Three Stage Helical Gearbox: A Review of Materials - Scope and Challenges

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Abstract: Many research articles on various helical gearbox stages are accessible in reputable journals. The majorities of earlier research, despite the fact that triple step helical gearboxes have several benefits, were confined on single step and double step helical gears. Lately, most researching experts who work in this field have started paying close attention to the importances of three stage helical gearboxes. Throughout this research, authors seek to carry out an exhaustive evaluation of the current triple step helical transmission articles for examining the most widely used survey designs, approaches, tools & techniques. The above investigation expansively analysed 315 journal articles on helical gearbox various stages and then used content analysis procedure with an inductive method of research for carrying out an organized review of 45 literatures on three step helix transmission box that appeared in different scientific publications over the preceding two decades. Apart from this; the study presents a broad assessment of currently utilized materials, several future possibilities and problems in employing different materials for various parts of gearbox and its casing. This important research finding indicates there's an enormous potentiality towards dominating the area of research as well as continuing more chances for exploring growth of three stage helical gearboxes, which provides novel career opportunities for both experts and industrial professionals.

Keywords: Helical gear, Transmission gearbox, Materials, Research design & methodology, Research tools & techniques

I. INTRODUCTION

In the world today, every industry must manufacture products that are better for the environment economically, ecologically, and socially responsible by fulfilling customer demands and satisfactions. It wouldn't be enough for any company by gaining an edge in the competitive market by focusing only upon the inside efficiencies and various production operations. Rather, produce goods which are beneficial for sole consumers as well as to the environment. As a result, it emerges that it's really essential to establish better efficient approaches of production and manufacturing for addressing these problems.

Majorities of industrial applications rely on gears for mechanical power transmission [1]. A gearing system is formed whenever this gear pairs or engages with the other gears of same or different types. This geared system is the most effective method for transmitting energy and rotational motions from the source to the applications regardless of the variation in speed, position or thrust force [2]. As a part of this transmission system; several forms of gears such as straight cut, single helix, double helix, miter, hypoid, rack & pinion are employed by various industrial sectors based on their needs and applications [3]. Upon reviewing the literature, it was observed that helical toothed wheel are commonly utilised as gears for power gearbox due to comparatively quiet & seamless operations, higher bearing load capability and more operational performances [4]. This gearing configuration typically enclosed in rigid compact structure called as gear transmission casing which farther serves foundation for preventing gears despite an uncertain environment while maintaining the toothed wheel, drive shaft and supports in proper lubricated position [5].

Moreover, distinct transmission stages like single, double, triple and multiple stages gearboxes are being used across various organizations based on industrial demands. After the investigation, it was revealed that just a few researches had really been conducted on three stage helical gears with vast majority studies on one and then two step helical transmission box. Although, this triple step gearbox provides several benefits over all other stages gearbox like when a sufficiently large speed reduction ratio is intended, then double stage reduction gearboxes necessitate relatively bigger size gear [6-8]. Thus; when employing triple step gearbox for higher aspect ratio, designers could reduce pitch gear size along with minimizing shell thickness. Also, stresses occurring on the shafts & bearing decreases as the speed reduction ratio is splitted across three separate stages [9-12]. Besides that; multiple stages transmissions are recommended due to their ability to achieve broad speed ratio range, minimalistic design size, varieties of applications, higher survival rates once effectively lubricated and capability of being integrated with other gear types [13-20]. Lastly; although having lower efficiency than standard

single stage gearbox, multi stage gearboxes give increased gear ratios [21-23].

Consequently, a much more accurate analysis of gearing components of the system becomes essential as the desire for efficient transition of power in machinery, vehicles, and escalators intensifies. Also; the transmission and its housing are exposed to an array of forces or loads that need to be accurately estimated before designing the gearbox [24-25]. Thus; whenever designer creates a gearbox, it is essential to take into account its strength, weight, manufacturability and affordability [26]. As a result; performing several numerical analyses along with exploration of various materials are needed as this approach facilitate the assessment of several outcomes, predicting the performance of gearbox components underneath statically and/or dynamically applied forces, stresses & pressures and determined model's safety over under predetermined or anticipated loads [27-30].

The purpose of this present investigation is to undertake a thorough evaluation of the currently available literatures on materials, several possibilities of futuristic materials and challenges faced in utilizing present or unexplored materials for various components of triple step helical transmission gearbox and its casing which can farther provide recommendations or suggestions in forthcoming research. In other words, studying earlier literatures pertaining to the subject of three stage helical gearboxes and identifying the requirements for the present study on materials are indeed the key goals of the current research.

A. Research Motives

With regard to the research underlying rationale outlined in above section, a current work aims to conduct an organized assessment of the literature on materials utilized for triple step helical transmission box and anticipate the state of the field's research by classifying & reviewing pertinent papers acquired during methodical investigation from variety of perspectives. Moreover, the researchers attempt in accomplish this goal by looking for solutions to the following research problems, such as:

- What is the ongoing research progress on triple step helix transmission gearbox?
- Which types of research design, methods, tools and/or techniques most frequently used for triple step helix transmission gearbox?
- What are the specific issues industries experiencing today with their gearboxes that could aid in defining or identifying the said research areas?
- Which varieties of materials are currently utilized by the industries, identify unexplored futuristic materials and challenges faced in employing present or undiscovered materials for various components of triple step helix transmission gearbox?
- Which types of decisiveness strategies are employed in the triple step helix transmission gearbox research?
- What sort of descriptive and categorical analyses prevailing research study yields?
- What are the significant contributions, research voids and multiple consequences derived from this research study?

B. Research Aims and Objectives

- To fulfill the growing needs for power transmission system due to their comparatively quiet & seamless operations, immense bearing load capability, quicker operating speed and greater operational efficiency.
- To comprehend the variety of influences and identify the primary root causes of a transmission system failure under operational settings so as to avert an unexpected breakdown.
- To enhance the demand & select the right ideal materials for an optimized helical gearbox design in order to provide best performance with least stresses, moderate directional distortions, minimal vibrations, lower weight, economical cost with improved strength.
- To prioritize the triple step helix transmission gearbox research across multiple stages and assess presently used optimal study designs, approaches, tools & techniques which can farther provide with insights & assist scholars/ industrialists in optimizing, overcoming major design challenges and suggesting futuristic research directions.

II. LITERATURE REVIEW

This section research aims to gain knowledge about earlier research on three stage helical gearbox and elucidating the needs of current investigation [28]. For accomplishing stated objectives in previous section, the current article evaluates 45 scholarly articles on triple step helix transmission gearbox which were published from or prior to 2010 until November 2023 in various standard journals like Springer, Elsevier, Taylor & Francis, IEEE, MDPI, Web of Science, Emerald Group, Hindawi, ASME, Sage Publications using structural literature review (SLR) approach. Further, this search procedure was executed out using a few search parameters in accordance with study goals in publications titles, abstract and keywords [31-32]. Furthermore; this investigation is divided into two segments namely the descriptive and categorical analysis. In descriptive approach, grouping is done based on number of articles published annually journal & publication wise. Conversely, category analysis involves classifications for various existing materials, upcoming potentiality and obstacles

entailed in employing it. Moreover; throughout this literature review, articles are divided into subcategories under consideration by a generalization process applying content analysis methodological approach in collaboration with an inductive research paradigm. However, the method of content analysis employed in this investigative study aims to accomplish few purposes. As a starting point, it outlines previously conducted studies by relating apparent major possibilities & obstacles in the pertinent study area. Subsequently, it assists in formulating a hypothesis, which serves as the theoretical framework for the research. Therefore, structural literature review strategies are employed throughout prevailing study to achieve desired research targets. Figure 1 shows research methodology framework used in current exploration.

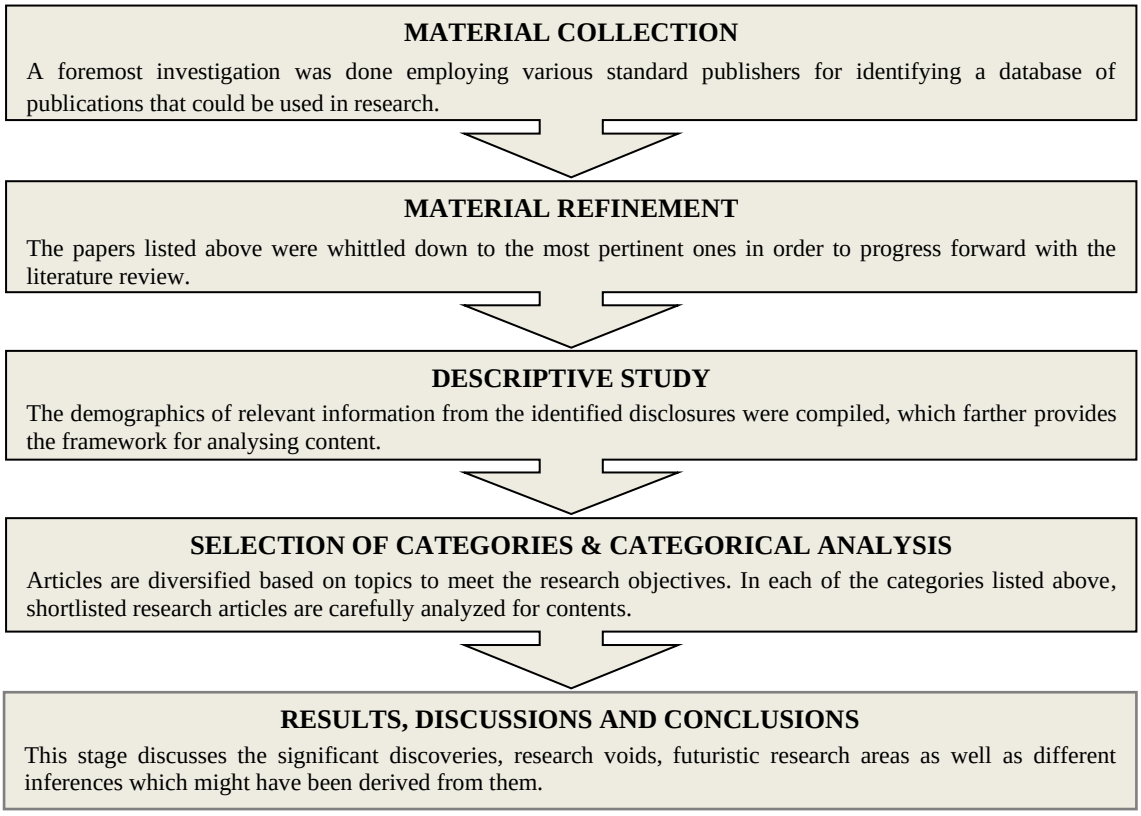

Fig. 1. Framework of research approach for developing triple step gearbox

A. Material Collection and Material Refinement

The beginning stage of collecting information is selecting an appropriate dataset and search parameters for articles. The data that is required to be gathered should be accurate although constrained by particular indications. In a structured review of the literature, choosing the pertinent research articles is incredibly important from various standard journals like Springer, Elsevier, Taylor & Francis, IEEE, MDPI, Web of Science, Emerald Group, Hindawi, ASME, Sage Publications and UGC Approved Journals. Therefore, it's appropriate to assume that all standard repositories mentioned above will be sufficient enough for choosing proper relevant publications. As a result, an organized search was undertaken applying numerous parameters for searching that incorporated the research's goals in the publication's title, abstract, and key phrases which resulted an initial set of 315 articles since inception of time till November, 2023 searched date.

Moreover, articles obtained from the initial assessment were improved using a variety of inclusion & exclusion criteria in order to filter out irrelevant periodicals to ongoing research. In the beginning; following the first filtration, publications were divided into single, double, triple, multiple stages and other groups according to reduction stages which left over 270 research articles. Additionally, publications were filtered out in the subsequent second stage that addressed document types such theses, scientific manuscripts, power point slideshows, white papers, events advertisement, major deliverables, periodicals, editorials and banners which left behind 262 scholarly articles.

Further; during third stage of filtration, publications were excluded which didn't utilize English language leaving over 258 academic articles. Furthermore, the fourth filter was employed to eliminate articles from different publishers with similar titles that totaled 254 articles. Afterwards; through abstract assessment and omission of studies solely based on computer

programs or algorithms, the fifth filter was used in order to scrutinize papers that effectively encompassed single, double, triple, multiple stage, and miscellaneous categories in accordance with the goals of research. Finally; out of 315 scholarly articles, 220 publications were remaining after all filters were applied. These 220 periodicals included 11, 32, 45, 18 and 121 research papers on single, double, triple, multiple stage and other groups respectively. Lastly, 45 articles related to the helical gearbox with three stages were selected ultimately for the literature survey. Figure 2 illustrates research articles refinement process employed in present investigation after applying certain filters respectively.

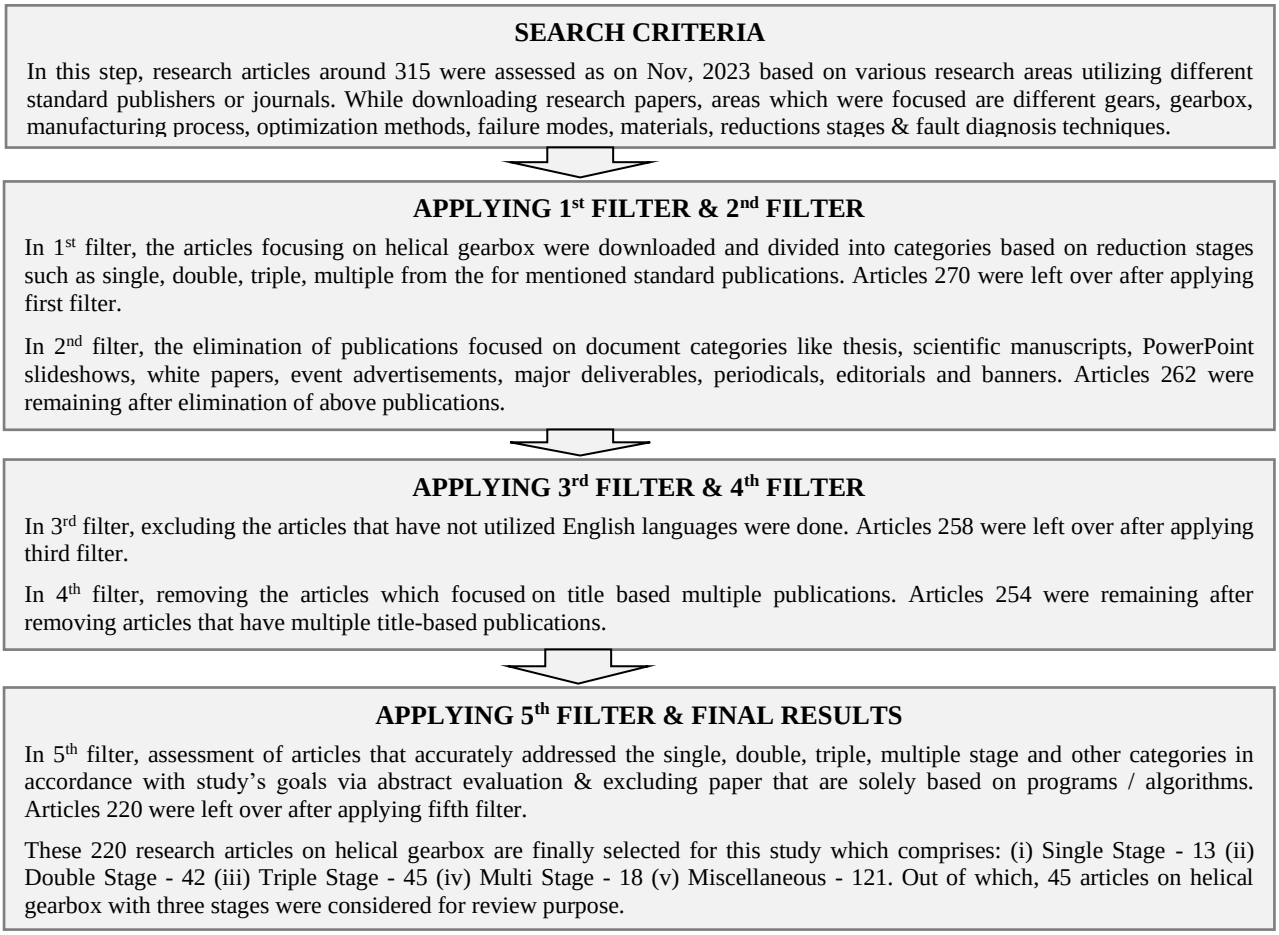

Fig. 2. Search criterion for scrutinizing research articles and its refinement process

B. Descriptive Study and Analysis

The subsequent content analysis's framework is built on this exploratory approach. A thorough investigations survey was carried out on three step helical gearboxes in order to: (i) Examine the various materials utilized by past and present scientists (ii) Examine several prospective possibilities for futuristic materials suggested by previous and current research scholars (iii) Identify and analyze difficulties faced in exploiting present and undiscovered materials (iv) Establish the proper scope for expanding prevailing research fields and make recommendations for potential studies. In this section, finalized 45 research publications about three stage helical gearboxes were reviewed and analysed according to frequency of articles produced in categories such as evaluation of papers relying on publishing years, assessment and interpretation about periodicals dispersed across multiple journals or publishing houses.

i. Articles assessment with regard to publishing years

The bibliographical information of publications throughout the span of each calendar year appears in figure 3. The purpose of the time frame analysis entails is to take a close glance at the development of three stage helical gearbox studies year by year. Hence, the shortlisted 45 research articles which were published between on or before 2010 and 2023 are laid out chronologically publications year wise. Thus, researchers can spend greater amounts of their time and effort towards the research on three-stage helical gearboxes, indicating that there is room for major growth in this field in upcoming decades.

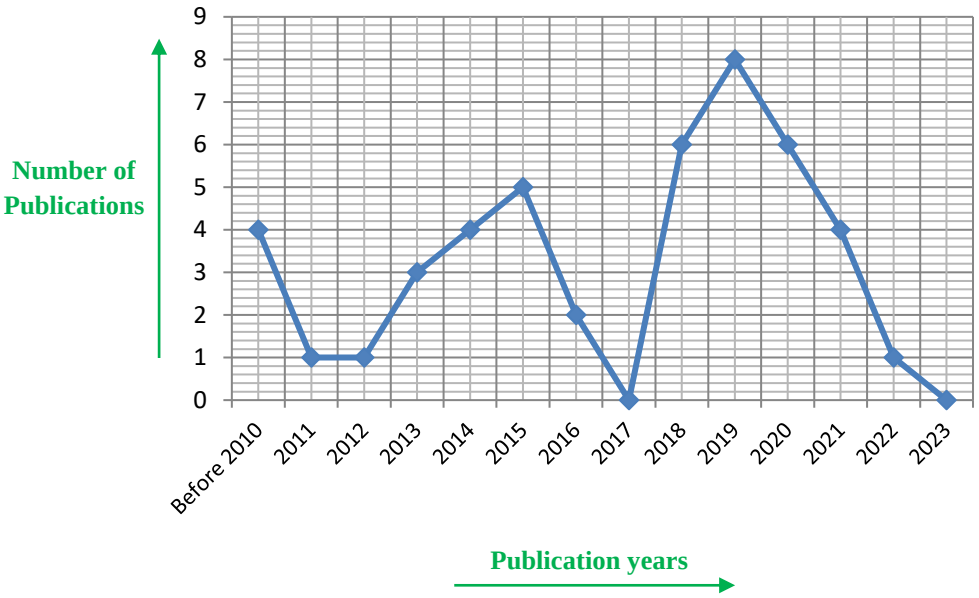

Fig. 3. Segregation of peer reviewed publications based on publishing years

ii. Articles assessment distribution with regard to various publishing houses

The aim of evaluating an allocation of journals specifically is to determine which peer reviewed publications are presently releasing research papers pertaining to three stage helical gearboxes. Based on same, the chosen 45 articles as summarized in table 1 are presented in different publications houses on three stage helical gearbox researches. Also, the vast range of publication diversity shows that current field of study been conducted is growing tremendously. On top of that, selected articles on helical gearboxes with triple stages have emerged in several publications recently, confirming preparedness of various journals to embrace developments in the field of current study. Lastly, the results show that a considerable number of scholarly articles are published in the realm of the study; as a result, these works can be thought of as the main journals with peer review for research on three stage helical gearboxes.

Table 1 Distribution of peer reviewed articles publishers wise

Publisher's name	**Frequency of articles**	**Possibilities (%)**
Springer Nature	11	24.44
Elsevier	6	13.33
Web of Science	10	22.22
Hindawi	5	11.11
IEEE	1	2.22
Taylor & Francis	1	2.22
Sage	1	2.22
ASME	1	2.22
MDPI	4	8.88
Others	5	11.11
TOTAL	**45**	**100.00**

C. Selection and Analysis of Categories

In this step, evaluation of materials is done wherein the 45 shortlisted articles for investigation undergoes comprehensive examination across each of the aforementioned categories like research design, approach, areas, tools and techniques etc.

i. Research design categorization

The present part of the section as depicted in table 2 focuses solely upon the study design involved in shortlisted articles for exploration like theoretical, mathematical, computational, experimental & combinational approaches. After categorization, it was observed that there will be plenty of potential for extending these methods with regard to this scientific study, as there are just two publications that emphasize on each of the three methods (theoretical/analytical, numerical, and experimental).

Table 2 Categorization of research for design

Research Design	Frequency of publications	Possibilities (%)
Theoretical Research	4	8.88
Statistical Research	3	6.67
Computational Research	12	26.67
Experimental Research	0	0
Theoretical + Computational Research	5	11.11
Statistical + Computational Research	10	22.22
Computational + Experimental Research	4	8.88
Theoretical + Computational + Experimental Research	6	13.33
Statistical + Computational + Experimental Research	1	2.22
TOTAL	**45**	**100.00**

ii. Research methods categorization

After a comprehensive articles analysis, table 3 displays the variety of research strategies investigators have employed like theoretical & case research; theoretical & mathematical; theoretical, mathematical & case research; modelling & investigation; modelling & optimization; modelling, investigation & optimization; modelling, investigation, materials & optimizations; modelling, investigation, materials, optimizations & manufacturing in their study. In addition, numerous papers on the modelling, investigation, and optimisation techniques as well as the modelling, investigation, materials, and optimisation strategies demonstrates the need for much more investigation to identify important issues with three stage helical gearboxes.

Table 3 Categorization of research for methods

Research Method	Frequency of publications	Possibilities (%)
Theoretical + Case Research	5	11.11
Theoretical + Mathematical Model	2	4.44
Theoretical + Mathematical Model + Case Research	8	17.77
Modelling + Investigation	2	4.44
Modelling + Optimisation	6	13.33
Modelling + Investigation + Optimisation	12	26.66
Modelling + Investigation + Materials + Optimisation	3	6.67
Modelling + Investigation + Optimisation + Simulation	4	8.88
Modelling + Investigation + Materials + Optimisation + Manufacturing	3	6.67
TOTAL	**45**	**100**

iii. Research areas categorization

The demographic information about the research areas adopted by scholars in various studies of triple step helical gearbox investigations is displayed in table 4 such as reducing overall cost, production defects, backlash, interference, unsteadiness, weight, size, tremors, sound, stresses, distortions; minimization & improvement of endurance, performance, reliability or durability of gearbox; optimization of process design, factor of safety & transmission ratio selection and combinational approaches including the optimisation and reduction of numerous variables. Finally, the data revealed that only a small percentage of researchers focused on enhancing gearbox strength, fatigue life, overall efficiency and reliability.

Table 4 Categorization of research for thrust areas

Research Areas	Frequency of publications	Possibilities (%)
Reduction of mass, size, tremors, disturbances, directional stresses & distortions, backlash, disruption, unsteadiness, manufacturing defects and overall expenditure.	9	20.00
Enhancement of gearbox strength, fatigue life & overall effectiveness or dependability or life span	5	11.11
Refinement of several design variables, development process, appropriate selection for factor of safety and gear box ratio	12	26.67
Case (i) + Case (ii)	7	15.55
Case (i) + Case (iii)	7	15.55
Case (ii) + Case (iii)	1	2.22
Case (i) + Case (ii) + Case (iii)	4	8.88
TOTAL	**45**	**100.00**

iv. Research tools & techniques categorization

The following subsection discusses a wide range of research tools and techniques that have been previously employed for enhancing and optimizing three stage helical gearboxes. Statistics research as enclosed in table 5 revealed that most investigators have chosen numerical methods or blended methods over theoretical & experimental approaches because of several benefits. Additionally, throughout the survey, it emerged that different researchers favored distinct research tools & techniques in each approach based on their requirements.

Table 5 Categorization of research for tools & techniques

Research tools and techniques	**Number of papers**
(i) *Theoretical approach*	
○ Analytical Modelling	12
○ Algorithmic Programs	9
○ Manual Software Programs	5
○ Different Methods / Formulas / Theorems	10
○ Various Standardized Design Procedures	8
○ Optimization Approaches	7
(ii) *Numerical approach*	
○ Modelling Softwares	26
○ Investigations Softwares	20
○ Simulation Softwares	13
○ Matlab	6
○ Computer Programming Softwares	14
(iii) *Experimental approach*	
○ Failures Diagnosing Techniques	7
○ Condition Monitoring / Surveillance Techniques	5
○ Data Acquisition Techniques	4
○ Testing Techniques	7

v. Summary of Literature Survey

M. Hofstetter et.al. [1] performed multipurpose computer aided gear box design & optimization in xEV drives axle for improving performance, efficiency and supporting making judgments throughout the initial stages of development taking into account various constraints. For optimization, authors introduced new differential evolution based procedure which offers parameters of shafts, bearings, gears design & their own arrangements with given load, lifetime, package requirements to handle all optimization criteria in a multifaceted approach. In addition, 20MnCr5 material was utilized in existing arrangement (shafts, gears, bearings and housing) which resulted in higher stresses, vibration, weight due to which researchers recommended 8CrNiMo7-6 materials lastly in their modified design. Further, Maruti Patil et.al. [2] did innovative multifaceted refinement of the double step helical transmission taking tribological & comprehensive constraints ranges. Here, gearbox's overall volume and power loss are minimized respectively in the first & second formulated objective functions taking several design constraints such as bending, pitting stresses and tribological constraints like scuffing & wear into consideration by using Non Dominated Sorting Genetical Algorithm II (NSGA-II) for an three distinct gear profiles (unaltered, smooth meshing & heavy load), 4 ISO oil category and 2 speeds. Finally, a comparison was made between outcomes of typical single objective minimization with & without rheological restrictions as described in previous literatures to conclude that solutions retrieved from single objective minimization without rheological restrictions have a significant likelihood of wear failure and that adopting the multi objective approach reduces the gearbox overall power loss by 50%. Moreover, it was revealed that the single objective (volume reduction) study which has no tribological limitations was straightforward to conceive and carry out. But; in contrast to the multi faceted optimisation under rheological restrictions, it resulted in bigger power losses with significantly less volume. Along with it; when applying multi objective optimization, power loss was reduced by up to 50% in some circumstances. Also; in this single objective instance, the chance of failure due to wear was also found to be extremely high, whereas in the multifaceted optimization situation, it shows to be within safe limits less than 10%.

Besides, authors [3-9] have done optimization of different structures of helical, differential and spiral bevel & helical spur gears, casings, stiffeners for minimation of volume, weight, centre distance, vibration, stress, noise, component complexity, cost and improvement in efficiency, power transmitting capacity utilizing several optimization techniques and numerical approaches. Here, researchers have preferred microsoft visual C, selective breeding algorithms, evolutionary algorithms, solidworks, matlab, creo, hypermesh, finite element analysis, FFT analyzer, simulink software toolbox and other programming softwares for minimization, improvement and optimization of various parameters. The method of design

optimisation entails figuring out the most effective possible values for each and every choice variable, including power, module, thickness, and tooth counts. This result could decrease the gear's bulk and centre of mass while improving its power and effectiveness. Also, volume models for different structures of several gears are built in few papers to study influence of bottom, clearance volumes on gearbox efficiency and performances. Moreover, respective scholars performed structural modification, analysis and optimization in order to reduce the gearbox component complexity, weight, cost & study the effects of vibration generated at various locations in the gearbox. Here, investigators have done modal, vibration, harmonic analysis contemplating die cast ALSi132, Alloy Steel (40Cr and C45) and 20CrMnMo materials followed by validation of experiment result from fourier frequency transformer analysis with theoretical modal & vibrational analysis results. Over and above that, some author's developed the multiple stage optimization model of spiral-bevel, helical-spur, helical gear reducer utilizing the matlab optimization toolkit & its corresponding algorithms by selecting the proper design variables and setting constraint conditions in order to save additional materials and make the reducer simpler. Last but not least, an examination of the results in comparison to the design data revealed that the optimised objective value had decreased by 35.28% and the centre distance by 11.60% respectively. This matlab optimization toolbox used by analyzer simplifies the complexity of programming and improve efficiency & quality of the design. Also, researchers in certain articles often utilized rib reinforcements around bearing points to lessen vibrations. These inclusions of rib stiffeners certainly add weight but improve level of rigidity significantly. Farther, it has been found that positions and quantities of stiffeners variables are often overlooked which have substantial impact on dynamic behaviour of entire gearbox without affecting mechanical functionality, strength and durability of the component.

Furthermore, B.Venkatesha et.al. [10] examined the simultaneous impact of face width, module, helix angle and gearing ratio on the crushing and bending stress characteristics of alloyed steel helical gears over an array of constant gear ratios (i) = 7, helix angle (β)= 25 & face width of 41 / 43 / 45 / 47 / 49 sets keeping module varying from 16-24 utilizing numerical approach. Also, Xiaohe Deng [11] analyzed and predicted gear fatigue life using different fatigue performance analysis for different materials, batches, test sites, standard parts and standard test procedures. Next, authors [12-13] observed critical, bending, contact & fatigue load strength and spread of stresses using both analytical & finite element methods in helical and spur gear systems. Moreover; FEA was implemented for carrying out structural, contact, and durability examines with the goal to discover metrics related to performance and evaluate the consequences of important performance indicators across different helical gear tooth systems, covering single, herringbone and crossed helical gear which was farther compared with theoretical / analytical techniques based on helical gear pair AGMA standards.

Additionally, author [14-30] performed design, analysis, optimization and modification of different stages respective helical reduction transmission gearbox and casing for improving strength, reducing overall weight, materials cost, oriental deformations, directional vibrations & noise and calculating the protection factor beneath bending & surface fatigue strengths for both gears as well as addressing the reason behind the pinion teeth distortion. Likewise, a couple of researchers focussed on minimizing contact stress or equivalent von misses stress including friction coefficient between the helical gear pairs for several helical gear sets (0^o, 5^o, 10^o, 15^o, 20^o, 25^o) with average static friction coefficients value varies from 0 to 0.3 under static & dynamic loading conditions. Over and above that, few scientists investigated various causes of gearbox failures & analysed the manner in which the asymmetrical coefficient affects the helical gear's durability and contacting ratio for suggesting various remedial measures to minimze such failures in end. In addition, majority of investigators utilized numerical approaches like creo parametric & solidworks and FEA for designing & analysis purpose separately followed by experimental methods. For the same, several analysis like modal, vibrational, harmonic, frequency response, thermal, static & dynamic analysis were performed contemplating suitable materials like gray cast iron (Grade FG 150, FG 200, FG250 & FG 260), alloy steel (17CrNiMo6, 15Ni4Cr1, 20MnCr5, 15Ni2Cr1Mo15, 40Ni2Cr1Mo28, 15Ni2Cr1Mo15, Al-SiC, SAE 8620, EN8, EN19 & EN31), structural steel (Grade A36, AISI 9310, SCM420H & SCM415), carbon steel (Fabsteel IS2062 steel, 40C8, 45C8 & Invar), nylon 66 (plastic), aluminum casting alloy (LM24 & LM25), case carburized steel (HRC13 & HRC61), aluminum alloy (6061-T6 & 7071-T6), composites materials (glass filled polyamide, carbon fiber reinforced polyamides, carbon fiber epoxy resin, metal matrix & ceramic matrix), brass, bronze, powdered metals, nylatron GS etc. Lastly, authors concluded firstly that contact stresses results increases & decreases with rise in values of friction coefficient & helix angle of gear pairs respectively. Secondly, surge in the pressure angle on drive side shows improvement in helical gear strength. Also, investigator noted that majority of industrial gearbox is overcoming resonance conditions. Further, researchers in majority articles discussed that unregulated tremors may generate sound, expedite wear rates leading to safety malfunctions which reduce effectiveness & occasionally may lead to the expensive breakdown of machine components. Beyond that, few scientists highlighted the various causes for vibrations like environmental disruptions, changing loads, malfunctions in the transmission, gear mesh stiffness, periodic stimulation, variable speed or torque & many other reasons. Lastly, they suggested that it's crucial for analyzer to determine and establish the limits of vibrations & noise in intial design phase using ansys followed by FFT analyzer. Furthermore, the evaluation of system's inherent frequencies & dynamic responses for the excitation frequencies and their harmonics were assessed using modal, random vibration and harmonic analysis which will farther help scholars to keep the natural frequency outcomes far from resonance frequencies to avoid

resonance or fatigue failure problem. Besides, this investigation was carried out similarly in three distinct cases like only design modification, without design modification only material change & with both design modification & material change for obtaining best optimized model having low weight, stress, vibrational effects and high strength without increasing cost. On top of that, this reduction in weight could lead to several advantages like better stability, increased efficiency, superior aesthetics and saving energy according to authors. Plus, some paper also described that convection effect between the inner surface of casing and the circulating oil was found small and thus neglected.

Similarly, researchers [31-45] performed modelling, investigation, refinement and production of three stage industrial transmission gearbox utilizing blended (theoretical, numerical & experimental) approaches. The main purpose of this assignment was to provide an efficient gear box with low reduction ratio, less weight and indentify all design, manufacturing defects & other failure causes. Further, authors preferred autodesk fusion 360, solidworks, creo parametric 2.0, hypermesh 11.0 and ansys software to design & perform various static or dynamic analyses for recognizing the various stresses acting on the gearbox under distinct loading conditions. Moreover; according to investigators in the gearbox design, stress generated due to bending and surface rigidity of the gear tooth are considered to be the primary causes of gears set failure. Hence, the evaluation of stresses approach have gained significantly as an research area for gears in order to prevent failures while achieving the best possible gear design. Thus, some authors calculated bending stress at the root within the helical gear tooth employing analytical method (lewis bending stress equation). Also, gearbox failure as mentioned by few scientists occurs mainly due to the drafting issues, production errors, deficiency of lubricating oil, long halting time and heavy loading conditions. Therefore, authors have lessen the stresses caused in gear tooth profile by altering five different helix angles (13°, 18°, 23°, 28°, 33°) and conducting static, dynamic as well as perturbation analysis on transmission box for obtaining stress & frequency and deformation & frequency graphs respectively. Furthermore; gearbox failures as stated by author may occurs due to resonance. So, rigorous engineering analysis have to be done in the initial design phase to prevent resonance or design the gearbox having minimum weight and still have sufficient rigidity to overcome failure of gearbox. Also; from some researcher's point of view, the noise emitted into the surroundings by gearbox is mostly an consequence of natural fluctuation between housing, shafts and gears due to mesh stiffness variation, manufacturing defect & assembling errors which can be minimze by proper stress calculations, material & reduction ratio selections and optimization in design of gearbox using finite element analysis adopting standard procedures until satisfactory results are achieved. For the same, specific analysis were perfumed like modal, vibrational, harmonic, frequency response, thermal, static & dynamic analysis considering relevant materials such as carbon steel (45C8, 40Cr, AISI 1060, AISI 5160 OQT400, SM45C, AISI 304, AISI 5115, AISI 8620), alloy steel (18CrNiMo, FEE 580, SAE 8620, 20MnCr5, 16MnCr5, Ni-Cr steel, 20CrMnTi, 38CrMoAl), ferrous cast iron (Grade CI 20, CI 150, CI 200, CI 220, CI 250, CI 260, EN- GJS 600-3), aluminum alloy (AlSi7Mg), powdered metals, composites (Glass fiber reinforced, Glass filled polyamides, Carbon fibers in epoxy matrix, Aluminium silicon carbide metal matrix, HS carbon epoxy, E glass polyester resin) etc. In the end, majority of authors verified and validated the gearbox's vibration properties employing both empirical and theoretical methods. Finally, authors concluded that composite material have advantage over conventional materials like greater strength, more durability, lighter mass, faster critical velocity, improved force carrying ability and design, analysis & optimization gearbox approach have evolved a prominent field of exploration to diminish the failures and optimizing gearbox model. This makes it necessary to complete several kinds of analyses for the current gearbox in order to predict how enclosures subjected to separate static & dynamic working environments would operate. Nevertheless, for finding optimized design of gearbox, authors did several geometry modifications with different dimensions such as web thickness, housing depth, housing thickness & results were taken for all the geometries until satisfactory efficiency values are achieved. At the last; the outcomes were examined and assessed wherein different configurations of the design variables were utilized to attain better model deformation characteristics i.e. minimal performance failing under heavier loads.

III. CONCLUSION

In the past few decades, studies on various helical gearboxes stages have grown & developed at a rapid pace. By looking into 315 research articles on the different helical gearboxes stages and carrying out an methodical analysis of 45 papers focusing on triple step helical transmissions box materials that have appeared within the past two decades, the present investigation seeks to broaden the field's understanding. Laterly, the papers were subsequently categorized in accordance with a predetermined set of factors based on their contents and farther by analysing such data, it was possible to identify & discuss significant discoveries related to triple stage gearbox materials. In addition; with a purpose of looking into various research designs and methodologies, study areas, tools and techniques, the aforementioned systematic review adopted a content evaluation approach accompanied by an inductive investigation paradigm. Undoubtedly, there nevertheless remain some potential issues (research study gaps) that require to be addressed even if there have been a lot of examination into the execution of triple stage helical gearbox concepts against other stages gearbox in industrial organisations due to some noteworthy benefits like higher & wide ranges of reduction ratio, lower strain on the coupling load and driveshaft, compact design and broad application areas etc. Furthermore, issues with multiple sectors making use of their particular triple step helical gearboxes, refining essential parameters as well as comprehending distinct causes for gearbox deterioration under

typical circumstances for stationary and/or changing loads farther call for optimisation of complex practical challenges by effectively recognizing and exploring multiple approaches to research design, methods, tools & techniques that can support academician in cutting edge research.

In an effort to fully comprehend a variety of concepts across research fields, this suggested broad examination (categorical analysis) provides a insight awarness of three stage helical gearbox study field which have expanded throughout a course of the last twenty years. Thus; the prospective scholars, paranormal investigators, academics, experts, specialists, legislators are able to employ the discovered study gaps and possible research possibilities as an initial step perspectives for advancing three stage helical gearbox research on materials. Put differently, the facts addressed above will act as motivation for the intended objectives while making it simpler to adopt a far more significant attention during subsequent research on triple step helical gearbox materials.

IV. RESEARCH REVIEW HIGHLIGHTS

This research review publication –

- Utilized a method of inductive research in conjunction with content analysis approach for carrying out a structured review of the literature.
- Recognized that regardless of the triple stage helical gearbox's numerous benefits over traditional stage gearboxes, very little prior research has been done on the subject especially materials used in the three step helical gearbox.
- Analyzed the currently utilized several identical studies areas, designs, strategies, tools & techniques used in existing research on triple stage helical gearbox.
- Determined key research discoveries, notable features, availability & lacking for broadening the aforementioned investigations on triple stage helical gearbox materials.
- Acknowledged the potential for futuristic research possibilities where studies can be refocused on three stage helical gearbox materials.

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