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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE TRADEMARK TRIAL AND APPEAL BOARD

Proceeding	91190278
Party	Plaintiff NAC Harmonic Drive, Inc.
Correspondence Address	Michael J. Feigin, Esq. Law Firm of Michael Feigin, Esq. 103 The Circle Passaic, NJ 07055 UNITED STATES michael@patentlawny.com
Submission	Motion for Summary Judgment
Filer's Name	Michael J. Feigin, Esq.
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Attachments	NAC001-05o-MotionforSummaryJudgment - draft2.pdf (14 pages)(136110 bytes) NAC001-05o-MotionforSummaryJudgment - draft2-sigpage.pdf (1 page)(51188 bytes) NAC001-05p-SummaryJudgmentDeclaration.pdf (5 pages)(150901 bytes) NAC001-05d-ExhibitC.pdf (8 pages)(11910050 bytes) NAC001-05e-ExhibitDshort.pdf (19 pages)(16683472 bytes) NAC001-05f-ExhibitE.pdf (8 pages)(398840 bytes) NAC001-05f-ExhibitF.pdf (8 pages)(403239 bytes) NAC001-05g-ExhibitG.pdf (4 pages)(3368830 bytes) NAC001-05h-ExhibitH.pdf (10 pages)(335976 bytes) NAC001-05i-ExhibitI.pdf (16 pages)(1547006 bytes) NAC001-05j-ExhibitJ.pdf (6 pages)(23261 bytes) NAC001-05k-ExhibitK.pdf (1 page)(18629 bytes) NAC001-05l-ExhibitL.pdf (9 pages)(1451887 bytes) NAC001-05m-ExhibitM.pdf (1 page)(69004 bytes)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE TRADEMARK TRIAL AND APPEAL BOARD

In the Matter of:

Trademark:	**HARMONIC DRIVE**	
Serial No.:	77/373,925	Opposition No. 91190278
Filed:	January 17, 2008	
Published:	January 20, 2009	

NAC HARMONIC DRIVE, INC.

Opposer,

v.

HARMONIC DRIVE LLC.

Applicant.

OPPOSER'S MOTION FOR SUMMARY JUDGMENT
AND MEMORADUM IN SUPPORT THEREOF

Pursuant to 37 C.F.R. §§ 2.116 and 2.217 and Federal Rule of Civil Procedure 56, Opposer NAC Harmonic Drive, Inc. ("NAC") respectfully submits this Motion of Summary Judgment and Memorandum in Support Thereof. The records of the United States Patent and Trademark Office ("USPTO") and pleading herein evidence that there is no genuine issue as to any material fact and that Opposer is entitled to judgment as a matter of law. Accordingly, Opposer respectfully submits it is entitled to summary judgment on the ground of genericness. In particular, Applicant Harmonic Drive LLC's ("Harmonic") mark HARMONIC DRIVE has been a generic term for a gear drive that has been used in industry for more than 40 years.

In support of its motion, Opposer relies on the accompanying Memorandum, the pleading herein, Internet printouts downloaded from NAC and Harmonic's respective websites and competitor websites, Internet printouts of competent sources (i.e. dictionary definitions, trade journals, and other online publications), Internet printouts from USPTO's patent database, prosecution file histories of Harmonic's marks and the Declarations of Michael J. Feigin, Esq. and Jose Pujol with attached exhibits.

I. INTRODUCTION

Applicant's mark HARMONIC DRIVE is subject to refusal in the instant proceeding on the ground of genericness. By this Memorandum in support of Opposer's Motion for Summary Judgment, NAC establishes that the term HARMONIC DRIVE is used throughout the gear & motor industry consistently to identify a genus of gear, i.e. a drive system that uses inner and outer gear bands to provide smooth motion and does not uniquely identify products offered under the HARMONIC DRIVE mark or as originating with Applicant.

II. STATEMENT OF FACTS

Rule 56 of the Federal Rules of Civil Procedure mandates entry of summary judgment when there is no genuine issue as to any material fact and the moving party is entitled to judgment as a matter of law. Fed.R.Civ.P. 56(c). The pleadings and records of the USPTO on file show that the following material facts are undisputed.

On January 17, 2008, Harmonic filed an application seeking to register the mark HARMONIC DRIVE for the following goods in International Classes 7 and 9:

> "Electric motors; motor shaft retention brakes; adjustable shaft couplings and couplings for machines; servo motors for positioning in response to electrical control signals; drives and transmissions in the nature of speed and power increasers and reducers, all except for land vehicles.
>
> Electric rotary actuators and electronic controllers for producing control signals for electric rotary actuators and motor shaft retention brake."

Harmonic filed its application under a section 1(a) filing basis with a first use in commerce date of 1960. On January 20, 2009, Harmonic's application for the HARMONIC DRIVE mark was published for opposition. Declaration of Michael J. Feigin, Esq. ("Feigin Decl.") ¶ 2, Exhibit A.

On May 19, 2009, NAC filed the above-captioned Opposition against application Serial No. 77/373,925. On June 26, 2009, the Board entered an order granting Applicant's motion for extension of time for answer and discovery. On July 24, 2009, Applicant filed its answer to the subject Opposition. Pursuant to that order, discovery opened on August 27, 2009 and is not set to close until February 23, 2010.

Opposer NAC is a supplier of harmonic drive gearboxes and component sets and sells harmonic drive units through an expanding global network. NAC established U.S. offices to sell harmonic drive gearboxes, and the like, in 2007 and has sold such products since that time. NAC serves the aerospace, machine tool, electronics, printing, robotic and motion control industries and has used "harmonic drive" in the advertising, promotion and sale of components and gearheads for precision motion control applications since at least as early as 2007. Declaration of Jose Pujol, Jr. ("Pujol Decl.") ¶ 2, Exhibit B.

From about 1988 until about 2005, two entirely separate entities, Harmonic Drive Technologies and HD Systems, Inc. advertised and sold "harmonic drive" products. Harmonic Drive Technologies and HD Systems, Inc. merged in about 2006. Pujol Decl. ¶ 3. Applicant has failed to indicate and mark clearly, in most or all of its marketing materials and catalogs, that "harmonic drive" is a source indicated for its goods, as opposed to a description of a generally known and used functional apparatus. For example, a review of Harmonic's own website reveals that the term "harmonic drive" is generic of the type of gear drive of which Harmonic provides, stating "We offer the motion control design engineer the widest choice of harmonic drive gearing products" and "[we] are committed to providing harmonic drive gearing and motion control products…" Additionally, an advertising article from HD Systems, Inc. dated December 1, 1998 uses the term "harmonic drive" in a descriptive manner. A further example includes a brochure by the Applicant, one of dozens of which state, for instance, "If any roller moves out of alignment, …a harmonic drive differential unit will correct alignment…" Further, even Harmonic Drive System's trademarks use the term for a description of goods. (<u>The World of Harmonic Drive Gearing</u>, "Printing Presses", No. 8804-01R-CB, Harmonic Drive Systems, Inc., pg 8, undated). Feigin Decl. ¶ 3 Exhibit C, Exhibit K.

Applicant claims that it has been using all of the goods alleged in the application since 1960. In fact, many of the goods recited in Applicant's application were either not yet in existence or not sold by applicant as early as 1960, rendering the present application fraudulent and subject to refusal solely for this reason. Pujol Decl. ¶ 4.

On more than one occasion, Applicant has abandoned its registration attempts for this mark and derivatives thereof. On October 10, 2005, Applicant filed an application for the mark HARMONIC LINER DRIVE (Serial No. 77/017,392). In its Office Action dated December 15, 2006, the Examiner requested a disclaimer for the terms "harmonic" and "drive" claiming they merely described a feature of the goods. The Examiner attached as evidence web pages showing descriptive use of the term "harmonic" in conjunction with drives and gears, as well as dictionary definitions of harmonic, transmission and drive. On June 14, 2007, the Applicant expressly abandoned the application in light of this requirement. Feigin Decl. ¶ 4, Exhibit D.

On October 27, 2006, the Applicant filed a trademark application for the mark HARMONIC LINEAR DRIVE (Serial No. 77/030,648). In its Office Action dated December 15, 2006, the Examiner refused registration based on Section 2(e)(1) for descriptiveness. The Examiner attached as evidence web pages showing descriptive use of the term "harmonic" in conjunction with drives and gears, as well as dictionary definitions of harmonic, transmission and drive. On January 15, 2008, applicant disclaimed "drive" due to a genericness rejection while claiming "harmonic" is a coined term and at best suggestive. On January 17, 2008, a mere two days later, Applicant filed the present application and proceeded to abandon the non-allowed '648 application, taking a second bite at the apple with another Examiner. Feigin Decl. ¶ 4, Exhibit D.

A search for the exact term "harmonic drive" on the Google search engine generates 79,000 hits as of November 1717, 2009. Attached are select pages evidencing these hits and showing generic usage of the term by companies in journal articles, online encyclopedias, books, blogs, and even advertisements. Feigin Decl. ¶ 5 Exhibit E.

For years, and pervasive throughout the (harmonics are used in many industries) industry, the term "harmonic drive" has been used and continues to be used to refer to a genus of gear drive that uses inner and outer gear bands to provide smooth motion. A review of the online dictionary definitions from *Merriam-Webster, Answers.com, Wikipedia and Britannica* evidence the generic status of the term "harmonic drive." Feigin Decl. ¶ 6 Exhibit F. (Note especially the "History" section of the Wikipedia article indicating the multiple companies producing harmonic drive gearing. It should be noted that on October 6, 2009, this article was purposely defaced during this ongoing proceeding by an "unknown" user using the IP address of 165.170.128.65 in a bad faith attempt to tamper with evidence, e.g. make this editable article refer to the Applicant only. The Wikipedia editors marked the article "advertising material" in need of change, recognizing the genericness of the mark in improperness of referring only to the Applicant.) Moreover, "harmonic drive" is listed as one of many types of "gear drives" on the Internet with manufacturers and retailers. Feigin Decl. ¶ 9 Exhibit L.

Further evidence that the term "harmonic drive" is a commonly used term to identify a genus of gear is found in online trade journal articles, competitor websites, engineering forums and textbooks. Feigin Decl. ¶ 6 Exhibits G-I.

The USPTO has accepted "harmonic drive" as a title in more than 40 issued patents, and the term is mentioned descriptively in over eight hundred issued patents as evidenced by a search of USPTO patent database. Referring now to the Manual of Patent Examining Procedure, 8th Edition, used by the U.S. Patent Office to examine patents, chapter 2173.05(u) citing *Ex parte Simpson*, 218 USPQ 1020 (Bd. App. 1982) states, "If the trademark or trade name is used in a claim as a limitation to identify or describe a particular material or product, the claim does not comply with the requirements of the 35 U.S.C. 112, second paragraph." Thus, in order for Applicant to support registration of their mark for "harmonic drive" as referring to their specific product line only, Applicant would also have to argue that the U.S. Patent Office has incorrectly issued over 800 patents and most, if not all, of these patents, including those to Harmonic Drive, LLC and its predecessors are invalid. This subject matter has long been descriptively referred to as a harmonic drive in numerous text books, learned journal articles, and Applicant's own marketing materials and catalogs. Feigin Decl. ¶ 7 Exhibit J.

The USPTO has further accepted "harmonic drive" as an acceptable generic description of goods in a trademark registration. United States Trademark Registration No. 1,540,128 by the Applicant, Harmonic Drive Systems, Inc., has the following description of goods in Class 7:

> "harmonic drive assemblies primarily for use in industrial robots, machines tools, medical equipment, and solar energy devices."

This registration was issued on May 23, 1989. Feigin Decl. ¶ 8 Exhibit K.

Not only does the Applicant use the mark generically in it's trademark, but further does so on it's own website stating that it is the largest manufacturer of harmonic drives. . Feigin Decl. ¶ 8 Exhibit M.

NAC was justified in filing its Notice of Opposition against Harmonic's HARMONIC DRIVE application in the instant proceeding. Opposer will be damaged by the registration of Application Serial No. 77/373,925 insofar as the registration would be prima facia evidence of: (a) the validity of the registration, (b) Applicant's ownership of the HARMONIC DRIVE mark for the goods specified in the registration, and (c) Applicant's exclusive right to use the HARMONIC DRIVE mark in commerce when, in fact, Applicant is not entitled to such rights by virtue of the descriptive or generic nature of the mark.

III. ARGUMENT

A. Legal Standard and Applicable Law

Summary judgment is appropriate in Board proceedings where there are no genuine issues of material fact as to one or more elements essential to a pleaded claim or defense and more evidence that is already available could not reasonably be expected to change the result. See, e.g., Pure Gold, Inc. v. Syntex (U.S.A.) Inc., 221 USPQ 151 (TTAB 1983), aff'd, 739 F.2d 624, 222 USPQ 741 (Fed. Cir. 1984). Under Rule 56 of the Federal Rules of

Civil Procedure, a party is entitled to summary judgment if the pleadings, depositions, answers to interrogatories, and admissions on file, together with the affidavits, if any, show that there is no genuine issues as to any material fact and that the moving party is entitled to judgment as a matter of law. Fed.R.Civ.P. 56(c). Accordingly, this standard provides that "the mere existence of some alleged factual dispute between the parties will not defeat an otherwise properly supported motion for summary judgment." Anderson v. Liberty Lobby, Inc., 477 U.S. 242, 247-48 (1986).

The moving party bears the burden to show the absence of any genuine issue of material fact and that it is entitled to judgment as a matter of law. See Celotex Corp. v. Catrett, 477 U.S. 317 (1986), and Sweats Fashions Inc. v. Pannill Knitting Co., 833 F.2d 1560, 4 USPQ2d 1793 (Fed. Cir. 1987). The moving party may meet this burden by demonstrating that there is an absence of evidence to support the nonmoving party's case. Celotex Corp., 477 U.S. at 317. Further, a dispute over a fact that would not alter the Board's decision on the legal issue will not prevent entry of summary judgment. See, e.g., Kellogg Co. v. Pack'Em Enterprises, Inc., 14 USPQ2d 1545 (TTAB 1990), aff'd, 951 F.2d 330, 21 USPQ2d 1142 (Fed. Cir. 1991).

B. Harmonic Drive LLC's Mark HARMONIC DRIVE is Generic

It is well established that a generic term cannot function as an indicator of the source of a product, and thus as a trademark, because the relevant public understands the term primarily as the common name for a product. In re Steelbuilding.com, 415 F.3d 1293, 1296 (Fed. Cir. 2005) citing In re Dial-A-Mattress, 240 F.3d 1341, 1344 (Fed. Cir. 2001). Generic marks "give the general name of the product; they embrace an entire class of products" and receive no trademark protection. Kendall-Jackson Winery, Ltd. v. E. & J. Gallo Winery, 150 F.3d 1042, 1047 (9th Cir. 1998).

The USPTO bears the burden of proving a mark is generic. In re Reed Elsevier Properties Inc., 482 F.3d 1376, 1378 (Fed. Cir. 2007) citing In re

The Am. Fertility Soc'y, 188 F.3d 1341, 1345 (Fed. Cir. 1999). In proving genericness, any competent source is sufficient to establish the relevant public's understanding of a contested term, including purchaser testimony, consumer surveys, dictionary definitions, trade journals, newspapers, and other publications. In re Merrill Lynch, Pierce, Fenner & Smith, Inc., 828 F.2d 1567, 1570 (Fed. Cir. 1987).

The USPTO itself has used the phrase "harmonic drive" in its generic form. Specifically, United States Registration No. 1,540,128 owned by the Applicant for the stylized HD SYSTEM mark (a predecessor company to the Applicant) recites the following generic description of goods: "*Harmonic drive assemblies primarily for use in industrial robots, machine tools, medical equipment, and solar energy devices.*" Moreover, "harmonic drive" is descriptively referred to in over eight hundred patents and there are over 40 issued U.S. patents which use "Harmonic Drive" in the title of the patent. Feigin Dec. ¶¶ 7-8 Exhibits J-K.

Genericness is determined by applying the following two-pronged test—(1) a determination of the genus of goods or services at issue; and (2) whether the term sought to be registered is understood by the relevant public primarily to refer to that genus of goods or services. H. Marvin Ginn Corp. v. Int'l Ass'n of Fire Chiefs, 782 F.2d 987, 990 (Fed. Cir. 1986). An inquiry into the public's understanding of a mark requires consideration of the mark as a whole. Even if each of the constituent words in a combination mark is generic, the combination is not generic unless the entire formulation does not add any meaning to the otherwise generic mark. In re Steelbuilding.com, 415 F.3d at 1297 citing In re am. Fertility Soc'y, 188 F.3d 1341, 1346 (Fed. Cir. 1999)' In re Dial-A-Mattress, 240 F.3d at 1345.

Applying the above-mentioned two-pronged system, it is undoubtedly clear that the mark "harmonic drive" is generic for the goods identified in Applicant's application

(1) The Genus of the Goods at Issue is a *Gear Drive*.

Under the first prong of the genericness inquiry, the genus of the goods at issue in Applicant's application is a gear drive. A proper genericness inquiry focuses on the description of goods set forth in the application. Magic Wand, Inc. v. RDB, Inc., 940 F.2d 638, 640 (Fed. Cir. 1991). Here, there can be no dispute as to the genus of the goods.

The subject application covers the following goods: *"Electric motors; motor shaft retention brakes; adjustable shaft couplings and couplings for machines; servo motors for positioning in response to electrical control signals; drives and transmissions in the nature of speed and power increasers and reducers, all except for land vehicles. Electric rotary actuators and electronic controllers for producing control signals for electric rotary actuators and motor shaft retention brake."* Applicant's website states "Harmonic Drive LLC offers precision gears, gearheads, servo actuators and motion control systems." Feigin Decl. ¶ 3 Exhibit C. Moreover, a search on the Internet reveals that "harmonic drive" is a type of gear drive. Examples of this can be found with manufacturers and retailers that list types of gears, such as Ashoka Group and Gears Hub. "Harmonic drive" is listed as one of many type of gear drives. Feigin Decl. ¶ 9 Exhibit L. Thus, it is clear that the genus of goods is a gear drive.

Further, the significant number of hits (79,000 as of November 3, 2009) on the Google search engine for the term "harmonic drive" overwhelmingly confirms "harmonic drive" is indeed a generic term. Feigin Decl. 5 Exhibit E. A review of those results, only a sampling of which is attached, demonstrates on its face that the term "harmonic drive" is in use in the relevant market place by entities unrelated to the Applicant. Thus, this lends further proof that "harmonic drive" is a genus of gear drive as opposed to a unique product mark originating with Applicant.

Additionally, Internet dictionaries support the position that "harmonic drive" is a genus of gear. For example, Answers.com defines the term as "a drive system that uses inner and outer gear bands to provide smooth motion." Wikipedia defines "harmonic drive" as "an input/output gearing mechanism." Feigin Decl. ¶ 6 Exhibit F.

Finally, the Trademark Examiner in Applicant's applications for HARMONIC LINEAR DRIVE and HARMONIC LINER DRIVE recognized the generic nature of harmonic in connection with gears, and that the term was not specific to a product of the Applicant's. In particular, in her Office Actions, she states: "attached as evidence are web pages showing descriptive use of the term 'harmonic' in conjunction with drives and gears…" Feigin Decl. ¶ 4 Exhibit D.

(2) The Term "Harmonic Drive" is Understood by the Relevant Public Primarily to Refer to a *Gear Drive*.

Under the second prong of the genericness inquiry, the relevant public within the meaning of the trademark statute is the public which does or may purchase goods or services in the marketplace. Magic Wand, Inc., 940 F.2d at 640; 15 U.S.C. § 1064(3). In a Board proceeding to determine whether a registered mark has become generic, evidence of purchaser understanding may come in the following types: direct testimony of consumers, consumer surveys, dictionary listings, newspapers, and other publications. Magic Wand, Inc., 940 F.2d at 640 citing In re Northland Aluminum Prods., Inc. 777 F.2d 1556, 1559 (Fed. Cir. 1985). Here, the relevant public of Applicant's motor goods may include purchasers of such goods, including, among others, the motor, aerospace, machine tool, electronics, printing, robotic and motion control industries.

Courts look to other sources to determine genericness such as whether competitors use the mark, use by the media and the plaintiff's own use of the mark. Classic Foods, 468 F. Supp. 2d at 1189-91. Courts view a mark's use by competitors as "strong evidence of how the public perceives the term." Id. at 1190. Naturally, when more members of the public see a mark used by several producers in the industry, the less likely they will identify a particular producer with that mark. Id. In Classic Foods, the Central District of California, examining the genericness of "kettle chip," looked at several competitors who used the term "kettle" both in their name, as a category of potato chip and in describing the cooking process for their product. Id. at 1191. The court stated that "when consumers see 'kettle' linked directly to the cooking process by several companies, they are informed that a kettle chip is a potato chip that has . . . been [ ] cooked in a kettle" and "does not help identify the source of the product." Id. The court concluded that the term "kettle" was a type of chip as well as the name of a process of making chips and was not associated with any one source. Id. at 1194. "Kettle chip" lacked distinctiveness, classifying it as generic and therefore ineligible for trademark protection. Id.

Similarly in Schwan's, the Eighth Circuit determined that the mark "brick oven" could not be trademarked in reference to pizza because four competitors used the phrase concurrently with the plaintiff. Schwan's, 460 F.3d at 973. Even though the plaintiff used the term exclusively when it began making brick oven pizzas, the term had become popular among competitors. Id. In Schwan's, the plaintiff admitted in its USPTO application that "brick oven" refers to a pizza with specific qualities such as crispiness and a soft interior crust attained from a unique baking process. Id. Since the mark referred to a type of pizza and not a producer, the court determined that it was generic. In the case at hand, in considering usage by competitors, the evidence weighs in favor of the Opposer that the mark "harmonic drive" is generic.

The Schwan's court looked at articles, newspapers and other restaurants using the term "brick oven" in a generic manner to grant summary judgment for the defendant and rule that the mark was generic. Schwan's, 460 F.3d at 974-75. Similarly, the Ninth Circuit in Surgicenters of Am., Inc. v.

Med. Dental Surgeries, Co., 601 F.2d 1011, 1013 (9th Cir. 1979), determined that the district court correctly examined exhibits of "magazine and medical journal articles, letters and a television transcript" that used the term "surgicenter" to grant summary judgment that the mark was generic. Id.

A small sampling of publicly available documents and information unquestionably demonstrates that the relevant segment of public understands "harmonic drive" to refer to a genus of gear drive. As shown in the attached exhibits for the instant motion, it is widely pervasive in the industry that a harmonic drive is generally known as a type of gear drive. In particular, many online dictionaries and trade publications refer to this type of gear as being common in the relevant industries. Thus, the term "harmonic drive" is in wide generic use throughout the relevant industry. For example, competitor websites from Danfoss, the ABB Group and ICH evidence their use of "harmonic drive" as a gear drive and not as a product originating from Applicant. Feigin Decl. ¶ 6 Exhibit G. Additionally, an Internet printout from an engineering forum also evidences that the relevant public views "harmonic drive" as a generic type of gear drive. Feigin Decl. ¶ 6 Exhibit H. Searching types of gear drives on the Internet also reveals that "harmonic drive" is just one type of many. Feigin Decl. ¶ 9 Exhibit L. Finally, attached are at least ten different journals, articles and books that refer to "harmonic drive" in a generic sense to identify a genus of gear. Feigin Decl. ¶ 6 Exhibit I.

Lastly, courts will also look to the trademark holder's own use of the mark to determine genericness. Colt Def. LLC v. Bushmaster Firearms, Inc., 486 F.3d 701, 707 (1st Cir. 2007); *Rudolph*, 482 F.3d at 1198; Retail Services, Inc. v. Freebies Publ'g, 364 F.3d 535, 545 (4th Cir. 2004). This evidence is "relevant because '[a] kind of estoppel arises when the proponent of [a] trademark use is proven to have itself used the term before the public as a generic name." Colt, 486 F.3d at 707 (citing McCarthy § 12:13) (alterations in original).

In Colt, the plaintiff used the term "M4" to describe a type of gun in a patent application and summary judgment was accordingly granted in favor of the defendant. Id. Likewise, the Retail Services court found the owner's use of the trademarked term in a generic sense important in determining the validity of the mark. Retail Services, Inc. v. Freebies Publ'g, 364 F.3d 535, 547 (4th Cir. 2004). There, the trademark holder used the term "freebie" throughout its website to indicate something that a consumer is usually charged for but receives for free. Id. For example, its website included the phrase "fabulous freebies offered by your own special team" which the court found indicated that "freebie" was being used generically. Id. In addition, the court looked at this use of the term and found it identical to the use of the term on many other websites. Id.

Applicant's use of the term "harmonic drive" is likewise inconsistent with its assertion that the mark is not generic. Opposer presents evidence of Applicant using the phrase "harmonic drive" on its own website and marketing materials in describing the product. For example, "We offer the motion control design engineer the widest choice of harmonic drive gearing products" and "[we] are committed to providing harmonic drive gearing and motion control products..." Feigin Decl. ¶ 3 Exhibit C.

Applicant's predecessors companies, HD Systems and Harmonic Drive Technologies were independent direct competitors. These competitors each used the term "harmonic drive" as a generic term in their advertising, publications and websites. After the merger of HD Systems and Harmonic Drive Technologies, Applicant, in it's present corporate form, was created. Applicant sought to recast the generic term "harmonic drive" into a trademark. Pujol Decl.

As discussed above, the evidence presented on summary judgment includes competitors using the mark, journal and textbook authors using the mark as a reference to a type of gear, and plaintiff's own use of the mark in a generic manner. This evidence clearly demonstrates that the mark "harmonic drive" is generic and therefore invalid.

IV. CONCLUSION

As set forth above, Opposer NAC establishes that the term "harmonic drive" is a type of gear drive widely used throughout the industry and does not uniquely identify products offered under the mark "harmonic drive" or as originating with Applicant Harmonic Drive LLC. Accordingly, Opposer respectfully requests the Board to grant the instant motion on the ground of genericness.

Respectfully submitted,

Law Firm of Michael J. Feigin, Esq.

Dated: 12/9/2009

By: [signature]

Michael J. Feigin, Esq.
Attorney for Opposer

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE TRADEMARK TRIAL AND APPEAL BOARD

n the Matter of:

'rademark:	**HARMONIC DRIVE**	
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'iled:	January 17, 2008	
'ublished:	January 20, 2009	

JAC HARMONIC DRIVE, INC.

Opposer,

v.

IARMONIC DRIVE LLC.

Applicant.

DECLARATION OF MICHAEL J. FEIGIN, ESQ. IN SUPPORT OF
<u>OPPOSER'S MOTION FOR SUMMARY JUDGMENT</u>

, Michael J. Feigin, Esq., declare:

1. I am an attorney, duly licensed to practice law in the States of New 'ersey and New York and registered to practice before the U.S. Patent and 'rademark Office. I am founder of the Law Firm of Michael J. Feigin, Esq. and ounsel for NAC Harmonic Drive, Inc. ("NAC"). I make this declaration in upport of Opposer's Motion for Summary Judgment. If called upon to do so, I ould and would competently testify to the following:

2. Attached hereto as Exhibit A is a true and correct copy of the ;tatus Information for the HARMONIC DRIVE mark (Application No. '7/373,925), downloaded from the USPTO's TARR database.

3. Attached hereto as Exhibit C are true and correct copies of Internet rintouts from Harmonic Drive LLC's websites, as well as a copy of an

dvertising article from their predecessor HD Systems, Inc. titled "Hallow Shaft ctuators with Harmonic Drive Gearing."

4. Attached hereto as Exhibit D are true and correct copies of rintouts downloaded from the USPTO's TARR database evidencing the status f Applicant's applications for the marks HARMONIC LINEAR DRIVE (Serial No. 7/030,648) and HARMONIC LINER DRIVE (Serial No. 77/017,392). Copies of he Office Actions issued in connection with these applications, as well as their xpress abandonments are also enclosed.

5. Attached hereto as Exhibit E is an Internet printout from Google howing 79,000 hits for the term "harmonic drive" on the Google search engine s of November 6, 2009. This demonstrates that the term "harmonic drive" is 1 wide use in the relevant market place by entities unrelated to Applicant.

6. Attached hereto as Exhibits F-I are true and correct copies of nternet printouts of online dictionary definitions, competitor websites, ngineering forums and trade journal articles and textbooks evidencing the sage of "harmonic drive" as a gear drive.

7. Attached as Exhibit J is a list from the USPTO website identifying ne issued U.S. patents that include "harmonic drive" in the title. Also ttached are two patent samples that show use of "harmonic drive" generically. 'he harmonic drive apparatus is the subject of expired patent 2,906,143 'Strain Wave Gearing"), and this subject matter has long been descriptively eferred to as a harmonic drive in over eight hundred patents.

8. Attached hereto as Exhibit K is a true and correct copy of the tatus Information from the USPTO TARR database for United States egistration No. 1,540,128 for the mark HD SYSTEM (Stylized) which shows ne phrase "harmonic drive" as an acceptable generic description of goods.

9. Attached hereto as Exhibit L are true and correct copies of pages ownloaded from the Internet listing types of gear drives, including "harmonic rives."

I declare the above states to be true and correct under penalty of erjury under the laws of the United States. Executed on 12/9/09 n NJ.

Michael J. Feigin, Esq.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE TRADEMARK TRIAL AND APPEAL BOARD

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IAC HARMONIC DRIVE, INC.,

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Applicant.

DECLARATION OF DUANE JACOBSEN IN SUPPORT OF
OPPOSER'S MOTION FOR SUMMARY JUDGMENT

, Vicnent Genovese, declare:

1. I am Chairman of Opposer NAC Harmonic Drive, Inc. ("NAC"). I nake this declaration in support of Opposer's Motion for Summary Judgment. f called upon to do so, I could and would competently testify to the following:

2. NAC is a leading supplier of ISO9001 certified harmonic drive earboxes and component sets and sells harmonic drive units through an xpanding global network. NAC established U.S. offices to sell harmonic drive earboxes, and the like, in 2007 and has sold such products in the United tates and worldwide since that time. NAC serves the aerospace, machine tool, lectronics, printing, robotic and motion control industries and has used harmonic drive" in the advertising, promotion and sale of components and

gearheads for precision motion control applications since at least as early as 2007.

3. From about 1987 until about 2005, both Harmonic Drive LLC and HD Systems, Inc. advertised and sold "harmonic drive" products. Applicant and HD Systems, Inc. merged in about 2006. I have direct knowledge of this because from about 1990 I was a customer of both companies and continued buying from Harmonic Drive LLD into 2009 and have a product brochure and technical library of published information from the 1970's to 2009.

4. Applicant claims that it has been using all of the goods alleged in the application since 1960. In fact, many of the goods recited in Applicant's application were either not yet in existence or not sold by applicant as early as 1960.

I declare the above statements to be true and correct under penalty of perjury under the laws of the United States. Executed on 12/8/2009 in STATE OF NJ.

Vincent Genovese, Chairman

Vincent Genovese

Chairman, NAC Harmonic Drive

The World of Harmonic Drive Gearing

Communications Equipment

Solar Energy Applications

Medical Equipment

Electronic Parts Production Equipment

Total Motion Control System

Industrial Robots

Measuring Instruments

Metal Working Machines

Machine Tools

Printing Presses

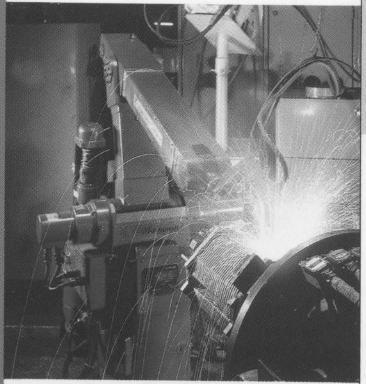
INTRODUCTION

Harmonic drive gearing is in a class of its own when it comes to mechanical power transmission design. Combining unique operating principles with constructions that minimize size and weight, harmonic drive transmissions offer advantages such as high reduction ratios in a single stage, very low backlash and in-line input/output that cannot be equalled by conventional gear trains.

The major applications of this innovative principle in power transmission range from use in industrial robots and machine tools to medical equipment and solar energy devices.

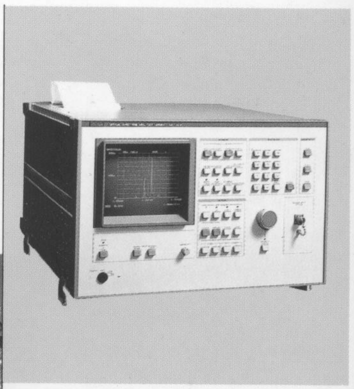
Harmonic Drive is a registered trade name in Japan, the Republic of Korea, and the Republic of China.

2 OPERATING PRINCIPLES AND ADVANTAGES



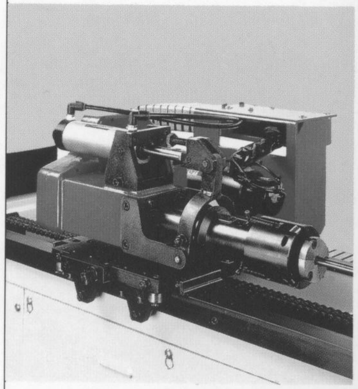
4 INDUSTRIAL ROBOTS

Harmonic drive transmissions provide the high rotational and positional accuracy required of precision drive mechanisms and control systems essential to today's advanced industrial robots.



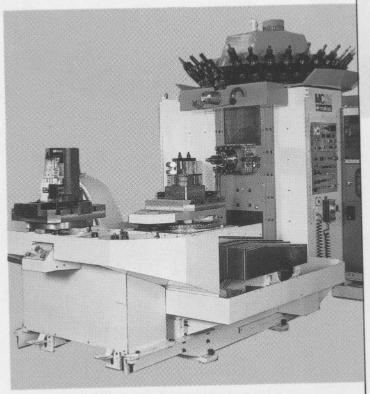
6 MEASURING INSTRUMENTS

Precision and compact harmonic drive actuators find wide use in optical spectrum analyzers, multi-axis laser systems, and other measuring instruments providing micro-motion control.



6 METAL WORKING MACHINES

Metal working machines such as CNC pipe benders and presses require highly accurate motion control.

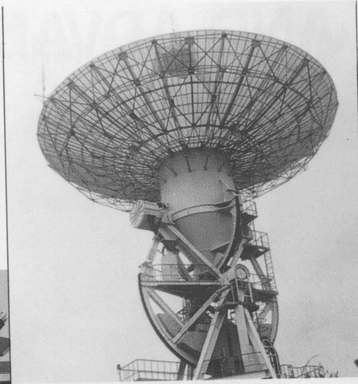


7 MACHINE TOOLS

Noted for its mechanical efficiency, precision and reliable service life, harmonic drive gearing has become a standard component in the necessarily reliable drive systems of a variety of machine tools including grinding machines, NC lathes and electro-discharge machines.

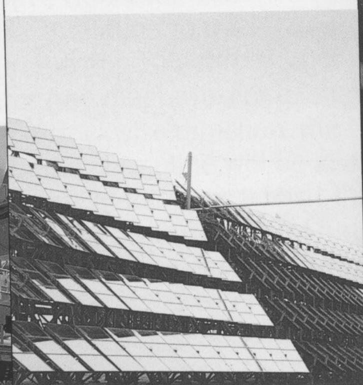
8 PRINTING PRESSES

Harmonic drive gearing is unsurpassed in performance and flexibility in applications requiring controlled variable speed and phasing of rotating shafts, and its compact size makes for effective stream-lining of these operations.



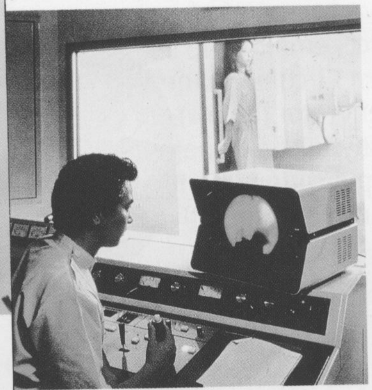
10 COMMUNICATIONS EQUIPMENT

Drive systems capable of holding backlash to an absolute minimum are compulsory in high-gain radar and satellite tracking antennas because of the extremely precise directional nature of their beams. Harmonic drive gearing has been used for years under harsh weather conditions in numerous antenna systems to meet essential performance requirements.



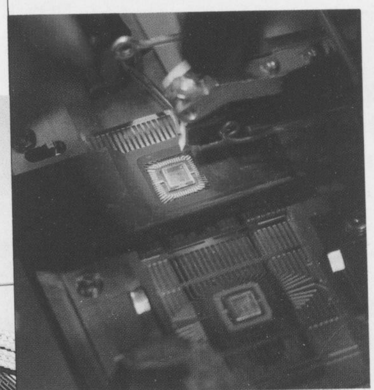
11 SOLAR ENERGY APPLICATIONS

Solar energy technology is expected to contribute greatly toward meeting future energy needs. Harmonic drive gearing is already part of this new technology, used in the drive systems of heliostats to ensure an accurate and reliable tracking of the sun's course.



12 MEDICAL EQUIPMENT

Such inherent advantages as very high reduction ratios in a compact package, and quiet operation thanks to a unique principle which allows for slow speed tooth engagement, make harmonic drive transmissions exceptionally well suited for use in medical equipment.



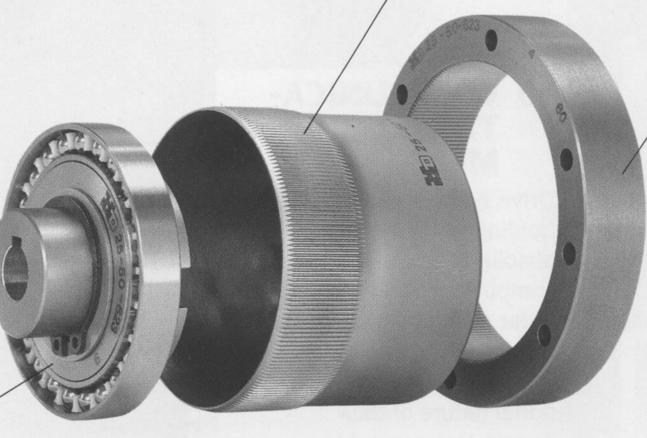
13 ELECTRONIC PARTS PRODUCTION EQUIPMENT

Precise transmission of motion is of paramount importance to ensuring the precision feed and indexing essential to equipment utilized in the production of microscopic electronic parts. Harmonic drive transmissions are being utilized in the drive mechanisms of such equipment to improve positional accuracy and smooth operational speeds.

14 HARMONIC DRIVE GEARING AND TOTAL MOTION CONTROL SYSTEM

OPERATING PRINCIPLES AND ADVANTAGES

All harmonic drive products employ the same three basic elements: a Circular Spline, a Flexspline and a Wave Generator (below). Although these elements may take alternate forms depending on their application, the types described here are typical and representative.



THREE BASIC HARMONIC DRIVE ELEMENTS

CIRCULAR SPLINE

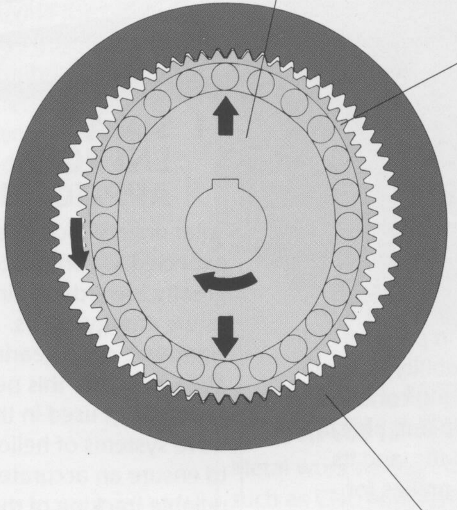
The Circular Spline is a thick-walled, rigid ring with internal spline teeth. It normally functions as the fixed or nonrotating member but can, in certain applications, be utilized as a rotating output element as well.

FLEXSPLINE

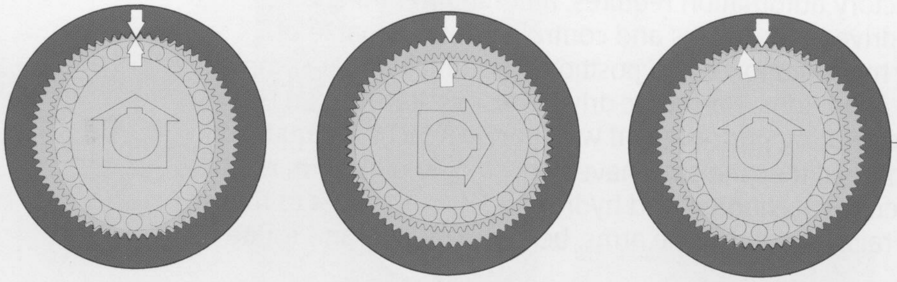
The externally toothed Flexspline is a nonrigid or flexible, thin-walled, cylindrical cup which is smaller in circumference and has two less teeth than the Circular Spline. It is normally the rotating output element but can be utilized as the fixed, nonrotating member when output is through the Circular Spline.

WAVE GENERATOR

The Wave Generator is an elliptical cam enclosed in an antifriction ballbearing assembly. It normally functions as the rotating input element. When inserted into the bore of the Flexspline, it imparts its elliptical shape to the Flexspline, causing the external teeth of the Flexspline to engage with the internal teeth of the Circular Spline at two equally spaced areas 180 degrees apart on their respective circumferences, thus forming a positive gear mesh at these points of engagement.



THE PRINCIPLES OF HARMONIC DRIVE GEARING



1 2 3

The diagram shows the three basic harmonic drive elements (Circular Spline, Flexspline and Wave Generator) assembled in a normal configuration. Ordinarily, the Circular Spline is held stationary or fixed and input is through the Wave Generator, while output is via the Flexspline. Under these circumstances, operation of the harmonic drive unit is as follows.

As the Wave Generator is rotated by the primary power source, it imparts a continuously moving elliptical form or wave-like motion to the Flexspline. This causes the meshing of the external teeth of the Flexspline with the internal teeth of the Circular Spline at their two equidistant points of engagement to progress in a continuous rolling fashion. It also allows for full tooth disengagement at the two points opposite the minor axis of the Wave Generator. Since the Flexspline has two less teeth than the Circular Spline and because full tooth disengagement is made possible by the elliptical shape of the Wave Generator, each complete revolution of the Wave Generator causes a two tooth displacement of the Flexspline in relation to the Circular Spline. This displacement is always in the opposite direction of the rotation of the Wave Generator (see diagram). For example, if the Wave Generator is rotating in a clockwise direction, the two-tooth-per-revolution displacement of the Flexspline will be in a counterclockwise direction and vice versa. In this way, a basic three element harmonic drive component set is capable of functioning as a speed reducer. Input from a main power source through the Wave Generator is at a high speed, but the two-tooth-per-revolution displacement causes the Flexspline, which is the output element, to rotate in the opposite direction of, and at a considerably slower speed than, the Wave Generator. The reduction ratio which results can be calculated by dividing the number of teeth on the Flexspline by two (the difference between the number of teeth on the Circular Spline and the Flexspline). If a fixed Circular Spline had 202 teeth and an output Flexspline has 200 teeth, the ratio would be

$$\frac{200}{200-202} = 100{:}1.$$

ADVANTAGES

The inherent advantages of harmonic drive gearing over other, more conventional gear trains are apparent. A simple three-element construction combined with the unique harmonic drive principle puts extremely high reduction ratio capabilities into a very compact and lightweight package. This remarkable union of simplicity of construction with an operating principle that is unique also enables backlash to be held to an absolute minimum, an exceedingly important factor from the standpoint of reliability and the transmission of accurate motion.

The three diagrams at the top of this page schematically represent the two-tooth per revolution displacement of the Flexspline in relation to the Circular Spline as discussed below. Observe that the Flexspline has two less teeth than the Circular Spline.

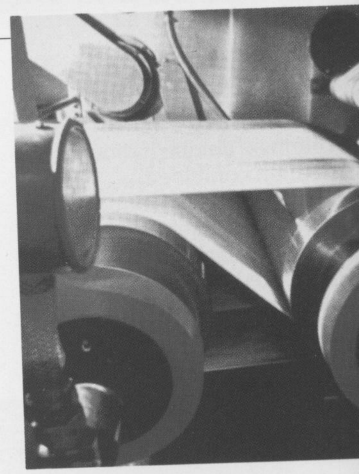
The arrow in Diagram One indicates the Flexspline tooth in the 12 o'clock position in relation to the Circular Spline, prior to the clockwise revolution of the Wave Generator. Notice that due to the elliptical shape of the Wave Generator full tooth engagement only occurs at the two areas directly opposite its major axis, which is in the vertical position in Diagram One. The teeth in the two areas opposite the minor axis are completely disengaged. This is crucial to an understanding of the tooth displacement phenomenon.

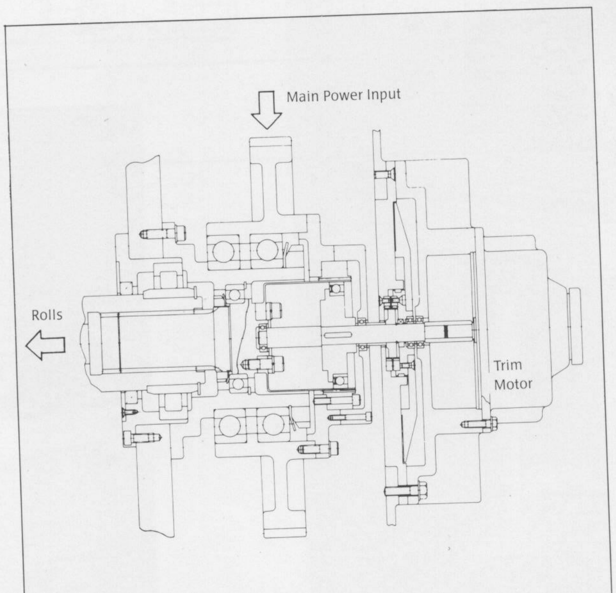
Diagram Two shows the position of the Wave Generator after a 90 degree clockwise rotation. The arrow is still pointing to the original Flexspline tooth, which has already begun its anti-clockwise rotation or displacement. Without full tooth disengagement opposite the minor axis of the Wave Generator this displacement would not be possible.

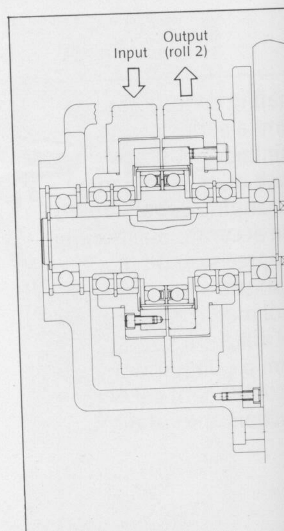
Diagram Three illustrates the position of the Wave Generator after one complete clockwise rotation. The arrow indicates the two-tooth per revolution anti-clockwise displacement of the Flexspline tooth originally shown in the 12 o'clock position in Diagram One.

PRINTING PRESSES

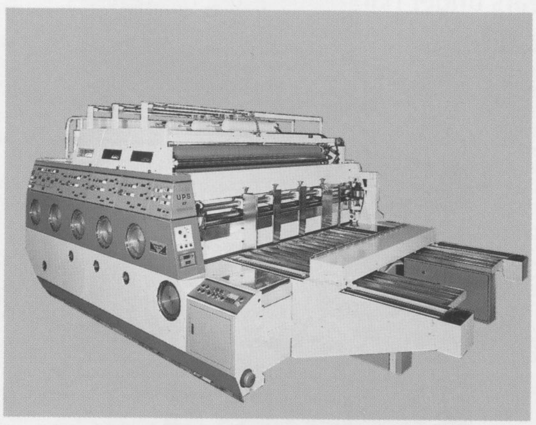
In multiple-color offset rotary printing presses, synchronized rotating rollers apply ink of various colors to designated patterns. If any roller moves out of alignment, causing color overlap or misprinting, the adjustment mechanism incorporating a harmonic drive differential unit will correct alignment without necessitating a shut-down of the press. In a typical example illustrated here, during normal operation the ink rollers are driven by the primary motor alone, with the trim input rotationally locked. When misalignment occurs, the trim motor intervenes to minutely increase or decrease the speed of the roller until angular phase adjustment is achieved.







When applied in differential drives for web tensioning, shaft phasing, roll registration, and other applications requiring controlled variable speed and phasing of rotating shafts, harmonic drive differential gearing represents exceptional performance and design flexibility unsurpassed by conventional differential mechanisms. The compact differential units developed specially for providing precise and minute adjustments enable the effective streamlining of the entire system, with a significant cost-saving advantage.



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No.8804-01R-CB

Printed in Japan

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Trademarks
P.O. Box 1451
Alexandria, VA 22313-1451
www.uspto.gov

Jan 23, 2008

NOTICE OF ABANDONMENT

TM103

BASSAM N. IBRAHIM
BUCHANAN INGERSOLL & ROONEY, P.C.
PO BOX 1404
ALEXANDRIA, VA 22313-1404

ATTORNEY REFERENCE NUMBER:
1030673-218

SERIAL NUMBER:	77/030648
MARK:	HARMONIC LINEAR DRIVE
APPLICANT:	Harmonic Drive Systems Inc.

THE ABOVE IDENTIFIED TRADEMARK APPLICATION WAS ABANDONED ON 01/22/2008 FOR THE FOLLOWING REASON: APPLICANT'S LETTER OF EXPRESS ABANDONMENT WAS RECEIVED IN THE PATENT AND TRADEMARK OFFICE ON 01/22/2008. (TRADEMARK RULE 2.68).

PTO Form 1957 (Rev 9/2005)
OMB No. 0651-0050 (Exp. 04/2009)

Response to Office Action

The table below presents the data as entered.

Input Field	Entered
SERIAL NUMBER	77030648
LAW OFFICE ASSIGNED	LAW OFFICE 103
MARK SECTION (no change)	
ARGUMENT(S)	
The examining attorney has refused registration of the applied-for mark under Section 2(d) of the Trademark Act based on a likelihood of confusion with U.S. Serial Nos. 1728918 and 1727054 for the marks HARMONIC DRIVE TECHNOLOGIES and HARMONIC DRIVE TECHNOLOGIES and Design. Both registrations are owned by Harmonic Drive Technologies Nabtesco, Inc. Harmonic Drive Technologies Nabtesco, Inc. and Harmonic Drive Systems, Inc. are related companies. Applicant's attorneys are in the process of obtaining evidence regarding this relationship and will provide additional information once this evidence-gathering is complete. If the examining attorney has any further questions or concerns, applicant respectfully requests that she contact applicant's attorneys at the number listed in the correspondence section of the application.	
SIGNATURE SECTION	
RESPONSE SIGNATURE	/JLW/
SIGNATORY'S NAME	Jennifer L. Williston
SIGNATORY'S POSITION	Associate Attorney, Buchanan Ingersoll & Rooney, PC
DATE SIGNED	01/15/2008
AUTHORIZED SIGNATORY	YES
FILING INFORMATION SECTION	
SUBMIT DATE	Tue Jan 15 18:35:02 EST 2008
TEAS STAMP	USPTO/ROA-12.4.123.125-20080115183502883514-77030648-410e6481a3f440c02e336aee159735d73-N/A-N/A-20080115180724105251

PTO Form 1957 (Rev 9/2005)
OMB No. 0651-0050 (Exp. 04/2009)

Response to Office Action

To the Commissioner for Trademarks:

Application serial no. **77030648** has been amended as follows:

ARGUMENT(S)
In response to the substantive refusal(s), please note the following:

The examining attorney has refused registration of the applied-for mark under Section 2(d) of the Trademark Act based on a likelihood of confusion with U.S. Serial Nos. 1728918 and 1727054 for the marks HARMONIC DRIVE TECHNOLOGIES and HARMONIC DRIVE TECHNOLOGIES and Design. Both registrations are owned by Harmonic Drive Technologies Nabtesco, Inc. Harmonic Drive Technologies Nabtesco, Inc. and Harmonic Drive Systems, Inc. are related companies. Applicant's attorneys are in the process of obtaining evidence regarding this relationship and will provide additional information once this evidence-gathering is complete. If the examining attorney has any further questions or concerns, applicant respectfully requests that she contact applicant's attorneys at the number listed in the correspondence section of the application.

SIGNATURE(S)
Response Signature
Signature: /JLW/ Date: 01/15/2008
Signatory's Name: Jennifer L. Williston
Signatory's Position: Associate Attorney, Buchanan Ingersoll & Rooney, PC

The signatory has confirmed that he/she is an attorney who is a member in good standing of the bar of the highest court of a U.S. state, which includes the District of Columbia, Puerto Rico, and other federal territories and possessions; and he/she is currently the applicant's attorney or an associate thereof; and to the best of his/her knowledge, if prior to his/her appointment another U.S. attorney or a Canadian attorney/agent not currently associated with his/her company/firm previously represented the applicant in this matter: (1) the applicant has filed or is concurrently filing a signed revocation of or substitute power of attorney with the USPTO; (2) the USPTO has granted the request of the prior representative to withdraw; (3) the applicant has filed a power of attorney appointing him/her in this matter; or (4) the applicant's appointed U.S. attorney or Canadian attorney/agent has filed a power of attorney appointing him/her as an associate attorney in this matter.

Serial Number: 77030648
Internet Transmission Date: Tue Jan 15 18:35:02 EST 2008
TEAS Stamp: USPTO/ROA-12.4.123.125-20080115183502883
514-77030648-410e6481a3f440c02e336aee159
735d73-N/A-N/A-20080115180724105251

To:	Harmonic Drive Systems Inc. (bassam.ibrahim@bipc.com)
Subject:	TRADEMARK APPLICATION NO. 77030648 - HARMONIC LINEAR DRIVE - 1030673-218
Sent:	12/15/2006 1:11:58 PM
Sent As:	ECOM103@USPTO.GOV
Attachments:	Attachment - 1 Attachment - 2 Attachment - 3 Attachment - 4 Attachment - 5 Attachment - 6 Attachment - 7 Attachment - 8 Attachment - 9 Attachment - 10 Attachment - 11 Attachment - 12 Attachment - 13 Attachment - 14 Attachment - 15 Attachment - 16 Attachment - 17 Attachment - 18 Attachment - 19 Attachment - 20 Attachment - 21 Attachment - 22 Attachment - 23 Attachment - 24 Attachment - 25 Attachment - 26 Attachment - 27 Attachment - 28 Attachment - 29 Attachment - 30 Attachment - 31 Attachment - 32 Attachment - 33

Attachment - 34
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Attachment - 40
Attachment - 41
Attachment - 42
Attachment - 43
Attachment - 44

UNITED STATES PATENT AND TRADEMARK OFFICE

SERIAL NO: 77/030648

APPLICANT: Harmonic Drive Systems Inc.

77030648

CORRESPONDENT ADDRESS:
BASSAM N. IBRAHIM
BUCHANAN INGERSOLL & ROONEY, P.C.
PO BOX 1404
ALEXANDRIA, VA 22313-1404

RETURN ADDRESS:
Commissioner for Trademarks
P.O. Box 1451
Alexandria, VA 22313-1451

MARK: HARMONIC LINEAR DRIVE

CORRESPONDENT'S REFERENCE/DOCKET NO: 1030673-218

CORRESPONDENT EMAIL ADDRESS:
bassam.ibrahim@bipc.com

Please provide in all correspondence:

1. Filing date, serial number, mark and applicant's name.
2. Date of this Office Action.
3. Examining Attorney's name and Law Office number.
4. Your telephone number and e-mail address.

OFFICE ACTION

RESPONSE TIME LIMIT: TO AVOID ABANDONMENT, THE OFFICE MUST RECEIVE A PROPER RESPONSE TO THIS OFFICE ACTION WITHIN 6 MONTHS OF THE MAILING OR E-MAILING DATE.

MAILING/E-MAILING DATE INFORMATION: If the mailing or e-mailing date of this Office action does not appear above, this information can be obtained by visiting the USPTO website at http://tarr.uspto.gov/, inserting the application serial number, and viewing the prosecution history for the mailing date of the most recently issued Office communication.

Serial Number 77/030648

The assigned examining attorney has reviewed the referenced application and determined the following.

Search Results

The Office records have been searched and no similar registered or pending mark has been found that would bar registration under Trademark Act Section 2(d), 15 U.S.C. §1052(d). TMEP §704.02. However, registration is refused on the following ground.

Section 2(e)(1) - Descriptive Refusal

Registration is refused because the proposed mark is merely descriptive of applicant's goods and/or services. Trademark Act Section 2(e)(1), 15 U.S.C. §1052(e)(1); TMEP §§1209 *et seq.*

A mark is merely descriptive under Section 2(e)(1) if it describes an ingredient, quality, characteristic, function, feature, purpose or use of the specified goods and/or services. *In re Gyulay*, 820 F.2d 1216, 3 USPQ2d 1009 (Fed. Cir. 1987); *In re Bed & Breakfast Registry,* 791 F.2d 157, 229 USPQ 818 (Fed. Cir. 1986); *In re MetPath Inc.*, 223 USPQ 88 (TTAB 1984); *In re Bright-Crest, Ltd.*, 204 USPQ 591 (TTAB 1979); TMEP §1209.01(b). A mark that describes an intended user of a product or service is also merely descriptive within the meaning of Section 2(e)(1). *See Hunter Publ'g Co. v. Caulfield Publ'g, Ltd.,* 1 USPQ2d 1996 (TTAB 1986); *In re Camel Mfg. Co.*, 222 USPQ 1031 (TTAB 1984).

A term is merely descriptive if it conveys an immediate idea of the ingredients, qualities, or characteristics of the identified goods or services. *In re Abcor Dev. Corp.*, 588 F.2d 811, 200 USPQ 215, 218 (CCPA 1978); *Goodyear Tire & Rubber Co. v. Cont'l Gen. Tire, Inc.,* 70 USPQ2d 1067, 1069 (TTAB 2003); *In re TMS Corp. of Ams.*, 200 USPQ 57, 58 (TTAB 1978).

However, for the purpose of a Section 2(e)(1) analysis, a term need not describe all of the purposes, functions, characteristics or features of the goods and/or services to be merely descriptive. *In re Dial-a-Mattress Operating Corp*., 240 F.3d 1341, 1346, 57 U.S.P.Q.2d 1807 (Fed. Cir. 2001). It is enough if the term describes only one significant function, attribute or property. *In re Oppedahl & Larson LLP*, 373 F.3d 1171, 1173, 71 USPQ2d 1370, 1371 (Fed. Cir. 2004) ("[A] mark may be merely descriptive even if it does not describe the 'full scope and extent' of the applicant's goods or services.") (quoting *In re Dial-A-Mattress Operating Corp.*, 240 F.3d 1341, 1346, 57 USPQ2d 1807, 1812 (Fed. Cir. 2001)).

The determination of whether a mark is merely descriptive is considered in relation to the identified goods and/or services, not in the abstract. *In re Abcor Dev. Corp*., 588 F.2d 811, 814, 200 USPQ 215, 218 (CCPA 1978); *see, e.g.*, *In re Polo Int'l Inc.*, 51 USPQ2d 1061 (TTAB 1999) (DOC in DOC-CONTROL would be understood to refer to the "documents" managed by applicant's software, not "doctor" as shown in dictionary definition);*In re Digital Research Inc.*, 4 USPQ2d 1242 (TTAB 1987) (CONCURRENT PC-DOS found merely descriptive of "computer programs recorded on disk" where relevant trade uses the denomination "concurrent" as a descriptor of this particular type of operating system); *see* TMEP §1209.01(b).

Attached as evidence are web pages showing descriptive use of the term "harmonic" in conjunction with drives and gears, which shows that the term "harmonic" is descriptive as to applicant's goods. Also attached is Wikipedia entry of the word "harmonic," which defines harmonic drive as an input/output gear reduction mechanism.

Attached are copies of printouts from the USPTO X-Search database, which show third party registrations in which the word "LINEAR" has been disclaimed. These printouts have probative value to the extent that they serve to suggest that the word "linear" has long been treated as a descriptive word with respect to machine parts such as actuators and transmissions and therefore disclaimed in other registrations.
Attention is also directed to applicant's own identification of goods/services in which applicant has used the term "linear" in a descriptive manner.

Also attached are definitions of the words "transmission" and "drive" as evidence that the word "DRIVE" is descriptive as to applicant's goods, namely, power transmissions.

The Encarta World English Dictionary defines "transmission" as:

4. automotive mechanism transferring power to wheels: the mechanical system, including gears and shafts, by which power is transmitted from the engine of a motor vehicle to the drive wheels

5. automotive set of gears: a set of gears and the protective casing that covers this in a vehicle or engine

The Encarta World English Dictionary defines "drive" as:

4. engineering transmission of power: the means of converting power into motion in a machine such as a motor vehicle a car with four-wheel drive

Combination of Descriptive Terms
A mark that combines descriptive terms may be registrable if the composite creates a unitary mark with a separate, nondescriptive meaning. *In re Colonial Stores, Inc.*, 394 F.2d 549, 157 U.S.P.Q. 382 (C.C.P.A. 1968) (holding SUGAR & SPICE not to be merely descriptive of bakery products). However, the mere combination of descriptive words does not automatically create a new nondescriptive word or phrase. *E.*g., In *re Associated Theatre Clubs Co.*, 9 USPQ2d 1660, 1662 (TTAB 1988) (finding GROUP SALES BOX OFFICE descriptive for theater ticket sales services). The registrability of a mark created by combining only descriptive words depends on whether a new and different commercial impression is created, and/or the mark so created imparts an incongruous meaning as used in connection with the goods and/or services. Where, as in the present case, the combination of the descriptive words creates no incongruity, and no imagination is required to understand the nature of the goods and/or services, the mark is merely descriptive. *E.g.*, *In re Copytele Inc.*, 31 USPQ2d 1540, 1542 (TTAB 1994); *Associated Theatre Clubs*, 9 USPQ2d at 1662.

See, e.g., In re Tower Tech, Inc., 64 USPQ2d 1314 (TTAB 2002) (SMARTTOWER merely descriptive of "commercial and industrial cooling towers and accessories therefor, sold as a unit");*In re Sun Microsystems Inc.*, 59 USPQ2d 1084 (TTAB 2001) (AGENTBEANS merely descriptive of "computer software for use in development and deployment of application programs on a global computer network"); *In re Putman Publ'g Co.,* 39 USPQ2d 2021 (TTAB 1996) (FOOD & BEVERAGE ON-LINE merely descriptive of news and information service for the food processing industry); *In re Copytele Inc.*, 31 USPQ2d 1540 (TTAB 1994) (SCREEN FAX PHONE merely descriptive of facsimile terminals employing electrophoretic displays); *In re Entenmann's Inc*., 15 USPQ2d 1750 (TTAB 1990) (OATNUT held to be merely descriptive of bread containing oats and hazelnuts).

Applicant's mark, HARMONIC LINEAR DRIVE, comprises of a combination of descriptive terms that fails to result in a separate, nondescriptive meaning. Combined together, the entire mark merely describes goods or services related to a type of linear drive or power transmission.

The two major reasons for not protecting descriptive marks are: (1) to prevent the owner of a mark from inhibiting competition in the sale of particular goods or services; and (2) to avoid the possibility of costly infringement suits brought by the registrant. This thus enables businesses and competitors to have the freedom to use common descriptive language when merely describing their own goods or services to the public in advertising and marketing materials. *In re Abcor Development Corp*., 588 F.2d 811, 200 USPQ 215 (C.C.P.A. 1978); *In re Colonial Stores, Inc.*, 394 F.2d 549, 157 USPQ 382, 383 (C.C.P.A. 1968); *Armour & Co. v. Organon Inc*., 245 F.2d 495, 114 USPQ 334, 337 (C.C.P.A. 1957); *In re Styleclick.com Inc*., 58 USPQ2d 1523, 1526-1527 (TTAB 2001); *In re Styleclick.com Inc.*, 57 USPQ2d 1445, 1448 (TTAB 2000).

Although the trademark examining attorney has refused registration, applicant may respond to the refusal to register by submitting evidence and arguments in support of registration. If applicant chooses to respond to the refusal(s) to register, then applicant must also respond to the following requirement(s).

Identification of Goods/Services

In the identification of goods, applicant must use the common commercial or generic names for the goods, be as complete and specific as possible, and avoid the use of indefinite words and phrases. If applicant uses indefinite words such as "accessories," "components," "devices," "equipment," "materials," "parts," "systems" or "products," such words must be followed by "namely," followed by a list of the specific goods identified by their common commercial or generic names. TMEP §§1402.01 and 1402.03(a).

The wordings "gears, gear devices" in the identification of goods is indefinite and must be clarified because it is too broad. TMEP §1402.01. Applicant may adopt the following identification of goods/services, if accurate:

> Class 007 Linear actuators, gears {describe the product and intended consumer as well as its main purpose and intended uses, e.g. for industrial machinery}, gear devices, namely, {specify the common commercial name and intended consumer as well as its main purpose and intended uses, e.g. gear cutters}, gears for motors {further specify its use, e.g. for industrial machinery}, gears for machines, transmission gears for machines; power transmissions for machines, and gearing for machines, not for land vehicles.

Applicant classified the goods and/or services "linear actuators" in International Class 012;however, the correct classification is International Class 007. Applicant must either delete these goods and/or services from International Class 012. 37 C.F.R. §§2.32(a)(7) and 2.85; TMEP §1401.04(b). Applicant may adopt the following identification of goods/services, if accurate:

> Class 012 Gears for vehicles, gear devices, namely, {specify the common commercial name and intended consumer as well as its main purpose and intended uses, e.g. gear shifts}, gears for motors for vehicles, transmission gears land vehicles; power transmissions and gearing for land vehicles.

For assistance with identifying and classifying goods and/or services in trademark applications, please see the online searchable *Manual of Acceptable Identifications of Goods and Services* at http://tess2.uspto.gov/netahtml/tidm.html.

Please note that, while the identification of goods/services may be amended to clarify or limit the goods/services, adding to the goods/services or broadening the scope of the goods/services is not permitted. 37 C.F.R. §2.71(a); TMEP §1402.06. Therefore, applicant may not amend the identification to include goods/services that are not within the scope of the goods/services set forth in the present identification.

Declaration

Applicant must submit a written statement attesting to the facts set forth in the application, and confirming that applicant had a bona fide intention to use the mark in commerce on or in connection with the goods or services listed in the application as of the application filing date. This statement must be dated and signed by a person authorized to sign under 37 C.F.R. §2.33(a), and verified with a notarized affidavit or signed declaration under 37 C.F.R. §2.20. 15 U.S.C. §1051(b)(3)(B); 37 C.F.R. §§2.34(a)(2)(i), (a)(3)(i) and (a)(4)(ii); TMEP §§804.02, 806.01(b), 806.01(c), 806.01(d) and 1101. No signed verification was provided with the application.

To satisfy this requirement, applicant may add the following declaration paragraph at the end of its response, properly signed and dated:

> The undersigned, being hereby warned that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and that such willful false statements and the like may jeopardize the validity of the application or any resulting registration, declares that he/she is properly authorized to execute this application on behalf of the applicant; he/she believes the applicant to be the owner of the trademark/service mark sought to be registered, or, if the application is being filed under 15 U.S.C. §1051(b), 1126(d) or 1126(e), he/she believes applicant to be entitled to use such mark in commerce; *that the applicant had a bona fide intention to use the mark in commerce on or in connection with the goods or services listed in the application as of the application filing date*; that the facts set forth in the application are true and correct; to the best of his/her knowledge and belief no other person, firm, corporation, or association has the right to use the mark in commerce, either in the identical form thereof or in such near resemblance thereto as to be likely, when used on or in connection with the goods/services of such other person, to cause confusion, or to cause mistake, or to deceive; and that all

statements made of his/her own knowledge are true and all statements made on information and belief are believed to be true.

____
(Signature)

____
(Print or Type Name and Position)

____
(Date)

If the declaration is filed electronically through TEAS, then applicant should sign the declaration by entering a "symbol" that applicant has adopted as a signature (e.g., */john doe/*, */drl/*, and */544-4925/*). The Office will accept *any* combination of letters, numbers, spaces and/or punctuation marks as a valid signature if it is placed between two forward slash ("/") symbols. 37 C.F.R. §§2.33(d) and 2.193(c)(1)(iii); TMEP §§304.07 and 804.05.

A person who is properly authorized to sign on behalf of an applicant is: (1) a person with legal authority to bind the applicant; (2) a person with firsthand knowledge of the facts and actual or implied authority to act on behalf of the applicant; or (3) an attorney as defined in 37 C.F.R. §10.1(c) who has an actual written or verbal power of attorney or an implied power of attorney from the applicant. 37 C.F.R. §2.33(a); TMEP §804.04.

Claim of Ownership

If applicant is the owner of U.S. Registration Nos. 2652327, 1728918, and 1727054, then applicant must submit a claim of ownership. 37 C.F.R. §2.36; TMEP §812. The following standard format is suggested:

Applicant is the owner of U.S. Registration Nos. 2652327, 1728918, and 1727054.

Information Requirement

The examining attorney requires information about the goods/services and/or the mark to determine whether all or part of the mark is merely descriptive as applied to the goods and/or services. TMEP §814. Applicant must specify whether the wording "HARMONIC," "LINEAR," "DRIVE" or "HARMONIC LINEAR DRIVE" have any significance in a foreign language, as a geographic location, in the machinery or vehicular trade or industry, or as applied to the goods/services described in the application. 37 C.F.R. §2.61(b).

Trademark Rule 2.61(b) states "[t]he examiner may require the applicant to furnish such information and exhibits as may be reasonably necessary to the proper examination of the application." The

Trademark Trial and Appeal Board has upheld a refusal of registration based on the applicant's failure to provide information requested under this rule. *In re Page*, 51 USPQ2d 1660 (TTAB 1999)(failure to comply with request for information constitutes grounds for refusal); *In re Babies Beat Inc.*, 13 USPQ2d 1729 (TTAB 1990)(failure to submit patent information regarding configuration).

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Trademark Examining Attorney
Law Office 103
Phone - 571-272-8810
Fax No. 571-273-8810
wendy.jun@uspto.gov

HOW TO RESPOND TO THIS OFFICE ACTION:

- ONLINE RESPONSE: You may respond using the Office's Trademark Electronic Application System (TEAS) Response to Office action form available on our website at http://www.uspto.gov/teas/index.html. If the Office action issued via e-mail, you must wait 72 hours after receipt of the Office action to respond via TEAS. **NOTE: Do not respond by e-mail. THE USPTO WILL NOT ACCEPT AN E-MAILED RESPONSE**.
- REGULAR MAIL RESPONSE: To respond by regular mail, your response should be sent to the mailing return address above, and include the serial number, law office number, and examining attorney's name. **NOTE: The filing date of the response will be the *date of receipt in the Office*,** not the postmarked date. To ensure your response is timely, use a certificate of mailing. 37 C.F.R. §2.197.

STATUS OF APPLICATION: To check the status of your application, visit the Office's Trademark Applications and Registrations Retrieval (TARR) system at http://tarr.uspto.gov.

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GENERAL TRADEMARK INFORMATION: For general information about trademarks, please visit the Office's website at http://www.uspto.gov/main/trademarks.htm

FOR INQUIRIES OR QUESTIONS ABOUT THIS OFFICE ACTION, PLEASE CONTACT THE ASSIGNED EXAMINING ATTORNEY SPECIFIED ABOVE.

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Harmonic drive

From Wikipedia, the free encyclopedia

A **harmonic drive** is an input/output gear reduction mechanism.

History [edit]

The basic concept was introduced by C.W. Musser in 1957. It was first used successfully in 1964 by Hasegawa Gear Works, Ltd. and USM Co., Ltd.

Mechanics [edit]

The harmonic drive theory is based on elastic dynamics and utilizes the flexibilty of metal. The mechanism has three basic components: a wave generator, a flexspline, and a circular spline. More complex versions will have a fourth component normally used to shorten the overall length or to increase the gear reduction within a smaller diameter, but still follows the same basic principles.

External links [edit]

- Waltmusser.org
- HDSI.net

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SHIFTING GEARS WITH STEPPING MOTOR GEARHEADS

Since the stepping motor and other control motors are designed to allow accurate positioning, the gearheads used for these motors must provide the same level of accuracy. Accordingly, Oriental Motor has developed a mechanism to minimize backlash in gears used with stepping motors in order to ensure low backlash properties. The basic principles and structures of typical control motor gears are explained below.

Gear Type	Max. Holding Torque (lb-in)	Max. Backlash (Arc min)	Min. Resolution (° /step)
TH Gear	106	10-45	0.0120
PN Gear	530	3	0.0072
HG Gear	480	0	0.0036

*Note values vary depending on the series, frame size and gear ratio.

Tapered Hob (TH) Geared

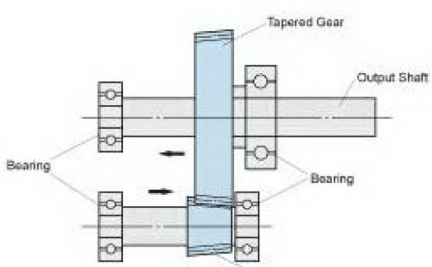
Planetary (PN) Geared

Harmonic (HG) Geared

Tapered Hobbed (TH) Gears

Tapered hobbed gears are used for the final stage of the spur gear's speed reduction mechanism and the meshing gear. The tapered gear is produced through a continuous profile shifting toward the shaft. The tapered gears used at the final stage are adjusted in the direction of the arrows (see illustration below).

Click to enlarge image



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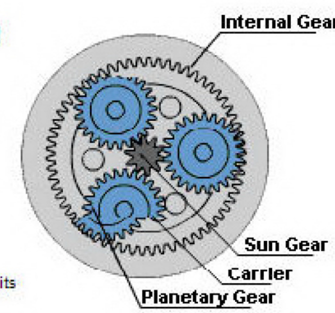
Structure of TH gear's final stage

Available for the AlphaStep AS & ASC Series, 5-Phase RK Series and 5-Phase CSK Series stepping motors from Oriental Motor.

Planetary (PN) Gears

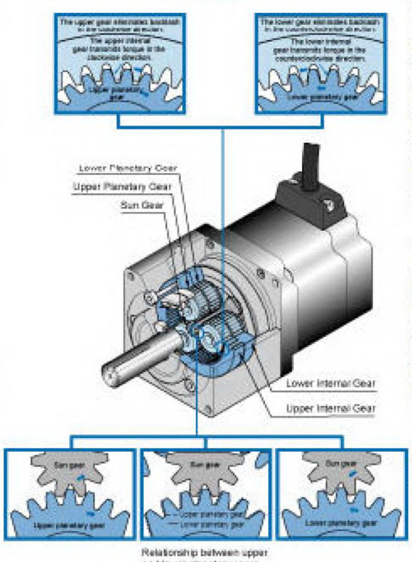
The planetary **gear** mechanism is comprised of a sun **gear**, planetary gears and an internal tooth **gear**. The sun **gear** is installed on the central axis (in a single stage type, this is the motor shaft) surrounded by planetary gears enclosed in an internal tooth **gear** centered on the central axis. The revolution of the planetary gears is translated into rotation of the output shaft via carriers.

Planetary (PN) Gears



- Sun **Gear**: A **gear** located in the center, functioning as an input shaft.
- Planetary Gears: Several external gears revolving around the sun **gear**. Each planetary **gear** is attached to the carrier, onto which the **gear's** output shaft is securely fixed.
- Internal **Gear**: A cylindrical **gear** affixed to the gearbox, having teeth on its inside diameter.

(Click to enlarge image)



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The PN **gear** achieves the specified backlash of two arc minutes through the improved accuracy of its components and the backlash elimination mechanism. That mechanism is comprosied of two sets of internal and planetary gears on the upper and lower levels with the internal **gear** teeth twisted in the circumferential direction. The upper level internal gears and planetary gears reduce clockwise backlash; the lower level internal gears and planetary **gear** reduce counterclockwise backlash.

In conventional spur-**gear** speed reduction mechanisms, gears mesh one to one, so the amount of torque is limited by the strength of each single **gear**. On the other hand, in the planetary **gear** speed reduction mechanism, a greater amount of torque can be transmitted, since torque is distributed through dispersion via several planetary gears.

Available for the AlphaStep AS & ASC Series and 5-Phase RK Series stepping motors from Oriental Motor.

Harmonic (HG) Gears

The **harmonic gear** offers unparalleled precision in positioning and features a simple construction utilizing the metal's elastomechanical property. It is comprised of three basic components: a wave generator, flex spline and circular spline.

- Wave Generator: The wave generator is an oval-shpaed component with a thin ball bearing placed around the outer circumference of the oval cam. The bearing's inner ring is attached to the oval cam,

Seminars

In addition to Motor Fair, Oriental Motor offers FREE local product and motion control seminars throughout the United States. Simply submit your information and your local Oriental Motor representative will contact you with information on upcoming events in your area.

[Click here to register.]

Information

Oriental Motor USA Corp.
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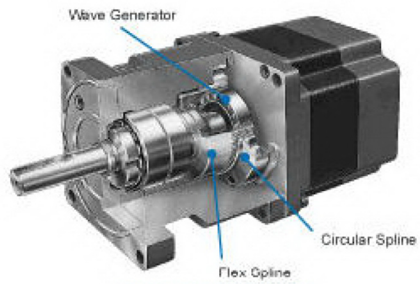
The bearing's inner ring is attached to the oval cam, while the outer ring is subjected to elastic defromation via the balls. The wave generator is mounted onto the motor shaft.

- **Flex Spline:** The flex spline is a thin, cup-shaped component made of elastic metal, with teeth formed along the outer circumference of the cup's opening. The **gear's** output shaft is attached to the bottom of the flex spline.
- **Circular Spline:** The circular spline is a rigid internal **gear** with teeth formed alonf its inner circumference. These teeth are the same size as those of the flex spline, but the circular spline has two more teeth than the flex spline. The circular spline is attached to the gearbox along its outer circumference.



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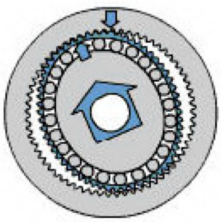
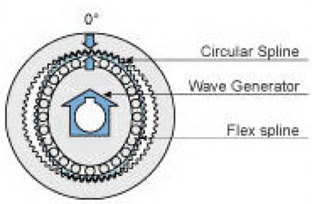
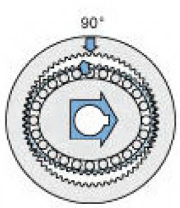


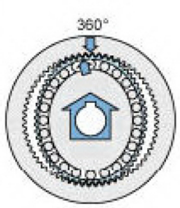
Harmonic (HG) Gears



The flex spline is bent into an oval shape by the wave generator. The teeth at the long axis of the oval mesh with the circular spline, while the teeth at the short axis of the oval are completely separate from it.



Rotating the wave generator (input) clockwise while keeping the circular spline fixed in position will subject the flex spline to elastic deformation, causing a gradual shift in the point of engagement between the circular spline and flex spline.



When the wave generator completes one revolution, the flex spline has rotated two fewer teeth than the other circular spline has, resulting in the movement of the flex spline for the difference in the tooth count (two teeth) in the opposite direction of the wave generator's rotation (i.e. counterclockwise). This movement translates into output, therby reducing the speed.

Unlike conventional spur gears, the **harmonic gear** is capable of averaging the effects of tooth pitch errors and accumulated pitch errors to the rotational speed, thus achieving highly precise, zero-backlash performance. However, the **gear's** own torsion may become the cause of a problem when performing ultra-high precision positioning at an accuracy of two arc minutes or less. When using a **harmonic gear** for ultra-high precision positioning remember the following three points.

- **Lost Motion** is the total value of the displacement produced when about five percent of permissible torque is applied to the **gear's** output shaft. Since **harmonic** gears have no backlash, the measuer indicating the **gear's** precision is represented as lost motion.
- **Hysteresis Loss** - when torque is gradually applied to the **gear** output shaft until it reaches permissible torque in the clockwise or counterclockwise direction, the angle of torsion will become smaller as the torque is reduced. However, the angle of torsion never reaches zero, even when fully returned to its initial level.
- **Torque and Torsion Characteristics** Displacement (torsion) is produced by the **gear's** spring constant when a load is applied to the output shaft of the **harmonic gear**. The amount of this displacement, which is caused when the **gear** is driven under a friction load, is the same as the value when the motor shaft is held fixed and torsion (torque) is applied to the **gear's** output shaft.

Available for the AlphaStep AS & ASC Series, 5-Phase RK Series and 5-Phase PMC Series.

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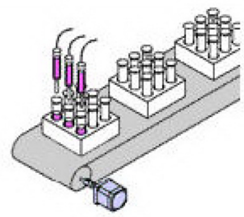
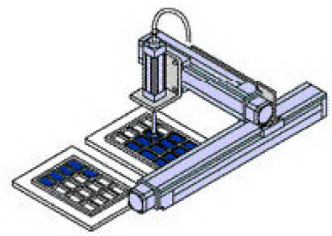
Introducing Oriental Motor's new online Application section (located under Support). Devoted to common motor and fan applications, the new section features over 50 common applications featuring Oriental Motor products.



In addition to basic application information, visitors with Flash* can see the applications in action. By clicking on the application images visitors will be able to watch the application in action to get a better idea of how the motor is applied to create motion (see examples to the right). Oriental Motor also offers recommendations for which products will best fulfill the needs of the application. Visit the new Applications section to learn even more about motion and motion control from Oriental Motor.



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MOTION CONTROL QUESTIONS? ASK AN ORIENTAL MOTOR ENGINEER

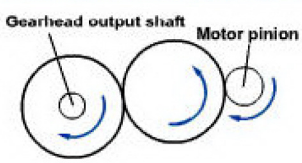
ASK?

Oriental Motor's Engineering Team is just a click away. Send your motion control questions to Oriental Motor's top engineers and we'll publish their response in an upcoming issue of New Motion.

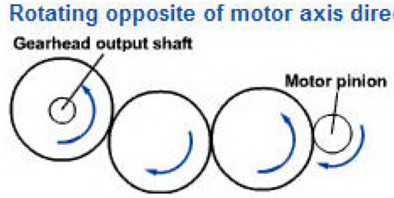
Question: Why do some gearheads output in the same direction as the motor while others output in the opposite direction?

Answer: Gearheads reduce the motor speed by 3:1 to 180:1. They do not, however, reduce the speed with a single **gear** stage, but with several. The number of **gear** stages depends on the **gear** ratio, so the direction of the output shaft rotation differs.

- **Rotating in motor axis direction**



- **Rotating opposite of motor axis direction**



Each issue, our Engineering Team will answer our readers' motion control questions. From how to use a stepping motor to proper motor sizing techniques and specific applications, ask an OM engineer and get your answer directly from the source. Our engineers are dedicated to continuous research and development in motion control technology. E-mail your motion control question to newsletter (Please be sure to include your e-mail address and contact information so our Engineering Team can follow up on your question.)

Visit our "Frequently Asked Question (FAQ)" section online.

Oriental Motor also offers 1-800 Technical Support. Our Technical Support Team is qualified to answer a wide variety of questions. Call toll free 1-800-GO-VEXTA (468-3982) to speak with an Oriental Motor associate or e-mail techsupport http://72.14.209.104/search?q=cache:W1ye-IRygEUJ:www.gears-manufacturers.com/harmonic-drives.html+harmonic+gear&hl=en&gl=us&ct=clnk&cd=7 12/14/2006 04:19:21 PM

GEARS manufacturers marketplace

Gear Drives > Harmonic Drives

Gears - A mechanical device that transmit power and motion between axes in a wide variety of commercial and industrial applications.

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Helical Gearbox

Geared Motors

Gear Applications
- Agro Industry
- Automotive Gears
- Conveyor Systems
- Instrumentation Gears
- Marine Gears
- Mill heads
- Mining Gears
- Power Station

Harmonic Drives

This is a mechanical speed changing device, invented in 1950s, that operates on a different principle form, and has capabilities beyond the scope of, conventional speed changers. They consist of a thin ring that deflects elastically as they roll on the inside of a slightly larger rigid circular ring.

The basic elements of harmonic drive are circular spline, flexspline, and wave generator, all assembled in a normal configuration. As the wave generator rotates, it imparts a continuous motion to the flexspline. This causes meshing of the external teeth of flexspine with internal teeth of the circular spline. The meshing moves in a rolling fashion. It allows for full tooth disengagement at the two point along the minor axis of the wave generator. Flexspline has two teeth less than circular spline, so each complete revolution of the wave generator causes a two-tooth displacement of the flexspline in relation to the circular spline. This displacement is in the opposite direction. This way harmonic drive works as a speed reducer.

Characteristics

A harmonic drive uses an egg-shaped metal cam to create speed reduction. This means that eccentric motion is inherent in the design and translates to a lack of smoothness or ripple in the velocity and torque profile. They have less stiffness due to flexspline. In order to achieve a near-zero backlash, this drive preloads the bearing and flexspline thereby reducing the operating life. Because of preloading they provide low efficiencies. They are very compact and lightweight drives offering low backlash and high reduction ratio capabilities. Due to its inherent low torsional stiffness, distinct speed or torque ripple, and low efficiency, the drive can be problem for certain precision applications like painting application in automotive plants.

Gear Drives:

Automatic Transmissions | Bevel Gear Drives | Combination Drives | Cycloidal Drives | Differential Gear Drives, Misc. | Dual Output Differential | Epicyclic/ Planetary Differential | Differentials, Tension Control | Differentials, Torque Control | Epicyclic Gear Drives | Harmonic Drives | Helical Gear Drives | Hypoid Gear Drives | Worm Drives | Tacho Drive | Marine Gear Drives | Miter Gear Drives | Spiral Bevel Gear Drives | Spur Gear Drives | Traction Drives | Variable Speed Drives | Manual Shift Transmission | Gear-Shift Transmissions

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harmonic drive

Sci-Tech Dictionary: harmonic drive

(här′män·ik ′drīv)

(*mechanical engineering*) A drive system that uses inner and outer gear bands to provide smooth motion.

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Harmonic drive

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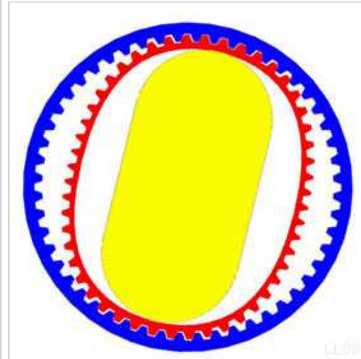


Harmonic drive animation

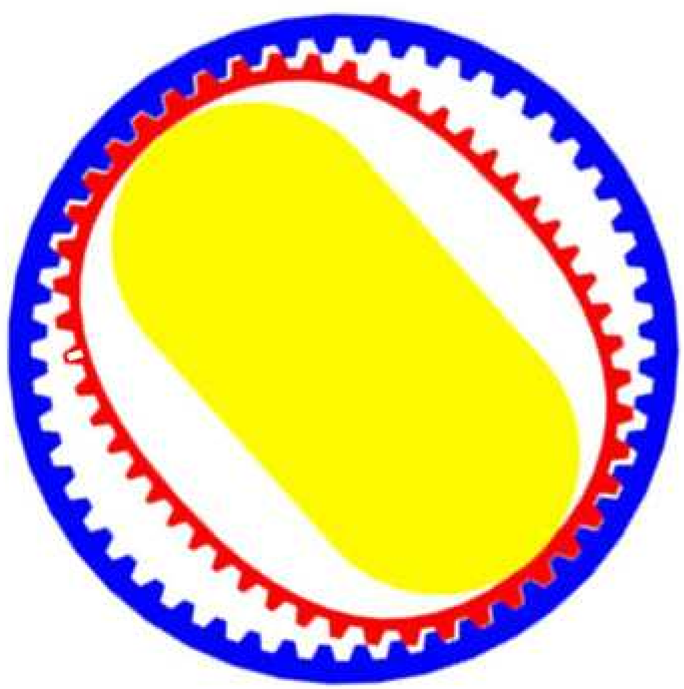
A **harmonic drive** is an input/output gearing mechanism. It is typically used for gearing reduction, but may also be used to increase rotational speed or for differential gearing. Very high gear reduction ratios are possible in a small volume (100:1 is possible in the space that Planetary gears typically only produce 10:1).

History

The basic concept of a harmonic drive was introduced by C.W. Musser in 1957. It was first used successfully in 1964 by Hasegawa Gear Works, Ltd. and USM Co., Ltd. Later, Hasegawa Gear Works, Ltd. became Harmonic Drive Systems Inc. located in Japan and USM Co., Ltd. Harmonic Drive division became Harmonic Drive Technologies Inc.

On January 1, 2006, Harmonic Drive Technologies/Nabtesco of Peabody, MA and HD Systems of Hauppauge, NY, merged to form a new joint venture, Harmonic Drive LLC (*Gear Product News*, April 2006, page 36). HD Systems, Inc. was a subsidiary company of Harmonic Drive System, Inc. Offices are maintained in both Peabody and Hauppauge.

Mechanics



The harmonic drive theory is based on elastic dynamics and utilizes the flexibility of metal. The mechanism has three basic components: a wave generator, a flex spline, and a circular spline. More complex versions will have a fourth component normally used to shorten the overall length or to increase the gear reduction within a smaller diameter, but still follows the same basic principles.

The wave generator is made up of two separate parts: an elliptical disk called a "wave generator plug" and an outer ball bearing. The gear plug is inserted into the bearing, giving the bearing an elliptical shape as well.

The flex spline is like a shallow cup. The sides of the "cup" are very thin, but the bottom is thick and rigid. This results in significant flexibility of the walls at the open end due to the thin wall, but in the closed side being quite rigid and able to be tightly secured (to a shaft, for example). Teeth are positioned radially around the outside of the flex spline. The flex spline fits tightly over the wave generator, such that when the wave generator plug is rotated, the flex spline deforms to the shape of a rotating ellipse but does not rotate with the wave generator.

The circular spline is a rigid circular ring with teeth on the inside. The flex spline and wave generator are placed inside the circular spline, meshing the teeth of the flex spline and the circular spline. Because the flex spline has an elliptical shape, its teeth only actually mesh with the teeth of the circular spline in two regions on opposite sides of the flex spline, along the major axis of the ellipse.

Assume that the wave generator is the input rotation. As the wave generator plug rotates, the flex spline teeth which are meshed with those of the circular spline change. The major axis of the flex spline actually rotates with wave generator, so the points where the teeth mesh revolve around the center point at the same rate as the wave generator. The key to the design of the harmonic drive is that there are fewer teeth (for example two fewer) on the flex spline than there are on the circular spline. This means that for every full rotation of the wave generator, the flex spline would be required to rotate a slight amount (two teeth, for example) backward relative to the circular spline. Thus the rotation action of the wave generator results in a much slower rotation of the flex spline *in the opposite direction*.

For a harmonic drive mechanism, the gearing reduction ratio can be calculated from the number of teeth on each gear:

Reduction ratio = (flex spline teeth - circular spline teeth) / flex spline teeth.

For example, if there were 202 teeth on the circular spline and 200 on the flex spline, the reduction ratio is: (200 - 202) / 200 = -0.01

Thus the flex spline would spin at 1/100th the speed of the wave generator plug and in the opposite direction. This allows different reduction ratios to be set without changing the mechanism's shape, increasing its weight, or adding stages. The range of possible gear ratios is limited by teeth size limits for a given configuration.

Harmonic Drive provides unique advantages such as:

- Zero Backlash
- High Reduction Ratio with Single Stage
- Compact & Light weight
- High Torque Capability
- Coaxial input & output shaft

Lauletta, Anthony. "The Basics of Harmonic Drive Gearing", *Gear Product News*, April 2006. pp 32-36.

External links

- Waltmusser.org (http://www.waltmusser.org/HD.htm)
- Harmonicdrive.net (http://www.harmonicdrive.net/reference/operatingprinciples/)
- Chrisdesign.com (http://www.chrisdesign.com/projects/hdinfonet/firstpage.htm)

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harmonic drive [här′män·ik ′drīv]
(mechanical engineering)

A drive system that uses inner and outer gear bands to provide smooth motion.

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(*mechanical engineering*) A drive system that uses inner and outer gear bands to provide smooth motion.

Harmonic Drive

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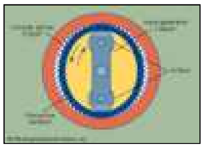
Main

machine component

mechanical speed-changing device, invented in the 1950s, that operates on a different principle from, and has capabilities beyond the scope of, conventional speed changers. It consists of a thin ring that deflects elastically as it rolls on the inside of a slightly larger rigid circular ring.



The three elements of the basic Harmonic Drive are shown in the **Figure**. The circular spline has internal teeth that mesh with external teeth on the flexspline. The flexspline has fewer teeth and consequently a smaller effective diameter than the circular spline. The wave generator is a link with two rollers that rotates within the flexspline, causing it to mesh with the circular spline progressively at diametrically opposite points. If the wave generator (the input) rotates clockwise while the circular spline is fixed, the flexspline (the output) will rotate or roll around on the inside of the circular spline at a much slower rate in a counterclockwise direction.

The ratio of the input speed to the output speed depends on the difference in the number of teeth in the circular spline and in the flexspline. Speed ratios as high as 320 to 1 can be produced in single-reduction Harmonic Drives that are lighter, smaller, and more efficient than conventional high-ratio drives. Compound drives can produce ratios as high as 1,000,000 to 1. Either the circular spline, the flexspline, or the wave generator may be fixed while the other two elements serve as input and output.

A unique and useful characteristic of the Harmonic Drive is its ability to transmit motion through sealed walls. The flexspline teeth can be placed near the centre of a long, hermetically sealed, flexible, cylindrical tube. The wave generator can be inside the tube and by its rotation deflect the flexspline and produce a slow rotation of the encircling circular spline. A rotary-to-linear version of the Harmonic Drive uses a screw and moves the **control rod** in a **nuclear reactor** head without mechanical contact through a sealed tube. Harmonic Drives have been employed in a variety of applications that range from such low-cost consumer applications as vending machines and rotating home-television antennas to sophisticated systems for military and aerospace use.

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PREFACE

Mechanical design is concerned with all aspects of the design of machines and machine systems. In this broad sense, the term *mechanical design* is almost a definition of mechanical engineering and includes much that is basic to other fields of engineering, particularly aerospace, agricultural, electrical, and industrial. The author believes that introductory courses in mechanical design should start where courses in mechanics, strength of materials, properties of materials, and manufacturing processes end to show how the background gained in these courses can be combined with additional information and reality to design machines and machine systems to fulfill human needs.

Since the pressure to find time for new subjects is intense and ever-increasing, the scope of introductory courses must necessarily be limited to presenting ideas, concepts, principles, and information that will be of use to the greatest number of students in their professional work after leaving college. The author believes that every student who may be involved in mechanical design should, as a minimum, be introduced to the specification of motion requirements, the selection of mechanisms that will provide the

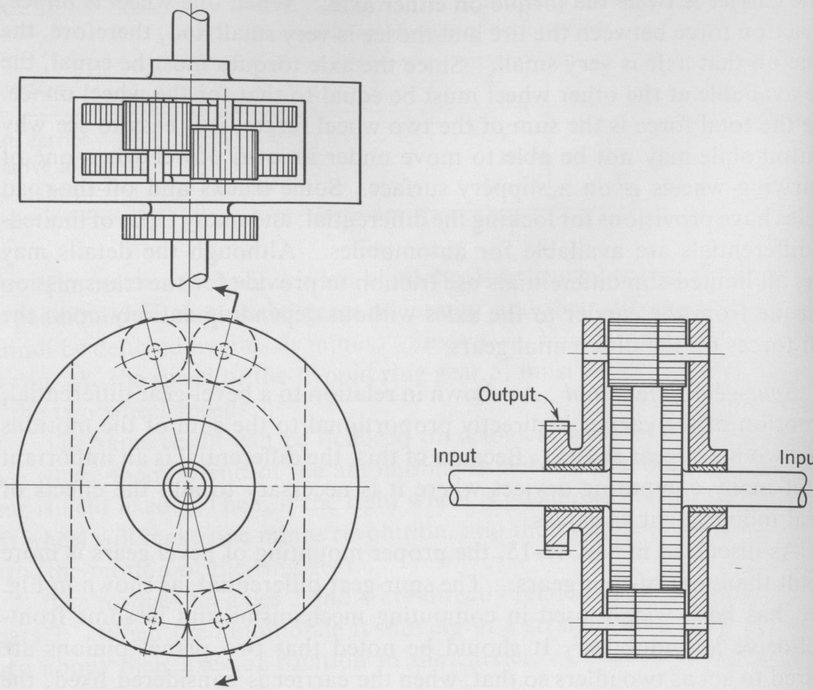

Fig. 17-16 Spur-gear differential.

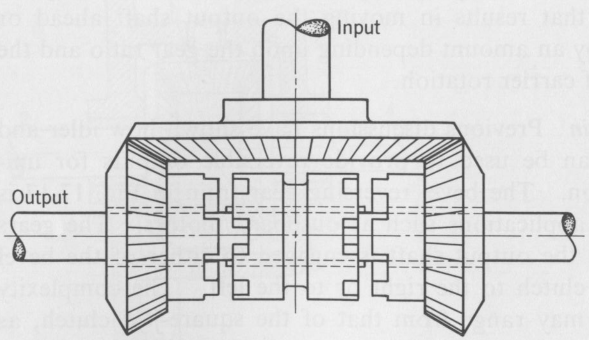

Fig. 17-17 Bevel reversing gear train.

17-6 HARMONIC DRIVE

The Harmonic drive utilizes toothed members in a unique way to provide large ratios for speed reduction or increase with high torque capacities in a small space. The three basic components, shown in Fig. 17-18*a*, are a rigid circular spline, a flexible circular spline, and an elliptical wave generator. The flexible spline, called a *flexspline*, normally has two fewer teeth than the rigid circular spline. When the unit is assembled, as shown schematically in Fig. 17-18*b*, the wave generator deforms elastically the flexspline so that teeth are fully engaged at the diametrically opposite points corresponding to the major axis of the wave generator and are completely disengaged at the points corresponding to the minor axis of the wave generator. Assuming the rigid circular spline to be fixed, rotation of the wave generator will deform the flexspline such that the points at which the teeth are fully engaged are always lined up with the major axis of the wave generator. Since the teeth must engage in succession, it can be seen that in one revolution of the wave generator the flexspline will have engaged with its own number of teeth on the rigid circular spline. Thus, if the flexspline has 200 teeth and the circular spline has 202 teeth, the flexspline will have rotated backward a distance of 2 teeth. In this case, the velocity ratio would be 100:1 and the output shaft (flexspline) would rotate in the direction opposite to that of the input shaft (wave generator). The general equation for the reduction ratio is

$$\frac{\omega_{in}}{\omega_{out}} = \frac{N_O}{N_C - N_F} \tag{17-34}$$

where N_O = number of teeth on rotating output member
N_F = number of teeth on flexspline
N_C = number of teeth on circular spline

When the flexspline is fixed and the circular spline is the output, the input and output shafts will rotate in the same direction.

Standard units are available with reduction ratios from 64:1 to 320:1 and with torque output capacities up to 240,000 lb-in. (27,100 N-m).

17-7 VARIABLE-SPEED DRIVES

Gears and chains must be used if a change in angular velocity is required while maintaining a definite phase relationship between the input and output shafts. Chain reduction units have been used in relatively large-capacity slow-speed oil-field applications. If more than two different speeds are required, the size and cost of chain drives become relatively high. Gear

Accepted for publication Journal of Dynamic Systems, Measurements, and Control, ASME Publications.

Modelling and Parameter Identification of Harmonic Drive Systems

H.D. Taghirad and **P.R. Bélanger**

Center for Intelligent Machines,
Department of Electrical Engineering,
McGill University, Montréal, H3A 2A7

Abstract

The unique performance features of harmonic drives, such as high gear ratios and high torque capacities in a compact geometry, justify their widespread industrial application, especially in robotics. However, harmonic drives can exhibit surprisingly more complex dynamic behavior than conventional gear transmissions. In this paper, a systematic way to capture and rationalize the dynamic behavior of the harmonic drive systems is examined. Simple and accurate models for compliance, hysteresis, and friction are proposed, and the model parameters are estimated using least–squares approximation for linear and nonlinear regression models. A statistical measure of variation is defined, by which the reliability of the estimated parameter for different operating condition, as well as the accuracy and integrity of the proposed model is quantified. Finally, the model performance is assessed by a simulation verifying the experimental results on two different harmonic drives.

1 Introduction

Since its inception in 1955, the harmonic drive has found widespread acceptance among practitioners. This mechanical transmission, occasionally called "strain-wave gearing", employs a continuous deflection wave along a *non-rigid gear* to allow for gradual engagement of gear teeth. Because of this unconventional gear-tooth meshing action, harmonic drives can deliver high reduction ratios in a very small package. In fact, the radical mechanical operation of this gear train defies conventional understanding of gear behaviour and creates a new arena for exploration and understanding.

The harmonic drive exhibits performance features both superior and inferior to those of conventional gear transmissions. Its performance advantages include high torque capacity, concentric geometry, lightweight and compact design, near–zero backlash, high efficiency, and back drivability. Harmonic drive systems suffer however, from high flexibility, resonance vibration, friction and structural damping nonlinearities. The unique performance features of the harmonic drive have captured the attention of designers in many fields. It has been used in industrial and space robots, assembly equipment, and measuring instruments, as well as heavy duty applications such as machine tools and printing presses. Additionally, space and aircraft systems often employ harmonic drives for their light weight and compact geometry.

Throughout its short existence, the harmonic drive has enjoyed increasing international attention from designers as well as researchers. The Russians were perhaps the first who initiated substantial research on the dynamic behavior of harmonic drives [1, 24].

More recently Tuttle and Seering performed an extensive effort to model the stiffness, positioning accuracy, gear tooth-meshing mechanism and friction of the harmonic drive [22, 23]. Their experimental observations show that the velocity response to step commands in motor current are not only contaminated by serious vibration, but also by unpredictable jumps. The velocity response observations were used to guide the development of a series of models with increasing complexity to describe the harmonic drive behavior. Their most complex model involved kinematic error, nonlinear stiffness, and gear-tooth interface with frictional losses.

Kircanski and Goldenberg have also attempted to model the harmonic drive in detail [13]. They used the drive system in contact with a stiff environment, in contrast to unrestrained motion experiments used by Tuttle and Seering [23], and illustrated that in this case nonlinear stiffness, hysteresis and friction are more tractable. Simple models for soft-windup, hysteresis, and friction were proposed and the parameters were identified by restrained motion experiments.

Hsia [11], Legnani [14], Marilier [16], and Seyfferth [17] are among others who attempted to model the stiffness, friction, and position accuracy of harmonic drive systems. All these researchers noted the inherent difficulties in finding an accurate model for the system.

In this paper a moderately complete model of harmonic drive system is developed. Restrained and unrestrained motion experiments are use to identify the model parameters and illustrate the fidelity of the model for two different types of harmonic drive systems. It is shown that a linear stiffness model for stiffness combined with a velocity dependent structural damping model can replicate the hysteresis torsion curve of the system compliance. The frictional losses of the transmission have been modelled using Coulomb friction, viscous damping and Stribeck friction. Both high speed, and low speed friction terms have been identified using unrestrained and restrained motion experiments respectively. Finally, the simulation of the system, built in Simulink, has been used to verify the model fidelity by experiments. It has been verified that the simulation accurately predicts the restrained and unrestrained experiments.

2 Experimental Setup

Two harmonic drive testing stations were used to monitor the behaviour of two different harmonic drives. A picture of those setups is illustrated in Figure 2, in which the harmonic drive is driven by a DC motor, and a load inertia is used to simulate the robot arm for unrestrained motion. Also a positive locking system is designed such that the output load can be locked to the ground for restrained motion experiments. In the first setup, a brushed DC motor from Electro–Craft, model 586-501-113, is used. Its weight is 1.36 Kg, with maximum rated torque of 0.15 Nm, and torque constant of 0.0543 Nm/amp. The servo amplifier is a 40 Watts Electro–Craft power amp model Max-100-115. The harmonic drive in this setup is from RHS series of HD systems model RHS-20-100-CC-SP, with gear ratio of 100:1, and rated torque of 40 Nm. In the second setup the DC motor is a brushless Kollmorgen Inland motor, model RBE-01503-A00. Its weight is 475 gr, with maximum rated torque of 5.6 Nm, and torque constant of 0.1815 Nm/amp. The servo amplifier is a FAST Drive Kollmorgen, model FD 100/ 5E1. The harmonic drive is from CFS series of HD Systems, Inc. with gear ratio 160:1, and rated peak torque of 178 Nm.

In the first experimental setup, the circular spline is fixed to the ground and the output is carried by the flexspline, while in the other setup, the flexspline is fixed and the circular spline is used for output rotation. By this arrangement, the behavior of the transmission under different operating configurations can be examined. Each setup is equipped with a tachometer to measure the motor velocity, and an encoder on the load side to measure the output position. The output torque is measured by a Wheatstone bridge of strain

ABB's Ultra-low Harmonic Drive earns double gold in "Product of the Year Award" (POY) poll of CSE subscribers

2006-10-07 - The drive earns both the most votes in the "Motors, Starters, Drives" product category -- and the most overall votes among all products in the poll

NEW BERLIN, WI, October 6, 2006 . . . Subscribers and online visitors to a leading trade journal serving mechanical, electrical and plumbing system designers have voted ABB's Ultra-low Harmonic Drive the best product in the Motors, Starters, Drives category; and, the drive earned more votes than all other product entries, making ABB's entry a double-gold winner.

"Consulting-Specifying Engineer Magazine" (CSE), which produces the POY (Product Of the Year) program, noted, in alerting ABB to the awards, that the "awards program was established to provide the magazine's print and electronic engineering subscribers with the best, peer-reviewed new products in the major M/E/P engineering system disciplines CSE regularly covers: Automation & Control, Electrical, Fire Protection, HVAC, Lighting, Motors/Drives, Security & Communications and Power Quality/Reliability."

Judges and Engineers Decide

The program is a two-step process, according to the editorial team, led by CSE editor Jim Crockett. "First, we had our independent panel of engineering judges score all POY entrants earlier this year," he said. "We then eliminated products that did not score high enough for our finalist criteria. Subscribers and web users then scored each product in each category 1-10, with 10 being the best. The highest totals won."

"We are delighted to learn this group of engineers voted this way," said Michael Vallier, the product line manager at ABB, Low Voltage Drives, who was responsible for the introduction of the drive. "It confirms a growing reality of the marketplace: that both HVAC and Industrial drives and motors users are dealing with harmonics issues as a reality in the specifications they are asked to meet, and in the installations that they help with."

Jeff Miller, vice president of ABB Low Voltage Drives' HVAC business, noted that harmonics issues related to motor installation and control "have grown up in the HVAC side of the market, as drives installed in buildings are placed alongside a wide, and growing, array of microprocessor-controlled equipment. The challenge is growing rapidly to help end users minimize radio frequency interference and, increasingly, prevent, rather than mitigate, any harmonic generation to a facility's power network," he said.

Ease of Integration a Critical Criterion

CSE will report ABB's POY and all award winners, including the Silver and Bronze finalists, in the November 2006 issue. ABB's entry qualified for the award, because the drive was introduced to the market between January 1, 2004 and December 31, 2005.

One of the criteria that judges used to select finalists was ease of integrating the ABB product, compared to other contest entries, within the category. ABB's ultra-low harmonic drives offers users extremely precise motor control and prevention of harmonics via built-in, active filtration. Offered in wall-mount units (7.5 to 125 horsepower range), and cabinet-built configurations (125 to 2,800 Hp), the ultra-low harmonic drives are compact in size and do not require any multi-pulse transformer, external filters or other additional equipment for harmonics reduction.

LV Drives' Ultra-low Harmonic Units Earn Double-gold Awards from Engineers who Read "CSE" Media.

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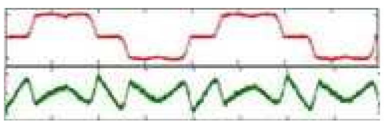

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Hollow Shaft Actuators with Harmonic Drive Gearing

HD Systems, Hauppauge, New York
Tuesday, December 01 1998

They can be used in demanding applications such as industrial robots and servo systems.

Harmonic drive gearing is recognized by designers for its zero backlash, high gear ratios, and compact design features. A recent development by HD Systems incorporates a large hollow shaft through the actuator, offering many benefits to the machine designer. The FHA hollow shaft actuator series allows cables, shafts, or tubing to be passed concentrically through the center of the actuator. Through this innovation, the series provides precision motion control and high torque capacity in very compact packages.

Another technical stride incorporated in this series is the patented "S" tooth profile, yielding higher torque capacity and torsional stiffness as well as twice the rated life of conventional harmonic drive gearing. Using this tooth profile, the CSF series delivers twice the performance of conventional harmonic drive gearing in roughly half the axial length. The SHF series offers the performance of the CSF with the additional benefit of a hollow shaft through the center of the gear.

Harmonic drive gears are made up of three basic parts (Figure 1). The circular spline (right) is a rigid ring with internal teeth, engaging the teeth of the flexspline (center) across the major axis of the wave generator. The flexspline is a nonrigid, thin cylindrical steel cup with external teeth on a slightly smaller pitch diameter than the circular spline. It fits over and is held in an elliptical shape by the wave generator, a thin raced ball bearing fitting onto an elliptical plug serving as a high-efficiency torque converter.


Figure 1. Harmonic drive gear System Components.

The three basic parts of the CSF series gears function in the following way (Figure 2). The flexspline is slightly smaller in diameter than the circular spline and usually has two fewer teeth. The wave generator's elliptical shape causes the teeth of the flexspline to engage the circular spline at two opposite regions across the major axis of the ellipse. As the wave generator rotates, the zone where the teeth of the flexspline engage those of the circular spline travels with the major elliptical axis. For each 180° clockwise movement of the wave generator, the flexspline moves counterclockwise by one tooth relative to the circular spline. Each complete clockwise rotation of the wave generator results in the flexspline moving counterclockwise by two teeth from its original position relative to the circular spline.

The reduction in the axial length of the CSF—depending on frame size, it can be almost 50 percent shorter than a conventional harmonic drive gear—is made possible by the "S" tooth profile. The wave generator imparts its elliptical shape onto the flexspline, which provides tooth engagement between it and the circular spline. The greater the ellipticity of the wave generator, the greater the radial deflection experienced by the flexspline. This deflection must not produce stresses above the fatigue limit of the material.

The "S" tooth harmonic drive gearing has a wave generator with far less ellipticity than conventional harmonic drive gearing. Thus the flexspline is subjected to less radial deflection. This allows its axial length to be shortened without increasing the stress level. As a result, HD Systems engineers have successfully delivered shortened axial length, high performance, and infinite life.

By combining increased performance with shortened axial length, the CSF achieves a fourfold increase in performance on a per-volume basis. For example, a robot's performance is determined by its payload, and the weight of the robot limits the payload capacity. The CSF decreases the robot's size, and thus its mass, and so it can increase its payload capacity.

Figure 2. Operating Principle of the harmonic drive gear.

The SHF series takes the additional step of incorporating a large through-bore capacity through the center of the gear. This is made possible by the development of the innovative "silkhat" flexspline. The conventional flexspline has a mounting boss on a smaller diameter than the toothbed. It has the shape of a cup, with the toothbed on the open end and the mounting boss on the bottom of the cup. The "silkhat" type has a mounting boss on a much larger diameter than the toothbed. It resembles a top hat, with the mounting boss on the rim. Since the mounting boss's diameter usually limits the available through-bore, the silkhat design provides a much larger through-bore capacity. This allows machine elements such as tubes, shafts, or ballscrews to be passed through the center.

The input element can be driven by a hollow-shaft brushless motor. Another configuration involves using a pulley to drive the wave generator from a motor mounted on a parallel shaft, yielding the advantage that the motor can be mounted a short distance from the SHF gear for an optimum package size.

The "S" tooth profile, shown in Figure 3, significantly increases the region of tooth engagement. For the traditional tooth profile, about 15 percent of the total number of teeth are in contact, while for the new profile up to 30 percent are in contact. Figure 4 shows a region of tooth engagement. One end of this region is at the major axis of the wave generator ellipse where the teeth are totally engaged. The other end is where the teeth become totally disengaged. The increase in engagement results in a 100-percent increase in torsional stiffness in the low and medium torque ranges.

The new tooth profile also features an enlarged tooth root radius, which results in a higher allowable stress and a corresponding increase in torque capacity. Furthermore, the enlarged region of tooth engagement leads to a more even loading of the wave generator bearing, resulting in more than double the bearing's life expectancy.

The FHA series actuators feature a through-bore up to 45 mm in diameter. These units consist of a DC brushless pancake motor, an encoder, and a precision harmonic drive gearhead. An encoder is built integral with the motor to reduce the axial length to a minimum. Rated torques up to 1730 in.-lb. and positional accuracy better than 1 arc-minute can be achieved. The FHA series is available in five frame sizes, ranging from 116 to 248 mm in length, and 128 to 300 mm in diameter.

For more information on harmonic drive gearing systems, please contact Brian St. Denis, HD Systems, *Hauppauge, NY 11788; (516) 231-6630; fax: (516) 231-6803;* [*http://www.HDSystemsInc.com.*](http://www.HDSystemsInc.com)

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OFFENDING COMMAND: get

STACK:

/quit
-dictionary-
-mark-
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Harmonic Driver

Harmonic Driver X50series

CNC Machine, Machine center, Robot, Spaceflight, War Industry, Artificial Limb

Harmonic Driver X30 Component X31series

CNC Machine, Machine center, Robot, Spaceflight, War Industry, Artificial Limb

Harmonic Driver X30series

CNC Machine, Machine center, Robot, Spaceflight, War Industry, Artificial Limb

Harmonic Driver X10 Crisscross"+" Component X14series

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Harmonic Driver X10 Pin Hole Component X12series

CNC Machine, Machine center, Robot, Spaceflight, War Industry, Artificial Limb

Harmonic Driver X11series

Harmonic Driver X10, X20series

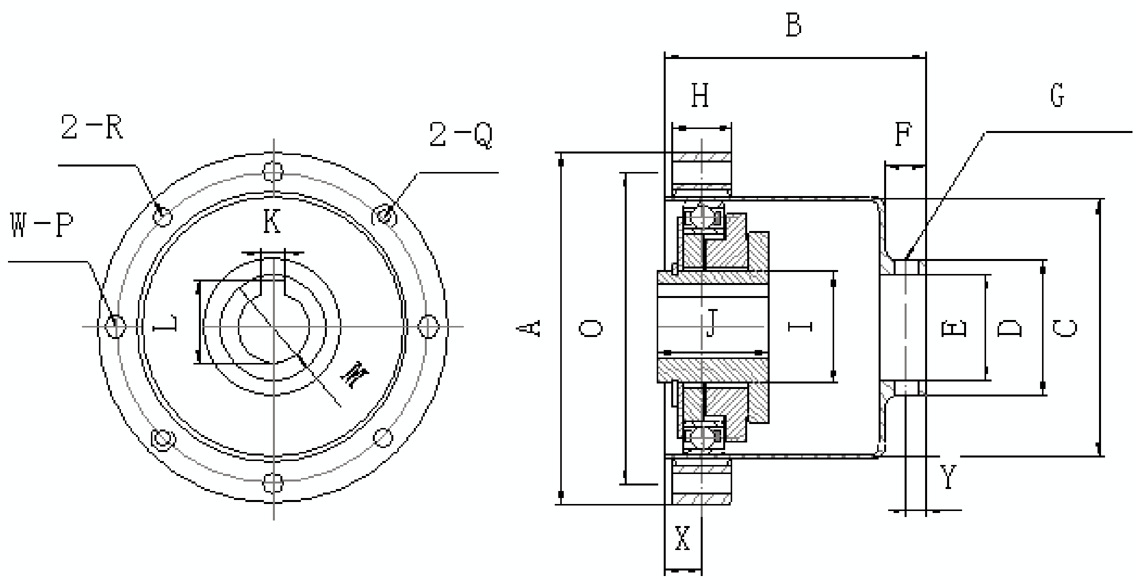
Page: 1

Harmonic Driver X10 Crisscross"+" Component X14 Series

Application	Complementary Products:
CNC Machine, Machine center, Robot, Spaceflight, War Industry, Artificial Limb	High reduction ratios with concentric shafts Very low backlash and vibration

Mechanical Dimensions

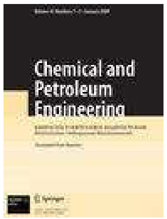
CrissCross "+" Components



Dimension Data

Model	A	B	C	D	E	F	G	H	I	J	K	L	M	O	P	Q	R	W	X	Y
	(g7)				(H7)								(H7)							
25	40	29	25.5	14	10	6	3	9	12	14.6	2	7	6	34	3.5	M3	3	4	4	3
32	50	34	32.6	17	13	6	3	10	15	16	3	9.4	8	43	3.5	M3	3	4	5	3
40	60	42	40.7	24	18	7	4	11	18	19	3	11.4	10	51	4.5	M4	4	4	6	4
50	70	52	51	31	21	8	5	12	22	22	4	13.8	12	62	4.5	M4	4	4	8	4

Journal Article



Harmonic-drive gear with controllable transmission ratio

Journal	Chemical and Petroleum Engineering
Publisher	Springer New York
ISSN	0009-2355 (Print) 1573-8329 (Online)
Issue	Volume 9, Number 5 / May, 1973
Category	From Foreign Technology
DOI	10.1007/BF01155654
Pages	476-477
Subject Collection	Chemistry and Materials Science
SpringerLink Date	Thursday, February 17, 2005

A. V. Brazhnikova

Without Abstract

Translated from Khimicheskoe i Neftyanoe Mashinostroenie, No. 5, p. 44, May, 1973.

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HARMONIC-DRIVE GEAR WITH CONTROLLABLE TRANSMISSION RATIO*

A. V. Brazhnikova UDC 621.83.061.1(088.8)

A unit which provides for the rotation of screw centrifuge assemblies, including main and auxiliary drives with controllable angular velocity, is described.

Figure 1 shows the harmonic-drive gear 3 (stressed induction element), gear wheel 8 with internal teeth and elastic ring 5. The projections 1 and 7 of the harmonic-drive gear have two angular locations 2 and 6 at which the teeth of the elastic ring engage with the teeth of the wheel 8. In the intermediate locations 4 and 9 there is no engagement.

The harmonic-drive gear rotates in a clockwise direction and causes angular displacement of the 2 and 6 projections in the same direction and at the same velocity; the elastic ring 5 rotates counterclockwise and at a lower speed. During rotation of the harmonic-drive gear the elastic ring interacts with the projections 1 and 7 through ball bearings.

Figure 2 shows the gear wheel 4, connected by a belt drive to the main motor (not shown in Fig. 2). In the casing 1 there is a collector 2 for oil, and at the opposite end there is a pressure chamber connected with the oil collector by channels. The screw 17 is rotated by means of the elastic ring, in this case the external teeth of the latter comprising part of a sloping cylinder, attached by a dowel to the flange of the screw conveyor 17 shaft, engage with the gear wheel 4.

The harmonic drive is mounted on the shaft 15 and includes the bearings 14, by means of which the projections 1 and 7 (see Fig. 1) distort the wall of the elastic ring 5. The pulley 11 is attached to the drum 10 and is rotated from an auxiliary current source (not shown in Fig. 2). The drum is fitted with attachments, by means of which both the velocity and direction of movement are changed. The auxiliary drive for the harmonic-drive gear for different rates of rotation (in any direction) is the belt drive 8.

Two delivery tubes 13 with nozzles, which are located in the pressure chamber, are fitted to the flange 12, attached to the shaft of the harmonic-drive reducing gear. The nozzles of the delivery tubes are so

*Abstract of Patent of the De Laval Separator Company (USA) No. 3482770, 9.12.69.

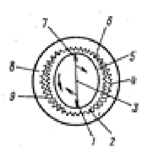

Fig. 1. Diagram of harmonic-drive gear.

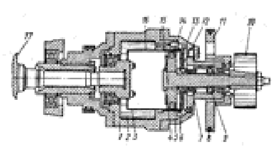
Fig. 2. Gear wheel.

Translated from Khimicheskoe i Neftyanoe Mashinostroenie, No. 5, p. 44, May, 1973.

476

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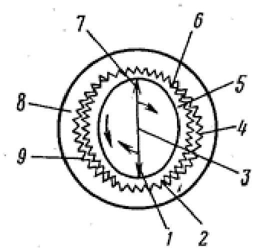

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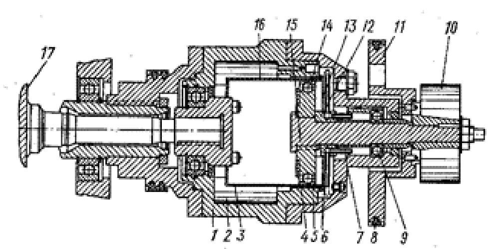

Fig. 2. Gear wheel.

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Journal Article

Disturbance-observer-based adaptive feedforward cancellation of torque ripples in harmonic drive systems

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Yu-Sheng Lu[1] and Shuan-Min Lin[1]

(1) National Yunlin University of Science and Technology, 123, Section 3, University Road, Touliu, Yunlin, 640, Taiwan, R.O.C.

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Abstract This paper proposes a scheme for controlling the output torque of a harmonic drive actuator equipped with a torque sensor. The control scheme consists of the internal model control (IMC) and an adaptive feedforward cancellation (AFC) based on a disturbance observer (DOB). The relationship between the IMC and the DOB is presented in this paper, and the IMC is adopted as a feedback compensator for its ease in design and implementation. The DOB, on the other hand, is suitable for estimating an unknown disturbance, and its output is applied to the AFC resonator that generates an adaptive dither to compensate for the torque ripples induced by harmonic drives. Compared with the conventional AFC, the salient features of the proposed DOB-based AFC include the independence of designing the AFC's adaptation gain from the plant and the feedback compensator, fast convergence of the disturbance-cancellation error, and no influence of aperiodic reference changes upon the adaptive dither. The effectiveness of the proposed scheme is demonstrated through experimental results, in which its performance is shown to be superior to that of the conventional AFC.

Keywords Harmonic drive actuator - Torque control - Torque ripple - Adaptive feedforward cancellation - Disturbance observer - Internal model control

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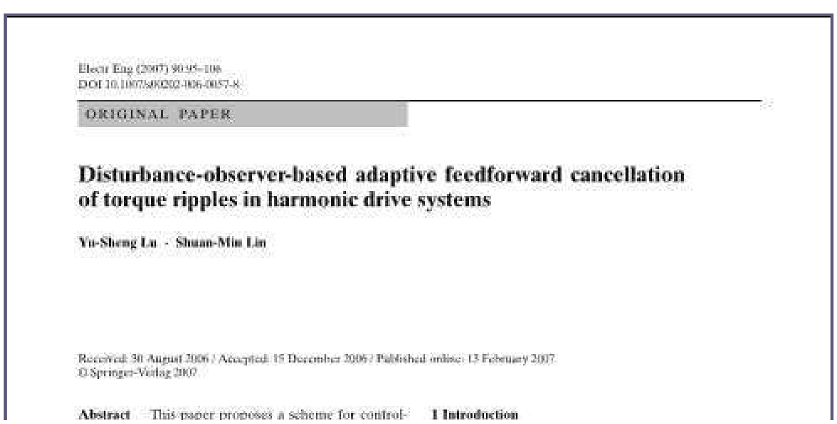

Electr Eng (2007) 90:95–106
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ORIGINAL PAPER

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Abstract This paper proposes a scheme for control- **1 Introduction**

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ORIGINAL PAPER

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Yu-Sheng Lu · Shuan-Min Lin

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Abstract This paper proposes a scheme for controlling the output torque of a harmonic drive actuator equipped with a torque sensor. The control scheme consists of the internal model control (IMC) and an adaptive feedforward cancellation (AFC) based on a disturbance observer (DOB). The relationship between the IMC and the DOB is presented in this paper, and the IMC is adopted as a feedback compensator for its ease in design and implementation. The DOB, on the other hand, is suitable for estimating an unknown disturbance, and its output is applied to the AFC resonator that generates an adaptive dither to compensate for the torque ripples induced by harmonic drives. Compared with the conventional AFC, the salient features of the proposed DOB-based AFC include the independence of designing the AFC's adaptation gain from the plant and the feedback compensator, fast convergence of the disturbance-cancellation error, and no influence of aperiodic reference changes upon the adaptive dither. The effectiveness of the proposed scheme is demonstrated through experimental results, in which its performance is shown to be superior to that of the conventional AFC.

Keywords Harmonic drive actuator · Torque control · Torque ripple · Adaptive feedforward cancellation · Disturbance observer · Internal model control

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1 Introduction

Gear transmissions are usually incorporated in machines that need to provide high torque within a limited space. Among gear transmissions, harmonic drives have the advantages of high gear reduction ratio, compact size, and high torque-to-weight ratio with virtually no backlash. These excellent features make harmonic drives ideal for precise motion mechanisms such as lightweight service robot manipulators [1], force-feedback haptic devices [2] and steer-by-wire systems in the vehicle steering technology [3]. A typical harmonic drive is shown in Fig. 1 [3], which consists of a wave generator, a flexible spline, and a circular spline. The rigid wave generator has an elliptical shape and is enclosed by a flexible race ball bearing. The flexible spline, or "flexspline" for short, is a thin-walled hollow cup, the external gear teeth of which are located at the open end while the closed end of the flexspline is usually connected to an output shaft. The circular spline is a rigid internal gear with two teeth more than the number of teeth on the flexspline. When assembled, the open end of the flexspline becomes elliptic due to the shape of the wave generator, and the flexspline teeth at the major axis of the ellipse engage with the teeth of the circular spline. In the most common configuration, the circular spline is fixed, and a motor drives the wave generator while a load is connected to the flexspline.

In a harmonic drive system, transmission flexibility would cause output oscillations, and frictional forces would deteriorate its output accuracy. To control the output torque of a harmonic drive actuator, Kazerooni [4] employed a sensitivity loop-shaping technique to design a linear controller for the system. Moghaddam and Goldenberg [5] designed a torque controller in an

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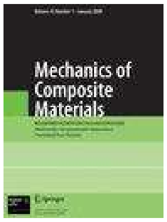

Investigation of the fatigue properties of rigid polymers used in making harmonic drives

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Abstract The fatigue properties of rigid polymers used for making harmonic drive components have been investigated. Certain data on the fatigue of flexible shells under complex loading conditions have been obtained. The effect of the polymer structure on the fatigue properties of a series of compounds with various antifriction fillers and plasticizing additives is evaluated.

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INVESTIGATION OF THE FATIGUE PROPERTIES OF RIGID POLYMERS USED IN MAKING HARMONIC DRIVES

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UDC 678.01 : 539.434

The fatigue properties of rigid polymers used for making harmonic drive components have been investigated. Certain data on the fatigue of flexible shells under complex loading conditions have been obtained. The effect of the polymer structure on the fatigue properties of a series of compounds with various antifriction fillers and plasticizing additives is evaluated.

The use of plastics in harmonic drives is of considerable interest, since the conditions under which such systems operate and the presence of a flexible link permit the unusual mechanical characteristics of polymers to be successfully exploited.

It has been reported [1] that thermoplastics can be used to fabricate the flexible elements in harmonic drives. At the same time, where high levels of accuracy and dimensional stability over extended periods are required, rigid thermosets based on epoxy resins with modifications, especially filled compounds, look promising.

The linear coefficients of thermal expansion of these materials are fairly close to the corresponding characteristics of certain metal alloys.

The stresses that develop in the rim of the flexible element under load are alternating; consequently, the performance of the element is chiefly determined by the fatigue properties of the polymeric material.

It should be noted that the fatigue properties of the materials in question have not been sufficiently thoroughly investigated. The present article is devoted to the fatigue properties of certain rigid polymeric materials tested under simple loading with the object of obtaining experimental data on polymers recommended for use in harmonic drive construction. At the same time, we have obtained the mechanical characteristics of rigid polymers needed for practical harmonic drive calculations and certain data on the fatigue of flexible shells under complex loading conditions.

In order to estimate the effect of the structure of a polymer on its fatigue properties we investigated a series of compounds with various antifriction fillers and plasticizing additives, namely: the epoxy-novolac polymers 6ÉI-60 and 6ÉI8N-60, and the epoxy-novolac compounds 6ÉI-60M30 containing 30% molybdenum disulfide and 6ÉI-60G30 containing 30% finely dispersed flake graphite. As the plasticizer we used AG-2 polyester oligomer in the amount of 30 wt.%.

Control and methodological experiments were performed on traditional polymers of the Kaprolon V type.

The fatigue properties of the polymers at a loading frequency of 100 Hz were investigated using cylindrical specimens and flexible elements in the form of thin cylindrical shells. The specimens of epoxy-novolac polymers were obtained by free molding with subsequent high-temperature polymerization. For comparison we tested both cast and machined specimens. The Kaprolon specimens were machined from blocks. The flexible elements were also obtained by machining.

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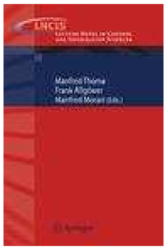
Book Chapter



A New Control Algorithm for Manipulators with Joint Flexibility

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Abstract

The new industrial robot is equipped with gear-boxes such as harmonic drives, which introduce elastic deformations at the joints. These deformations are regarded a source of problems, especially when accurate trajectory tracking of high sensitivity to end-effector forces is mandatory. It is shown that the joint elasticity should be taken into account in modeling a robotic manipulator and designing a control algorithm. If we assume that the elasticity may be modeled as a linear spring, we obtain a dynamic model which is twice of the order of the model of the same robot with rigid joints. In this case the design of a control algorithm is a difficult task. If dynamic parameters are not known exactly, adaptive control laws must be designed to guarantee stabilization or tracking. Control of a system with uncertain elements has been discussed in the robotics literature [1], [4], [6], [8]. In this paper, we consider an adaptive tracking controller for a manipulator with only revolute joint. This algorithm is an extension of the controller proposed by Loria and Ortega [9]. We have assumed that the model in [9] has in addition dynamic friction components on both link and motor sides. We have incorporated a harmonic drive into our system. The construction of this controller is based on Lyapunov theory [1], [2], [5], [12]. We assume that link and motor positions are available for measurements. Under these assumptions we propose a semiglobal adaptive tracking control algorithm. The paper is organized as follows. The mathematical description of the robot model and the control algorithm are described in Section 11.2. The concluding remarks are given in Section 11.3.

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A New Control Algorithm for Manipulators

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A New Control Algorithm for Manipulators with Joint Flexibility

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11.1 Introduction

The new industrial robot is equipped with gear-boxes such as harmonic drives, which introduce elastic deformations at the joints. These deformations are regarded a source of problems, especially when accurate trajectory tracking of high sensitivity to end–effector forces is mandatory. It is shown that the joint elasticity should be taken into account in modeling a robotic manipulator and designing a control algorithm. If we assume that the elasticity may be modeled as a linear spring, we obtain a dynamic model which is twice of the order of the model of the same robot with rigid joints. In this case the design of a control algorithm is a difficult task. If dynamic parameters are not known exactly, adaptive control laws must be designed to guarantee stabilization or tracking. Control of a system with uncertain elements has been discussed in the robotics literature [1], [4], [6], [8]. In this paper, we consider an adaptive tracking controller for a manipulator with only revolute joint. This algorithm is an extension of the controller proposed by Loria and Ortega [9]. We have assumed that the model in [9] has in addition dynamic friction components on both link and motor sides. We have incorporated a harmonic drive into our system. The construction of this controller is based on Lyapunov theory [1], [2], [5], [12]. We assume that link and motor positions are available for measurements. Under these assumptions we propose a semiglobal adaptive tracking control algorithm. The paper is organized as follows.

Modeling a harmonic drive gear transmission

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INSPEC Accession Number: 4690831
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Abstract
In order to capture the dynamic behavior of harmonic drives, dynamic models must include accurate representations of transmission friction, compliance, and kinematic error. Experimental observations are used to guide the development of a model to describe harmonic-drive operation. This model is able to replicate many of the features observed in actual harmonic-drive dynamic response. Valuable insights are gained about the factors which govern harmonic-drive dynamic response. Using these insights to guide the gradual development of a harmonic-drive model, the tradeoffs between model accuracy and complexity are exposed. In particular, despite careful measurement and characterization of transmission friction, compliance, and kinematic error, model performance cannot be improved without acknowledging gear-tooth rubbing losses as well. When a model incorporating gear-tooth behavior is implemented, predicted results reproduce many of the complexities of the experimental dynamic response

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TRADEMARK
PRINCIPAL REGISTER

HARMONIC DRIVE SYSTEMS, INC. (NEW YORK CORPORATION)
89 CABOT COURT
HAUPPAUGE, NY 11788

FOR: HARMONIC DRIVE ASSEMBLIES PRIMARILY FOR USE IN INDUSTRIAL ROBOTS, MACHINE TOOLS, MEDICAL EQUIPMENT, AND SOLAR ENERGY DEVICES, IN CLASS 7 (U.S. CL. 23).

FIRST USE 8-26-1987; IN COMMERCE 8-26-1987.

NO CLAIM IS MADE TO THE EXCLUSIVE RIGHT TO USE "SYSTEM", APART FROM THE MARK AS SHOWN.

SER. NO. 696,870, FILED 11-23-1987.

KATHRYN DOBBS, EXAMINING ATTORNEY

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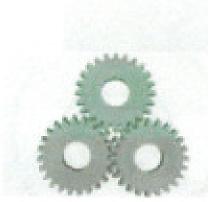

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Gear Products

Gear Types

Gear Assembly

Gear Application

Gear Drives

- Automatic Transmissions
- Bevel Gear Drives
- Combination Drives
- Crown Gear Drives
- Cycloidal Drives
- Gear-Shift Transmissions
- Harmonic Drives
- Helical Gear Drives
- Miter Gear Drives
- Spiral Bevel Gear Drives
- Spur Gear Drives
- Traction Drives
- Variable Speed Drives
- Worm Drives

Gear Manufacturing

Effectively sums up all that is happening in the world of gears.

- Gear Blank
- Gear Cutting
- Gear Hobbing
- Heat Treatment of Gears

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Gear Resources

- What is Gear?
- Classification of Gears
- What's New in Gears
- Gear Selection Guide
- Optimizing Gear Performance
- FAQ's
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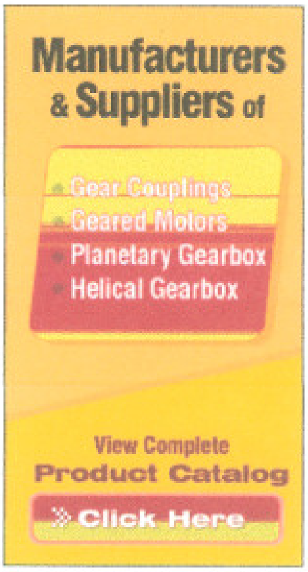
- Gear Materials



Technical Information

- Gear Terminology
- Gear Formula
- Metric Gears
- Installation Tips

Gear Drives

A Gear Drive System is an integrated form of different gears which are arranged in series form. Gear Drive is a system, in which all the require gears are brought under a single system. This Gear Drive system transmits force and motion between two shafts. A motor is required to turn all these gears to do work. There are two gears which are arranged at two opposite ends of the gear box. Gear at the first end which supplies power, is called as Input Gear and gear at the other end of the gear drive system is called as Output Gear. The output gear does the actual work of the gear drive system.

Following are the major Gear Drives:

- Automatic Transmissions
- Bevel Gear Drives
- Combination Drives
- Crown Gear Drive
- Cycloidal Drives
- Gear-Shift Transmissions
- Harmonic Drives
- Helical Gear Drives
- Miter Gear Drives
- Spiral Bevel Gear Drives
- Spur Gear Drives
- Traction Drives
- Variable Speed Drives
- Worm Drives

Selection: Gear Drive System

The reliability of a Gear Drive system depends upon its quality of components, accurate assembly of these components and solid design. The proper combination of all these things makes it an accurate and precision system. A complete and efficient selection process is required for proper gear drive application, and various operating parameters influence the selection process. These operating parameters include load demand, duty cycle, external loads, input power, system accessories, facility needs and environment. A Service factor is another factor on the basic of which the selection of the drive is determined. This service factor accounts for the varying of torque by the driven machines and the driving gear.

Application of Gear Drive in Cars

In a car, first, the motor turns the shaft which is attached to the gears. So, the gears also start to turn one after another. Gradually, this turning process passes from one gear to another. When, the last gear a starts to turn which is attached to the car's axle, the axle starts to move. As a result, the wheels of the car start to move. This is how a gear system moves a car.

Calculation of Inertia of Gear Drive

If any change takes place in the rotational speed of the gears in the Gear Drive, the load inertia will return back to the motor through the gears. The inertia of a gear drive system can be calculated with the help of the following equation.

$$S_m = \frac{S_l \times N_l}{N_m}$$

Motor Speed

$$T_m = \frac{T_l}{Ne}$$

Motor Torque

$$J_r = \frac{J_l}{N^2}$$

Reflected Load Inertia

$$J_t = \frac{J_l}{N^2} + J_m$$

Inertia realized at Motor

Where:
Sm = Motor Speed, rpm
Sl = Load Speed, rpm
Nl = Number teeth on load gear
Nm = Number teeth on motor gear
N = Gear Ratio
Tm = Torque of Motor, lb-in
Tl = Torque of Load, lb-in
e = Efficiency
Jl = Load Inertia, lb-in.-sec2
Jm = Drive Motor Inertia, lb-in.-sec2
Jr = Reflected Load inertia
Jt = Total Inertia, lb-in.-sec2

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Gears Drive

A gear drive is an assembly of gears turned by the motor to perform the specific task. The first gear attached to the motor supplies the power and are known as input gear, while the gear that amplifies the mechanical energy is called the output gear.

To ensure the proper functioning of the gear drive, it requires a proper selection based on different parameters including input power, load demand, external loads, duty cycle, environment, system accessories etc. Another important factor that decides the selection of the drive is service that accounts for the non-uniformity of torque by the driving and driven machines.

The gear drive includes the following:

- Automatic Transmissions
- Bevel Gear Drives
- Combination Drives
- Cycloidal Drives
- Differential Gear Drives
- Dual Output Differential
- Epicyclic/Planetary Differential
- Differentials, Tension Control
- Differentials, Torque Control
- Epicyclic Gear Drives
- Harmonic Drives
- Helical Gear Drives
- Hypoid Gear Drives
- Worm Drives
- Tacho Drives
- Marine Gear Drives
- Miter Gear Drives
- Spiral Bevel Gear Drives
- Spur Gear Drives
- Traction Drives
- Variable Speed Drives
- Manual Shift Transmission
- Gear-Shift Transmissions

Automatic Transmissions

Automatic transmission is the most complicated component in today's automobile. Automatic transmissions contain mechanical systems, hydraulic systems, electrical systems and computer controls, all working together in perfect harmony. There is no clutch pedal and gearshift in an automatic transmission.

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Bevel Gear Drives

Bevel gear drive is a transmission which is used to drive one or more shafts which do not line up with the output

shaft. It is also called bevel gear transmission. They are capable of handling heavy loads and offer higher torque. They transmit engine power smoothly onto the main clutch pulley. The bevel gear housing absorbs loading of the power band and enables the use of a short power band. Hydrostatic drive pump, hydraulic main pump and hydraulic infinitely variable length of cut-pump are flanged to a new carrier housing, adding more reliability.

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Combination Drives

Combination drive is an arrangement where a right angle gear drive is connected to the horizontal power source, providing a stand over the gear drive for mounting the vertical power source.

Combination drives are easiest to use, simplest to understand and provide high performance. They are widely used in computer industry to play and burn CDs and play DVDs. They deliver the function of two drives for a low price. They help to store move and share large amounts of data on CDs with the similar ease and convenience. They save both time and money. These drives are an asset to the mobile PC users.

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Cycloidal Drives

Cycloidal drives combines a compact cycloidal input gear set with a slow speed helical output gear set to provide an extremely efficient, quiet and durable gearbox. It consists of high-speed shaft with eccentric bearing assembly and a slow-speed shaft assembly. It also has cycloid discs with one less lobe than the ring gear pins. The ring gear roller and pins are fixed.

The term cycloidal is derived from hypocycloidal, which is defined as the curve traced by a point on the circumference of a circle that is rotating inside the circumference of a larger fixed circle. A common example of this is the path traced by a tooth of a planetary pinion rotating inside a ring gear.

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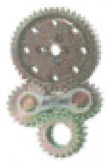
Differential Gear Drives



These are set of gears with three independent, rotating members with a speed and torque relationship to each other. There are two application types:

- First consists of one input and two outputs. The automobile differential is the best example here. The two outputs are connected mechanically.
- Second application has two inputs and one output. This is used to solve industrial problems when the superimposition of one motion relative to another is required, such as phase shifting on textile industry equipment.

Differential efficiency is a function of the relative speed of the three elements. As relative speed increase, the inherent losses due to basic gear efficiency, seals, and bearings also increase; thus efficiency decreases.

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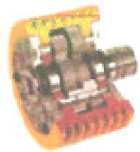
Epicyclic Gear Drives

Epicyclic gear drive illustrates motion of a gear train consisting of a 60-tooth sun gear and arm carrying a 24-tooth planet gear riding extremely on the sun gear. Epicyclic motion is the path traced on a fixed end plate by a scribing point attached to the planet gear.



An epicyclic drive has its planet gears integrated into separately built planet assemblies. Each planet assembly includes a pin which extends through the planet gear and an antifriction bearing located between the gear and the pin. The bearing also has rolling elements organized in two rows between the inner and outer raceways. The pins have mounting ends which lie beyond the ends of the planet gear to anchor the planet assembly in a carrier. Seals fit into the planet gear and around the pin and retain grease within the bearing and prevent oil that lubricates the teeth from entering the bearing and deteriorating the grease. The bearing is set with considerable precision so the planet gear does not skew with respect to sun and ring gears with which it meshes during operation at the epicyclic drive.

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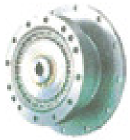
Harmonic Drives

This is a mechanical speed changing device, invented in 1950s, that operates on a different principle form, and has capabilities beyond the scope of, conventional speed changers. They consist of a thin ring that deflects elastically as they roll on the inside of a slightly larger rigid circular ring.



The basic elements of harmonic drive are circular spline, flexspine, and wave generator, all assembled in a normal configuration. As the wave generator rotates, it imparts a continuous motion to the flexspline. This causes meshing of the external teeth of flexspine with internal teeth of the circular spline. The meshing moves in a rolling fashion. It allows for full tooth disengagement at the two point along the minor axis of the wave generator. Flexspline has two teeth less than circular spline, so each complete revolution of the wave generator causes a two-tooth displacement of the flexspline in relation to the circular spline. This displacement is in the opposite direction. This way harmonic drive works as a speed reducer.

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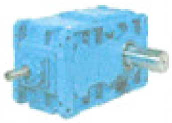
Helical Gear Drives

A helical gear drive is an improvement over straight cut spur gear because the number of teeth meshing together is increased providing more averaging of the gear errors. This is a drive with the steel helical gears close coupled to the fold rolls providing solid reliability. A positive gear drive assures no slippage between fold rolls for more consistent folds.



Helical gear drive can be single or double. In a single gear drive each shaft is always against the thrust bearings. The external axial thrust that acts on the gear shaft under load due to the friction in the tooth coupling, cannot cause momentary overloading of one helix as is the case with double helical gears. An external thrust can have some detrimental effects on a double helical gear in connection with axial compensating shift due to tooth errors.

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Our Domain

Gears. Girth Gears. Differential Gears. Ground Gears. Ring Gears. Rack Gears. Spur Gears. Bevel Gears. Cycloidal Gears. External Gears. Helical Gears. Marine Gears. Mining Gears. Pinion Gears. Planetary Gears. Involute Gears. Non-involute Gears.Worm Gears. Idler Gears. Face Gears.Angular Bevel Gears. Winch Gears. Herringbone Gears.Crown Gears.Hypoid Gears.Miter gears etc.

Types of Gears	Gears Application	Axle Positioning Gears
Gear Accessories	Gears Drive	Gears Drive Classification
Gear Material		

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Gears /Gearboxes

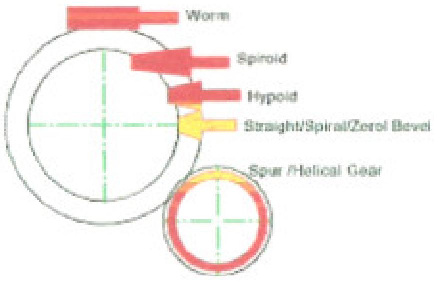
Gear Selection Options

When a drive application requires rotary motion to be transferred with speed change and ortorque change a number of options are available controlled by system layout, economics and power capacity. The drive transmission selection is selected from the options below in order of convenience.

1. Belt Drive (flat, vee , synchronous)
2. Chain drive
3. Gearbox - geared motor
4. Purchased Stock gears- unlubricated(Plastic/metal- plastic/plastic)
5. Purchased Stock gears- metal lubricated
6. Engineered gears

It must be emphasised that designing and manufacturing a gear system is relatively, expensive and inconvenient if a proprietory system is available which will do the job..

Types Of Gears



Note: More details and pictures of all gear types below are to be found at the links below table

Type	Notes	Further Notes
Spur	Majority of gears are spur. Relatively easy to design and make. Parallel shafts. High efficiency (99% per train). No side thrust. Can back drive. Single Ratio up to 1:10. Can be made very accurate with low vibration /noise. Normally steel pinions require lubrication. Plastic gears can be used requiring no lubrication	Spur Gears
Internal Spur	Similar performance to normal spur. Results in compact drive geometry. Used in manufacture of epicyclic / planetary gears.	
Helical	Single Helical have similar properties to spur. However drive results in axial thrust. Gears are smoother/quieter for the same size/spec. The gears can run at high speeds up to large diameters. Higher torque/life capabilities for same size as spur.	Helical Gears
Double-Helical	Similar benefits to single helical but with no generated side thrust. Higher performance compared to single helical	
Crossed-Helical	Shaft at 90^{o}. Difficult to make accurately. Smooth drive.	
Worm	Offset shafts at 90^{o}. Very high ratios possible in single stage. Sliding action. One gear is normally copper allow (bronze). Low efficiency at higher ratios and low speeds. Lubrication essential for mechanical and thermal reasons. Cannot backdrive at high ratios.	Worm Gears

Bevel Gear	Mainly used for drive transmission through 90°. Only low ratios used (4:1 and less). Lubrication required. Some vibration on spur type: Helical type smoother.	Bevel Gears
Spiroid	Perform a similar function to worm boxes but the gears have characteristics which combine those of the bevel and worm gears. High powers and speed ratios are possible and mechanical efficiencies higher than worm boxes for equivalent ratios.	
Harmonic Drive	Performance advantages include high-torque capacity, concentric geometry, lightweight and compact design, zero backlash, high efficiency, high ratios (up to 320:1), and back drivability. Harmonic drive systems suffer however, from high flexibility, resonance vibration. Used in robotics	Harmonic Drives

Brief Comparison

Type	Normal Ratio Range	Pitch Line Velocity (m/s)	Efficiency Range
Spur	1:1 to 6:1	25	98-99%
Helical	1:1 to 10:1	50	98-99%
Double Helical	1:1 to 15:1	150	98-99%
Bevel	1:1 to 4:1	20	98-99%
Worm	5:1 to 75:1	30	20-98%
Crossed Helical	1:1 to 6:1	30	70-98%

Additional Notes on Gear Efficiency

Gear Box Notes

Gearboxes	Epicyclic Gears	Differential Gearboxes	Gear Lubrication	Gear Heat Transfer

Links to Gear Box Information

1. Gear Design ...A comprehensive source of Gear Design Information
2. Efunda ...Efunda -> Design Centre-> Gears.. Some useful Notes.
3. How to Specify and Choose Gears ... A Useful Guide in preparation
4. Gear Design Topics ... A Site devoted to theorical "esoteric" analysis of Gear Design/Manufacture, Amazing Graphics
5. SEW Eurodrive...All the information on Gearboxes you will need
6. Gears & Gear Drives...A comprehensive review of gear design in 16 pages
7. Reliance Precision Ltd...UK supplier of gears and related products
8. Omnigear...A site including dimensions of gears/splines/chains etc to various standards
9. Speed-reducers.org...Speed And Gear Reducers Manufacturers
10. David Brown ...UK supplier of Gearboxes and Transmisson Products

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