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Gear Hobs: Advanced Tools and Techniques for Spur Gear Manufacturing

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***Abstract* - This study offers a comprehensive overview of cylindrical gear manufacturing technologies, with a particular focus on cutting tools and related topics. Key scientific sources have been analyzed to gather and systematize data, highlighting the primary areas of focus in recent research. The investigation delves into several critical aspects, including the chip-forming process, cutting tool lifespan, materials for gear hob production, temperature and lubrication effects, cutting tool geometry, cutting parameters, design methodologies, and optimization techniques. Identified research gaps, particularly in gear hob design, are discussed in the context of organized knowledge, industrial needs, and socio-economic priorities. These findings provide a foundation for proposing future research directions in spur gear manufacturing and cutting tool development. The primary contribution of this work is a framework to support and guide scientific advancements in spur gear production technologies.**

Keywords: cutting processes; chip formation; tool performance; gear hob; spur gear; gearing processes; gearing technologies; gear hob design; review; gap in literature; future research directions.

I. INTRODUCTION

The evolution of gear manufacturing technologies dates back to the mid-19th century, beginning with Christian Schiele, who first proposed a worm-derived generating tool for spur and worm gear cutting. However, it wasn't until 1889 that George B. Grant patented the first gear hobbing machine in the United States, followed by Robert Herrmann Pfauter in Europe, who pioneered the industrial production of hobbing machines. Early gear cutting relied on carbon steel tools, with significant advancements occurring after the discovery of high-speed steel (HSS) in the early 20th century. The introduction of HSS in 1910 by Crucible Steel marked a leap in cutting tool durability, though challenges in profile conservation persisted. Key innovations, such as Hans Baerbalck's profiling extension for lathes in 1907 and later relieving lathes, significantly improved gear hob geometry and precision.

Parallel developments included Edwin R. Fellows' gear shaper machine in 1897, which became a cornerstone for internal gear production, and Max Maag's gear planing machine in 1913, known for its precision but limited productivity. The automobile industry further spurred advancements in bevel and hypoid gear manufacturing, though much of the innovation was protected by patents.

In spur gear manufacturing, progress has been closely tied to advancements in cutting tool materials and machine technology. The development of tungsten carbide inserts in the 1980s enabled higher cutting speeds and productivity, while physical vapor deposition (PVD) coatings in the late 1990s further enhanced tool performance, allowing for the machining of hardened materials with near-grinding quality. Modern CNC hobbing machines now enable precise surface modifications, such as crowning, contributing to quieter gear operation.

Today, gear hobbing remains one of the most efficient and widely used methods for producing cylindrical gears, accounting for approximately 50% of gear-cutting machines globally. Its popularity, especially in the automotive industry, stems from its unparalleled productivity compared to other methods like shaping and planing. The significance of gear hobbing is underscored by projections that the global gear manufacturing market will reach USD 39.4 billion by 2025, with hobbing leading among cutting methods.

This paper focuses on the gear hob, the most critical tool in hobbing technology, and explores its design, manufacturing, and usage. A review of over 25,000 references from scientific databases highlights the substantial research interest in this field. The work identifies key advancements, research gaps, and bottlenecks in gear hob design and hobbing processes. By addressing these gaps, this study aims to guide future research directions and foster further innovation in cylindrical gear manufacturing.

II. A LITERATURE REVIEW

The gear hobs and gear hobbing technologies belong to a very well-established domain. The gear hobbing process was patented in 1835, and the first specialized gear hobbing machine appeared in 1897 [4]. The first article on gear hobbing was published in 1963 [8]. Such a well-established domain, with a long history, is worthy of interest for scientific re- search. This literature review targets three main aspects related to the gear hobbing process and gear hobs: the cutting process itself, the design of gear hobs, and their manufacturing peculiarities, each of them with several specific issues.

2.1 The Gear Hobbing Processes

The gear hobbing process is one of the most complex cutting processes. This is because of the special needs in terms of the kinematics of the machine tools, the complexity of the cutting tool used, the chip-forming conditions, the specific geometry of the gear hob in terms of the cutting angles of the cutter, and so on.

A careful investigation of scientific production may reveal very interesting aspects the scientific researchers have faced.

2.1.1 The Mechanism of the Gear Hobbing Process

The mechanism of the gear hobbing process is considered one of the most complex generating processes. Litvin offers in his book known worldwide 'Gear Geometry and Applied Theory' [9] a clear definition and classification of the generating processes. The cylindrical gear surfaces generating process is described here as an example of two-parameter meshing. In this process, the rotation of the gear hob (the first parameter) combined with an imaginary axial shifting determined by the helix parameter forces the cutting edges to reconstruct the basic worm surface which contacts by lines the surfaces of a mobile generating rack. The second parameter is a translation along the axis of the workpiece, the named axial feed, in order to draw the tooth surfaces of the generating rack on their height, which means technologically the machining of the cut gear on whole width. If the cut gear is helical, the helix effect must be compensated for through an additional rotation of the rotary table. The corresponding settings are given in all machine tool handbooks.

2.1.2 Chip-Forming

The chip-forming at gear hobbing is a complex process, mainly because of the long cutting edge and its differently oriented zones. Due to its significant influence on the cutting forces, and the temperature in the cutting zone, the process of chip-forming raised the interest of specialists both in terms of theory and experiment. Ueda, Y., et al. [11] studied experimentally the chip-forming under the conditions of ultra-high-speed hobbing implemented on a gear grinding machine. To achieve such a high cutting speed, as fast as 2450 m/min, a large diameter gear hob was used with a grinding machine tool.

The workpiece material quality was SCM415 (equivalents: GB 15CrMo, JIS SCM415, DIN 15CrMo5) with 610 N/mm2 tensile strength and 180 HBW hardness. The gear hobs were built with the WC-Co tungsten carbide. Due to the cutting tool material, experiments were completed in dry cutting conditions. To explore the hardness of the machined surface, tests were conducted using a micro-Vickers hardness tester at a load of 980 mN. After hobbing, the chips and gear surfaces were analyzed using a scanning electron microscope (SEM) and energy-dispersive X-ray spectrometer (EDX). Cross-sectional samples of chips were made using focused ion beam equipment and were inspected with a transmission electron microscope. The residual stress on the gear surface was measured using portable X-ray diffraction equipment. The main findings revealed that the quality and the hardness of the machined surface were high, and the wear of the hob was insignificant. The teeth quality of the surface machined on the gear was illustrated by images taken from the microscope. A comparison of the images taken from samples machined by a cutting speed of 200 m/min, and a feed rate of 0.3 mm/rev and 2450 m/min, 0.3 mm/rev, respectively, emphasizes the difference between the surface layers affected in the two cases. Despite the temperature rising with the cutting speed, the increase in temperature in the workpiece and the hob was small, because most of the heat was removed through the chips. A schematic model of the way the heat migrates and is distributed to the gear hob, workpiece, and chip is also presented for low and high cutting speeds, as shown in Figure 1 [11].

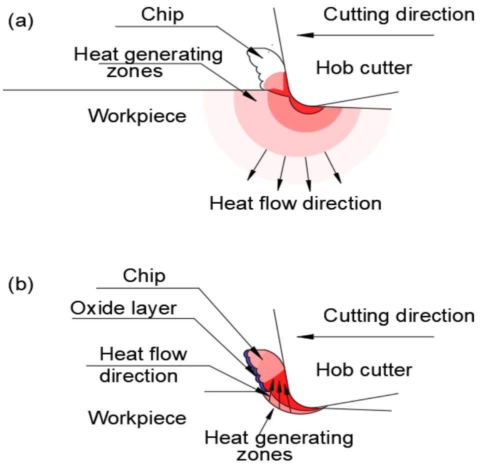

Figure 1: Schematic models for heat flow directions at different cutting speeds: (a) low cutting speed, (b) high cutting speed [11]

Because of the high temperature of the chips, they are highly oxidized. According to another conclusion, the color of the chip can be considered as a significantly accurate indicator of the temperature during their formation, and thus it can be used as a criterion for the optimization of cutting parameters. The color of the chips can also provide pieces of information to be used for enhancing the geometry of the cutting tool, i.e., the cutting angles. In order to obtain a consistent database for cutting geometry improvement, the chip-forming process was studied with highly sophisticated finite element method (FEM) models [12]. The results were confirmed by the experiments. Furthermore, the action of the chips on the gear flanks was modeled. A virtual machining environment was designed, aiming to study the chip-forming process without the need for experiments [13]. The research aimed to provide a tool to reduce cutting costs by determining the conditions to form un-deformed chips and to predict the cutting forces. The proposed method proved to be much faster and more accurate than the traditional numerical methods. A means to calculate the chip thickness is an analytically determined relationship [14]. Based on some variables (basically, the cutting parameters) and using non-linear regression of the experimental data, a mathematical relationship was developed to determine the maximum chip thickness. It was proved by case studies that the relationship was precise enough.

Despite the numerous research studies developed, the chip-forming process is still to be studied, to better understand its mechanics, and how it can be positively influenced by the gear hob's geometry. A general approach to chip-forming is presented in [14], regardless of the cutting process, but including gearhobbing. The final goal of the deep research is supposed to be the cutting force decrease.

Regarding the complexity of the chip-forming process during gear hobbing, one can admit that a chip results in a process of oblique cutting with a variable edge inclination angle (this is called the 'back rake angle', but in our opinion, the edge position by this angle determines much more the flow direction of the chip than it contributes to the chip-forming conditions; the phenomenon is controlled by the cutting speed and the orthogonal rake angle value). The nose radius in terms of turning can be adopted as the rounding radius by the gear hob tooth, meaning the circular arc edge part that links the side edge with the addendum edge. It is set in usual practice at the standard value, ρ0 = 0.38mn. It also must be mentioned here that the quality of the cut gear dedendum transition profile has an outstanding importance regarding the fatigue resistance and the load capacity of the cut gear. There exists research dealing with the influence of the rounding radius on the properties mentioned before [15]. It must be taken into consideration that the nose radius must be carefully correlated with the cutting parameters, especially the feed, because there exists a minimal limit chip thickness determined by these two parameters under which chip removal is not possible, and the cut surface result will be brittle and scaled. This problem was in extenso studied in [16] for a turning process, but we consider that the results can be admitted in the hobbing process too.

2.1.3 Cutting Forces

Chip-forming is just one of the aspects approached to design the gear hobbing process, another very important one being the cutting forces. An empirical formula to calculate the cutting force is developed, presented, and commented on [17]. It is based on experimental data, and some correction coefficients are used to consider the specific cutting conditions. This is a reason why the precision of the results is rather poor. The cutting factors considered are the maximum thickness of the chip, the modulus, the workpiece teeth number, the bevel angle of teeth, the axial feed, the cutting depth, and the number of teeth of the gear hob. Because of the complexity of the formula, it was further processed by advanced software means, to enhance it [18]. However, the newly obtained formula is applicable only for modules smaller than 30 mm. To find out more about the cutting forces, and to validate the theories related to cutting forces, different systems thought to measure the cutting force at gear hobbing were designed. One is based on the Kistler platform [18]. This allows obtaining by calculi, and based on the measured values, data about each component of the cutting force, as shown in Figure 2. The distribution of the magnitude of each force component is graphically represented depending on the nine successive orientations of the gear hob along its complete rotation. The graph gives a very good image of the way the gear hob is cyclically stressed.

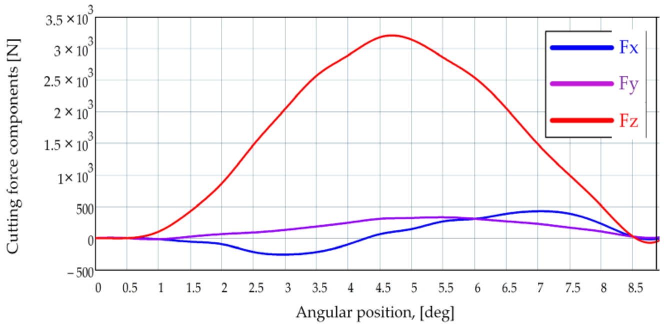

Figure 2: Cutting forces calculation for the hob's reference tooth during hobbing [18]

Another set of experiments was designed to perform measurements while hobbing gears made of brass [19]. Experiments were performed to study the similarities and/or differences between dry and wet machining. The monitored parameters were the profile precision, the tooth lead, and the cutting force by the other hand. In order to monitor the stability of the operation, a process capability indicator was introduced, as the quotient between the upper limit and the mean value difference and 3σ. Each experiment consisted of machining a sample of 45 gears. The conclusion was that in terms of gear precision, cutting forces, and process capability, the two are almost the same. It is to be noted that this conclusion cannot apply to other materials, especially if they are of harder machinability.

The cutting forces are used as one of the optimization criteria of the machining parameters [20]. Finding the best values of cutting parameters is often completed experimentally. This is a time-consuming task and generates supplementary costs. To avoid this, a special experimental system was designed, and it was used for the face hobbing of bevel gears.

One can appreciate that keeping under control the cutting forces at gear hobbing is an important objective since cutting forces have an important impact on the wear of cutting tools and they are always a source of vibration. As well, the energy consumption is directly influenced by the cutting forces. A deeper understanding of the way some factors such as cutting parameters, cutting conditions (dry, or wet), and the gear hob's geometry influence the cutting forces is desirable.

2.1.4 Temperature during the Gear Hobbing Process

It is obvious that the heat produced in the cutting area arises from two sources. The first one is the chip-forming process itself, which is discussed in a previous section. Here the heat is generated by the material deformation and flow. The second heat source is the friction between the different couples of actors involved in the gear hobbing process: the hob's rake face and the chip, respectively, and the relief face and the machined surface [21]. When it comes to friction, one of the main heat-generating phenomena, it can be reduced using cutting fluids. Their roles are both to cool the cutting area (help evacuate the heat) and to lubricate it, that is, to contribute to the decrease in friction forces. Despite the beneficial effects of the cutting fluids, they must be used under strict control, because of their bad impact on the environment and health. For these reasons, much research has been carried out on lubrication and cutting fluids. The main result was the appearance of bio-lubricants, able to successfully replace the mineral ones [22]. To diminish the bad effect of the cutting fluids, new techniques were developed. The cutting tools equipped with cutting inserts made of special materials (mono or multilayer-coated cemented carbides) can work without cooling. The so-called dry cooling techniques [23] eliminate the usage of cutting fluids or replace them with liquified gases delivered under high pressure (cryogenic cooling) [24]. Another approach aimed at giving up the cutting fluids in studies that targeted the durability of the cutting tools [25].

In conclusion, one can say that there is still room for research on the temperature at gear hobbing: the way it influences the precision of the machined part and the wear of the gear hob, resulting in the development of efficient and eco-friendly ways to remove the heat from the cutting zone. As well, further clarification on how the cutting fluid can contribute to chip-forming, chip-breaking, and chip removal is needed. In these terms, inner cooling that feeds the gear hob with cutting fluid from its inside is a possible direction of research.

2.1.5 Wear and Durability of Gear Hobs

The wear and durability of the gear hob are closely connected, the first determining the second. This is why both here, and in the literature, they are treated together. While durability has direct implications for the effectiveness of the gear hobbing process, the wear of the hob directly and strongly influences the dimensional and geometrical precision and quality surface of the machined parts.

In the literature, much research that approaches lubrication [20–25] touches on aspects regarding the wear of the gear hob. This is normal, because the lubrication aims, among other things, to keep the cutting edge wear under control.

The gear hob wear is approached from different perspectives in the literature. Research on wear and durability is generally expensive, but when it comes to gear hobs, it becomes even more expensive because of the long time and many resources necessary to spend to obtain a result in experimental research. For this reason, scientific researchers focused on alternative ways to study the subject. An effective method to do that is simulation. Despite the very complex mathematical models needed to describe the phenomena involved, much research has been carried on based on this method.

Based on simulation methods, an interesting theoretical investigation tool was developed [23]. The evolution of the gear hob geometry affected by the wear is analyzed by this theoretical-experimental method. According to the simulation, several specific factors of the gear hobbing process can be predicted with acceptable accuracy, the most important of which are the temperature and cutting forces. In terms of gear hob wear rate, the predicted values are validated by experimental data. A study on the complex process of gear hobbing under conditions of high-speed and dry machining conditions [24] revealed interesting aspects about different forms of wear and how they evolve. The experimental research confirmed the simulated results, so they can be used confidently in the prediction of wear under different cutting parameters. The different ways each gear hob tooth acts to generate the tooth gaps on the machined gear determine different wear modes.

A special and very laborious study [25] was devoted to modeling the different wear types of the successive teeth of the gear hob involved in the cutting process. It showed the high complexity of chip-forming in a gear hobbing process. The form of wear, in terms of cutting theory, was considered the relief face wear, in the transition region between the addendum and the lateral edge, because this is the most stressed part of the tooth. It is defined as flank wear. Experimental research was performed to compare the evolution of the flank wear at a simple HSS-hob and a SUPERTIN-coated one. Results showed that the considered admissible value of the flank wear of 0.3 mm was achieved after a ten-times-larger number of cuts in comparison with the uncoated hob. The evolution of the wear was modeled using a computer program that considers the number of cuts, the equivalent chip thickness, the cutting length, and the cutting speed. Using this prediction model, the goal of the optimization was declared to be the uniform wear of all hob teeth. To achieve this, the vertical (axial) feed was completed with the tangential feed, resulting in a diagonal machining procedure. All experiments were performed with a flying cutter instead of a hob, but the results are accepted.

In gear applications, the designers often use specific tooth profile corrections of the tooth profile, aiming for different purposes. Accordingly, this involves modifications of the gear hob profile. A study [5] explains the way the cutting edge modified shape of the gear hob influences its wear, the shape of the chips, and the distribution of temperature in the gear hob's teeth. Simulations were used to provide models that can help understand the phenomena and save time devoted to experimental research. The similarity between the simulated results and those obtained experimentally is proved by pictures taken from the simulation and from chips physically obtained through the cutting process.

As mentioned before, research that deals mainly with high-speed gear hobbing [8] makes a very interesting conclusion about the wear of the cutting tool: the wear is not significantly affected by the increase in cutting speed, even if it reaches values in the domain of the ultra-high-speed (up to 2450 m/min). Research [7] aimed to find out the extent to which the wear of the gear hob is influenced by the lubricant used in machining. The influence of the presence of alumina nanoparticles in the mineral lubricant was the particularity of the study. Two identical gears made of DIN1.7131 material were machined with identical gear hobs, using lubricants with and without alumina nanoparticles. Experimental research proved that the alumina nanoparticles have a beneficial contribution to reducing the craters and the wear of the flanks. The quality of the machined surfaces expressed by the roughness was better, as well. The influence of the cutting speed on the gear hob wear under different lubrication conditions revealed that the general tendency is that the wear progresses faster when the cutting speed increases. The two lubrication methods were wet lubrication (wet machining—VM) and Minimum Quantity Lubrication (MQL). The cutting speed was varied in four steps within the range of 34.4 to 69.9 m/min. The type of wear analyzed is illustrated in Figure 3 [38].

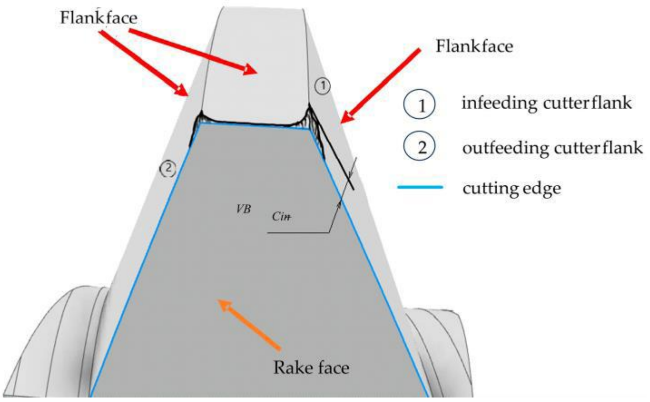

Figure 3: Locations and types of analyzed wears [38]

The number of teeth affected by the wear was also analyzed, and it was found that the teeth were differently worn depending on their position on the gear hob. The numbering of the teeth is shown in Figure 4. The study revealed that the bigger number of affected teeth reported was always in the case of MQL lubrication. The wear evolution was quite similar for the two lubrication methods, but there was identified a threshold value of the cutting speed of about 50 m/min. where the MQL method does not provide satisfactory results anymore.

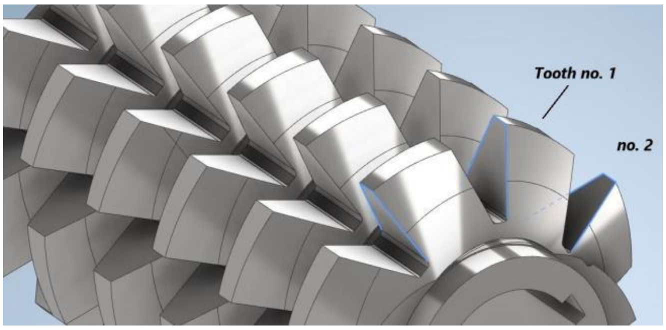

Figure 4: The numbering of the gear hob teeth [38]

2.1.6 Gear Hobbing Machine Tools

Machine tools are a very important element of the gear hobbing process. They in- fluence decisively the precision, effectiveness, and the cost of the gear hobbing process. Furthermore, their capabilities determine the possibility of generating gears of various shapes. Obviously, the kinematics of the gear-cutting machine tools play a crucial role in the precision of the machined gears. This is a reason the researchers focused their attention on this domain.

The CNC machine tools are very agile in generating sophisticated tool paths, so they become important to the specialized machine tools for gear hobbing.

To conclude the review of the gear hobbing processes, one may say that any of the topics presented in this subsection leave room (more or less) for new research meant to improve the gear hobbing processes. Based on this assertion, and the gaps identified in the scientific research, some new future research directions will be stated by the end of this article.

2.2 Gear Hobs

Gear hobs are the primary cutting tools for manufacturing spur gears, ensuring the efficiency and precision of the cutting process. While gear hobs are highly specialized for gear production, they have continued to be a focus of research to enhance their performance. Understanding the latest advancements in gear hob technology requires a systematic analysis of the key challenges associated with their use. The main aspects of gear hob research identified in the literature include:

Structural configurations (single block vs. cutting inserts)
Design principles
Cutting materials
Rake face geometry and regrinding techniques
Undercutting issues

2.2.1 Structural Configurations

Gear hobs can be broadly categorized into two types: single block (monolithic) hobs and composite hobs with cutting inserts.

Single Block Gear Hobs:

These hobs are made from a single material and are crafted from a cylindrical blank. Known for their excellent geometrical accuracy, single block hobs are ideal for finishing operations, although they are also suitable for roughing. While their precision decreases with repeated regrinding, they remain the most commonly used type of gear hob. However, their complexity in design and maintenance, coupled with lower overall effectiveness compared to composite hobs, presents certain drawbacks.

Composite Gear Hobs:

Composite hobs consist of a main body and replaceable cutting inserts, usually made of specialized materials for better durability and cutting efficiency. These inserts can be replaced when worn, avoiding the need for regrinding. Despite their advantages in machining efficiency and durability, composite hobs exhibit lower precision due to difficulties in positioning the inserts accurately. Various advancements, including curvilinear cutting edges and optimized insert positioning, have been proposed to address these limitations and improve their performance.

2.2.2 Design of Gear Hobs

The design of gear hobs is driven by the type of gear to be machined, its geometry, and the capabilities of the hobbing machine. According to Litvin's theory, the edges of the hob must replicate the surface of an involute worm to ensure accurate gear generation. The design process includes defining the geometric elements of the basic worm, determining cutting edge geometry, and calculating the parameters for grinding and relieving operations. While advances in mathematical modeling have improved design precision, further research is needed to address inherent inaccuracies and optimize design processes.

2.2.3 Cutting Materials

Traditionally, small and medium-sized gear hobs were made from High-Speed Steel (HSS). However, the demand for high-performance cutting tools has led to the adoption of materials like powder-metallurgical High-Speed Steel (PM-HSS) and carbide, often coated with wear-resistant layers using physical vapor deposition (PVD). These coatings, including (Ti,Al)N and oxide-based materials, significantly enhance durability and thermal stability. Despite the higher costs of carbide tools, their suitability for dry machining and extended lifespan make them an attractive choice for modern manufacturing.

2.2.4 Rake Face and Regrinding

The rake face and rake angle are crucial elements of a gear hob's geometry. While a 0° rake angle is easier to design and introduces fewer profile errors, a positive rake angle offers better cutting conditions. Regrinding, which is performed exclusively on the rake face, gradually alters the tool's geometry, leading to inaccuracies in the cutting edge profile. Advanced grinding techniques, such as CNC-generated profiles and optimized grinding wheel shapes, have been developed to minimize these effects and extend the tool's usability.

2.2.5 Undercutting

Undercutting is an undesirable phenomenon that occurs during gear hobbing and rake face regrinding. Preventing undercuts requires careful design adjustments and precise tool manufacturing. Computational modeling and simulation tools are now being used to predict and mitigate undercuts by optimizing gear hob geometry.

2.2.6 Manufacturing of Gear Hobs

Gear hob manufacturing involves two primary aspects: the performance of the hob during gear cutting and the production techniques for the hob itself. For composite hobs, CNC machining plays a critical role in ensuring high precision and consistent positioning of inserts. However, single block hobs demand advanced grinding methods to achieve the required geometrical accuracy. Despite significant progress, the literature indicates that the manufacturing process of gear hobs remains underexplored, offering potential avenues for future research.

Discussion

2.3 Systematization of Literature

This literature review identifies and classifies the most relevant scientific works into two primary categories: gear hobbing processes and gear hobs. Each category is further divided into subdomains, providing a structured overview of the research landscape.

For gear hobbing processes, the following subdomains were considered most pertinent:

Chip formation
Cutting forces and torque
Temperature in the cutting area and lubrication
Wear and durability
Other general aspects
Gear hobbing machines

The “Other general aspects” subdomain encompasses a variety of narrow topics that do not neatly fit into the previous categories, making it the most comprehensive section. The inclusion of "gear hobbing machines," while distinct from the other subdomains, reflects its critical role in the cutting process and justifies its separate listing. Related topics, such as temperature, lubrication, wear, and durability, have been grouped together due to their close interrelation.

The gear hobs category is divided into five subdomains:

Constructive solutions
Designing gear hobs
Cutting materials
The rake face and regrinding
Undercuts

Some subjects overlap between these categories due to the inherent connection between cutting tools and cutting processes. Specific topics, such as the design hypotheses for gear hobs or machining the clearance face, remain underexplored in existing literature, highlighting potential avenues for future research.

2.4 Gaps and Challenges in Current Research

Despite progress in gear hobbing technologies, several key areas remain insufficiently addressed or entirely unexamined. Key issues identified include:

Simplifying assumptions in gear hob geometry, leading to reduced precision.
Underutilization of CAD/CAM systems for simulating cutting processes and detecting interferences.
Exclusive use of gear hobs with 0° rake angles for finishing, resulting in high cutting forces.
Loss of gear hob precision after regrinding due to reduced diameter and altered cutting angles.
Challenges in regrinding gear hobs with undercuts.
Lack of gear hob designs with planar rake faces, which could simplify profile determination and regrinding.
Low geometric precision of composite gear hobs remains underexplored.
Absence of inner cooling systems, despite the importance of cooling during gear hobbing.
Insufficient side relief angles caused by helical relieving processes on the clearance face.
Limited exploitation of CNC machine tools for gear hob production.
Addressing these gaps requires innovative research and bold approaches to develop new solutions for improving gear hob and gear hobbing technologies.

2.5 Future Research Directions

The review identified several promising research directions:

2.5.1 Improving Gear Hob Design and Production

Developing innovative methods to determine gear hob profiles without simplifying assumptions, ensuring accurate geometry.
Designing gear hobs that maintain precision after regrinding, minimizing profile alterations.
Exploring geometries that allow regrinding without undercuts, including planar rake face designs.

Investigating methods for determining theoretical profiles with positive rake angles for dual-purpose gear hobs (roughing and finishing).
Creating clearance face designs that ensure consistent clearance angles along the cutting edges.

2.5.2 Advancing Gear Hobbing Technologies

Three main objectives for improving gear hobbing technologies are proposed:

Enhancing Productivity.
Expanding the use of high-speed machining.
Increasing feed rates and optimizing cutting parameters.
Introducing durable cutting materials.
Designing versatile gear hobs for both roughing and finishing.
Improving Geometrical and Dimensional Precision
Manufacturing gear hobs with error-free profiles.
Ensuring consistent profile precision post-regrinding.
Maintaining adequate clearance angles across all cutting edges.
Promoting even wear on gear hob teeth.
Adopting Eco-Friendly Practices
Implementing dry machining and minimum quantity lubrication (MQL).
Replacing mineral lubricants with eco-friendly alternatives.
Incorporating inner cooling systems.
Reducing energy consumption and carbon footprints across the product lifecycle.

Finally, the integration of Artificial Intelligence (AI) into gear hob design, production, and simulation is identified as a critical direction for advancing research and innovation in the field.

III. CONCLUSIONS

This work provides a comprehensive, though not exhaustive, review of gear hob and gear hobbing technologies for spur and helical gears. The key contributions include:

A systematic classification of existing literature into two main categories (gear hobs and gear hobbing processes) and their subdomains.
Identification of research gaps requiring further exploration.
Proposals for future research directions aimed at advancing the field.

The classification facilitates focused exploration of specific challenges in gear hobbing technologies. Observing the research landscape from a distance allowed the identification of overlooked areas and unsolved challenges. These gaps highlight the need for further study, especially in designing gear hobs with high precision and ensuring sustainable practices in gear manufacturing.

One critical area is the development of gear hob geometries that eliminate simplifying assumptions, achieving accurate profiles that align closely with theoretical models. Leveraging CAD/CAM systems and CNC machine tools can ensure optimal clearance angles and preserve gear hob precision after regrinding.

Integrating AI and advanced technologies will likely play a pivotal role in addressing these challenges. Despite its maturity, the field of gear hobbing remains ripe for innovation, with significant potential to improve productivity, precision, and sustainability.

REFERENCES

[1] Rominger, G.S. Worm. Gear. Cutting Machine. U.S. *Patent 405*,030, 24 January 1893.

[2] Baerbalck, H.; Hamilton, O.H.; Carr, R.S. Relieving Mechanism for Engine Lathes. *U.S. Patent* 870,759, 12 November 1907.

[3] Fellows, L.E.R. Machine for Grinding Gear Generating Cutters. *U.S. Patent* 686,599, 12 November 1890. (Application filed 24 June 1899).

[4] Verified Market Reports. Available online: https://www.verifiedmarketreports.com/product/gear-manufacturing-market/ (accessed on 1 March 2024).

[5] Boral, P.; Gołe˛bski, R.; Kralikova, R. Technological aspects of manufacturing and control of gears—Review. *Materials* 2023, 16, 7453.

[6] Xiao, Q.; Li, C.; Tang, Y.; Pan, J.; Yu, J.; Chen, X. Multi-component energy modeling and optimization for sustainable dry gear hobbing. *Energy* 2019, 187, 115911.

[7] Web of Science. Available online: https://www.webofscience.com/wos/woscc/full-record/WOS:000245459700171 (accessed on 2 March 2024).

[8] Chu, C.T.; Shen, S.H.; Hu, C.Y.; Chen, C.C. A universal hob for corrected circular arc-tooth point-meshing gears. *Sci. Sinica* 1963, 12, 723.

[9] Litvin, F.L.; Fuentes, A. Gear Geometry and Applied Theory; *Cambridge University Press: Cambridge, UK*, 2009.

[10] Ueda, Y.; Sakurai, N.; Takagi, T.; Ishizu, K.; Yan, J. Exploratory investigation of chip formation and surface integrity in ultra-high- speed gear hobbing. *CIRP Ann. 2022*, 71, 89–92.

[11] Bouzakis, K.D.; Friderikos, O.; Tsiafis, I. FEM-supported simulation of chip formation and flow in

gear hobbing of spur and helical gears. *CIRP J. Manuf. Sci. Technol.* 2008, 1, 18–26.

[12] Habibi, M.; Chen, Z.C. A semi-analytical approach to un-deformed chip boundary theory and cutting force prediction in face-hobbing of bevel gears. *Comput. Aided Des*. 2016, 73, 53–65.

[13] Gupta, K.; Laubscher, R.; Davim, J.P.; Jain, N. Recent developments in sustainable manufacturing of gears: A review. *J. Clean. Prod.* 2016, 112, 3320–3330.

[14] Yldiz, Y.; Nalbant, M. A review of cryogenic cooling in machining processes. *Int. J. Mach. Tools Manuf*. 2008, 48, 947–964.

[15] Troß, N.; Brimmers, J.; Bergs, T. Tool wear in dry gear hobbing of 20MnCr5 case-hardening steel, 42CrMo4 tempered steel and EN-GJS-700-2 cast iron. *Wear* 2021, 476, 203737.

[16] Fratila, D. Evaluation of near-dry machining effects on gear milling process efficiency. *J. Clean. Prod*. 2009, 17, 839–845.

[17] Kharka, V.; Jain, N.K.; Gupta, K. Sustainability and performance assessment of gear hobbing under different lubrication environments for manufacturing of 20MnCr5 spur gears. *Sustain. Mater. Technol*. 2022, 31, e00388.

[18] Kharka, V.; Jain, N.K.; Gupta, K. Influence of MQL and hobbing parameters on microgeometry deviations and flank roughness of spur gears manufactured by MQL assisted hobbing. *J. Mater. Res. Technol*. 2020, 9, 9646–9656.

[19] Kharka, V.; Jain, N.K.; Gupta, K. Performance comparison of green lubricants in gear hobbing with minimum quantity lubrication. *Tribol. Int*. 2022, 173, 107582.

[20] Zhang, S.; Sun, Z.; Guo, F. Investigation on wear and contact fatigue of involute modified gears under minimum quantity lubrication. *Wear* 2021, 484, 204043.

[21] Yuan, S.M.; Yan, L.T.; Liu, V.D.; Liu, O. Effects of cooling air temperature on cryogenic machining of Ti–6Al–4V alloy. *J. Mater. Process. Technol*. 2011, 211, 356–362.

[22] Sujan, D.; Moola, M.R.; Qua, S.Y. Environmental friendly cutting fluids and cooling techniques in machining: A review. *J. Clean. Prod.* 2014, 83, 33–47.

[23] Dong, X.; Liao, C.; Shin, Y.; Zhang, H. Machinability improvement of gear hobbing via process simulation and tool wear predictions. *Int. J. Adv. Manuf. Technol.* 2016, 86, 2771–2779.

[24] Cheng, Y.N.; Ma, C.; Zhang, J.; Zhou, H.; Xin, L.; Wang, X. Simulation and experimental study of tool wear in high-speed dry gear hobbing. *Int. J. Adv. Manuf. Technol.* 2022, 119, 3181–3204.

[25] Bouzakis, K.D.; Kombogiannis, S.; Antoniadis, A.; Vidakis, N. Gear hobbing cutting process simulation and tool wear prediction models. *J. Manuf. Sci. Eng*. 2002, 124, 42–51.

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