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Productivity Improvement in Gear Hobbing Process by Using Different Cutter Materials-A Re view

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ABSTRACT

To meet the future goals of higher productivity and lower production costs, the cutting speeds and feeds in modern gear hobbing applications have to increase further. Basically, the parameters that have an influence on the cutting process should be known and possible to control. Gear manufacturing is highly important in automotive industry. The prevalent manufacturing method is gear hobbing with gear. Through the experimental investigations and theoretical studies of significant parameters such as speed, feed, depth of cut, material, surface finish, cost etc. a continuous process optimization is necessary to satisfy the customer demands. Changing the substrate material is a basic approach in optimization of operation times. Taguchi method can be used for selecting the design of experiments and Principle Component analysis can be used to optimize the process. To address such a problem by using Principle Component analysis method it is expected to increase the productivity by 10-20%.

***Keywords*— Gear Hobbing, Optimization, Principal Component Analysis, Productivity**

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I. INTRODUCTION

The competition between companies and industrial countries of industrial and emerging countries is advancing with globalization. In the past years the demand for gearsis continuously increasing.The majority of gears are manufactured for the requirement of automobile industry. Therefore high productive and manufacturing processes are needed currently and in the future. Hobbing is the dominating manufacturing process for helical gears and external spur hobbing is of major importance for gear production. In the hobbing both the tool and the machine can be optimised. These components are developed continuously. A basic approach is to fully exploit the potential of existing tools and their substrate material to increase the productivity in an industrial environment [3].

Gear Hobbing

For massive production ofexternal gears,gear hobbing is a highly utilized flexible manufacturing process.Hobbing is a machining process for gear cutting splines, cutting sprockets, and cutting on a hobbing machine, which is a special type of milling machine. The hob is a cutting tool by which the teeth or splines are progressively cut into the workpiece by a series of cuts. Hobbing is relatively inexpensive but still quite accurate as compared to other gear forming processes, thus it is used for a broad range of parts and quantities [1].Current processes for producing transmission gears involve hobbing, milling or shaping of a forged stock to obtain the gear shape. Gears are typically formed by hobbing tools made from solid tooling material, such as tungsten carbide, and have dozens of teeth [3].By using higher cutting speeds the productivity of machining operations can be expanded and the quality of products can be improved than the applied traditional methods. Developments in machine tools, work materials and cutting tools have resulted in the spread of high speed cutting (HSC) technology [5].

Hob tool

A cutting tool used to cut the teeth into the workpiece is known as hob. It is cylindrical in shape with helical cutting teeth. These teeth have grooves that run the length of the hob, which aid in chip removal and cutting. For special gears such as the spline and sprocket gears special hobs are designed. The cross-sectional shape of the hob teeth are almost the same shape as teeth of a rack gear that would be used with the finished product. For the generating purposes slight changes are made to the shape, such as extending the hob's tooth length to create a clearance in the gear's roots.Each hob tooth is relieved on the back side to reduce friction [6].

Fig. 1 Hob Tool

Most hobs are single-thread hobs, but double-, and triple-thread hobs increase production rates. The downside is that they are not as accurate as single-thread hobs. Depending on type of gear teeth to be cut, there are custom made hobs and general purpose hobs. Custom made hobs are different from other hobs as they are suited to make gears with modified tooth profile [13]. A hard coating with a thickness of 2 to 3 µm increases the life of the hobs or permits higher cutting rates.Coated solid type hobs with a high no. of gashes are ideally suited to high performance hobbing of straight spur gears. The stability of solid type hobs is more than any other type of hob. The no. of gashes are directly proportional to the rate of chip removal, and the tool life is increased substantially by the coating and where applicable, recoating. Compared to conventional hobs, high performance hobs are required to have:

- At least equal if not superior gear quality higher tool life quality;
- Shorter machining times;
- A higher tool life quality.

Hobs can be optimized only in consideration of the machining environment. Based upon the material, the geometry and quality characteristics of the gear in question, the cutting parameters and the hob design must be matched such that the requirements are broadly fulfilled [2].

Hob tool materials

There are many materials that may be used for the manufacture of gear cutting tools. Cutting tools must simultaneously withstand big mechanical loads and high temperatures. Temperature in the chip/tool interface reaches more than 700 °C in some cases. Additionally, the friction between tool and removed chip, on one hand, and tool against the new machined surface, on the other, is very severe. Bearing this in mind, the main factors for a good tool design and post-manufacturing are:

- Cutting-tool substrate material must be very stable chemically and physically at high temperatures.
- Material hardness must be kept to the high temperatures suffered at the chip/tool interface.
- Tool material has to present a low wear ratio, both for the abrasion and adhesion mechanisms.
- Tool material must present enough toughness to avoid fracture, especially when operation to perform implies interrupted or intermittent cutting.

The most commonly used materials for manufacturing the hob tools are High speed steel and sintered carbide.[13]

II. LITERATURE REVIEW

The machining time for hobbing process can be determined on one hand by number of teeth and the gear width and on the other by number of starts, hob diameter, cutting speed and axial feed. The cutting speed is highly dependent upon the gear material, and its tensile strength and machinability [2]. For the machining of steels, Cemented carbide is the most commonly used cutting tool material. Despite their high toughness, cemented carbide tools have lowhardness values, which restrict their use in the HSM of hardened steels. To improve the machining performance of carbide cutting tools, they are usually coated with single or multi-layers of hard, wear resistant TiCN, TiN and TiAlN coatings by physical vapour deposition (PVD) orchemical vapour deposition (CVD)techniques [3]. Gears are typically formed by hobbing tools made from solid tooling material, such as sintered carbide, high speed steel, tungsten carbide, etc. and have dozens of teeth [4]. The most common tool material for machining of castings and alloy steels is carbide. Compared to advanced tool materials such as CBN and ceramics. These tools have high toughness, but poor wear characteristics. In order to improve surface conditions and the hardness, carbide tools are coated with hard materials such as TiAIN, TiN and TiCN by physical vapor deposition (PVD) and chemical vapor deposition (CVD). The cutting tools used in HSC of different work materials [5]. Some of the modifications in two sets of experimental data published by the past researchers and the PCA-based approach are analyzed using this modified procedure. It was observed that the PCA-based optimization can give better results than multi response S/N ratio based methods and the constrained optimization, which can be attributed to the fact that the possible correlation among the multiple responses is taken care in the PCA-based approach[6]. For the optimization of process parametersTaguchi’s robust design method has been extensively used. Taguchi method uses the S/N ratio of the response instead of the response itself to decide the level of the input parameter to optimize the output response. Such a procedure is beneficiary when it is used to optimize single response, but fails to optimize multiple responses. By using MRSN technique such multi response problems can be solved where the total loss function is computed using to summing up weighted loss functions of individual response variables and then transformed to MRSN followed by optimizing the MRSN, determining the weightage for each response which is a difficult task is one of the major limitations of this method. Principle component analysis is one such method which eliminates these problems, where the numbers of variables are reduced to few, interpretable combinations. Each of this combination corresponds to a principal component and is uncorrelated with each other [7].It is observed that powder metallurgical high-speed-steel (PM-HSS) and carbide are mainly used as cutting materials. In the last few years the usage of the more productive tungsten carbide in hobbing is decreasing, because of its high price and its sensitivity to impacts. So, the importance of PM-HSS has increased. In conjunction with high-performance coatings based on chromium-aluminum, the development of dry cutting is increasing regarding rising cutting parameters and productivity. However dry cutting with high cutting speeds leads to failure and requires a higher technological effort than wet cutting [8].Productivity and quality are two of the most important indices in any manufacturing operation. But it is found that the productivity is inversely proportional to quality. Hence it becomes essential to optimize both productivity and quality simultaneously. The processing time get affected by the surface roughness [9].Nowadays there are required high demands on cutting tools for a gear production. Cutting tool live increase is the most important demands which is to be focused. New trends are mainly focused on develop of coating films and high wear-resistance materials which decrease final cost for gear production and increase the tool live. Cutting tool live is dependent on a lot of other factors, which cause cutting tool wear. Research of the factors and their elimination respectively optimization can decrease wear, maximal increase tool power and extend cutting tool live [10].Gear manufacturers would like to increase their productivity and reduce their production costs to be competitive on the global market. Therefore, feed rates and cutting speeds have increased significantly over the last years. Additionally, to meet these demands new substrate materials like carbide have been established in many hobbing applications. Since the price for carbide tools is usually two to three times higher than the price of an HSS tool, the cycle times have to be much smaller to realize economically efficient manufacturing processes. The TiN coating is still commonly usedbecause of its relatively low price compared to its performance, especially in wet cutting operations [11]. In order to improve cutting tool productivity in manufacturing processesthe evolution of Physical Vapour Deposition (PVD) technologies facilitated the development of enhanced cutting tool coating. Coatings, tool geometries and tool materials have a considerable importance due to the increasing requirements of modern and innovative production processes. PVD coatings as well as the Supernitride coating (especially at elevated cutting temperatures) on cemented carbides inserts improve the cutting tool performance. Moreover the inferiority of the tool wear behavior in gear hobbing and milling when using reconditioning cemented carbides tools, could be drastically reduced [12].

III. Future work

In order to find out the optimal parameters use of optimization is an effective tool to achieve the required result. To optimize process parameters such as speed, feed depth of cut etc. the Taguchi method combined with Principle component analysis method will be used. The experimentation will be carried out for the different values of the process parameters to obtain the desired results. The results can be validated by experimentally and by using any one cad software.

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