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Computer-Aided Automotive Design and Development

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Abstract: The recent surge of varied software packages and computer aided platforms has enabled a simpler and a much more efficient design and development process for existing automobile systems. Drafting and simulation techniques have speeded up the design process while cutting costs at the same time. Resolving complications, a has never been easier and complicated parts are being developed without additional experimentation. This paper presents analysis of benefits computer based design applications on complex vehicle systems.

Keywords: Automotive industry, Computer-Aided Design, CAE. CAM, Manufacturing, Design, Vehicle Development, Modelling, Optimization, Testing, Industry 4.0.

I. INTRODUCTION

The development of a vehicle and its systems requires a set of challenging tests and experiments. Upcoming technologies have facilitated these tasks with development of various software solutions. The diverse nature of software enables wide applications in load analysis of parts, vehicle design, ergonomics.

Since earliest days of technology graphical simulations, creation of models and 3D interpretation has had an important role in stages of development. Principles of mathematical sciences, descriptive geometry, informatics and applied electronics form the basis of these technologies.

Development of automobile software mainly lies in 3 fields: design, engineering and production. Computer Aided Design is using computer systems for creating, modifying, analysing and optimizing design of a component. Computer-aided engineering is using computer systems for engineering analysis tasks like finite element analysis (FEA), computational fluid dynamics (CFD), multibody dynamics (MBD). For production purposes are Computer-aided manufacturing software are used.

II. VEHICLE DEVELOPMENT PHASE

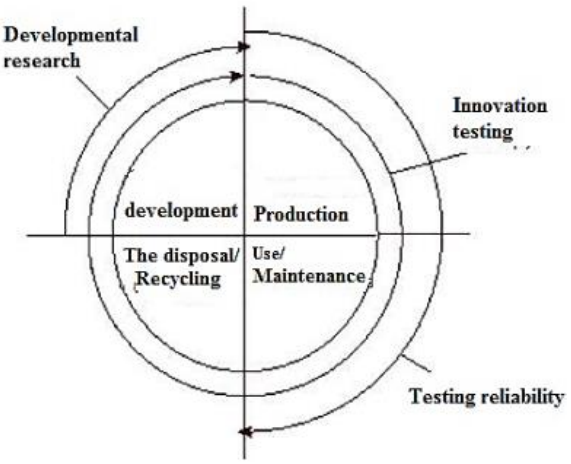

Fig. 1 An overview of tests in a vehicle's life cycle

Phases of the development of a vehicle and all its products in its life cycle require different tests and different studies. The tests being highly complex, the application of CAD/CAE is of great benefit due to its advantages in relation to the real experiments. These virtual laboratories greatly reduce the cost of testing and the time for research.

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Using existing databases, the latest equipment and information is available from any place at any time. Precision being of great importance CAD technology is used for the making of accurate and precise technical documentation.
Testing of new innovations and possible changes to already existing systems are studied with the help of CAE technologies to determine all characteristics of such altered system.
Reliability being of great importance in a vehicle. CAE techniques accurately predict the reliability of each system even after a certain period of usage

III. VIRTUAL VS PHYSICAL EXPERIMENTATION

Physical testing was an essential stage of vehicle development in the past. The shortcomings of a design could be detected and managed before the vehicle came into the customer's hands.
Nowadays, the ability to analyse various aspects of a design using the computer-assisted engineering tools has reached the point where virtual product development is considered a realistic and better alternative.
The control over the experiment, the repeatability and reliability of performance and results, the accelerated testing, the safe implementation of the experiment, the simulation of real conditions, the optimization of implementation of the experiment etc. all work in the favour of virtual experimentation.
In addition to the mentioned advantages, the use of modern computer aided drafting and engineering technologies considerably reduces the cost of testing and the research.
Despite the development and advancement of existing technologies, there are cases when it is not possible to apply modern technology in the automotive industry in the development of certain systems in the vehicle.
The major reason being that certain theories have not been sufficiently explored and such simulations cannot be properly or at all completed. Certain simulations are not available because it is difficult to simulate some physical phenomena like the analysis of the fatigue of the hot exhaust system is extremely difficult for a simulation study (uncertainties about certain properties of the material and change in the properties of the material at elevated temperature, the influence of the geometry of the welds, crack propagation at elevated temperatures), although it is relatively easy to set the exhaust system to the engine and test whether the exhaust system will develop cracks. These systems are often better developed using physical testing because if the working conditions are not specified it becomes very difficult to have confidence in the results of the virtual experiment

IV. DESIGNING A VEHICLE

Advanced technologies have made it possible to accurately model the desired shape of a vehicle. Designers now have an overview in the design phase. Creating 3 dimensional parts in the space provides an insight into the complete vehicle geometry. The various parts of the vehicle are then easily grouped into assemblies and sub-assemblies.

Fig. 2 An overview of vehicular designing

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It is possible to create desired view at the drawing, the expenses of probing the body of the car are reduced, the co-operation of co-workers is simplified etc. So the process of development of vehicle models accelerates. These models allow the comparison of the quality of various parts of a vehicle and effects on performance under certain conditions.

V. VEHICLE DESIGN ANALYSIS

Other than designing, CAD technology plays a substantial role in simplifying the testing of a known design.
Like aerodynamic study, the flow of air over the surface of a vehicle, air resistance plays a very important role in all resistances, therefore it is always a priority to maximize the aerodynamic efficiency of a vehicle.
By use of these techniques critical points on the vehicle can be accurately determined and vehicle can be redesigned if there is a suspicion that flow is separating or air spinning is increased. In these cases, it is very beneficial to use such methods because it is possible to reconstruct the design of a vehicle without expensive aero tunnels and prototypes. So costs are greatly reduced and absence of prototype saves time in the vehicle development.

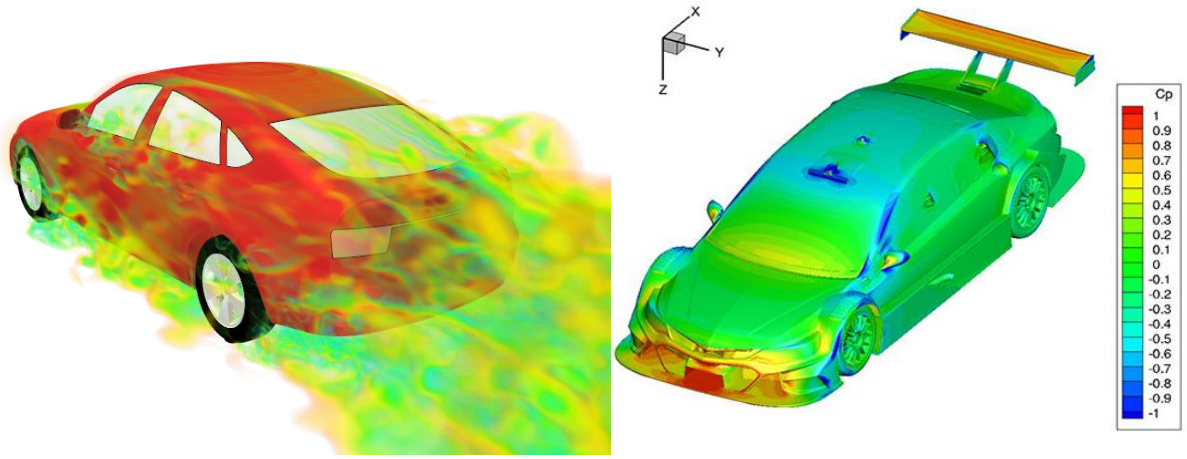

Fig. 3 A demonstration of a vehicle's aerodynamic testing

Further CAE tools are extensively used in simulation of crash tests and vehicle's body safety checks. These tests being expensive require specialized testing centres with rigorous and precise testing equipment as well as prototypes of vehicles being tested. CAE technology produces precise results of vehicle deformations and loads during testing, corrections modifications are suggested afterwards which are applied to the virtual model of the vehicle.

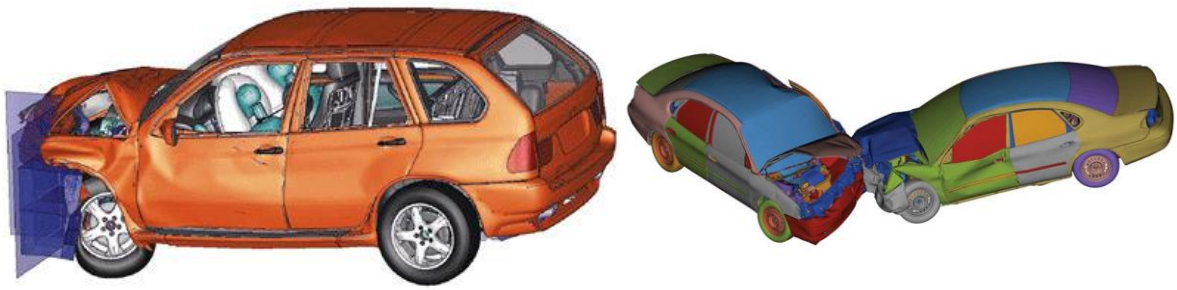

Fig. 4 Safety test of the body of a vehicle

VI. VEHICULAR ERGONOMICS

Ergonomic analysis of a vehicle is very essential for the reduction of fatigue and facilitation of car driving. A major ergonomics tool, developed according to the principles of CAE technology in cooperation with the German automobile industry for the ergonomic development of vehicles is RAMSIS.
Ergonomics is a major quality factor and is becoming a significant differentiation criterion. RAMSIS is used for design and analysis of vehicle's interior design and checking the ergonomic characteristics of the vehicle and the comfort of the driver and passengers.

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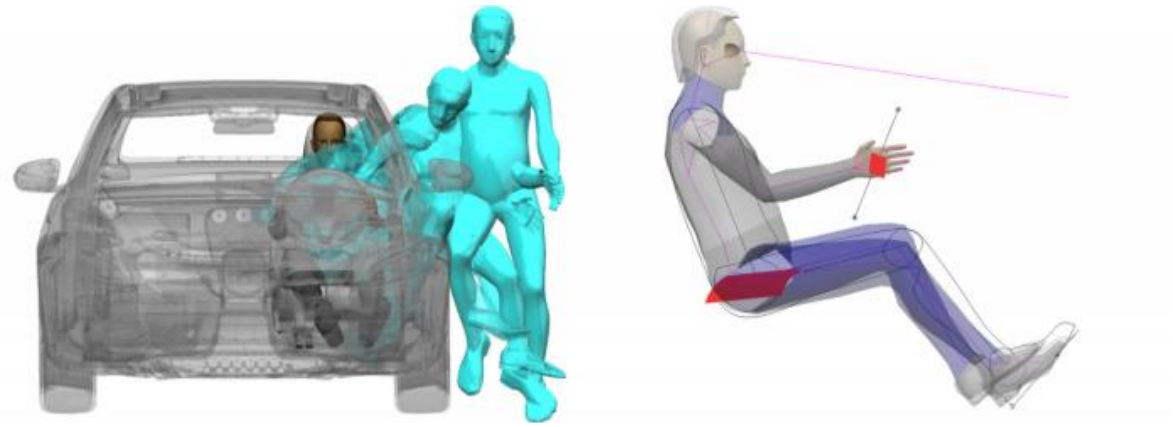

Fig. 5 The analysis of the driver's comfort in the vehicle and the analysis in the CAE software

VII. PASSIVE INTERIOR SAFETY

CAE tools are being increasingly used in the examination of the operation of elements of passive safety like airbag which should prevent the driver from hitting the steering wheel in the case of a traffic accident.
Analysis of driver's impact is very important in the analysis of the position and shape of the airbag as it replaces long-term and highly complex physical work about driver's impacts in the airbag, as well as the complex analysis of the shape and position of the impact along with passenger in a traffic accident.

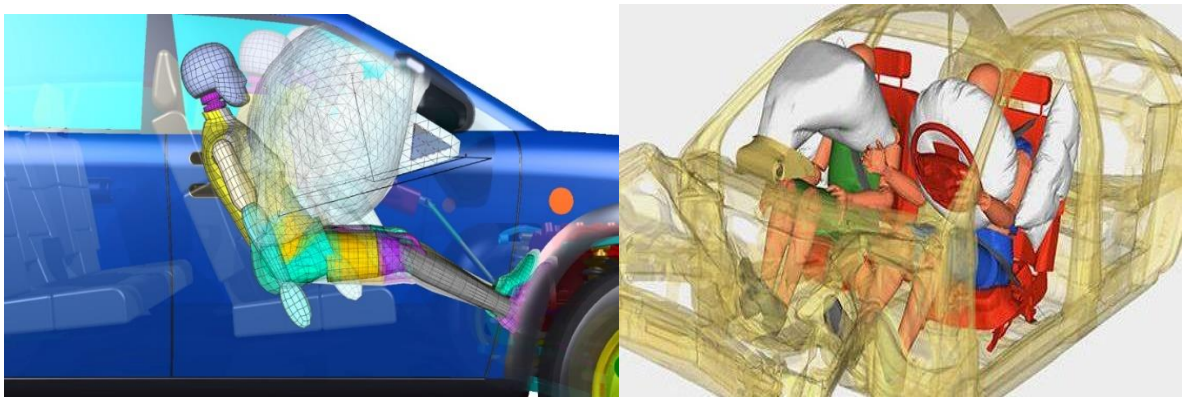

Fig. 6 A demonstration of the analysis of driver's impact in the air bag by using CAE technology

VIII. PERFORMANCE OF CERTAIN VEHICLE SYSTEMS

CAE methods also displays the flow of certain fluids through various systems on the vehicle. So it is used for testing air conditioning system as the flow of air in the vehicle can be accurately determined and the impact on air temperatures in different vehicle zones measured. Thus, CAE simplifies the testing of the operation of this system without complex experiments or expensive equipment. Further simulation of cooling down of the engine or the air flow in the engine compartment are also studied using these methods

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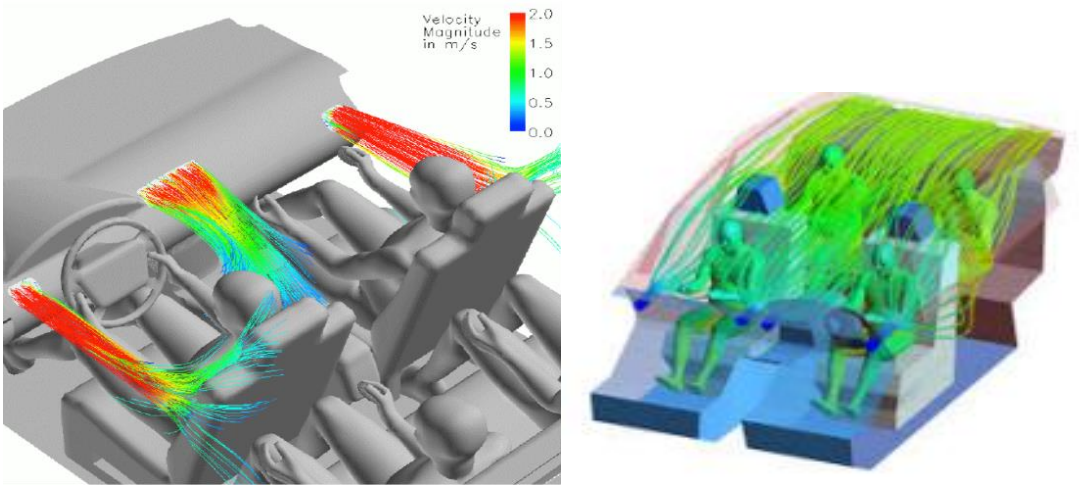

Fig. 7 Demonstration of air flow simulation using CAE technology

IX. VIRTUAL ENGINE MODELLING

Designing and production of an internal combustion engines cannot start without an adequate verification. As most motors are made mostly by altering the existing ones, that is, by modifying older solutions using modern tools. Major parameters are fed to the software that through a complex mathematical model mimics complex physical and chemical processes taking place in the engine. When this engine is put in operation various indication data parameters are collected using which a mathematical model is developed.

Models of the engine are made based on the laws of thermodynamics, chemical kinetics, fluid mechanics and combinations. Depending on the type of engine (2 stroke, 4stroke, slow-moving, high-speed, diesel, Otto-engine, etc.) software mimics the given engine.

Most of the processes and phenomena in the engine are modelled using a computer, major parts are designed and the engine itself, i.e., its assemblies and subassemblies is simulated on the computer. This virtual engine can be engineered, simulated, and tested on a computer before making the real prototype for tests. Programs display the gas temperature and pressures during the operation of the virtual engine, as well as the loads and temperature assumptions that certain mechanical parts of the engine are subjected to.

The engineer monitors the flow of temperature, pressure and flow rate of gas, and optimizes the virtual engine with various interventions. After the thermodynamic calculations and the first modelling stage, approximate dimensions and shapes of the motor parts are provided and thorough examination is performed using techniques like finite element method. These during the modelling give an insight about overloads and possible destruction of elements. are used today. These calculations and complicated analyses help solve complex problems straight away and allow easy change of engine performance parameters, saving both time and money.

X. SPECIALITIES OF CAD/CAM SYSTEMS

A number of CAD/CAM systems these days can write out or read in data that is compatible to open industry standard life-cycle management.

Most important factors for automotive software are ease of use, efficiency, functionality and compatibility with industry standard formats and devices. Nowadays advanced options, like surfacing, polygon mesh, tool-axis definitions, increased speed of computing designs, toolpaths and handling of large amounts of data, automation and customizing are also looked out for. Lastly human factor in support, hand-holding and troubleshooting play major role in support for a CAD/CAM system.

Reliable precision, flexibility, and speed are the major factors of success in automobile sector. Being a highly competitive and innovative industry, newer methods and machines are constantly developed for better returns on investment. Existing technologies are being applied like drive robots in machining and post machining operations in a high end flexible manufacturing system. Robotic cells not just provide flexibility and adaptability but also reduce setup costs, increase accuracy in prototypes and better finish off parts. Owing to the simplicity a CNC machine tool programmer quickly and efficiently generates toolpaths for a Robot to work desired shape and part.

The Auto Industry is the most challenging industry evolved so far. With strict safely norms, digital revolution impacting infotainment systems the auto industry is constantly challenged to bring better products to appeal varied requirements of

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consumers. CAD/CAM technology is helping automotive industry sustain these challenges right from concept phase to roll out phase. Clay models being replaced by digital models, components and assemblies being designed, drafted and simulated by CAD tools like CATIA , NX by or Creo. Stress, strain, fatigue, fracture or thermal analysis being done by CAE tools like MAPDL& Fluent by Ansys, NASTRAN etc. Production planning and control being handled by CAM tools and even inspection plans carried on automatic inspection systems. These CAD/CAM systems along with implementation of PDM and PLM tools are reducing the time to develop new models and drastically improving the efficiencies of design and manufacturing processes.

CAD/CAM compiling to form computer integrated manufacturing. CIM involves lot many components associated with it. Computer Aided Design involving designing of exterior styling with BIW, closures, interior trims, panels, cabin ergonomics and instrument panel, and components like seats and dashboard.
Involvement of modern software made it possible to adopt frequent design changes expected for customer requirements or enhancements. All major aspects of car body are simulated in virtual environment to avoid manufacturing or assembly challenges. Every part design goes through multiple iterations of CAE simulations for thermal, fatigue, structural analysis Other than this any statutory regulations have to be followed for safety and emissions. Crash tests are carried out virtually first at different speeds and loading conditions to get design certification for a certain car model. Maintain the bill of materials used in the car through the stages is an important task. PLM monitors all these aspects from design to manufacture to supply chain sequencing, scheduling, packaging, inventory management, inspections etc. It further promotes integration between components bringing CAD models, plans, automation lines etc. to CAM environment to adopt tool path generation for further CNC machining. CAD/CAM systems with PLM shorten development duration. Drafting increases accuracy to provide better designs, these efficient designs are further manufactured faster with reduced wastage and cost.

XI. Major Applications In Automotive Industry

Earlier, we used to create design or prototype manually making development process time-consuming, tedious and expensive. To avoid such hassles computer-aided design software were developed.
This software simplifies and digitalize the whole design process replacing the traditional drawing board. Allowing secure storage of data copies, drawings, and blueprints. Furthermore, including interior design, mechanics, architecture, modelling, animation, and engineering in design process CAD/CAE software are highly beneficial in automotive sector.

Vehicles having subtle curves, and blending between panels requires advanced surfacing tools which can handle aesthetic issues.
By providing templates to replace the designer's need to build construction elements, adding surfaces and modifying the results afterward according to manufacturing constraints, the use of modern tools has revolutionized the development process. This software allows designers to define and design specifications for the new vehicle and automatically generate high-quality surfaces that would meet all those specifications along with 3D curves together with their connections.

CAD models replaced clay models as they were easier to create and provided a realistic view of designs, with upcoming VR techniques still on rise. Blending and chamfering edges becomes efficient and designer can apply different tolerances of any edge and calculate the appropriate ones while connecting the surfaces. Design of thin walled parts of a vehicle require high quality systems capable of handling all changes that can occur in hollowing or thickening process. Further these systems support mold and die design environments.

XII. Major Upcoming Trends

CAD/CAE tools being essential part of the automotive development process not only serve for designing the appearance of a vehicle, but also for configuration and module systems. Being used for simulation and verification processes, such products include structure-related information and are used for digital mock-up investigations.
Over time CAD/CAM systems have evolved into advanced software programs providing countless possibilities to engineers which combined with network based development greatly reduced development duration.

XIII. Integrated Development Platforms

In recent times automobile software development is heading towards integrated packages which combines CAD and simulation tools. Major advantage being reduction in data interference losses.
These new intelligent geometric data exchange formats handle not only geometric data but enhanced product information as well. They increase the efficiency of virtual product development processes significantly and the development will become virtual from the very first concept phase to the aftermarket. Although proper integration of characteristics into

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3D models is needed to ensure correct behavior.
As of now seven integrated development platforms available which are quite complex, leading to disadvantages in efficiency and handling. Overloaded with tons of functionalities, and such platforms have turned into software giants offering more than ever.
Upcoming and improved development platforms are being developed to be smarter and provide integration of multiple disciplines easier handling and better efficiency. Also module-oriented systems moving towards flexible accounting considering individual software usage.
As of now open-source CAD systems seem to be the best alternatives. One example is BRL-CAD. Though not widespread but are high in demand, owing to their flexibility and simplicity. Based on open-source platforms like the Open CASCADE engine ,they provide the right amount of functionalities for vehicle and parts design.
CAD/CAM tools enable cloud-based development, so engineers and designers work together.

XIV. 3D PRINTING

3D printing is the creation of hardware models out of 3D-CAD virtual geometric data. Recent development allows the use of various materials like metal, plastic, textile, and ceramics for the instant generation of a model during development process. Characteristics being close to the ones out of serial production, enhancement of technology and significant cost-reduction are making it a part of mass production process with deeper integration into development.
New intelligent material being developed to combine hardware and virtual modelling into a single process. Like dynamic physical rendering projects on the development of flexible material based nanotechnology which can be controlled by geometry information from 3D-CAD and manual manipulation. Thus, 3D printing process goes form hardware model being reshaped by hand afterward. For these dynamic 3D forms robust software programs are being developed. This is known as Claytronics. Opening up a wide range of applications in component design it allows for much more productive and creative work.

XV. GENERIC PROGRAMMING

Although advanced CAD/CAE systems provide functionalities that support the smooth integration of automated computing routines, template models, and programs. These systems still lack in certain areas compared to available scientific applications, like MATLAB. Applied programming languages not being up-to-date for efficient programming within CAD have certain drawbacks in deployment and restricted support for enhanced operations or collaborations.
Upcoming CAD platforms provide advanced object-oriented programming. These include integrated functions for efficient problem-solving which will change the design processes organizing them into integrated development cycles, with dynamic simulations and layouts. Specialized automatisms will support designers in managing software packages.
Machine learning enabled systems are being developed to provide engineers with optimized processes and suggestions for design problems based on automated algorithms and databases. These future CAD programs will enable advanced knowledge-based engineering.
Implementation of generic programming to CAD environment with advanced algorithms to optimize the designing process would provide new approaches and possibilities for sophisticated vehicle design including complex system components.

XVI. CONCLUSION

Vehicle development is becoming a very complex process; modern products are more elaborate since there is a demand for optimized efficiency with minimal consumption of certain means. The automotive industry following this trend as reflected in the specifications of modern vehicles.
Use of modern software with CAD and CAE technology, enables the industry to perform various researches more effectively and efficiently, it is now possible to test modifications and alterations in order to improve the characteristics and develop them. Major benefit of these systems being their speed and reduced costs in research and development of vehicles.
The adoption of modern CAD/CAM/CAE tools and technology enables better communication between members of the vehicle development team, graphical representation of complex problems , better production of technical documentation, better inspection of faults on a system, possible repetition of each simulation with the possible modifications to the model itself, reduced costs, removal of creating prototype for testing, , testing of vehicle and systems several times under various constraints and conditions and elimination for expensive test equipment.
Virtual experiments may have certain disadvantages over physical testing but ongoing continuous development in the industry will eliminate all drawbacks.

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