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Hob Tool Life Technology Update

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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 method of cutting teeth on a cylindrical gear by the hobbing process has been in existence since the late 1800's. Advances have been made over the years in both the machines and the cutting tools used in the process. This paper will examine hob tool life and the many variables that affect it. The paper will cover the state of the art cutting tool materials and coatings, hob tool design characteristics, process speeds and feeds, hob shifting strategies, wear characteristics, etc. The paper will also discuss the use of a common denominator method for evaluating hob tool life in terms of meters [or inches] per hob tooth as an alternative to tool life expressed in parts per sharpening.

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Introduction

Up until the 19th century almost all gears were hand made and the gears were cut with form cutters shaped to correspond to the spaces between the teeth. The first known gear cutting by machine was developed by Juanelo Torriano (1501–1575). It was recorded that he was able to produce up to three gears per day on his hand-powered machine, using cutting tools that were nothing more than rotary files.[1] Much information about the history of gears can be found in the late Darle W. Dudley's book on "The Evolution of The Gear Art". The book was sponsored by the AGMA and published in 1969.

Figure 1 is taken from the English inventor Joseph Whitworth's patent of 1835 which clearly shows a hob cutting a gear. Whitworth claimed in the patent "...the construction and arrangement of mechanism by which I give a continuous rotary motion to the wheel or disc under operation, which motion is so proportioned to the speed of the rotary cutter that by every rotation of the cutter a segment of the wheel or disc shall be advanced equal to the distance of one tooth and space". The machine shown can be "...bolted on to a work bench, or placed in any other convenient situation".[2]

It is also interesting to note that in the 1871 patent of Philadelphia's Henry Belfield the cutting tool is referred to as a "hub", not as a hob.[2] George B. Grant was issued a patent for a spur gear hobbing machine in 1889.

The first machine capable of cutting both spur and helical gears was invented by Robert Hermann Pfauter of Germany in 1897. Hermann Pfauter's first prototype machine [Figure 2] included a horizontal workspindle on vertical ways, a hob swivel, a hob carriage fed along horizontal ways on the bed of the machine, and an upright for outboard support of the work arbor. The hob feed was accomplished manually with a crank on the end of a feed screw.[2]

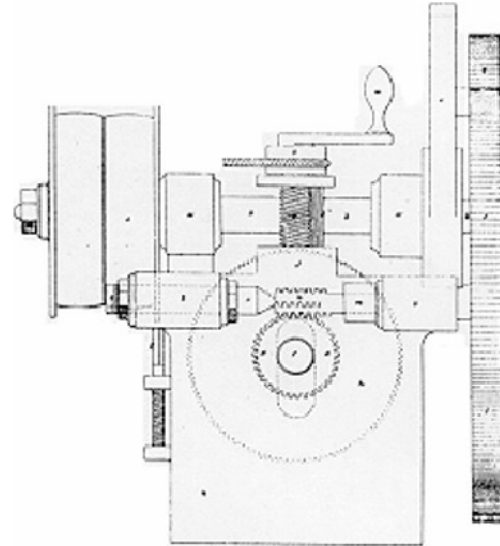


Figure 1. Whitworth's 1835 machine

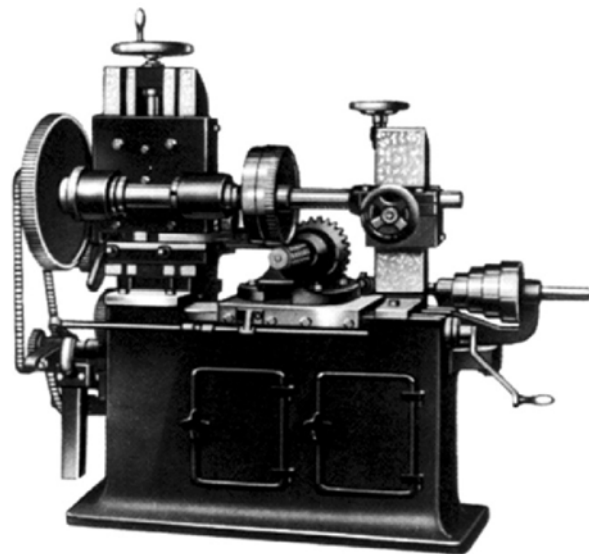


Figure 2. Robert Hermann Pfauter's prototype

Today, most hobbing machines are full six axis CNC controlled machines, capable of very high cutter and work table speeds. Many machines utilize direct drive hob and work spindles which present an interesting scenario in which we now produce gears with machines that do not have gears in them!

The hobbing process

In brief, to paraphrase what Joseph Whitworth said in his patent of 1835, hobbing is a continuous indexing process in which the cutting tool and the workpiece rotate in a constant relationship to each other while the hob tool is fed into the work. For generating helical gears, the rotation of the work is either slightly retarded or slightly advanced in relation to the rotation of the hob. As the hob is fed across the face of the work once, all the teeth in the work are completely formed. The hob can be fed axially, radially, diagonally, or tangentially, depending upon the application and the machine options available.

The hobbing process can be visualized as a worm and worm wheel running together – the hob is represented by the worm and the workpiece by the worm wheel. The hob has a worm thread that has been fluted to provide cutting edges with each tooth relieved to form clearance behind the cutting edges. It must be made from a material suitable for cutting the work piece material.

Cutting tool materials - high speed steel (HSS)

Early cutting tool materials [from the 1900's to 1940's] consisted of high speed steels designated as 18-4-1, which consisted of 18% tungsten, 4%

chromium and 1% vanadium.[3] Today we have many materials to choose from. Table 1 lists high speed steel materials in use today, their chemical composition and Rockwell C hardness.[4]

In the movement to cut gears without the use of coolant, carbide was initially selected as the hob tool material. Because of the expense of the carbide, the manufacturing costs, and the special handling required, high speed steel “bridge” materials were identified and have replaced the carbide in many applications. It is interesting to note that is not the case in bevel gear dry cutting production, where carbide remains the choice material for stick blades used in bevel cutter systems.[4] See below for more information on carbide material.

Figure 3 is a material selection upgrade guide based on what the desired output is: improving the red hardness (the property for retaining hardness at elevated temperatures) of the material, increasing the hob speed, and/or increasing the wear resistance of the material. Rex86, Rex121 and M35V are grouped together on the chart, and the choice of material within the group should be based on a cost per piece analysis. Because of the high alloy content of REX121 the hob sharpening technique is critical to avoid damaging the substrate material. Availability of a specific material can be a factor in your choice.

Table 1. High speed steel materials

	C	Cr	W	Mo	V	Co	HRC
CPM M2	1.0	4.2	6.4	5.0	2.0	–	64
ASP 2023	1.3	4.2	6.4	5.0	3.1	–	64
CPM M4	1.4	4.3	5.8	4.5	3.6	–	64
CPM REX 54	1.45	4.3	5.8	4.5	3.6	5.3	65
CPM REX 45	1.3	4.1	6.3	5.0	3.1	8.3	66
ASP 2030	1.3	4.0	5.0	6.5	3.0	8.0	66
CPM T15	1.6	4.0	12.3	–	5.0	5.0	66
CPM REX 76	1.5	3.8	10.0	5.3	3.1	9.0	67
CPM REX 86	2.0	4.0	10.0	5.0	5.0	9.0	68
ASP 2060	2.3	4.0	6.5	7.0	6.5	9.0	68
CPM REX 121	3.3	3.8	10.0	5.3	9.0	9.0	70
M35V [Conventional]	1.2	4.1	6.0	5.0	3.0	5.0	66

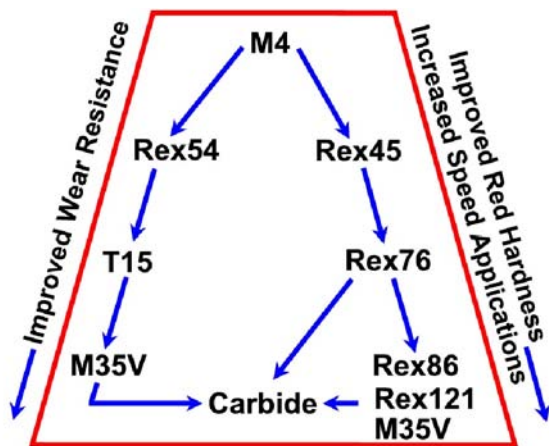


Figure 3. Material upgrade selection

Carbide grades

Even though HSS “bridge” materials have replaced many early applications, carbide is used for applications such as steering pinions and armature shaft pinions [Figure 4] – generally small diameter fine pitch applications. Carbide is also used in hard finishing applications where gears are finish hobbled after heat treatment.

Basically, there are two classifications of carbide grades: “P” and “K”. It is important to understand that the grades refer to the recommended working conditions and not the exact composition of the material.

Cemented carbides are a range of composite materials that consist of hard carbide particles bonded together by a metallic binder. The proportion of carbide phase is generally between 70–90% of the total weight of the composite.

ISO “K” grades of carbide are a simple two-phase composition consisting of tungsten carbide (WC) and cobalt (Co). A typical composition of a “K” grade carbide is 90% WC and 10% Co by weight. “K” grades have good edge stability and abrasion resistance with a grain size range of 0.5 μm – 0.9 μm .

ISO “P” grades of carbide are three-phase alloyed compositions consisting of tungsten carbide (WC), cobalt (Co) and cubic carbides. The cubic carbide binders can be titanium carbide (TiC), tantalum carbide (TaC) and niobium carbide (NbC). A typical composition of a “P” grade carbide is 73.5% WC, 8.5% TiC, 8% TaC and 10% Co by weight. The cubic carbides are softer and have larger grain size – 2 μm to 4 μm is normal for these alloy materials.

Most carbide applications in use today are ISO “K” grade. Note that traditional titanium base coatings cannot be stripped from ISO “P” grade carbides. See Table 2.



Figure 4. Carbide shank hob

Table 2. Coating re-conditioning guidelines

Guideline	TiNite® TiN	CarboNite® TiCN	AlNite® TiAlN-S	TiAlN-X	AlCroNite® AlCrN
Strippable from HSS	Yes	Yes	Yes	Yes	Yes
Strippable from K-grade carbide	Yes	Yes	Yes	Yes	Yes
Strippable from P-grade carbide	No	No	No	No	Yes
Recoatable over itself	Yes	Not recommended	Yes	Yes	No
Number of recoatings	3 – 7	--	2 – 4	2 – 4	--