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Development of a CAD Modeling Automation Tool for Spur Gear Design in SolidWorks

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Abstract

For transferring the power from one shaft to another, the spur gear is frequently used component. Because of its extensive usage, the spur gear design needs to be made better continually. Hence, researchers always want to improve design quality by adopting new and better design methods. The effectiveness of the design process might be considerably increased by a knowledge-based system. This means that in order to automatically manage design and CAD (Computer-aided design) modelling challenges, a knowledge-based solution is required. This article provides a simple method for automatically developing the spur gear based on the primary design criterion inputs.

Keywords

Computer aided design, Modeling automation, SolidWorks, Spur gear design, Gear performance

Introduction

Shipbuilding, aerospace, architectural design, and automotive are a few industries that frequently use CAD as a tool. Creation of 3D models and/or 2D drawings of actual components for engineering reasons is a typical application of CAD throughout the full engineering process. This calls for customization in order to increase their efficiency. The intricacy of the design and the dearth of qualified individuals accessible for CAD modelling make modelling a time-consuming operation. Companies and experts alike are looking at alternative procedures. The present generation must customize and enhance CAD's effectiveness and productivity. To meet this demand, an engineering and design knowledge-based system (KBS) is crucial. When using parametric modelling, the issue statement or task may be developed quickly compared to using people. Using the dimension-driven parametric modelling approach, engineering analysis-based current designs may be automatically reused.

Spur gear

Spur gears possess teeth that are cut in a manner parallel to the shaft's axis, owing to their distinctive tooth shape. Due to their parallel tooth design, these gears are typically employed when working with parallel shafts. A consistent involute curve that covers the whole width of the gear is used to construct the tooth profile. Shafts often experience radial loads when spur gears are used. Figure 1 is the graphic outlining the Spur Gear nomenclature.

Developing a CAD model for a spur gear requires a significant investment of both time and effort, and specifications are routinely changed to accommodate client requirements. Automated modelling is therefore crucial. Parametric modelling, which enables automatic creation depending on specified characteristics,

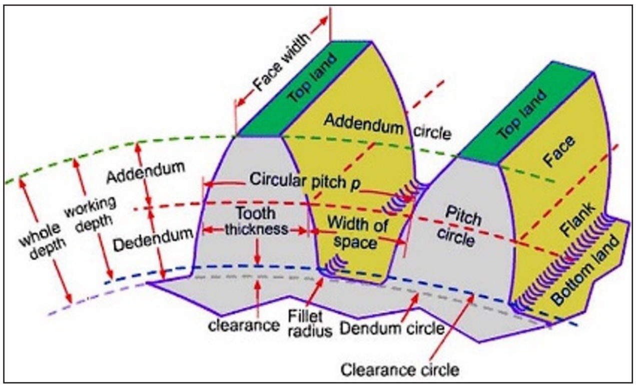

Figure 1: The spur gear's nomenclature [1].

is one sophisticated CAD modelling approach. Despite being a rapidly developing discipline, developing a knowledge-based engineering (KBE) framework through automation provides several benefits. Experts advise using specialized methods like KBS to speed up the modelling process [1]. This study suggests using a KBS to quickly create the spur gear's CAD model and saving important modelling time.

KBE model

One of the best examples of combining advanced design automation technologies is KBE, an engineering strategy that integrates CAD techniques with artificial intelligence technology [2-4]. The primary objectives of a KBE system involve processing product data, collecting data, simulating the engineering design process, and automating aspects of it through modeling. Computer-generated product models serve as internal representations of the product design and production processes. The emphasis is on delivering thorough data representation that faithfully represents the model's product. The KBE system's ultimate goal is to store priceless technical know-how and design techniques in a centralized knowledge base [3].

SolidWorks API

Using an Application Programming Interface (API), which entails incorporating code from one programming language into another application, different software programs can communicate with one another. To access the API's many methods, users can use Visual C++ 6.0, VB.NET, Visual Basic for Applications (VBA), Visual C#, and Visual C++/CLI. These techniques enable seamless access to SolidWorks functions such as drawing lines, integrating pre-existing components into a part, and verifying surface attributes. The modelling and assembly of components may be automated by utilizing the SolidWorks API. The SolidWorks API acts as a framework to arrange the program's features in a tree-like hierarchical structure [5-7].

Visual basic language

The computer language Visual Basic (VB), which Microsoft first released in 1991, is still quite popular today. It is well known for being user-friendly for beginners and having a quick turn-around for creating GUI (Graphical User Interface) windows programs. Additionally, the robust engine of VB enables the effective building of macros for many Microsoft programs. Likewise, VB has evolved into a versatile tool for generating a wide range of programming code, including code for applications such as SolidWorks [8].

Macros

A macro is a predefined set of instructions employed in computer science to dictate the transformation of an input sequence into an output sequence using specific techniques. Actively engaging with the model environment is crucial for improving the design automation process. CAD system users can employ macros to interact with the model environment via the system's API interfaces. Moreover, addressing real-world challenges often necessitates the sharing of data across diverse academic disciplines. In cases where commercial applications fall short of providing precise calculations, the development of advanced algorithms may become imperative [9].

Parametric modeling techniques

By specifying relationships and limitations between various parts and aspects of a design, parametric modelling approaches in CAD allow designers to construct 3D models. By enabling modifications to be made quickly and reliably, these strategies provide flexibility and efficiency in the design process. With the help of parametric modelling, you can swiftly experiment with different design iterations and adjust to changing project needs, ultimately saving time, and increasing design accuracy. By permitting the reuse of existing methodologies, this strategy enables speedy implementation of design modifications in accordance with current technical standards [10].

Objective of the work

The goal of this study is to provide an automated CAD modelling tool for SolidWorks spur gear design. The primary goal is to create a system that should be able to generate efficient and accurate spur gear's CAD models by significantly reducing the time required for this task compared to traditional manual methods. The integration of SolidWorks for CAD modeling, VBA for GUI development, and design calculations aims to streamline the gear design process and improve overall productivity. The automation tool's user-friendly GUI allows users to input gear specifications easily, making it accessible to a wider audience with varying levels of expertise in CAD modeling. Ultimately, the research aims to provide a practical and efficient solution for spur gear design, with the potential to enhance engineering and manufacturing processes in various industries.

According to numerous research papers, combining macro-programming with parametric modelling approaches is a potent method for obtaining exact and efficient solid form modelling. As highlighted in earlier research [3], these cutting-edge technologies are essential for streamlining the frequently complex modelling procedures, particularly when it comes to developing CAD-enabled models for spur gears [4].

Furthermore, the use of these technologies makes it possible to automate CAD modeling jobs, especially those that are repetitive in nature. These operations can be carried out using pre-defined algorithms or bespoke code [5]. Researchers like Cockerham and Waite [11] and Sun et al. [12] have recommended thorough techniques that smoothly integrate computer-aided manufacturing into spur gear design, providing an effective and organized approach to this field. Myung and Han [13] have proposed ground-breaking methods in the field of parametric modelling approaches with the goal of expediting the CAD modelling procedure and ultimately increasing productivity in design projects. Additionally, Xiong et al. [14] innovative method for developing dynamic gear models and performing structural analysis has opened up new avenues for the comprehension and improvement of gear mechanisms. Bakshe and Patil. [15] stress analyses on spur gears made of composite materials offer light on their functional behavior under various conditions, allowing for a deeper exploration of the performance elements of spur gears.

Nanotechnology application in spur gear design automation

As we know, the present market is looking at the development of the nanosized components for making the assembly to be more accurate and efficient. For this reason, the proposed system needs to address nanomaterials and nanotechnology. Here are some recent developments in CAD automation that took in creating spur gears with nanomaterials:

Integration of nanomaterial libraries

Libraries of nanomaterial properties have been implemented into CAD software tools as databases or libraries [12, 16]. Through this interface, engineers would be able to choose and use nanomaterials with particular properties immediately inside the CAD system, streamlining the material selection process. Large libraries of nanomaterial properties are now effortlessly included into sophisticated CAD automation tools [16]. The included nanomaterials are carbon nanotubes, graphene, nanostructured metals, nanocomposites, nano lubricants, nanocrystalline materials, nanostructured ceramics, quantum dots, nanofluids, functionalized nanoparticles, etc. Within the CAD environment, engineers can choose and apply nanomaterials with particular properties, such as increased strength, less friction, or improved thermal conductivity. By making material selection easier and assuring compatibility with specified gear performance characteristics, this simplifies the design process.

Material property predictions

Predictive modelling skills based on nanomaterial properties are included in advanced CAD automation systems like SolidWorks [17]. The CAD tool allowed engineers to enter desired gear performance criteria, and it then suggested the best nanomaterials and configurations to accomplish those objectives.

Simulation of nanomaterial effects

For gears enhanced by nanomaterials, CAD software will provide more sophisticated simulation capabilities [17]. Within the CAD environment, engineers might be able to see and evaluate how nanoparticles affect things like strength, wear resistance, and thermal qualities.

Automated nanomaterial coating designs

Designing automated nanomaterial coatings for gear surfaces is made possible by CAD automation technologies. The CAD system would produce the corresponding designs based on the type and thickness of nano-coatings needed for improved performance [18].

Customizable nanomaterial manufacturing

CAD automation can expand to incorporate features for producing gears using nanomaterials that can be customized. Setting parameters for 3D printing or other cutting-edge production techniques designed for the integration of nanomaterials could be a part of this.

AI-driven material selection

Using past performance data and precise design specifications, AI and machine learning algorithms can be included into CAD automation systems to suggest nanomaterials [19].

Integration of real-time material testing

CAD automation systems can include real-time testing information for nanomaterials. Engineers might obtain information from ongoing testing and experiments with nanomaterials, enabling them to make quick design changes based on the most recent findings.

Collaborative nanomaterial design

CAD automation platforms have cooperative tools that enable material scientists and engineers to collaborate easily on designs [19]. This could promote interdisciplinary cooperation to improve spur gear designs boosted by nanomaterials.

Similar to this, researchers using platforms like SolidWorks that take advantage of knowledge-based methods for CAD modelling and manufacturing, such as Kumar et al. [20], Thuniki et al. [21], and Esanakula et al. [22], have built optimized design frameworks. Collectively, this research advances the discipline of parametric modelling and its use in the creation and evaluation of spur gears.

KBS, which fall under the umbrella of AI, were developed to acquire human expert knowledge for decision support. By utilizing given inputs and parameters, this computer program enhances the chances of generating sustainable modeling and simulation software [23]. While parametric modeling of materials received significant attention, spur gear, an essential component of energy transmission systems, was comparatively overlooked. The authors suggest the necessity for a specialized automated CAD modelling system particularly for producing spur gears in light of the existing state of the market and research landscape. In conclusion, significant improvements in CAD modelling and manufacturing have been realized utilizing parametric modelling approaches to speed up production rates with the right inputs and cut down on modelling time. By analyzing geometric data inside pre-defined textual data, an automated CAD model may be generated when SolidWorks is used as a development tool using VB.

Experimentation

Modeling and automation

Nowadays, component part models are often created using commercial CAD software using traditional means. For modeling purposes, the software accepts text-based input data that may be processed by computer programs. This specific method was used to collect the initial information for the aforementioned article. To create such software, a variety of programming languages, including Lisp, C++, VBA, and others, are utilized, with VBA being regarded as the most advantageous. SolidWorks CAD software, which was used by the developers to create an autonomous spur gear CAD model, uses VBA as its programming editor. Additionally, the spur gear CAD model is generated automatically using macro code.

In order to produce the CAD model of the spur gear, the generated macro code must be manually imported into the SolidWorks program. Although this transfer process is begun by the user, it is often simple and may be finished by following a set sequence advised by the SolidWorks program. It's crucial to remember that depending on the CAD programme being used, the particular procedures involved in this transfer operation may change.

Generating GUI

Users of SolidWorks are given the ability to design and customize their GUI thanks to VB help. Figure 2 shows the unique GUI created for creating the CAD model of the spur gear, and figure 3 shows the gear production button. This user interface was painstakingly designed to effectively gather crucial data from the user before sending those inputs to the logical algorithm in charge of carrying out the design calculations.

Program for design calculations

As already stated, the suggested system uses methods of logical computation, allowing it to carry out design calculations through a particular function. For design calculation VB language has been used as it is built in SolidWorks software. It is difficult and time-consuming to manually calculate correct dimensions using typical empirical approaches. A computer programme for design calculations has been created to address this complexity. All complex design and computing chores pertaining to the spur gears' geometrical dimensions are handled by this programme. Then, using the program's output data, the SolidWorks software creates a CAD model based on the computed geometrical properties. The process is streamlined by this automation of design and modelling operations. Figure 4 shows the recommended system's process flowchart. The empirical formulas used for the design of the spur gear are given below:

$$\text{Diametral pitch} = \frac{1}{m} \quad (1)$$

$$\text{Pitch circle diameter} = \frac{\text{Number of Teeth}}{\text{Diametral Pitch}} \quad (2)$$

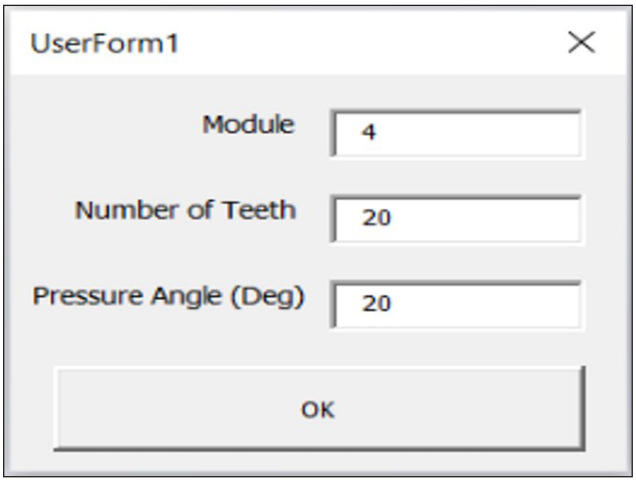

Figure 2: GUI for spur gear.

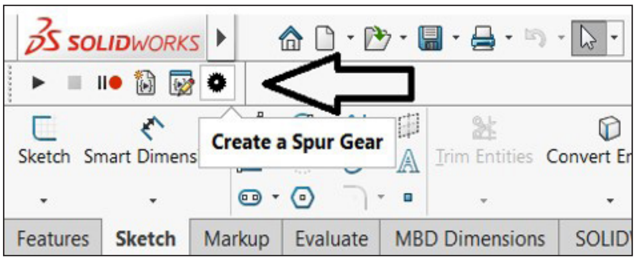

Figure 3: Spur gear CAD model generation button.

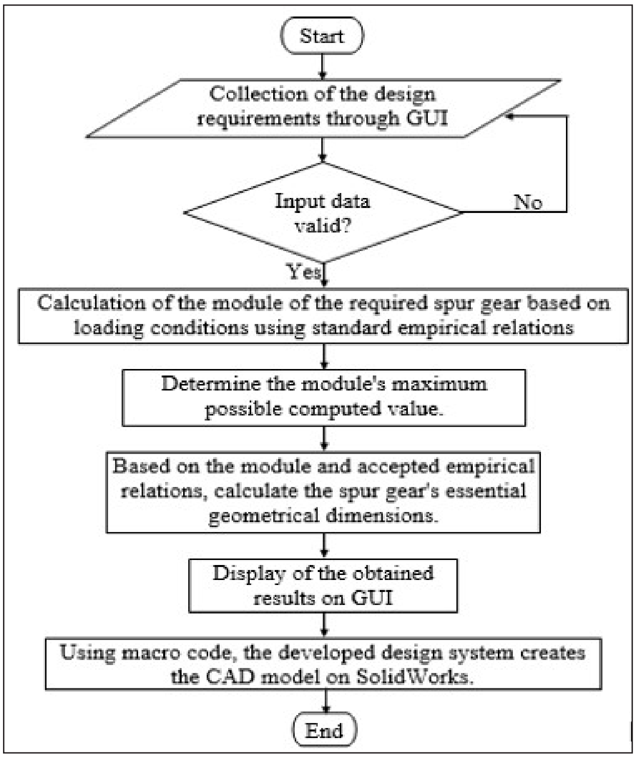

Figure 4: The suggested system's process flowchart.

$$\text{Base circle diameter} = \text{Pitch circle diameter} \times \cos(\theta) \quad (3)$$

Dedendum circle diameter = Pitch circle diameter − 2 x

$$\frac{1.25}{\text{Diametral Pitch}} \quad (4)$$

Addendum circle diameter = Pitch circle diameter + 2 x

$$\frac{1}{\text{Diametral Pitch}} \quad (5)$$

Where, Module = m; θ = pressure angle.

Results and Discussion

The proposed system has been successfully implemented and has shown promising results in terms of time efficiency compared to the manual CAD modeling process. This automation tool used SolidWorks for CAD modeling, VBA for GUI development and for incorporating essential design calculations. The proposed system has demonstrated its capability to generate the CAD model of a spur gear swiftly and accurately.

In this study, the proposed automation tool significantly reduced the time required for generating the CAD model of a spur gear. While the conventional manual approach typically takes human designers 150 - 200 h to complete the task [3], the developed system achieved the same results within a mere 15 sec based on the given input design data which is given in table 1. This substantial time-saving potential highlights the practical significance of the automation tool in the field of gear design and manufacturing.

By automating the gear design process, the tool reduces the dependence on manual efforts and minimizes the possibility of human errors, ensuring a more precise and reliable outcome. Furthermore, the GUI developed using VBA allows users to easily input the required parameters, streamlining the entire gear modeling process.

The accuracy and consistency achieved by the automation tool were also noteworthy. In comparison to traditionally constructed CAD models and the method described in the research [3, 7], the recommended process creates a CAD model with almost equal dimensional correctness. Through precise design calculations and SolidWorks' powerful modeling capabilities, the generated CAD models exhibited a high degree of conformity to the specified input values.

While the current implementation has delivered promising results, there might still be opportunities for further optimization and expansion of the tool's features. Additional validation and testing against real-world scenarios and varied gear specifications could enhance its robustness and reliability. Moreover, potential integration with other software and manufacturing processes could be explored to create a comprehensive and versatile gear design automation solution.

Table 1 presents an example of the input data used in the suggested system, while table 2 displays the output data, containing the dimensions of the spur gear, generated by the suggested system. The output of the proposed system, the spur gear, can be observed in figure 5.

Table1: Input data for the suggested system.

S. No.	Parameter	Value
1	Module	4
2	Number of teeth	60
3	Pressure angle	20°

Table 2: Dimensions of spur gear.

S. No.	Parameter (Diameter)	Value
1	Addendum circle	Ø 493 mm
2	Dedendum circle	Ø 456 mm
3	Base circle	Ø 447 mm
4	Pitch circle	Ø 476 mm

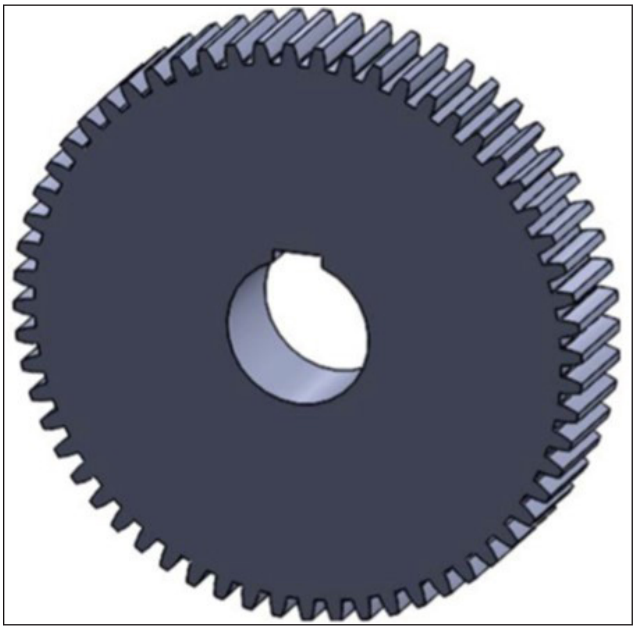

Figure 5: Proposed system generated CAD model of the spur gear.

The novelty of this research lies in the development of an automation tool that combines SolidWorks for CAD modeling, VBA for GUI development, and design calculations to generate CAD models of spur gears swiftly and accurately. The significant reduction in design time, from 150 - 200 h using manual methods to just 15 sec with the proposed system, showcases the innovation and practical impact of this research. The integration of a user-friendly GUI with macro code enhances usability, making it accessible to a broader audience and offering substantial advantages in gear design and manufacturing processes.

Conclusion

The use of a KBS to create a CAD model of a spur gear is suggested in this research. The VB and SolidWorks redevelopment technologies are used in this system. The design process is made reusable through the use of parametric modelling technology. The solution also has the benefit of being accessible from any computer having SolidWorks access. It distinguishes out as a practical and user-friendly tool. Notably, the proposed technique has demonstrated greater speed and efficiency in creating a CAD model of a spur gear when compared to traditional methods.

Acknowledgements

None.

Conflict of Interest

None.

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