the dynamic response of a system to excitation forces is an essential phase in the design of rotating machinery.

9.4.2.1 Vibration analysis

Vibration analysis shall consider the complete system including prime mover, gear drive, driven equipment, couplings, and foundations. The dynamic loads imposed upon a gear drive are the result of the dynamic behavior of the total system and not the gear drive alone. See 4.3.

9.4.2.2 Dynamic response

The dynamic response of a system results in additional loads imposed on the system and relative motion between adjacent elements. The vibratory loads are superimposed on the mean running load in the system and, depending upon the dynamic behavior, could lead to failure of system components.