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COMPREHENSIVE REVIEW OF SOLIDWORKS AND ANSYS FOR HYDRAULIC MACHINERY DESIGN AND ANALYSIS

An in-depth analysis of current computer-aided design (CAD) and systems engineering analysis (CAE) software is presented, focusing on SolidWorks and ANSYS. Particular attention is paid to their use in the design and analysis of hydraulic machines, where these tools play an essential role in the development of turbines, pumps, and other components. SolidWorks stands out as the leading tool for creating 3D models of hydraulic assemblies, allowing engineers to optimize designs and reduce hydraulic losses early in the design process. In addition, SolidWorks offers a user-friendly interface and powerful modeling capabilities, allowing you to perform fundamental analyses in a hydraulic simulation environment. A review of the widely used ANSYS program, recognized as a tool for performing complex engineering analyses covering a wide range of physical phenomena, including thermal, mechanical, electromagnetic, and hydrodynamic processes, is performed. The multiphysics capabilities of ANSYS allow engineers to model complex interactions of physical phenomena in a single simulation environment, which is especially important for tasks such as designing power plants or hydro turbines. A comprehensive review of simulation features, including Finite Element Analysis (FEA) and flow modeling, is performed to provide early detection of design problems. The application of ANSYS is proposed for the in-depth analysis of hydrodynamic phenomena occurring in turbines during their operation, which allows the optimization of the geometry of the blades and reduces the risk of cavitation. Furthermore, it is emphasized that integrating both software packages creates a powerful toolkit for engineers, allowing them to combine design and analysis in a single workflow. It is concluded that effective use of SolidWorks and ANSYS can significantly improve the quality of hydraulic machine development, reducing design time and increasing reliability. The article also provides practical examples of the use of these programs in real projects, demonstrating their effectiveness and impact on engineering solutions in the field of mechanical engineering.

Keywords: SolidWorks, ANSYS, hydraulic machines, design, computational fluid dynamics, numerical research.

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КОМПЛЕКСНИЙ ОГЛЯД SOLIDWORKS ТА ANSYS ДЛЯ ПРОЄКТУВАННЯ ТА АНАЛІЗУ ГІДРАВЛІЧНИХ МАШИН

Представлено глибокий аналіз сучасного програмного забезпечення для систем автоматизованого проєктування (CAD) та систем інженерного аналізу (CAE), з акцентом на SolidWorks та ANSYS. Особливу увагу приділено їх використанню в проєктуванні та аналізі гідравлічних машин, де ці інструменти відіграють важливу роль у розробці турбін, насосів та інших компонентів. SolidWorks виділяється як провідний інструмент для створення 3D-моделей гідравлічних агрегатів, що дозволяє інженерам оптимізувати конструкції та зменшувати гідравлічні втрати на ранніх етапах проєктування. Крім того, SolidWorks пропонує зручний інтерфейс і потужні можливості симуляції, дозволяючи виконувати базові аналізи безпосередньо в середовищі моделювання гідравлічних систем. Виконано огляд широко використовуваної програми ANSYS, що визнаний як інструмент для виконання складних інженерних аналізів, які охоплюють широкий спектр фізичних явищ, включаючи теплові, механічні, електромагнітні та гідродинамічні процеси. Мультифізичні можливості ANSYS дозволяють інженерам моделювати складні взаємодії фізичних явищ в єдиному середовищі симуляції, що є особливо важливим для таких завдань, як проєктування енергетичних установок або гідротурбін. Виконано всебічний огляд функцій симуляції, які включають аналіз кінцевих елементів (FEA) та моделювання потоків, що забезпечує раннє виявлення потенційних проблем у конструкції. Запропоновано застосування ANSYS для глибокого аналізу гідродинамічних явищ, що відбуваються в турбінах під час їх експлуатації, дозволяючи оптимізувати геометрію лопатей та зменшувати ризик кавітації. Додатково, підкреслено, що інтеграція обох програмних комплексів створює потужний інструментарій для інженерів, дозволяючи їм поєднувати проєктування та аналіз у єдиному робочому процесі. Зроблено висновок про те, що ефективне використання SolidWorks та ANSYS може значно покращити якість розробки гідравлічних машин, зменшивши час на проєктування та підвищивши їх надійність. У статті також представлено практичні приклади використання цих програм у реальних проєктах, що демонструють їх ефективність та вплив на інженерні рішення в галузі машинобудування.

Ключові слова: SolidWorks, ANSYS, гідравлічні машини, проєктування, обчислювальна гідродинаміка, чисельне дослідження.

Introduction. The continuous development of modern technology is transforming every industry, and computer-aided design (CAD) is no exception. Computer-Aided Design and Computer-Aided Engineering (CAE) systems have become indispensable tools for engineers, designers, and researchers, playing a crucial role in the innovation and optimization of products and processes. This article reviews modern CAD and CAE programs, focusing on SolidWorks and ANSYS, their capabilities, advantages, applications, and critical role in hydraulic machinery and hydro turbine construction.

Modern CAD and CAE programs, such as SolidWorks and ANSYS, play a crucial role in designing and analyzing hydraulic machines, including hydraulic turbines and pumps. These tools allow engineers to create complex models, optimize designs, and conduct detailed performance analyses of hydraulic systems. In hydro turbine engineering, SolidWorks is used for the 3D modeling turbine components, such as runner blades and guide vanes, ensuring high precision during the design phase. Meanwhile, ANSYS performs complex calculations, including fluid flow and thermal process analysis, which are critical for improving turbine efficiency under various operating conditions.

SolidWorks: A Versatile Tool for 3D Design. SolidWorks is one of the most widely used CAD programs globally, especially in hydraulic engineering and hydro turbine construction. Its user-friendly interface (Fig. 1) and comprehensive tools allow engineers to efficiently design complex hydraulic components such as turbine blades, casings, and guide vanes. For example, SolidWorks enables precise parametric modeling of runner blades in hydraulic turbine development, helping optimize their shape for improved fluid flow. This precision ensures efficient energy conversion in hydraulic turbines under various operational conditions [1–7].

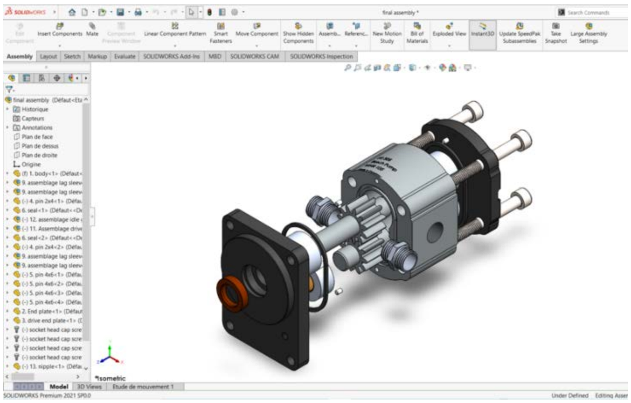

Fig. 1. SolidWorks Interface

Key Features of SolidWorks. 1. Parametric Solid Modeling: SolidWorks's core is its parametric solid modeling capability, which allows designers to create highly detailed parts and assemblies with exceptional precision. This feature is crucial in hydraulic machine design, such as for hydraulic turbines and pumps, where the geometry of components like turbine blades and casings needs to be optimized for maximum efficiency. The parametric design tools in SolidWorks make it easy to modify critical parameters, such as dimensions and angles, ensuring efficient iterative design processes. Engineers can quickly adjust designs to achieve optimal fluid dynamics and performance in hydraulic turbine construction. Parametric solid modeling in SolidWorks also facilitates the integration of design changes across complex assemblies, ensuring that all components remain coherent and functional throughout the iterative process. This capability is particularly beneficial in hydraulic machinery, where even minor adjustments can significantly impact overall system performance and efficiency [1–7].

2. Surface and Sheet Metal Design: SolidWorks also offers advanced tools for surface and sheet metal design (Fig. 2), essential in creating complex hydraulic components such as turbine housings and pump parts.

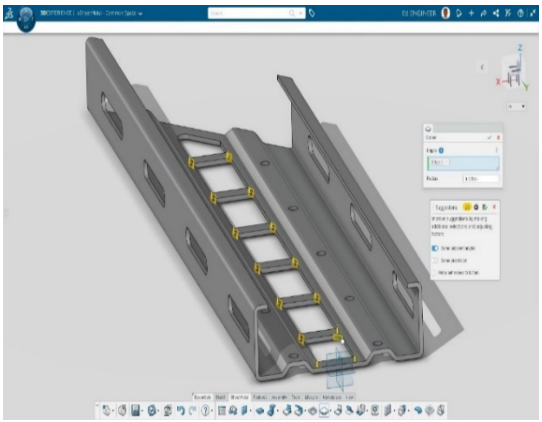

Fig. 2. 3D Sheet Metal Creator

These tools allow engineers to develop intricate bent shapes and ensure manufacturability by producing accurate flat patterns, particularly useful in the hydropower industry. The sheet metal features in SolidWorks streamline the production process, ensuring that designs meet the specifications for structural integrity and efficiency. Additionally, these tools enable engineers to quickly test and simulate the bending and folding processes, reducing the risk of material waste and ensuring that components will fit precisely during assembly, which is particularly beneficial when designing large-scale components for hydraulic turbines, where minor discrepancies can significantly affect performance and durability under operational loads [7].

3. Simulation Capabilities: Although primarily known as a CAD tool, SolidWorks includes built-in simulation features that allow for fundamental finite element analysis (FEA), motion studies, and thermal simulations. These tools are critical during the early stages of hydraulic machinery design, providing preliminary insights into how turbine blades, pump housings, and other components will perform under operational conditions. This initial analysis helps engineers identify potential performance issues before moving to more advanced simulations in ANSYS, ensuring the design meets structural and thermal requirements.

4. Collaborative Design and Data Management: SolidWorks facilitates collaboration among engineering teams with its Product Data Management (PDM) system. This system allows for efficient design data management, revision control, and real-time updates, which are essential for large-scale hydropower and hydraulic machinery projects. Multiple engineers can work simultaneously on different project parts, such as a turbine runner or a guide vane system, ensuring that all designs are consistent and up-to-date. This feature is handy in constructing complex hydraulic systems, where teamwork and data accuracy are vital [7].

5. Extensive Library of Standard Components: SolidWorks includes a comprehensive library of standard components, such as fasteners, bearings, and seals, frequently used in hydraulic machinery. This library speeds up the design process by allowing engineers to quickly integrate pre-designed, industry-standard parts into complex hydraulic systems, ensuring compatibility and reliability. Using these standardized components for hydraulic turbines and pumps reduces design time and ensures compliance with industry standards, making the final product more reliable and easier to maintain [7].

Applications of SolidWorks. SolidWorks is widely used across various industries, including automotive, aerospace, consumer products, and industrial equipment. However, its versatility makes it an essential tool for designing and developing hydraulic machinery, especially in the hydropower sector, where precision and efficiency are crucial.

1. Hydraulic Turbine Design: In the hydropower industry, SolidWorks is extensively used for designing critical components of hydraulic turbines (Fig. 3, 4), such as runner blades, guide vanes, and casings. The software's ability to handle complex assemblies makes it ideal for engineers working on large-scale hydropower projects, where all components must fit together seamlessly to ensure optimal energy conversion and efficiency. By utilizing SolidWorks, engineers can create detailed 3D models that allow for precise fluid dynamics analysis

within turbines, helping minimize hydraulic losses and improve overall performance [7].

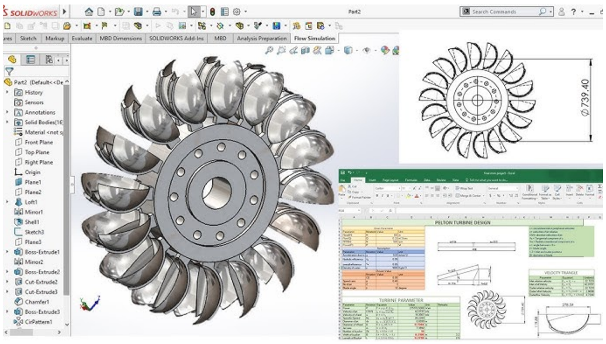

Fig. 3. 3D model of a Pelton turbine designed in SolidWorks

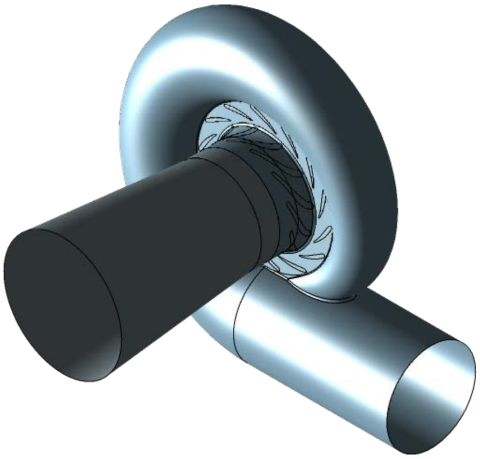

Fig. 4. 3D model of a Francis turbine designed in SolidWorks

2. Pumps and Fluid Handling Systems: SolidWorks is also applied in designing pumps and other fluid handling systems critical in water management and hydraulic infrastructure. Its ability to model complex flow paths and optimize mechanical components ensures that pumps operate efficiently under a wide range of fluid conditions. Engineers use SolidWorks to design high-precision pumps, reducing the risk of cavitation and other performance issues. Additionally, the software allows for the integration of standard components, simplifying maintenance and ensuring reliability in fluid handling systems.

3. Hydropower Station Equipment: SolidWorks is widely used to design industrial equipment for hydropower stations, including turbines, valves, and piping systems. The software's simulation capabilities allow engineers to test equipment under real-world conditions, such as varying water pressures and flow rates, ensuring that the designs meet the necessary durability and safety requirements and optimizing performance to reduce energy losses in power generation systems.

4. Industrial Hydraulic Systems: SolidWorks is also used to design hydraulic systems in industrial machinery and its application in hydropower. Engineers rely on the software's 3D modeling and simulation tools to create exact and reliable machinery, even in harsh working conditions. SolidWorks' ability to simulate the interaction between hydraulic components and fluid flow ensures that industrial hydraulic systems perform efficiently and are durable enough for long-term use in demanding environments [8].

ANSYS: Advanced Simulation and Engineering. ANSYS is a leading CAE software suite that analyzes and optimizes hydraulic machines like turbines. The software offers powerful_simulation tools for assessing fluid flow, thermal performance, and structural integrity of hydro turbine components under real-world conditions. For instance, in the design of Francis and Kaplan turbines, ANSYS enables engineers to simulate complex fluid dynamics within the turbine's flow path, optimizing efficiency and reducing hydraulic losses. Additionally, ANSYS helps ensure the structural durability of turbine blades by analyzing stress distribution under varying operational loads [9–11].

Key Features of ANSYS. 1. Finite Element Analysis (FEA): ANSYS is renowned for its powerful FEA capabilities, which allow engineers to analyze the structural integrity of their designs under different loads and constraints (Fig. 5). This feature is essential in industries where safety and reliability are paramount, such as aerospace and civil engineering.

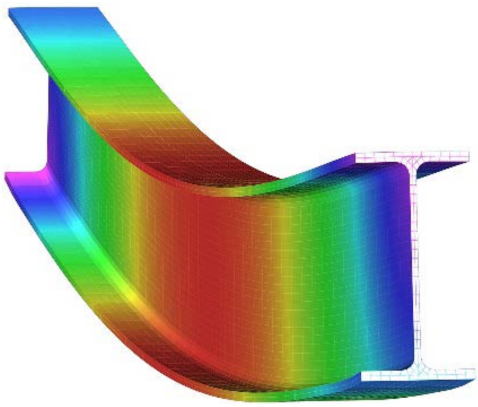

Fig. 5. FEA process in ANSYS with a multi-colored visualization of the stress and strain distribution on the model

2. Computational Fluid Dynamics (CFD): ANSYS includes advanced CFD tools that enable engineers to simulate fluid flow, heat transfer, and chemical reactions under different conditions [10]. These tools are invaluable in industries like automotive and aerospace, where optimizing aerodynamics and cooling systems is essential.

In the hydropower sector, CFD tools simulate water flow through hydraulic turbines (Fig. 6), allowing engineers to optimize blade geometry and reduce hydraulic losses. ANSYS CFD helps improve turbine efficiency and ensures that designs can handle varying flow conditions without performance loss. Additionally, CFD is essential for identifying potential cavitation zones and optimizing cooling systems in hydropower plants, ensuring efficient thermal management in high-power environments.

Furthermore, ANSYS CFD allows for the simulation of unsteady fluid flow, enabling engineers to analyze transient phenomena like pressure surges and flow oscillations, which are critical in maintaining the stability and safety of hydraulic systems.

3. Electromagnetic Simulation: ANSYS provides tools for simulating electromagnetic fields (Fig. 7),

essential for designing electronic devices, antennas, and power systems. These simulations help ensure designs meet regulatory requirements and perform as expected in real-world conditions [10].

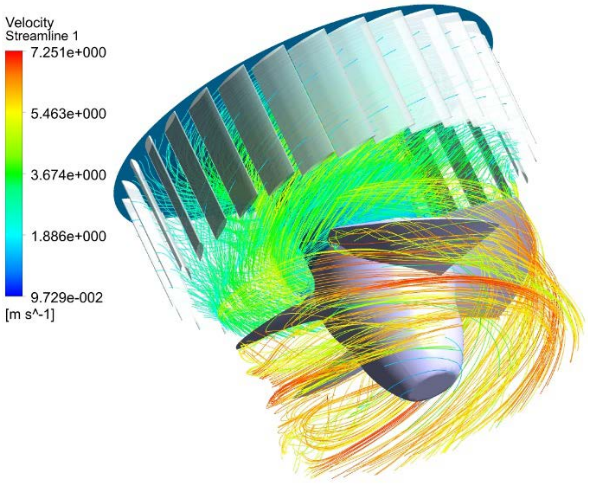

Fig. 6. Velocity distribution visualization in a Kaplan turbine using ANSYS CFD

4. Multiphysics Simulation: One of the standout features of ANSYS is its ability to perform multiphysics simulations (Fig. 8), where different physical phenomena are analyzed simultaneously. For example, engineers can simulate how a structure will behave under thermal stress while considering the effects of fluid flow and electromagnetic fields [10].

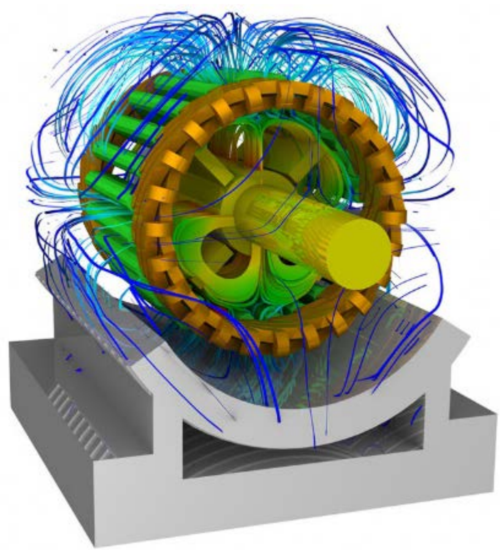

Fig. 7. Visualization of electromagnetic fields around an electronic device

5. Optimization and Design Exploration (Fig. 9): ANSYS includes tools for exploration and optimization, allowing engineers to identify the best design parameters to meet performance criteria [7]. This feature helps reduce the time and cost associated with prototyping and testing.

Applications of ANSYS. ANSYS is widely used across various industries to ensure that designs perform as expected under different conditions, and its advanced simulation capabilities make it an essential tool for engineers working on complex hydraulic projects. ANSYS's versatility is especially valuable in hydropower and fluid dynamics applications, where precise simulations of fluid flow, structural integrity, and thermal behavior are critical [9–12].

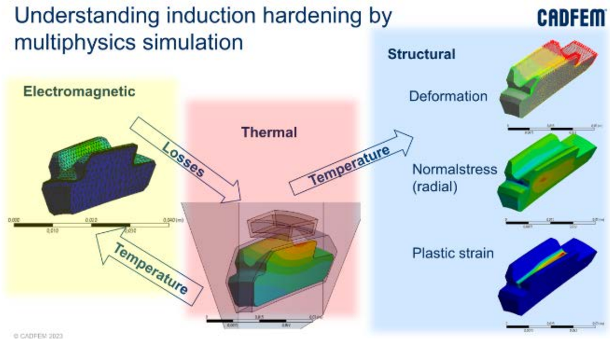

Fig. 8. Complex model showing the effects of thermal, mechanical and fluid processes simultaneously

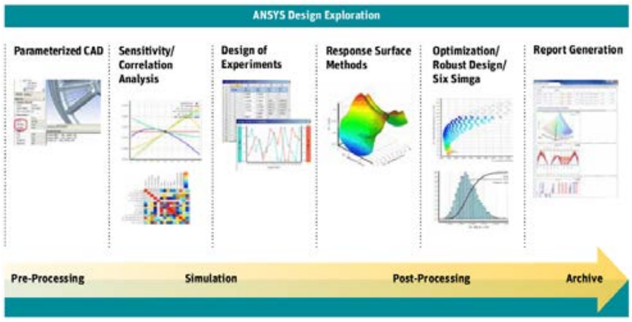

Fig. 9. Process of optimizing design parameters using ANSYS

- Hydraulic Turbine Engineering: In the design of hydraulic turbines, ANSYS is used to simulate fluid dynamics and structural integrity under operational loads. Engineers use ANSYS to optimize the performance of turbine blades and guide vanes by analyzing the effects of water flow and pressure distribution, which helps reduce hydraulic losses, improve efficiency, and ensure that turbine components withstand the stresses of high-speed water flow [1–3].

Additionally, ANSYS simulations help mitigate cavitation risks, which is a critical factor in prolonging the lifespan of hydraulic turbines [10];

- Pumps and Fluid Handling Systems: ANSYS plays a vital role in designing and analyzing pumps and fluid handling systems in the water management and industrial sectors. Engineers use ANSYS's Computational Fluid Dynamics (CFD) tools to optimize pump performance by analyzing flow characteristics and minimizing energy losses due to turbulence or cavitation, ensuring that pumps operate efficiently under varying fluid conditions, contributing to improved energy conservation and system reliability [2];

- Energy and Power Systems: In the energy sector, ANSYS is utilized to optimize the design and performance of hydropower plants, wind turbines, and solar energy systems. Its simulation tools help engineers assess turbines' thermal and structural performance under different operating conditions, such as fluctuating water flow or environmental changes. These analyses ensure energy generation systems' long-term reliability and efficiency. Additionally, ANSYS enables the integration of multiple physics (fluid, thermal, and structural) in a single simulation, which is vital for comprehensive hydropower system design;

- Civil Engineering: ANSYS is also employed in civil engineering for the design and safety analysis of hydraulic structures such as dams, reservoirs, and water channels. Its simulation capabilities allow engineers to model the effects of fluid pressure, wind, and seismic activity on these structures, ensuring their durability and safety in varying environmental conditions, which is especially important in hydropower stations, where dam integrity is critical for energy production and public safety [10].

Generative Design and AI Integration. Generative design and AI integration are transforming how hydraulic machines are designed, with SolidWorks and ANSYS providing advanced tools to optimize the development process (Fig. 10). In hydraulic engineering, AI-powered generative design can automatically generate and test multiple design iterations for turbine components such as impellers and diffusers, significantly reducing material usage and increasing efficiency. ANSYS plays a crucial role in simulating and validating these AI-generated designs, ensuring they meet performance criteria in real-world conditions, especially for optimizing the hydraulic performance of turbines [10–12].

In generative design workflows, engineers input key design constraints, such as load requirements and material limits, while the AI algorithm generates multiple potential solutions. These designs are then analyzed using ANSYS to evaluate structural integrity, fluid dynamics, and thermal performance. This ensures the final design meets operational criteria and is optimized for material usage and manufacturing efficiency. This iterative process is precious in hydraulic turbine design, where minimizing material use and maximizing performance are critical factors.

ANSYS's simulation capabilities complement generative design by enabling detailed evaluations of AI-generated models. Engineers can simulate complex interactions, such as water flow over turbine blades or thermal stresses within hydraulic components, ensuring that designs are efficient but also robust and reliable under real-world conditions. Integrating generative design with advanced simulations enables engineers to create highly innovative hydraulic machines that push the boundaries of traditional design methods.

Meanwhile, ANSYS Cloud provides scalable computational resources for running large-scale simulations of hydraulic turbines, such as analyzing fluid flow and stress across turbine blades and casings. This combination allows engineers to optimize hydro turbine performance remotely, reducing design cycles and enhancing project coordination [10–12].

Advanced Applications of SolidWorks and ANSYS in the Design and Analysis of Hydraulic Machines. SolidWorks and ANSYS are indispensable for developing hydraulic machinery, including pumps, compressors, and hydraulic turbines. SolidWorks is primarily utilized to create intricate 3D models, allowing engineers to optimize fluid pathways and mechanical components with high precision [9]. The parametric design features of SolidWorks enable fast iterations, making it easier to adjust critical components and enhance machine performance during the early design stages [3]. ANSYS, in turn, provides advanced simulation capabilities such as computational fluid dynamics (CFD) and structural analysis, which are critical for understanding how these machines will behave under various operating conditions, including extreme pressures and high fluid velocities. By integrating these two tools, engineers can predict and mitigate potential issues like cavitation or material fatigue, ensuring the efficiency and reliability of hydraulic machines. This workflow reduces the need for physical prototyping and shortens the time to market, especially in industries like renewable energy and water management.

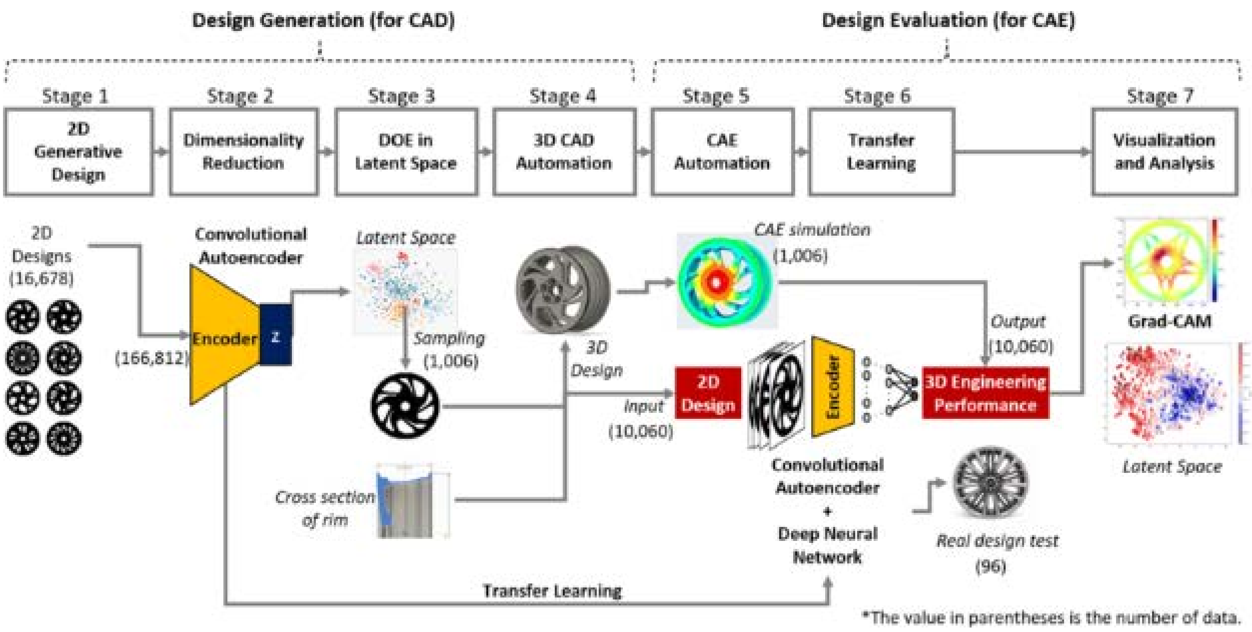

Fig. 10. Generative design and AI integration

Conclusions. Integrating SolidWorks and ANSYS in the design and analysis of hydraulic machinery, particularly hydraulic turbines, represents a significant advancement in modern engineering practices. SolidWorks's intuitive 3D modeling capabilities enable engineers to efficiently create detailed designs of complex hydraulic components such as runner blades, casings, and guide vanes. The parametric modeling features of SolidWorks allow for rapid design iterations, enabling engineers to make quick adjustments during the early stages of development, which is crucial for optimizing the efficiency and reliability of hydraulic machines.

On the other hand, ANSYS plays a pivotal role in the simulation and validation of hydraulic machinery designs. Its advanced capabilities in computational fluid dynamics (CFD), structural analysis, and thermal management provide engineers with detailed insights into how hydraulic turbines and other machinery will perform under real-world conditions.

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