

# **The Generation of Precision Spur Gears Through Wire Electrical Discharge Machining**

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**American Gear Manufacturers Association**



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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

## **ABSTRACT:**

The new generation of wire Electrical Discharge Machines (EDM) are capable of quite good generating accuracy. We have maximized the accuracy and repeatability of this tool through fixturing, controlled cutting methods, and optimized mathematical algorithms for the cutting path. The result is the verified generation of precise spur gears in pitches ranging from 5 to 41 DP. The advantage of the method is short lead times with accuracy approaching form ground while being cost competitive. The method is also suitable for producing small to medium lots of very accurate spur gears in any electrically conductive material.

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# The Generation of Precision Spur Gears Through Wire Electrical Discharge Machining

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## Introduction

In plastic gear mold-making, the wire EDM is often used to create the involute shape in the mold cavity. This has been a point of contention within the plastic community for years, with traditionalists arguing that a cavity burned with a hob cut electrode is inherently more accurate than a wire-burned cavity. With our own history of success using the EDM method, we decided the ultimate test would be to cut external spur gears in this fashion and use traditional gear inspection techniques to quantify their accuracy.

Our experiment was moreover based on need. The plastic gears we had designed for a gear driven lawn sprinkler required unique master gears. Lead times for form ground gears were unacceptable. With our customer's support we developed a method of cutting these gears that achieved the desired shapes on time and within cost constraints for fine pitch master gears. We then employed the same techniques to cut a 19 tooth 5 DP master gear in order to determine possible errors of scale. Profile inspection revealed similar accuracy of tolerance was possible for large coarse pitch gears as for fine pitch. In the following sections, we will present the methods we employed to achieve this level of accuracy, the inspection data from our work, comparisons with precision hob cut gears, and possible applications of this method to

other forms of gear generation.

## The EDM Process

Electrical Discharge Machining is based on the principal of erosion of an electrically conductive material by continuous spark discharge to its surface (1). With wire EDM, a metallic wire is continuously fed through arms suspended above and below the workpiece (Fig. 1). This charged wire is then guided through the specified tool path while cutting its way through the material. The process is relatively slow depending on wire diameter, work piece thickness, and machine settings. The servo-controlled tool path is quite accurate, typical for CNC type machinery. And the benign environment of the EDM machinery, with slow feed rates, extremely low forces, very little friction or vibration, and controlled temperature make even finer accuracy possible. The tool path can either be point-to-point or via simple arcs. Advanced mathematical curves are not directly programmable by software; these must be approximated with arcs and/or line movements. Both the involute and trochoidal sections of a gear fall into this general category. Specified dimensional accuracy and repeatability of the more advanced wire EDM's are on the order of .0001 inches. Surface finishes of 16 micro-inch can be attained through careful selection of machining parameters along with multiple finishing skim cuts on low power settings.



**Documents**

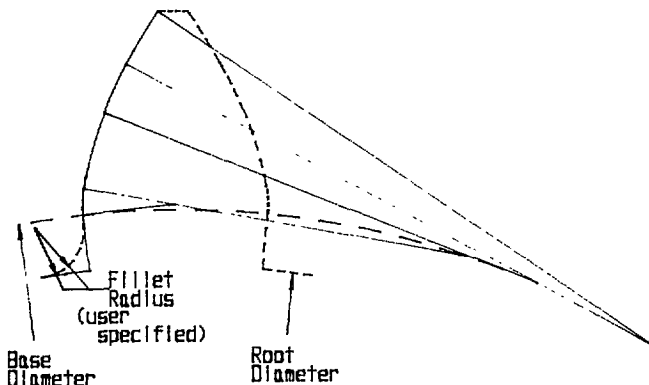
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Figure 1 - Wire EDM gear cutting setup

## Gear Cutting With Wire

The wire EDM is primarily a two-dimensional process, although the two wire guides can follow independent paths allowing slight 3-D modifications. EDM software exists that claims to create a wire path for the spur involute. The software requires standard gear geometry to be input along with tooth thickness, root, and outside diameters. Approximate arc segments are then fitted to the involute curve down to the root or to the base circle diameter, whichever comes first. If the base circle is located above the root circle, a straight radial line is connected from the base circle to the root diameter, and the user has the option of specifying a fillet radius for the intersection of those two features (Fig. 2).



Typical EDM Gear Involute

Figure 2

Difficulties with this method of generation are immediately apparent. By focusing only on the involute profile, the trochoidal (or root) area is left arbitrary and undefined. No provision is made for undercut even if it is required. One of the advantages of a hob cut gear is that any similar physical gear will fit within the envelope created by the generating hob. The reason for this is that the hob removes any possible interfering material in the root area that may physically interfere with another gear. A majority of non-undercut standard gears are not sensitive to this possible trochoidal interference since the standard whole depth provides sufficient clearance and mating teeth never reach below the base circle. However, as designers modify gear geometry to maximize function or if undercut exists, this area becomes critical through possible interference, or weakened by excessive relief. The mathematical generation of gear teeth must provide not only conjugate action but also designed clearance with any mating gear.

Another not-so-apparent difficulty with the generation of approximate arcs to the involute concerns the nature of the involute itself. With its ever increasing radius of curvature from the base circle, the involute is anything but a trivial curve fitting exercise. The desirability of making intersecting arcs tangent at their endpoints compounds the problem of fitting these arcs to the involute. Without careful fitting it is possible to