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A Review on Gear Hobbing Process

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***Abstract*—Gear hobbing is most dominant process for manufacturing gears. Vibration monitoring I gear hobbing is essential to improve quality and prevent catastrophic failure of hob tool. The aim of the paper is to review past researches conducted on gear hobbing process and suggest possible research directions.**

***Index Terms*—Gear hobbing, condition monitoring, vibration analsys.**

I. INTRODUCTION

GEARS are used as primary components for power and motion transmission .They are also employed for changing torque, speed or direction of power source. Gear drives provide a highly precise and controlled motion than other drives such as belt drives, due to constant velocity ratio and fixed tooth ratio. Gears are used in many geometries and applications such as machine tools, automobiles, industrial robots, speed drives, precision equipment etc. Thus, gear manufacturing industry forms most important part of various industrial segments. The ever increasing demand for quality assurance has imposed high standards on gear manufacturing industry. Continuous improvement is necessary to stay competitive in market.

Traditional machining techniques such as grinding and turning are employed to manufacture the common geometry element of gears. However, the aforementioned methods are feeble for manufacturing tooth gap. Additionally high quality and accuracy requisites on gears make it compulsory to use gear definitive manufacturing process. These technologies includes casting, forming, powder metallurgy, stamping and injection moulding. These can be broadly classified as Gear generating process Gear form cutting and gear generating are the two major gear manufacturing process. In gear generating process gear profile is formed by relative motion between rotation of cutting toll and translational or rotational motion of workpiece. The two primary generating processes are hobbing and shaping.Gear form-cutting uses formed cutting tools that have the actual shape, or profile, desired in the finished gear. The two primary form-cutting methods are broaching and milling . Bevel and cylindrical gears are the mostly used for such applications.

Gear Hobbing is acknowledged as the most advantageous or profitable manufacturing process for producing external gears[1-4]. Gear hobbing process undergoes same kinematics as a worm gear rolling on a worm drive[5].

In gear hobbing synchronous rotation exists between workpiece and hob tool along with simultaneous superimposition of feed of hob over the gear face on the rotation of the hob tool. Gear hobbing is regarded as perpetual generating process. Tangential, radial or axial feed can be given to the hob. In the production of worm wheels radial feed is employed. The axes of hob and tool are perpendicular in such case and the motion of tool takes place in radial direction. Whereas the axis of gear blank and hob is parallel in axial feed. In tangential feed the axis of hob is aligned horizontally although normal to the blank's axis. Before feeding forward axially the hob is maintained at full depth. The above mentioned practice is utilized for creating teeth profile in worm wheel and also for producing spur and helical gears.

During gear hobbing processes, many factors contribute to the overall cycle time and the gear qualities, including hob design , tool wear, workpiece deformation, and working temperatures. Hob cutters are highly expensive due to their complex geometry. Thus maximum utilization of hob tool's life. Capstan Meters, Jaipur reported recurring hob tool failures before fulfillment of expected life.. Machine tool cost decreases as production efficiency increases whereas contrasting behavior is observed in case of hob cost as it increases with production efficiency due to rapid wear and tear. Thus to achieve target cost the process parameters must lie within a specified range. Additionally to stay competitive in the industrial market domestically as well as globally manufacturers must produce highest possible quality at the minimum possible cost. The cost per piece is determined by quality , productivity and tool life. Hobbing process is influenced by characteristics of hob tool(Geometry ,structure, material, cutting) , machine tool (machinability, dynamic efficiency and service life), work piece(Geometry, machinability and material) and cutting parameters(Cutting speed, Axial feed rate and feed strategy). Catastrophic failure of any equipment may result in severe machine downtime, thus health monitoring or condition monitoring is essential for gear hobbing process. American Gear follows guidelines established by American Gear Manufacturers Association (AGMA) which is ISO 9001:2008 certified[6] . In gear hobbing certain conditions such as dislocation in tool or workpiece clamping or

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tolerance of tool and workpiece may occur which leads to deviations[7].The characteristics deviations are shown in Fig 1.1.

Industries are always apprehensive about effectiveness, protection and consistency of gear hobbing process[8].The ideal and operating performance of machine differs significantly. Condition monitoring is the tool which aids in reminiscing the ideal performance and efficiency of machine.

In spite of being efficient condition monitoring is arduous and laborious task as it requires maintenance crew to continuously monitor and troubleshoot the errors. This drawback can be

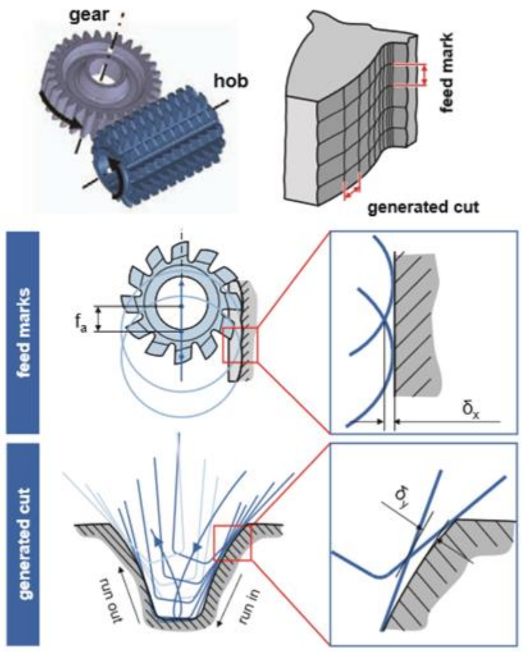

Fig 1.1 Characteristics cutting deviation in Gear hobbing[7]

swamped by vibrational analysis in condition monitoring of machine[9].Effective vibration signal extracting techniques have a critical part in diagnosing a machine.

The aim of this paper is to review past studies conducted on vibration analysis of gear hobbing machines. The rest of the paper is organized as follows: Section II summarizes the past researches in the mentioned domain. The obtained results are discussed in Section III. Section IV concludes the paper and Section V suggests possible research direction or future scope.

II. LITERATURE SURVEY

Quality of a gear, highlighted by its elements, is defined by the accuracy of applied manufacturing processes, as to achieve the geometrical and dimensional demands, required by functional conditions and using cycles, for each component of an assembly or subassembly [10] .In order to improve the hobbing precision of gear hobbing machines, the precision evolution mechanism of gear hobbing becomes a research focus in both academic and industrial fields[11].Scholars have conducted extensive studies on this topic, and several productive results have been reported in the literature. Hsu et al. [12] proposed an experimentally verified compensation method for a five-axis machine tool. Yang et al. [13] proposed an integrated positioning dependent geometric error (PIGE) identification and corresponding compensation method. Kono et al. [14] proposed an analysis method that can separate different kinds of geometric errors. Based on the hobbing method, a compensation method for the geometric errors was developed. Zhang et al. [15] proposed a convenient and effective measuring method for geometric error identification of the rotary table on five-axis machine tools by using double ballbar (DBB) as the measuring instrument. Andolfatto et al. [16] analyzed errors introduced by servo systems. Abukhshim et al. [17] investigated heat generation during the high-speed gear hobbing process as well as the pattern of heat transfer in the machine. Wang et al. [18] established an experimental platform to study the thermal deformation of gear hobbing machines and proposed a method to compensate for the thermal error caused by it. In addition, Wang et al. [19] conducted a study to discover the mapping relationship between the geometric error and geometric precision of gears. Based on that, the model, which shows the quota mapping relation between the hob profile deviation and gear profile deviation, was developed accordingly. Franco et al. [9,] studied the influence of tool error on tool surface quality. Friderikos et al. [20] investigated a type of failure of dry An essential feature of high quality gears is low vibration excitation in all operating conditions. Therefore, especially in the automotive industry, the tooth design phase focusses on optimized micro-geometry [21]. The aim is, to reduce transmission errors and thereby vibration excitation. This micro-geometry is influenced by the gear manufacturing processes, especially the finishing operations [22] this paper introduces a case-study, as to highlight the influence of two of these parameters, profile angle deviation (fHα) and tooth trace angle deviation (fHβ), on run-off cycle on test benches, for high-performance automatic transmission, designed for passenger vehicles.[23]. The noise level depends on quality not only of planetary gears, but of the other matting gears, as well, precisely ring gears and sun gears. An in process fuzzy rule based in process decision making approach is proposed in [24] for inspecting parameters of pinion being produced by gear hobbing process.Significant improvement in decision making under ambiguous conditions was incurred from the performance analysis. Thus the proposed method may lead to reduced defects and manufacturing costs,

In this context the gear is represented by the dexelmodelling technique. Coupling the model with a finite element simulation, the simulation framework is able to calculate deviations of the gears induced by the thermo-mechanical load during gear hobbing.[25] A method for

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obtaining optimized cutting torque in context of gear hobbing is proffered in [26]. The proposed system is based on Adaptive fuzzy control system. A large number of simulations and experiments have shown violent fluctuations in the cutting force of gear hobbing process[27-30], which makes the cutting conditions of the process very bad. So in order to avoid tool breakage and machine overload, conservative cutting parameters (e.g., feed rate and spindle speed) are usually selected in gear hobbing process. Therefore, the productivity will be relatively low when using constant cutting parameters. For these reasons, the adaptive control technique is very suitable for the process to increase the efficiency and protect the machine and cutting tool simultaneously by regulating the machining parameters online. Model-based techniques and intelligent control techniques have been used to realize adaptive cutting force control[31]. Fuzzy Logic Controller (FLC) is selected in this article from all the available techniques because it has proven useful in control and industrial engineering as a highly practical optimizing tool for its tolerance for imprecision, uncertainty and partial truth and its ability to model non-linear functions of arbitrary complexity[32]. For these reasons, FLC has been used in many industrial applications to achieve online adaptive machining[33].The authors in [34] have presented a force-induced error model for a dry hobbing machine functioning at high speed. The proposed model has high applicability and utilizes Finite Element Simulation and homogenous coordinate transformation of the entire gear hobbing machine. Another important advantage of the model is significant reduction in parameters in error estimation.

Exqusite insights during chip formation, i.e., stress, strain, strain rate, temperature gradients, etc., were provided. Zaeh et al. [35] conducted a numerical investigation on the dynamic response of gear hobbing machines and its influence on hobbing precision. Based on principles of gear skiving, Guo et al. [36] studied the relation between the process parameters and tooth surface quality. Compared to conventional hobbing machines, a high-speed dry hobbing machine is a kind of green manufacturing machine tool, which can effectively reduce pollution and resource waste. At present, gear hobbing technology is being developed toward high-speed, high-rigidity, high-precision, and large material removal. Although there is a long history of research on cutting force and the related force-induced deformation, there has been more focus on the conventional turning and milling process [37, 38]. Dong et al. [39] predicted cutting forces, torques, and temperature and stress distributions of the hobbing tools and workpieces by using a three-dimensional (3D) finite element model. Dimitriou et al. [40] developed a software program HOB3D that simulates accurately the manufacturing of spur and helical gears. The resulting three dimensional solid geometrical data provides the whole geometrical information needed for predicting of the cutting forces, tool stresses, and wear development. To reveal the characteristics of force-induced errors of hobbing machines, Wu et al. [41] developed an error model and conducted a univariate analysis of the influence of force-induced error on the quality of gear hobbing operation. A following onsite experiment validated the analyzed results. The authors developed a direct force induced error model for dry gear hobbing machine by using the analytical results obtained from Finite Element Simulation of entire system. Accordingly, the mapping relation between the force-induced error and gear hobbing precision was studied both theoretically and experimentally. The influence of machining accuracy of gear parameters on noise vibration harshness conditions has been tested and experienced, therefore, it can be observed that, in order to reduce the level of noise and vibrations, it is important not only the machining accuracy, but also the fine adjustment of some parameters, as to ensure a smooth gearing process, concerning the complexity of brand-new automatic transmissions [42].

Anna and etal[43] analyzed vibration behavior of two industrial gear hobbing machines. Experiment was performed on two gear hobbing machines with identical parameters. Natural frequencies were determined by accelerometer and impact hammer.. The sensors are connected to a dynamic signal analyzer to obtain Frequency Response Function for each system.. The frequency response function reveals that The vibrations coincided with input frequencies from the tool‘s teeth impacting on the work piece surface. This caused the entire system to vibrate excessively and induced disastrous limitations in tool life. The possible corrective actions suggested by authors include changing cutting parameters, changing frequency of vibration source and changing natural frequencies by structural modification. Bouzakis et al. [44], approximately linear tool wear progression at a steady rate was observed for the flank wear. Hence, a uniform wear rate could be assumed and the tool wear rate could be used to evaluate the tool wear in this study. To model the tool wear rate during gear hobbing processes, Usui’s tool wear rate model was implemented in [45], which was proven to successfully predict the tool wear rate of carbide tools by an extensive range of studies on machining processes [46–50].

Gear hobbing has accounted for nearly half of all gear fabrication operations, but this process has not benefited much from the enormous advances of condition monitoring techniques especially vibration analysis, as compared to turning, milling and drilling processes. At the same time, during gear hobbing process, there exists long strokes in both entry process and exit process, of which the cutting force is smaller. Furthermore, gear hobbing process is a signally multi-parametric and complicated gear fabrication method as many cutting processes based on the rolling principle[51].

Many past researches have tested the efficiency of various vibrational analysis techniques for fault diagnosis

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of rotatingmachinery.Most of the studies in past decades provide review of vibration monitoring techniques from different perceptions. For instance a survey of vibration monitoring techniques for rolling element bearing in both time and frequency domain is provided by Mathew and etal[52].

Health monitoring of a machine is crucial because even in the most excellent operating conditions vibrations exists due to minor defects. Therefore each machine has a natural or normal level of vibration which does not affects its performance. But in some situations such as onset of mechanical troublethe vibration level or noise level may elevate or become excessive .The common reasons behind such scenario are misalignment , looseness , worn gears or bearings, unbalance etc.,

Various sensors such as accelerometers, velocity transducers proximity sensors etc. are used to incur the vibration level of machine. The most commonly used sensor for the aforesaid purpose are accelerometers. Data acquisition, feature extraction and fault identification are crucial steps in fault diagnosis of rotating machinery. Feature extraction techniques influence the results to a great extent. Thus effective feature extraction techniques are critical for efficient condition monitoring. Noise is another foe as it contaminates the collected vibration signals. The corrupted vibration signals renders the entire system useless. Additionally certain vibration signatures may pass unnoticed.

McFadden, etal[53];proffered that machine faults can be detected and located precisely with feature extraction techniques. Kim and etal [54] tested the efficacy principal component analysis,classical non-parametric spectral analysis, joint time frequency analysis and the discrete wavelet transform. A review of statistical methods for feature extraction in gear box fault diagnosis was provided by Lebold etal [55]. An exhaustive review of acoustic and vibration signal techniques for fault diagnosis in rolling element bearing was presented by Tendon etal [56].

III. Results and Conclusion

Gear hobbing is the most dominant gear production process.. Additionally to stay competitive in the industrial market domestically as well as globally manufacturers must produce highest possible quality at the minimum possible cost. The cost per piece is determined by quality , productivity and tool life. Hobbing process is influenced by characteristics of hob tool(Geometry ,structure, material, cutting) , machine tool (machinability, dynamic efficiency and service life), workpiece(Geometry, machinability and material) and cutting parameters(Cutting speed, Axial feed rate and feed strategy). Catastrophic failure of any equipment may result in severe machine downtime , Thus health monitoring or condition monitoring is essential for gear hobbing process From the literature reviewed , it can be concluded that development of numerical and analytical model for simulation of gear hobbing process has remained prime research concern to determine un deformed chip geometry, cutting forces, and tool wear. But much less attention is paid towards vibrational analysys of gear hobbing machine.

IV. Future Scope

In future the author plan to implement vibration monitoring by using fuzzy logic techniques on industrial gear hobbing machine.

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