International Journal of Engineering Trends and Technology
ISSN: 2231–5381 / https://doi.org/10.14445/22315381/IJETT-V72I3P111

Volume 72 Issue 3, 106-115, March 2024

Original Article

Automated CAD Modeling of Universal Coupling Components: A Case Study

Jayakiran Reddy Esanakula[1], G. Konda Reddy[2], D. Rajendra[3]

[1,2]Department of Mechanical Engineering, Sreenidhi Institute of Science and Technology, Hyderabad, Telangana, India.
[3]Department of Mechanical Engineering, School of Engineering and Technology, Sri Padmavati Mahila Visvavidyalayam, Tirupati, Andhra Pradesh, India.

[1]Corresponding Author : ejkiran@gmail.com

Received: 31 October 2023 Revised: 09 February 2024 Accepted: 19 February 2024 Published: 17 March 2024

Abstract - *The creation and application of an automated CAD modelling system for universal couplings are presented in this work. The system builds CAD models based on user-provided shaft diameter input by utilising Knowledge-Based Engineering (KBE), parametric modelling, Visual Basic for Applications (VBA), and macro code within the SolidWorks environment. Surprisingly, the technology completes tasks that previously took 176 to 249 man-hours in just 22 seconds, revolutionising CAD modelling productivity. We emphasize the system's significance as a game-changer in engineering design by talking about its geometric accuracy, user-centric design, and revolutionary potential.*

Keywords - *CAD modeling, Universal coupling, Automation, Design automation, Engineering design.*

1. Introduction

The universal coupling, a crucial mechanical element well-known for its adaptability and pervasiveness, is essential in many engineering applications. It is fundamental to systems that need the transfer of rotational motion via misaligned shafts, making it essential to the automobile, aerospace, industrial, and other sectors of the economy. The universal coupling has a well-deserved reputation as an engineering wonder due to its capacity to effectively and consistently transfer torque, even in situations of angular misalignment. Figure 1 shows the key components of Universal coupling and its assembly.

1.1. Universal Coupling

The mechanical elements known as universal couplings or universal joints are essential for many engineering applications. In situations when the alignment of two spinning shafts is imperfectly coinciding, they perform well. Their main job is to transfer rotational motion and torque while compensating angular misalignment between these non-collinear shafts, guaranteeing the efficient and effective functioning of machines. Driveshafts are commonplace in automobile engineering, where universal joints are used to transfer power from the engine to the wheels. Universal joints are essential for this application because they require the capacity to transmit torque while accommodating the movement of the suspension system. Beyond the car sector, universal couplings are necessary for a wide range of industrial applications, including those requiring precise motion control in heavy machinery, production equipment, aeroplanes, and other industrial uses. They are also useful in robotics and precision instruments, where they enable complicated motion in systems that need both flexibility and accuracy. To accommodate a range of uses, universal couplings come in a variety of designs, including single and double universal joints (also called Cardan joints). Despite the variety of uses, its essential goal—to allow the transfer of rotational motion across misaligned shafts—remains the same.

1.2. Role of Automation in CAD Modeling

Automation has evolved beyond its status as a convenience element in the modern engineering design landscape to become a crucial driving force behind productivity and creativity. No other field exemplifies this more than Computer Aided Design (CAD) modelling [2, 3].

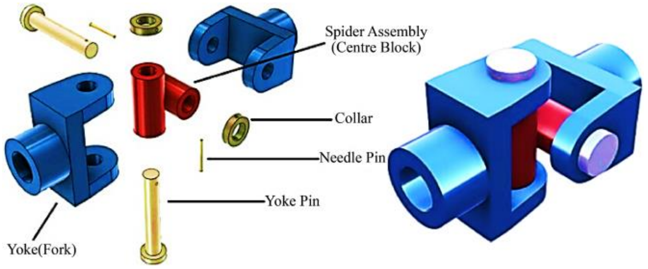


Fig. 1 Exploded view of universal coupling components and assembly [1]

Automation in CAD modelling is a revolutionary method that not only speeds up the design process but also improves its accuracy and guarantees compliance with the strictest design requirements. In the framework of this study, we explore the substantial influence automation has on the development of CAD models, paying special attention to intricate parts like universal couplings.

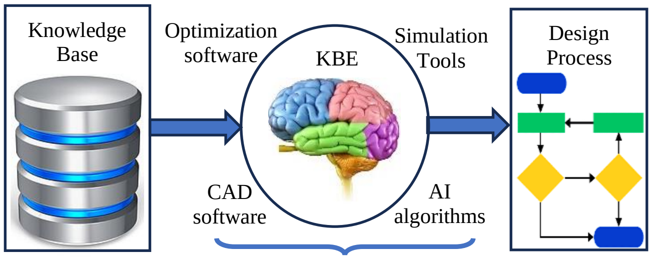
1.3. Knowledge-Based Engineering (KBE)

Our research project is underpinned by Knowledge-Based Engineering (KBE), which serves as its primary and guiding intelligence. This multidisciplinary strategy integrates the large human engineering experience pool with the computational power of contemporary technologies. KBE systems are fundamentally designed to record, organise, and formalise domain-specific knowledge. This information has been recorded throughout a broad spectrum, from basic engineering concepts and design guidelines to best practices and complex decision-making procedures. KBE is an approach to engineering that integrates tools for automation and explicit knowledge to speed up and improve the process of creating products. The architecture of the KBE is illustrated in Figure 2.

KBE is the compass that directs the system's design choices in the context of automated CAD modelling. It gives the system the ability to formulate exact design solutions based on a vast corpus of engineering knowledge. This information directs the system's decision-making about crucial design elements such as geometry relationships, material choices, and design constraints [4]. By incorporating KBE, the system is transformed from a simple computational tool to a knowledge-driven partner with the ability to coordinate complex design processes precisely.

1.4. CAD Modeling in SolidWorks

SolidWorks was used as our CAD modelling platform for strategic and practical reasons. Within the engineering world, SolidWorks is widely used and well-liked, and for good reason. It is an obvious choice for our research goals due to its extensive toolkit and strong capabilities.



KBE Benefits:

- Reduced design time
- Improved product quality
- Cost savings
- Increased innovation

Fig. 2 Architecture of the KBE

Particularly noteworthy are the parametric modelling capabilities of SolidWorks, which enable engineers to produce design models controlled by a set of variables and equations. We use this adaptability and parametric control as the foundation for automating CAD modelling procedures.

1.5. Design Automation

The idea of design automation is at the core of our study. Our suggested system's technology foundation is design automation. It represents the creation of systems with the ability to produce CAD models on their own based on user-defined parameters. Design automation speeds up and improves the accuracy of the design workflow by automating time-consuming and repetitive design operations. This lessens the possibility of human mistakes and guarantees that the produced CAD models adhere to the highest design requirements.

1.6. API and VBA

The effective usage of Application Programming Interfaces (APIs) and Visual Basic for Applications (VBA) is crucial for ensuring smooth user-CAD modelling system interaction. By bridging the gap between user input and CAD model development, these technologies act as the channels via which engineers may efficiently convey their design requirements to the CAD system. APIs offer standardised instructions and operations that let users communicate with SolidWorks programmatically. They stand for the vital connection between user-defined input parameters and the processing power of the CAD system. VBA, a flexible scripting language tightly linked with SolidWorks, gives engineers the ability to automate operations, alter design aspects, and create unique Graphical User Interfaces (GUIs) in conjunction with APIs. Together, these technologies provide a user-centric approach to design automation, where input parameters flow easily through the macro code of the system and automatically generate CAD models as a result.

1.7. Parametric Modeling

The generation of accurate and adaptive CAD models of universal coupling components is a crucial step in the process, and parametric modelling is a key element of our automated CAD modelling system. To define the links and dependencies between various design components, this modelling approach uses a collection of parameters, equations, and geometric restrictions. It allows for quick changes to design parameters, such as shaft diameter, length, or the number of connecting parts, without the need for manual reconfiguration. It allows us to capture the inherent diversity and flexibility in universal coupling components. Parametric modelling ensures that modifications are synchronised across all pertinent dimensions, features, and components by integrating design intent and restrictions within the model. This not only speeds up the modelling process but also improves the durability of our CAD models by making it simple to disseminate design changes throughout the entire system. In our method, parametric modelling serves as a conduit between user inputs and the later phases of our automated system, making it possible to produce highly customised and precise CAD representations of universal coupling components. Underscoring its relevance in revolutionising CAD modelling productivity within the engineering design domain is its function in capturing design intent and permitting quick adaptation.

1.8. Macro Code

The macro code, a carefully developed set of instructions that manages the complex dance of parameters, equations, and design principles, is at the heart of CAD modelling automation. By orchestrating user input, knowledge-based decision-making processes inside the system, and parametric modelling carried out within the SolidWorks environment, this code assumes the position of conductor. It serves as the glue that binds these disparate elements together, allowing for the seamless, automated, and highly accurate generation of CAD models.

2. Literature

This section presents an in-depth analysis of the current research on the automation of component design. A knowledge-based integrated strategy for optimising initial designs was investigated by Vinjanampati et al. [3]. They created a common product family architecture by merging Design Failure Mode and Effects Analysis (DFMEA), Design for Manufacturability and Assembly (DFMA), and the already-existing data. This method identifies crucial design components and applies CAD parametrization, sensitivity analysis, and automation of design scenarios using physics-based or hybrid models.

A hydraulic actuator case study serves as an example of how parametric linkages are established using the analytical Design of Experiments (DOE). A Knowledge-Based Automated Design (KAD) method for mechanical product design was introduced in 2021 by Xinjiani et al. [5]. The difficulty and expense of using specialised design methodologies are addressed by this methodology, also known as General Feature Design Flow (GFDF). It employs Case-Based Reasoning (CBR) and Support Vector Regression (SVR) to automate parameter solutions, even in the absence of direct expert input, and the Analytic Hierarchy Process (AHP) to quantify qualitative qualities. The KAD technique was used to develop maize huskers, which showed considerable improvements in automated, intelligent, and effective mechanical design. For quick component geometry development in additive manufacturing (AM), Manuel Biedermann et al. emphasises the use of automated design methods while minimising manual input [6]. The MOKA framework and a knowledge-based methodology are introduced in this paper, which also shows how this automated design process may be used to flow manifolds. Future studies could look at more extensive uses of automated design in AM for other fluid and process engineering devices. A knowledge-based automated mechanical design for a robot manipulator is presented by Robert et al. [7]. It is especially useful in situations involving fewer Degrees of Freedom (DOFs) or intricate industrial environments. They provide a technique for kinematic optimisation that blends real-element iterative selection with evolutionary algorithms. By bridging the gap between theoretical and practical kinematic designs, this method streamlines the design process. It demonstrates it by producing a five-DOF robotic arm for material handling between industrial machines that is both affordable and effective. In order to automate cube design, Dwaipayan Roy Chowdhury et al. [8] use a macro program-based approach in SolidWorks and VB.net.

This enables easy customization of cube sizes, materials, and colours. Similar to this, Balachandar Krishnamurty et al. [9] created a tool for pistons and connecting rods utilising macro scripts and the SolidWorks API, adding a user-friendly interface to make modelling and assembly easier. The design process is streamlined, and efficiency is increased thanks to these automated solutions that save time and money. A knowledge-based approach with the SolidWorks API and macro codes combined to speed up Spur Gear Design on previous study of this work.

An Inference Engine, a Graphical User Interface, and a Knowledge Base are all parts of their overall solution. Users or customers may access components more quickly because user-relevant data is saved in the interface. In contrast, standard component data and insights from design professionals are contributed to the Knowledge Base. A CAD system created by Andrijana Bocevska et al. [10] is specifically intended for designing specialised vehicle rims.

Engineers can model high-quality items more quickly and precisely using this CAD system since it makes use of macros in its user interface to promote user interaction. In the previous study of this work, automated CAD model development for a Universal Coupling using SolidWorks and its API framework. In contrast to traditional approaches, they used a knowledge-based approach to speed up modelling with small design changes, allowing for quick regeneration of parametric models. Joshi et al.'s [11] significant progress in automating CAD modelling for mechanical components led to a decrease in labour costs and time. The automation of a cotter joint design, which showed improved results and efficiency compared to typical human modelling, is an example of how their technique greatly boosted productivity, robustness, and overall quality. Utilising the SolidWorks Simulation Application Programming Interface, Rui Lyu et al.'s [12] main goal was to automate the simulation of vehicle chassis frame systems. With the flexibility provided by Visual Basic for changing material characteristics directly with macro codes, their method simplified the simulation process. Abhishek et al.'s [13] use of the SolidWorks Application User Interface to automate winding machine design led to an 80% time reduction in the development of a CAD model in under two hours. The large time and money savings realised through automation in complicated design processes were also demonstrated by this strategy, which resulted in cost reductions of up to 25%. For automated steering ball joint sizing, Necdet et al. [14] highlighted the efficiency of a "parametric design platform" inside a flexible design environment. This platform enables parametric change of a number of design parameters. It incorporates structured data throughout the product's lifespan, assuring accurate ball joint size and addressing safety-critical criteria in the automotive industry. According to the investigation of Purvesh et al. [15] on the Universal coupling, a slight change in the current design would greatly boost its strength and decrease its weight. The maximum stress values are significantly reduced, resulting in a uniform distribution of stress across the portion. By addressing numerous causes of component failure, the study seeks to decrease shear failure. Modifications to the pin design decrease von Mises stress from 704.71 MPa to 241.46 MPa and shear stress from 351.3 MPa to 120.04 MPa, thereby lowering the danger of shear failure. The other researchers [16-18] have also contributed to the betterment of universal coupling and, similarly, to automating CAD modeling. However, the method they used for this goal is not reliable for any of these techniques. Additionally, they are not entirely geared towards automation.

3. Methodology

The methodology section outlines the approach used to create and put into use the automated CAD modelling system for universal couplings. This section gives a thorough description of the seamless collaboration between Knowledge-Based Engineering (KBE), parametric modelling approaches, Visual Basic for Applications (VBA), and macro code to produce CAD models based on user-defined parameters, with an emphasis on shaft diameter.

3.1. Knowledge Capture

The journey starts with gaining information about a certain area. The system benefits from the experience of engineers and specialists in universal coupling design who have systematically codified their knowledge. This knowledge base covers design fundamentals, regulations controlling the interrelationships between design parameters, recommendations for material selection, and other crucial features of universal coupling design.

3.2. Rule-Based Engine

The rule-based engine is the brains of the system. This part transforms the codified information into useful design principles and reasoning for making decisions. The whole CAD modelling procedure, from parameter selection through geometry production, is governed by these guidelines. Every CAD model produced is guaranteed to follow industry standards and best practices by the rule-based engine.

3.3. Parametric Modeling Framework

The core of the CAD modelling process is parametric modelling. With shaft diameter as the user-specified input parameter, the system detects important design parameters. The size and connections of the CAD model are controlled by these parameters. The modelling framework incorporates parametric equations and constraints to make sure that any changes in the shaft diameter cascade through the whole model and uphold the integrity of the design.

3.4. GUI Development in SolidWorks

The main interface for user interaction in SolidWorks is the Graphical User Interface (GUI). It is made to be simple to use, intuitive, and responsive to user inputs. Users input crucial characteristics into the system using the GUI, such as shaft diameter, which forms the basis for the creation of CAD models.

3.5. Data Flow and Integration

The system processes the data after the user has provided it through the GUI. The CAD modelling technique centres on the shaft diameter value in particular. To dynamically build CAD models of universal coupling components, the system uses the information stored in the rule-based engine and parametric modelling framework. These parts, which are all made to fit the given shaft diameter, are the central block, fork, collar, taper pin, and pin.

3.6. Error Handling

The system's architecture includes reliable error-handling components. User inputs are painstakingly validated by the system to make sure they are within allowable bounds and ranges. The user receives educational feedback via the GUI in the event of erroneous input or system faults, directing them toward proper inputs or problem resolution.

3.7. Feedback Loop

The system's capacity to gather user feedback is a key feature. Users' insights and recommendations are crucial for system enhancement. The system may adapt and develop iteratively thanks to the feedback loop, increasing user happiness and improving the CAD models that are produced over time.

3.8. Testing and Validation

The technology is put through extensive testing to evaluate its effectiveness and precision. Extensive test cases are created to assess the system's capacity to produce CAD models that adhere to design standards. The accuracy and dependability of the system are ensured through comparisons with manually developed models and validation against industry standards.

3.9. Implementation and Deployment

The solution is smoothly integrated with the SolidWorks environment after passing testing and certification.

The implementation phase is accompanied by user training and thorough documentation, ensuring that engineers and designers can efficiently utilise the system's capabilities in their everyday workflow.

3.10. Performance Metrics and Evaluation

The effectiveness of the system is quantitatively assessed by gauging user happiness, design correctness, and time savings. These metrics offer concrete proof of the system's ability to automate CAD modelling while preserving accuracy and flexibility. A flowchart or block diagram illustrating the overall process of the proposed automated CAD modeling system is shown in Figure 3.

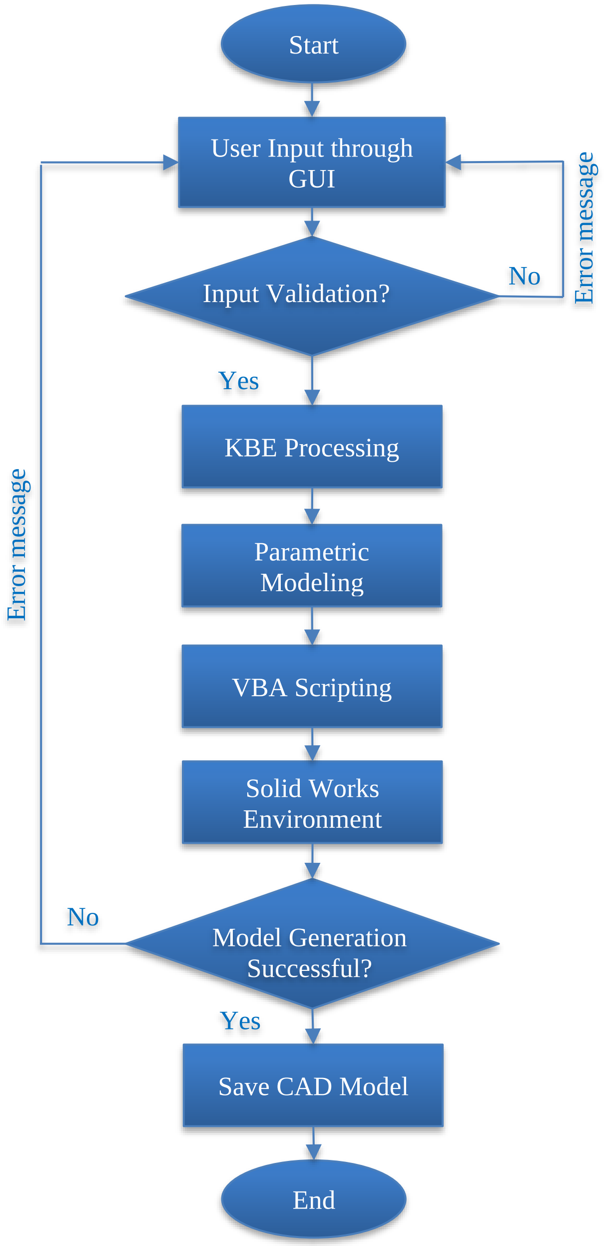


Fig. 3 Block diagram illustrating the overall process of the proposed system

4. System Implementation

We go into the technical details of creating and implementing the automated CAD modelling system for universal couplings in the System Implementation section. In order to produce CAD models based on user-provided shaft diameter input, this section discusses the practical application of Knowledge-Based Engineering (KBE), parametric modelling strategies, Visual Basic for Applications (VBA), and macro code within the SolidWorks environment.

4.1. Software and Technology Stack

The choice of appropriate software and technology forms the basis of the system. The solution is created within the SolidWorks environment, utilising its robust CAD modelling and design automation features. Important technologies are

- SolidWorks: The CAD modeling platform where the system is integrated.
- Visual Basic for Applications (VBA): The scripting language used for automation within SolidWorks.
- Macro Code: Custom-written code that orchestrates the CAD modeling process.
- GUI Development: The creation of a user-friendly interface within SolidWorks to gather user inputs.

4.2. GUI Development

The user's entry point into the system is the Graphical User Interface (GUI). It is made with the intention of being responsive, intuitive, and well-integrated with the SolidWorks environment. The GUI makes it easier for users to interact and input data, especially when specifying the shaft diameter, which is a crucial element for creating CAD models. The GUI developed for feeding the input data is shown in Figure 4.

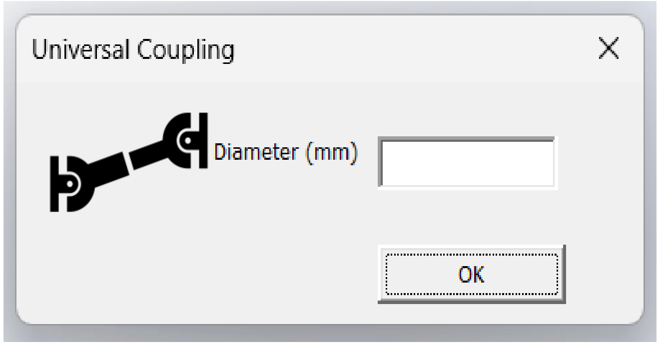
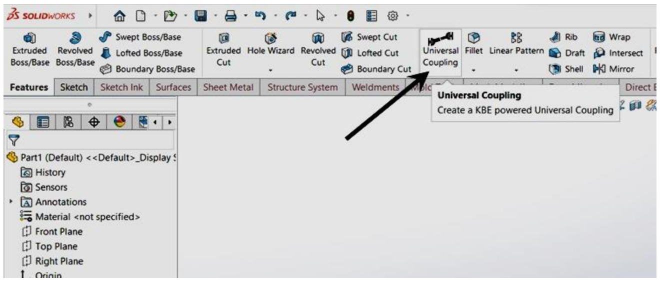


Fig. 4 GUI for universal coupling



Universal Coupling
Create a KBE powered Universal Coupling

Fig. 5 Macro Activation Button in SolidWorks

4.2.1 Integration of Macro Activation Button

A special button was carefully developed and added to the SolidWorks user interface in order to integrate our automated CAD modelling solution smoothly into the SolidWorks environment. This button is shown in Figure 5. This button is the entry point for running our macro code, which starts the quick creation of CAD models for universal coupling parts. The procedure entailed using Visual Basic for Applications (VBA's) flexibility to create a user-friendly interface component that fits with the SolidWorks ecosystem. Engineers and designers may easily activate our macro code thanks to the button's location within the SolidWorks environment, ushering in a paradigm shift in the efficiency of CAD modelling. This tactical integration demonstrates our dedication to giving engineers a simple, effective solution that allows them to fully utilize computerized CAD modelling for universal couplings.

4.3. Data Flow and Processing

When a user input is received through the GUI, the system carefully processes the data flow. The basis for creating CAD models is, in particular, the shaft diameter. This input is extracted and interpreted by the system, which then uses it as a driving parameter for the framework of parametric modelling.

4.4. Parametric Modeling Framework

The parametric modelling framework is at the heart of the system's CAD modelling capacity. This framework's primary focus on shaft diameter allows it to adjust to user-specified parameters dynamically. This framework contains parametric equations, design principles, and geometric connections. In order to ensure that the universal coupling components are made to suit the given shaft diameter, these equations are programmed to produce CAD models of those components.

4.5. Macro Code Execution

The CAD modelling process is orchestrated in large part by the macro code. It acts as a channel for the system's parts to communicate and work together. The rule-based engine is activated, parametric modelling is started, user inputs are interpreted, and CAD models are created under the macro code's supervision. It makes sure that the CAD models created follow the established design guidelines and criteria.

4.6. Error Handling and Feedback

The system's architecture includes reliable error-handling components. User inputs are extensively validated by the system to make sure they fall within allowable bounds. When a user enters incorrect data, or the system makes a mistake, the GUI provides them with helpful feedback. In addition to directing users toward legitimate inputs, this feedback aids in the system's continual improvement.

4.7. Integration with SolidWorks

For a unified and effective workflow, the system is smoothly integrated into the SolidWorks environment. SolidWorks interfaces are used by users to communicate with the system, improving usability and lowering the learning curve. SolidWorks must be modified as part of the integration process to work with the system's features, including the execution of macro and VBA scripts.Upon execution of the proposed system for the input data, i.e. 20 mm as the diameter of the shaft, the CAD model of the universal coupling is generated and is shown in Figure 6. The individual components of the generated universal coupling are shown in Figures 7 to 12.

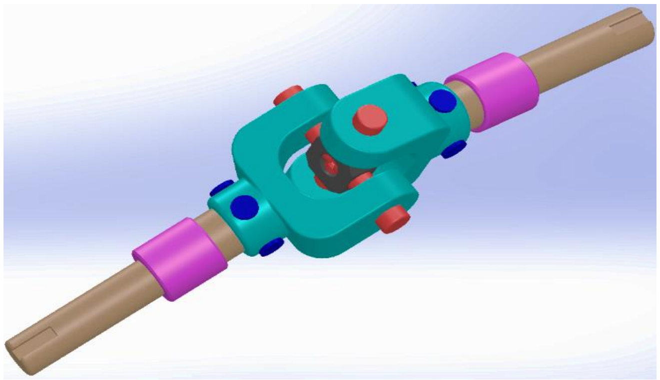


Fig. 6 Proposed system generated a CAD model of universal coupling

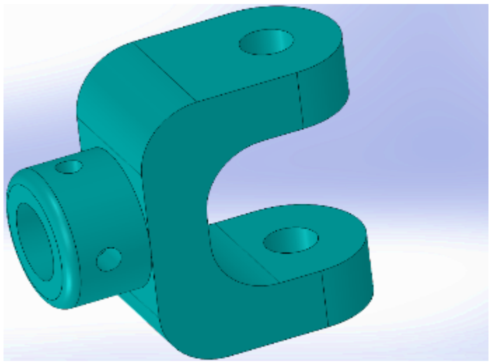


Fig. 7 Fork

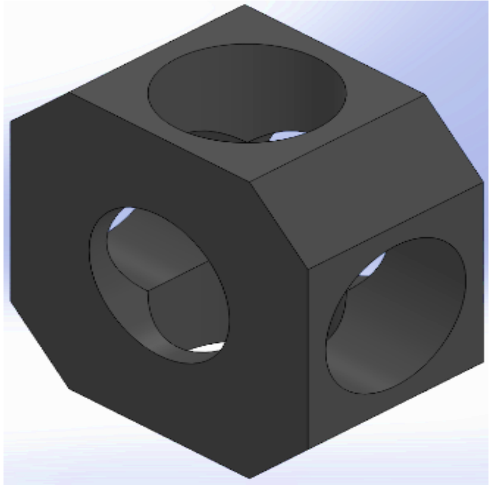


Fig. 8 Nut

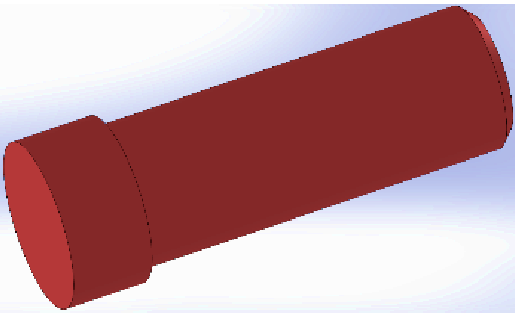


Fig. 9 Bolt

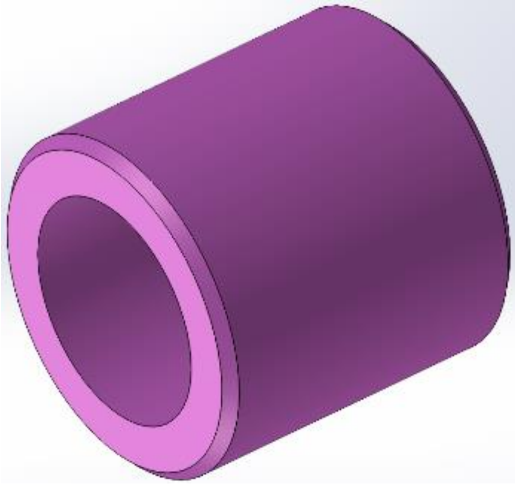


Fig. 10 Bush

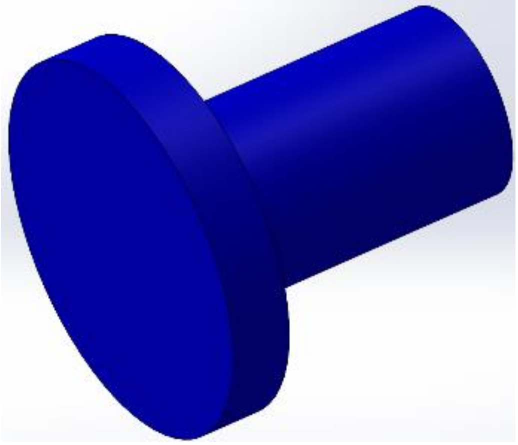


Fig. 11 Pin

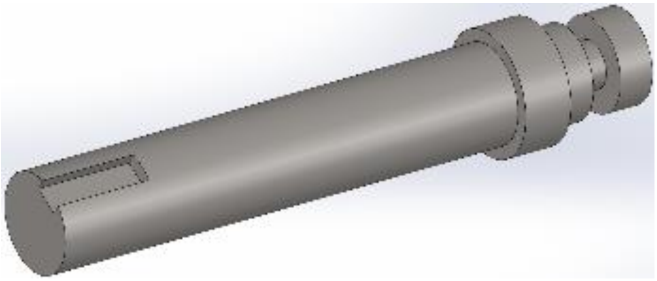


Fig. 12 Shaft

4.8. Testing and Validation

Thorough testing is done on the system to evaluate its reliability and performance. A carefully crafted set of test cases is used to assess the system's capacity to produce CAD models that adhere to design requirements. Comparisons with manually developed models and adherence to industry standards are also part of the validation process. The outcomes of these tests offer empirical proof of the system's accuracy and effectiveness.

4.9. User Training and Documentation

User training and thorough documentation are the results of a successful deployment. Engineers and designers receive training on how to use the system efficiently in their regular tasks. To ensure that users make the most of the system's capabilities, thorough documentation is provided with it.

5. Testing and Validation

An extensive testing and validation schedule was used to evaluate the functionality, accuracy, and effectiveness of our automated CAD modelling system for universal couplings. This part describes the thorough testing procedures, the validation procedure, and the outstanding time-saving accomplishments in comparison to conventional manual CAD modelling.

5.1. Testing Methodologies

In order to make sure that the generated CAD models adhered to exacting design standards and requirements, the performance of the system was examined across a number of dimensions throughout the testing process. Important testing techniques included:

- Functional Testing: Ensuring that the system's core functionalities, including user input, parameter-driven modeling, and CAD model generation, operated seamlessly.
- Parameter Validation: Validating the system's ability to interpret and adapt to user-provided parameters, with a specific focus on shaft diameter.
- Geometric Accuracy: Evaluating the geometric precision of the generated CAD models by comparing them to industry-accepted standards and manually created models.
- Error Handling: Rigorously testing the system's error-handling mechanisms, ensuring that it provided informative feedback in cases of invalid input or errors during the modeling process.

5.2. Validation Against Industry Standards

Comparing the system's performance to CAD modelling industry standards was one of the main criteria for certifying the system's performance. This required utilising our automated system to create CAD models of the universal coupling parts and evaluating them against generally acknowledged design criteria and tolerances.

5.3. Remarkable Time Savings

The time-efficiency comparison between our automated solution and conventional manual CAD modelling techniques produced the most startling result. The manual production of CAD models for universal coupling components generally takes 176 to 249 man-hours using the industry-standard technique, but our technology was able to complete the identical operation in just 22 seconds from the given input data (i.e. 20 mm is shaft diameter).

This dramatic decrease in the amount of time needed for CAD modelling is evidence of how automation has the power to revolutionise the industry. Our solution not only maintains accuracy and precision but also provides an unmatched advantage in terms of efficiency, allowing engineers and designers to devote their time and knowledge to more challenging and innovative areas of the design process.

5.4. User Feedback and Satisfaction

User opinions and satisfaction were crucial to the validation process in addition to quantitative testing. The system's usability, efficacy, and practical application were greatly improved by the engineers and designers who interacted with it. The system's design and functioning were greatly improved as a result of their input, further boosting its user-centric philosophy.

6. Results and Discussion

This section details the outcomes of our automated CAD modelling methodology for universal couplings, emphasizing the significant time savings compared to manual techniques. We also address the ramifications of these findings and the field's potential for transformation through automation.

6.1. Time Savings

The dramatic decrease in the amount of time needed for CAD modelling is the most convincing and quantitative result of our research. Traditionally, creating CAD models of universal coupling components required a time-consuming procedure that took between 176- and 249-man hours. In sharp contrast, our automated system completes this process in only 22 seconds thanks to Knowledge-Based Engineering (KBE), parametric modelling, Visual Basic for Applications (VBA), and macro code. This is a remarkable accomplishment in terms of time savings, revolutionising the rate at which CAD models may be created, improved upon, and iterated upon. The accompanying image shows a side-by-side comparison of CAD models created by our automated system and those created manually using conventional techniques. Our system's geometric correctness, conformance to design requirements, and consistency are obvious, highlighting its dependability and accuracy.

6.2. Discussion

The findings of our study redefine the potential of CAD modelling for universal couplings while also highlighting the power of automation. The discussion is focused on the following issues:

- Efficiency and Productivity: Our system's enormous time savings free engineering teams from the constraints of labor-intensive, repetitive work. Now that engineers and designers can focus their skills on more complex and imaginative design elements, overall productivity has increased.
- Accuracy and Consistency: By ensuring geometric accuracy and consistency between CAD models, the automated approach minimises the possibility of human mistakes that may occur during manual modelling.
- User-Centric Approach: User experience and satisfaction are prioritised by the user-friendly Graphical User Interface (GUI) and error-handling methods. User input is crucial for system improvement and refinement.
- Knowledge-Based Engineering (KBE): KBE is integrated to ensure that CAD models produced adhere to industry standards and best practices. This promotes informed design decisions.
- Iterative Refinement: The system's flexibility and ability to undergo iterative refinement place it in the position of a dynamic tool that changes in response to the needs of users and design specifications.

6.3. Future Prospects

The possibilities for automation in CAD modelling for universal couplings are positive when we consider the findings and implications of our study. Automation has the potential to revolutionise the engineering industry in ways that go beyond efficiency improvements. These include improved design quality, rapid innovation, and higher competitiveness.

7. Conclusion

Our automated CAD modelling solution for universal couplings represents a significant advancement in the field of engineering design with its development and implementation. The most important conclusions, contributions, and revolutionary potential of our technology in relation to CAD modelling for universal couplings are summarised in this section.

7.1. Key Findings

Our study's primary conclusions include the following:

- Remarkable Time Savings: The most noticeable result is the significant decrease in the amount of time needed for CAD modelling, with our technology doing what formerly took 176 to 249 man-hours in 22 seconds. The effectiveness of CAD modelling is revolutionised by this enormous time-saving accomplishment.
- Geometric Precision: Our system produces CAD models with unmatched geometric precision and consistency, which highlights the system's dependability and correctness.

- User-Centric Approach: User experience and satisfaction are prioritised by the user-friendly Graphical User Interface (GUI) and reliable error-handling methods. User input has been crucial in the system's improvement.
- Knowledge-Based Engineering (KBE): The incorporation of KBE guarantees that CAD models adhere to industry standards and best practices, promoting well-informed design decisions.

7.2. Contributions

Our study makes a substantial contribution to engineering design:

- Automation Revolution: The study shows how automation in CAD modelling has the power to revolutionise the industry. It frees engineering teams from labor-intensive chores so they may concentrate on innovation and creativity.
- Efficiency and Productivity: Our system's enormous time savings boost engineering departments' overall productivity and efficiency.
- Geometric Precision: The system guarantees consistent, precise CAD models, minimising the possibility of mistakes made by humans and design inconsistencies.
- User-Centric Design: User happiness and usability are prioritised through a user-friendly interface and responsive error management.

7.3. Possibility of Transformation

Our technology revolutionises the field of CAD modelling for universal couplings, making it more than just a technological improvement. Beyond time savings, its revolutionary potential includes:

- Design Quality: Automation ensures geometric accuracy and adherence to design standards, Enhanced producing CAD models of greater quality.
- Accelerated Innovation: By shifting their focus away from routine duties and towards innovative problem-solving, engineers may quicken the design iteration process.
- Competitive Advantage: By providing designs more quickly, more precisely, and in accordance with industry standards, organisations that adopt automation gain a competitive edge.

7.4. Future Scope

As we draw to a close, the future of CAD modelling for universal couplings clearly rests in automation, knowledge-based decision-making, and user-centric design. Future steps consist of:

- Integration with AI: Investigating the integration of machine learning and Artificial Intelligence (AI) to improve design automation and decision-making.
- Expanded Component Coverage: Increasing the system's capacity to accommodate a wider array of universal coupling parts and arrangements.
- Cross-Domain Applications: Applying automation and KBE principles to CAD modelling in different engineering areas.

In conclusion, the engineering design landscape has changed as a result of our automated CAD modelling solution for universal couplings.

Beyond efficiency improvements, it has the ability to revolutionize engineering by acting as a catalyst for creativity, accuracy, and competitiveness.

References

[1] Kanishk Yadav, and Harshit Jain, “Modeling and Finite Element Analysis of Universal Joint,” *Advancement in Mechanical Engineering and Technology*, vol. 4, no. 1, pp. 1-4, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[2] Alexander Ortner-Pichler, and Christian Landschützer, “Integration of Parametric Modelling in Web-Based Knowledge-Based Engineering Applications,” *Advanced Engineering Informatics*, vol. 51, pp. 1-13, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[3] Pavan Kumar Vinjanampati et al., “Knowledge-Based Integrated Parametric Product Design,” *10th SAE India International Mobility Conference*, United States, pp. 1-7, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[4] Tianyu Zhou et al., “Feature-Based Modeling for Variable Fractal Geometry Design Integrated into CAD System,” *Advanced Engineering Informatics*, vol. 57, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[5] Xinjiani Long et al., “A Knowledge-Based Automated Design System for Mechanical Products Based on a General Knowledge Framework,” *Expert Systems with Applications*, vol. 178, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[6] Manuel Biedermann, Patrick Beutler, and Mirko Meboldt, “Automated Knowledge-Based Design for Additive Manufacturing: A Case Study with Flow Manifolds,” *Chemistry Engineer Technology*, vol. 94, no. 7, pp. 939-947, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[7] Robert Pastor et al., “Knowledge-Based Automated Mechanical Design of a Robot Manipulator,” *Applied Sciences*, vol. 12, no. 12, pp. 1-14, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[8] Dwaipayan Roy Chowdhury, “Design Automation Methodology of a Cube Using Solidworks and VB.net,” *International Journal of Engineering Research & Technology*, vol. 9, no. 6, pp. 378-383, 2020. [Google Scholar] [Publisher Link]

[9] Balachandar Krishnamurty et al., “Macro Assisted Design Automation of Piston & Connecting Rod Using SolidWorks API,” *TEST Engineering & Management*, vol. 83, pp. 12964-12969, 2020. [Google Scholar] [Publisher Link]

[10] Andrijana Bocevska, Stefan Krsteski, and Snezana Savoska, “An Example of Application Design Using SolidWorks Application Programming Interface,” *Information Systems and Grid Technologies*, vol. 2656, pp. 159-166, 2020. [Google Scholar] [Publisher Link]

[11] Harshadeep Joshi et al., “Automated CAD Modelling of Mechanical Components,” *Advances in Intelligent Systems Research*, vol. 137, pp. 229-233, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[12] Rui Lyu, Otake Minoru, and Dongying Ju, “Application of Solidworks Application Programming Interface in Automobile Structural Analysis,” *Advances in Engineering Research*, vol. 141, pp. 690-694, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[13] Abhishek C. Lad, and A.S. Rao, “Design and Drawing Automation Using Solid Works Application Programming Interface,” *International Journal of Emerging Engineering Research and Technology*, vol. 2, no. 7, pp. 157-167, 2014. [Google Scholar] [Publisher Link]

[14] Necdet Geren et al., “Automated Sizing of Automotive Steering Ball Joints in Parametric CAD Environment Using Expert Knowledge and Feature-Based Computer-Assisted 3D Modeling,” *Advanced Engineering Informatics*, vol. 52, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[15] Purvesh Shah, and A.V. Patil, “Modeling & FEA of Universal Coupling of an Automobile Truck,” *International Journal for Innovative Research in Science & Technology*, vol. 3, no. 2, pp. 391-402, 2016. [Google Scholar] [Publisher Link]

[16] Abhishek Mandal, Utkarsh Sharma, and Harshit Pant, “Static Structural Analysis of Universal Joint to Study the Various Stresses and Strains Developed in Power Transmission Systems,” *International Journal of Engineering Research & Technology*, vol. 5, no. 3, pp. 144-146, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[17] Dhwani V. Sanghani, and Nayan. D. Gosvami, “Modeling & Analysis of Universal Coupling Used in Agro Industry,” *International Journal of Engineering Research and General Science*, vol. 3, no. 3, pp. 439-444, 2015. [Google Scholar] [Publisher Link]

[18] Yongming Wang, and Jiangtao Li, “UML Modeling and Parametric Design for Cross Shaft Universal Coupling CAD System,” *Journal of Software*, vol. 7, no. 9, pp. 2069-2075, 2012. [CrossRef] [Google Scholar] [Publisher Link]