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CAD Modelling of Lubrication Oil Cooling System

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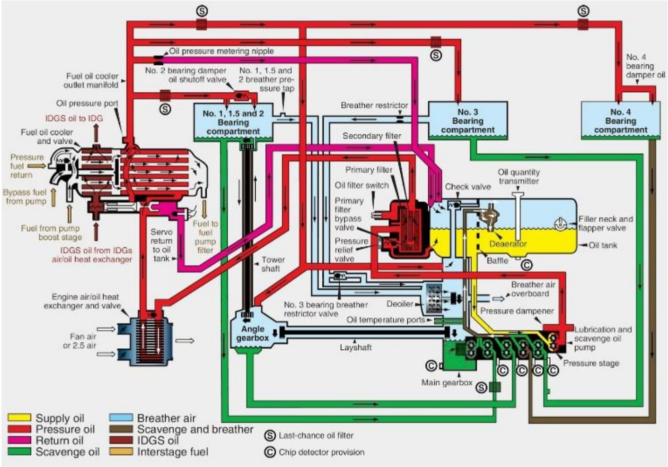
ABSTRACT

I have the developed of the project design on modelized lubrication oil cooling system for automotive engine using CREO Software. This project gives a simulator version of an automotive engine based totally on bodily, semi physical, mathematical and thermodynamic equations, which lets in speedy predictive simulations. The complete automotive engine device is divided into several purposeful blocks: cooling, lubrication, air, injection, combustion and emissions. The sub-fashions and dynamic characteristics of character blocks are hooked up in keeping with automotive engine operating principles equations and experimental facts amassed from a automotive engine. The typical automotive engine system dynamics is expressed as a set of simultaneous algebraic and differential equations the usage of sub-blocks and S-Functions of Matlab/Simulink. The simulation of this version, carried out on Matlab/Simulink has been confirmed and may be used to obtain automotive engine overall performance, pressure, temperature, efficiency, warmth launch, crank perspective, fuel rate, emissions at extraordinary sub-blocks. The simulator could be used, in destiny work, to study the automotive engine performance in defective situations, and may be used to assist automotive engineers in FDI (fault analysis and estimation) in addition to designers to are expecting the behavior of the cooling machine, lubrication machine, injection device, combustion, emissions, so one can optimize the dimensions of different additives. This application is a platform for fault simulator, to analyze the effect on sub-blocks automotive engine's output of changing values for faults parameters including: defective gas injector, leaky cylinder, worn fuel pump, damaged piston rings, a grimy turbocharger, grimy air clear out, dirty air cooler, air leakage, water leakage, oil leakage and infection, fouling of heat exchanger, pumps.

I. INTRODUCTION

LUBRICATION SYSTEM

An automotive engine is made of many moving parts. Due to continuous movement of two metallic surfaces over each other, there is wearing moving parts, generation of heat and loss of power in the automotive engine lubrication of moving parts is essential to prevent all these harmful effects..



General view of lubrication system

PURPOSE OF LUBRICATION

Lubrication produces the following effects: (a) Reducing friction effect (b) Cooling effect (c) Sealing effect and (d) Cleaning effect.

(a) Reducing frictional effect: The primary purpose of the lubrication is to reduce friction and wear between two rubbing surfaces. Two rubbing surfaces always produce friction. The continuous friction produce heat which causes wearing of parts and loss of power. In order to avoid friction, the contact of two sliding surfaces must be reduced as far a possible. This can be done by proper lubrication only. Lubrication forms an oil film between two moving surfaces. Lubrication also reduces noise produced by the movement of two metal surfaces over each other.

(b) Cooling effect: The heat, generated by piston, cylinder, and bearings is removed by lubrication to a great extent. Lubrication creates cooling effect on the automotive engine parts.

(c) Sealing effect: The lubricant enters into the gap between the cylinder liner, piston and piston rings. Thus, it prevents leakage of gases from the automotive engine cylinder.

(d) Cleaning effect: Lubrication keeps the automotive engine clean by removing dirt or carbon from inside of the automotive engine along with the oil.

Lubrication theory: There are two theories in existence regarding the application of lubricants on a surface: (i) Fluid film theory and (ii) Boundary layer theory.

(i) Fluid film theory: According to this theory, the lubricant is, supposed to act like mass of globules, rolling in between two surfaces. It produces a rolling effect, which reduces friction.

(ii) Boundary layer theory: According to this theory, the lubricant is soaked in rubbing surfaces and forms oily surface over it. Thus the sliding surfaces are kept apart from each other, thereby reducing friction.

WHAT IS CREO

Creo, the shorthand name for Creo Parametric, (formerly known as Pro automotive engineer) is a powerful and intuitive 3D CAD software optimized to address the challenges organizations face as they design, analyze, and share information with downstream partners. Developed by PTC, the original pioneers of parametric CAD, Creo is powerful foundational software supporting an integrated family of product design tools used by thousands of manufacturers worldwide.

The Creo family of design applications, modules, and extension speak a common language, meet the needs of different stakeholders, and truly combine parametric and direct modeling techniques. Creo helps build bridges instead of barriers between you, your ideas, your teammates, your partners, and your customers.Creo Parametric 3D CAD software can easily be customized and extended through the addition of modules and extensions, but the product family also contains stand-alone purpose build design applications such as Creo Simulate, Creo Direct, Creo Layout & Creo Options Modeler. Each stand-alone app serves a different purpose in the product development process. From concept to design to analysis, to effectively sharing your information with downstream partners (such as manufacturing and technical publications), Creo is a rock-solid foundation for any design group. It supports the needs of modern manufacturing and product development organizations.In short, it is a powerful, integrated family of product design software. It’s used by thousands of leading manufacturers across the globe. It is a PTC product – the originators of parametric CAD technology.

The way Creo works is that it is made up of individual apps, including:

- Creo Parametric
- Creo Simulate
- Creo Direct
- Creo Layout
- Creo Options Modeler

Each Creo app serves a different purpose in the product development process. This means that Creo takes you through every stage, including concept design work, design and analysis. Then it also enables you to communicate effectively with downstream partners, for instance manufacturing and technical publications.

SIMULATION

PTC’s simulation software is designed uniquely for the automotive engineer, complete with the common Creo user interface, automotive engineering terminology, and seamless integration between CAD and CAE data, allowing for a more streamlined process. Best of all, the results are accurate and reliable and can be easily calculated with very little input from non-simulation experts.The simulation software is a complete structural, thermal and vibration analysis solution with a comprehensive set of finite elements analysis (FEA) capabilities that allow you to analyze and validate the performance of your 3D virtual prototypes before you make the first part.

CREO PARAMETRIC

When you work with Creo Simulate, your goal is to create a simulation model that reflects both the physical nature and the real world environment of a part or assembly, analyze the model, and evaluate the results of the analysis. To help you complete these tasks efficiently,

Creo Simulate provides a tool—Process Guide—that leads you through each step in the simulation process. Process Guide is available for 3D Structure modeling in both native mode and FEM mode. You can use Process Guide for both parts and assemblies.

Process Guide also provides the user interface to Creo Simulate Lite, the free limited functionality version of Creo Simulate. Process Guide serves several purposes. In its simplest form, it leads you through the process and workflow and prompts you to complete the following steps involved in successfully creating and analyzing a basic simulation model:

II. METHODOLOGY

The feature-based parametric modelling technique enables the designer to incorporate the original design intent into the construction of the model. The word parametric means the geometric definitions of the design, such as dimensions, can be varied at any time in the design process. Parametric modelling is accomplished by identifying and creating the key features of the design with the aid of computer software. The design variables, described in the sketches and features, can be used to quickly modify/update the design.

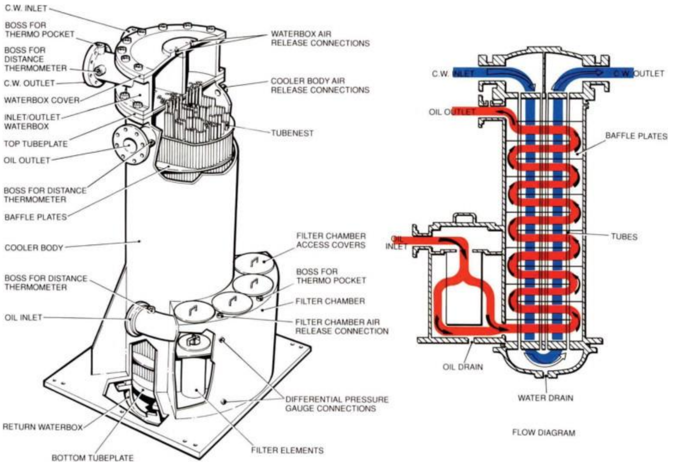
OVER VIEW ON LUBRICATION SYSTEM IN AUTOMOTIVE ENGINE CONFIGURATION OF FLYING CAR

Lubrication plays a key function inside the existence expectancy of an engine. Without oil, an engine might succumb to overheating and seizing very quickly. Lubricants assist mitigate this trouble, and if well monitored and maintained, can amplify the lifestyles of your motor.

MAKEUP OF ENGINE OIL

To appreciate the whole impact of the engine lubrication procedure, you need to apprehend how oils are formulated. All engine oils have two components: components and base oil. The total quantity of additives in motor oil can range from 20 to 30 percentages, relying on emblem, formulation and alertness. These components can enhance, suppress or upload homes to the bottom oil.

A traditional additive bundle found in engine oil would encompass a detergent and a dispersant. These two components paintings collectively to help rid the engine system of deposits due to the burning of gas and contributed to by way of blow-with the aid of gases. Dispersants and detergents are small debris that has a polar head and an oleophilic tail. The polar heads are interested in contaminants in the oil and surround them, forming a shape referred to as a micelle.



Engine Oil Systems

This additionally prevents a method called congealing. During congealing, soot particles begin to stack upon every different or congeal into a larger particle. Smaller soot particles that could pass through additives without interrupting the fluid film can congeal to make large particles, which may disrupt the movie and damage surfaces.

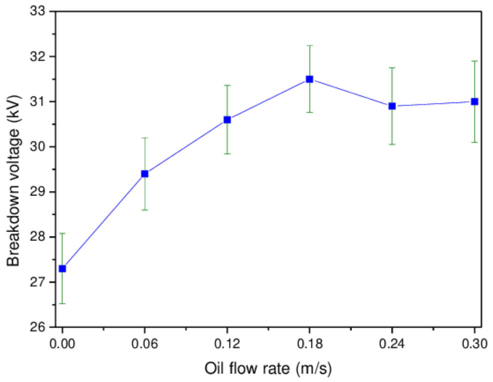
Most vehicle engines use a few form of multi-grade oil. This kind of oil has an additive known as a viscosity-index (VI) improver. A commonplace instance would be 10W-30 or 5W-40. These VI improvers are lengthy-chain organic molecules that alternate shape because the temperature in their surroundings modifications.

When in cold environments (engine startup), these molecules are tightly sure. As the oil heats up, they begin to stretch out. This permits an oil to flow extra comfortably at less warm temperatures however nonetheless maintain an acceptable viscosity and, extra importantly, a lubricating layer within the running temperature variety.

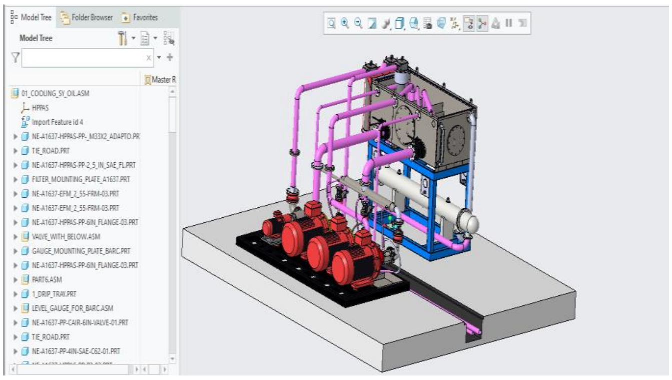
Another not unusual additive might be anti-wear (AW) components. AW additives have debris which might be fashioned just like detergents and dispersants; however the polar heads of those molecules are interested in steel surfaces. Once attached to a steel surface, AW components shape a sacrificial layer that protects the surfaces beneath them from degradation under boundary situations. Zinc dialkyldithiophosphate (ZDDP) is a commonplace form of this additive.

OIL BREAKDOWNS

Engine oils are problem to numerous forms of failures. Contamination poses a huge hassle within engines. Environmental contaminants can expedite the procedure of oxidation and cause untimely filter plugging. Fuel infection can decrease the viscosity of the oil, leading to boundary situations inside the engine's moving elements. Glycol (antifreeze) contamination does the other, increasing viscosity so the oil doesn't drift as nicely into places that require thinner oil. Overheating and long drain intervals can also hasten the degradation of the oil and bring about oxidation and bad lubricate.



DESIGN OF LUBRICATING OIL COOLING SYSTEMS



Design Profile of model flying car

This invention relates to turbofan automotive engines utilizing a mechanical constant speed drive and particularly to the cooling system for the lubricant used in the constant speed drive.

As is well known the constant speed drive, which is a gear and clutch arrangement, serves to generate electricity for the aircraft. In a turbofan driven aircraft, the fan air/lubricant cooler is located in the fan duct (as shown in FIG. 2) and extends into the fan airstream. Associated with this type of plate/fin heat exchanger is a pressure loss which is reflected in terms of aircraft performance penalty. In a given installation utilizing the JT-9D automotive engine (manufactured by the P&WA division of UTC, the assignee) this pressure loss amounted to approximately a loss of 0.8% of TSFC (thrust specific fuel consumption).

It has also been well known that a typical constant speed drive lubricant cooling system would use a single heat exchanger which is of the plate/fin type in the fan airstream as described above.

We have found that we can improve TSFC by reducing the size of the fan air/oil heat exchanger because fan stream pressure losses have been reduced by utilizing the automotive engine/oil heat exchanger that is already in existence. When the JT-9D was upgraded to increase its thrust, a doubling in size of the existing fan air/oil cooler would have been necessary. By virtue of this invention, the size of the cooler on the upgraded automotive engine was actually reduced in size by a factor of 6, or approximately 1/3 of the predecessor automotive engine cooler. In terms of TSFC, an improvement of 1% was realized.

Moreover, there are advantages gained from utilizing the automotive engine fuel/oil cooler that wasn't available heretofore. Namely, because of fuel pump inefficiency and automotive engine oil heat transfer, a large temperature rise of the fuel is occasioned during aircraft descent. This is primarily due to the pilot cutting back on the power lever reducing thrust and automotive engine power, which causes the fuel to recirculate resulting in a higher fuel temperature. Connecting the CSD lubricant to the automotive engine fuel/oil heat exchanger now serves to reduce the temperature of the fuel prior to it being admitted to the automotive engine's combustor. This lower fuel temperature, in effect, reduces the adverse effect of the higher temperature fuel during descent on the combustor, resulting in a longer life of the combustor.

By locating the CSD fuel/oil portion of the automotive engine fuel/oil cooler in a downstream position, relative to fuel flow, the heat transfer from the CSD lubricant does not interfere with the automotive engine lubrication system

III. ANALYSIS TECHNIQUES FOR LUBRICATION SYSTEMS

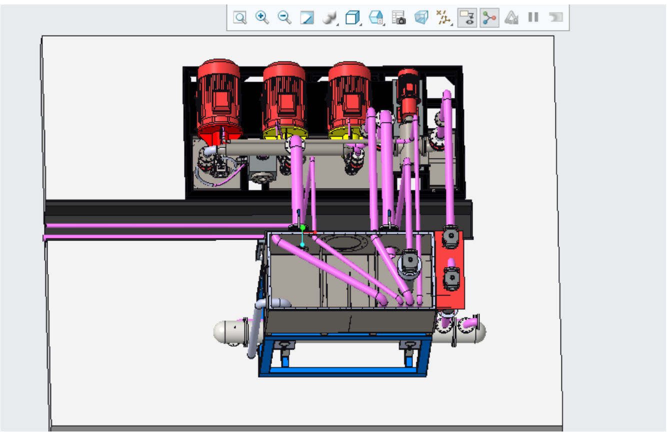
Whilst fluid flows in engines are three dimensional the lubrication system can be simplified and treated as a series of one dimensional passages, and the method of solution adopted can be simplified to steady state and isothermal with oil viscosity and density calculated for different thermal conditions of the engine.

Traditionally engine designers have used oil pressure in specific parts of the engine to gauge acceptable lubrication with the majority of the lubrication system considered during the engine development phase. However for most critical components satisfactory performance is governed by the volumetric oil flow rate and flow balance in the system. The engine speed can be simulated by considering the oil pump delivery (taking into account volumetric efficiency), and, since positive displacement pumps are most commonly used in engine applications, oil pump delivery is theoretically proportional to engine speed . In practice volumetric efficiency varies slightly with pump speed, oil pressure and the type of oil pump. Flow characteristics over the speed range would be given by results for steady state isothermal solutions at a number of engine speeds or more accurately for the equivalent oil pump delivery.

Optimising the lubrication system is a complex task, having to consider flow balances, optimum flow requirements and specifications for relief valves simultaneously leading to an iterative process. This is further complicated for systems with oil coolers and thermostatically controlled by-pass valves. Once a model has been analysed results for interrogation against acceptable guidelines are:

i. Volumetric flow and velocity of oil through piston cooling jets per cylinder or average flow rate per engine cycle for pistons directly fed through the connecting rod.
ii. Average flow through major bearings per engine cycle.
iii. Flow through pressure relief valves.
iv. Oil velocity in pick-up pipe.
v. Oil pressure at critical components, hydraulic lash adjusters for instance.
vi. Hydrodynamic pumping requirement (parasitic losses due to oil pumping only).

In some cases the lubrication system is required to provide a pressure (with little or no flow) for specific functions (e.g. hydraulic lash adjusters). Here, the system may be designed by using fluid power techniques and may be analysed separately with knowledge of the pressure distribution with engine speed from the flow analysis.



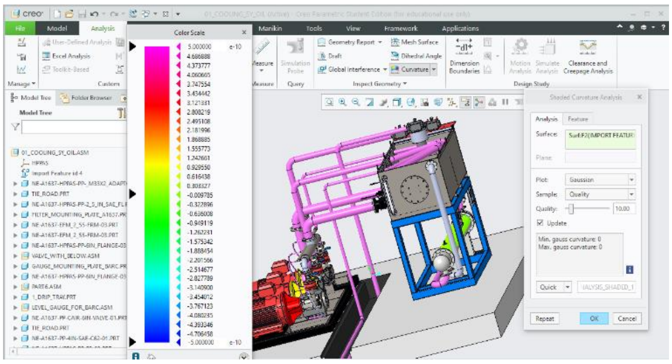
VIEW OF OIL TANK

IV. TESTING AND RESULT

A number of complete vehicle drive cycle replications were performed in a climatic wind tunnel. Available are comprehensive measurements of various temperature, pressure and flows quantities in the cooling system, aero engine and underhood. Temperatures and flows on all sides of the heat exchangers are logged continuously during steady state and transient driving scenarios. Key performance parameters such as aero engine torque, speed and vehicle speed are also logged. Continuous runs of driving cycle "Hamburg-Kassel hills" are reproduced at constant preset ambient temperatures. In such a test the vehicle's driving wheels are in contact with a chassis dyno, which can be adjusted to provide a desired level of resistance regulated by a control system continuously during the test as dictated by the pre-defined drive cycle. The vehicle's accelerator pedal is continuously depressed by a trained operator in order to satisfy the torque demand. Meanwhile, the climatic equipment generates ram air corresponding to the vehicle's driving speed at the desired temperature level. The test facility allows for an authentic replication of complete continuous, unsteady drive cycles, including cold-start tests but also for steady-state simulations.

V. SIMULATION RESULTS

1 SIMULATION RESULTS



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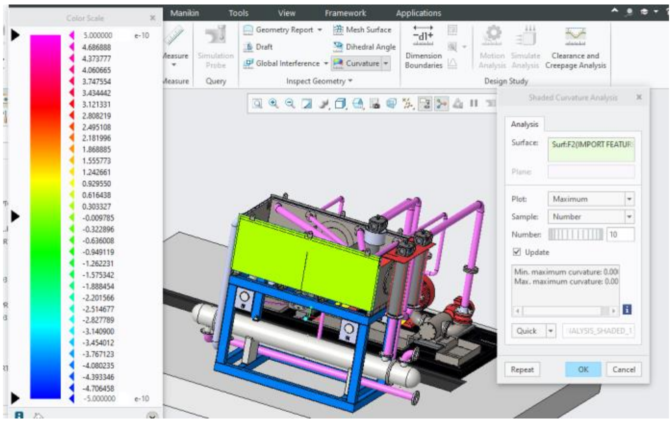

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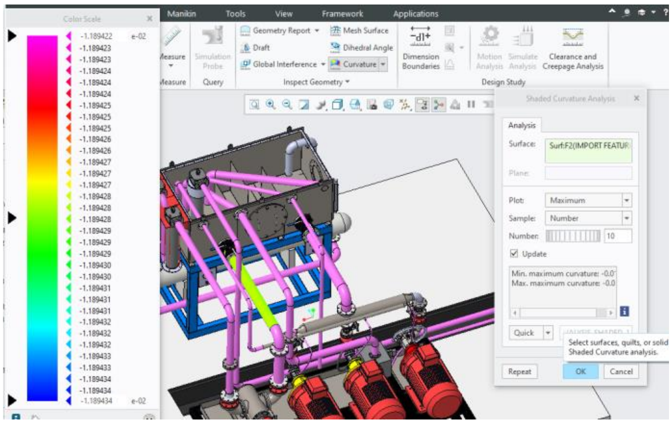
Figure – 7.1 oil reservoir simulation

Traditional finite difference simulators dominate both theoretical and practical work in reservoir simulation. Conventional Fluid Dynamics (FD) simulation is underpinned by three physical concepts: conservation of mass, isothermal fluid phase behavior, and the Darcy approximation of fluid flow through porous media. Thermal simulators (most commonly used for heavy crude oil applications) add conservation of energy to this list, allowing temperatures to change within the reservoir.

Numerical techniques and approaches that is common in modern simulators:



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Most modern FD simulation programs allow for construction of 3-D representations for use in either full-field or single-well models.2-D approximations are also used in various conceptual models, such as cross-sections and 2-D radial grid models.

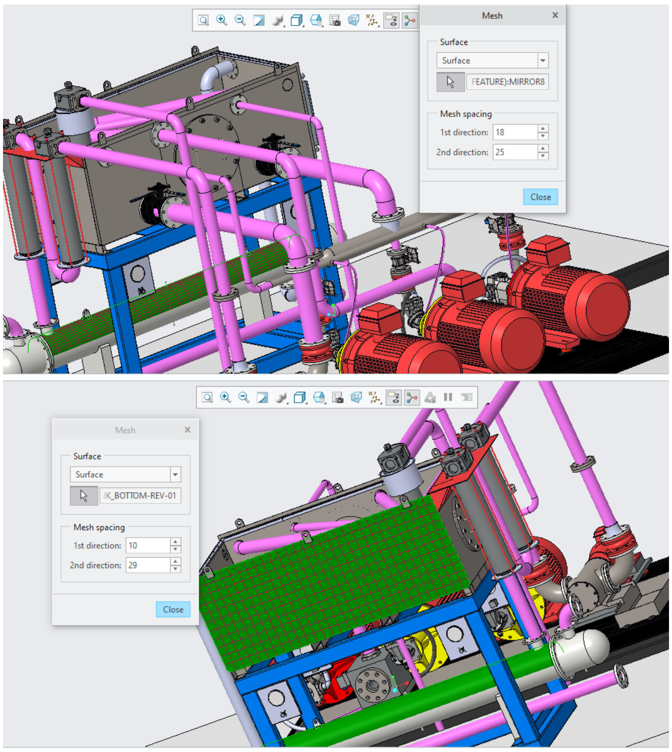
Theoretically, finite difference models permit discretization of the reservoir using both structured and more complex unstructured grids to accurately represent the geometry of the reservoir. Local grid refinements are also a feature provided by many simulators to more accurately represent the near wellbore multi-phase flow effects. This “refined meshing” near wellbores is extremely important when analyzing issues such as water and gas coning in reservoirs.

Representation of faults and their transmissibilities are advanced features provided in many simulators. In these models, inter-cell flow transmissibilities must be computed for non-adjacent layers outside of conventional neighbor-to-neighbor connections.

Natural fracture simulation (known as dual-porosity and dual-permeability) is an advanced feature which model hydrocarbons in tight matrix blocks. Flow occurs from the tight matrix blocks to the more permeable fracture networks that surround the blocks, and to the wells.

A black oil simulator does not consider changes in composition of the hydrocarbons as the field is produced. The compositional model, is a more complex model, where the PVT properties of oil and gas phases have been fitted to an equation of state (EOS), as a mixture of components. The simulator then uses the fitted EOS equation to dynamically track the movement of both phases and components in field.

The simulation model computes the saturation change of three phases (oil, water and gas) and pressure of each phase in each cell at each time step. As a result of declining pressure as in a reservoir depletion study, gas will be liberated from the oil. If pressures increase as a result of water or gas injection, the gas is re-dissolved into the oil phase.



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2nd direction: 25

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Figure – 7.2 oil reservoir Mesh condition

A simulation project of a developed field usually requires “history matching” where historical field production and pressures are compared to calculated values. The model’s parameters are adjusted until a reasonable match is achieved on a field basis and usually for all wells. Commonly, producing water cuts or water-oil ratios and gas-oil ratios are matched.

7.2 CONTINUOUS TRANSIENT DRIVE CYCLE SIMULATIONS

Presented are predictions for a number of physical properties of interest to cooling system analysts including radiator inlet temperature, CAC outlet temperature, fan speed, coolant mass flow rate, etc.

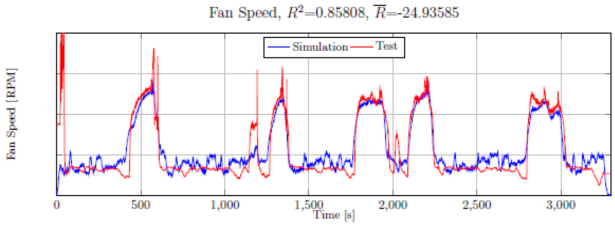


Figure – 7.3 RPM Flow testing

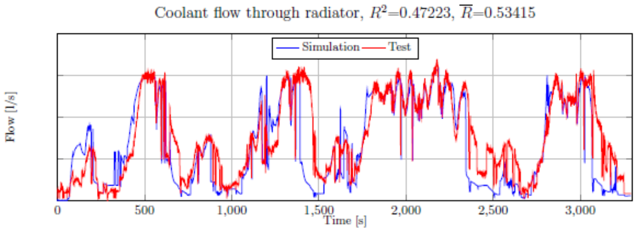


Figure – 7.4 Coolant flow testing

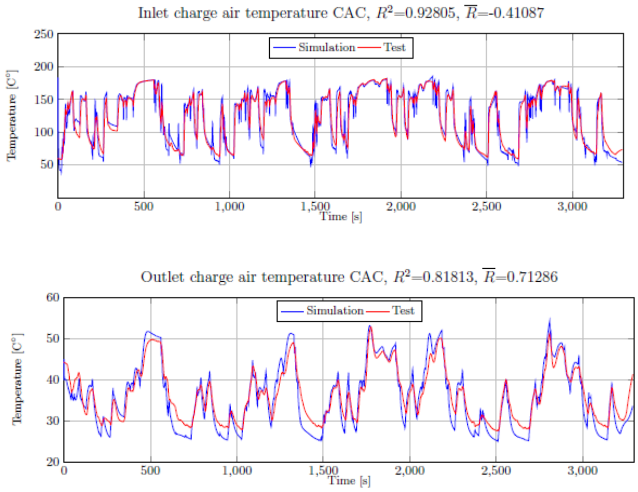


Figure – 7.5 Temperature testing

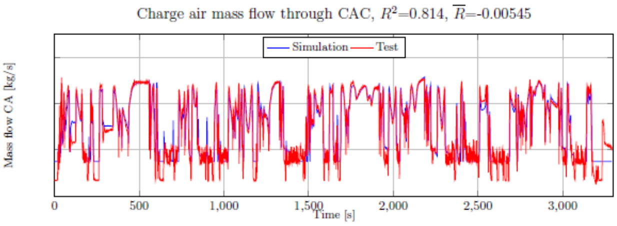
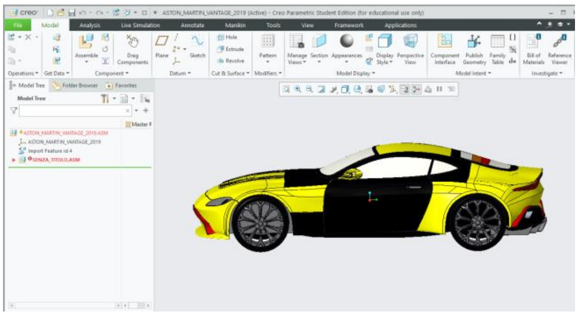


Figure – 7.6 Mass Flow testing

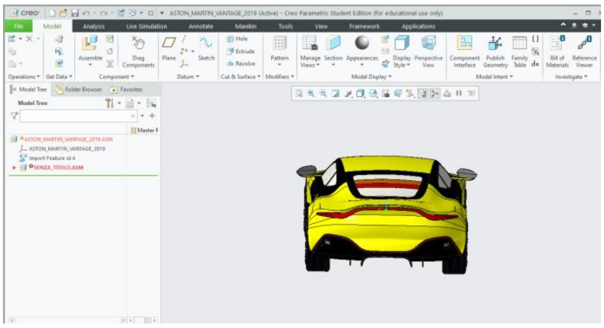
Nineteen steady state simulations were performed to replicate test measurements from a dynamometer wind tunnel. Measured values for vehicle speed, fan speed, radiator inlet temperature and mass flow, CAC inlet temperature and mass own are imposed as boundary conditions to the model. The computations were performed on 200 cores. Most cases converged within less than 3000 iterations and 3 hours (600 CPU hours). A representation of the temperature field in a central section plane, parallel to the longitudinal axis of the vehicle, is shown on figure. The non-uniform mass-flow and temperature distribution through the cooling package are shown on figure.

PROTO TYPE MODELS OVER VIEW – TRUCK

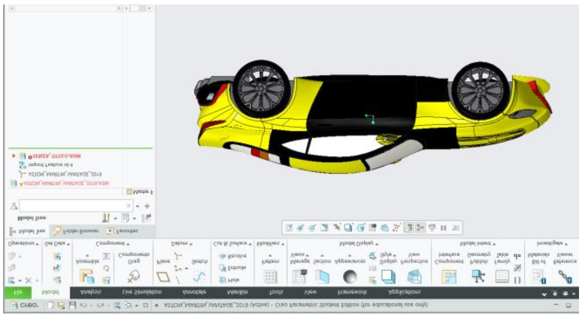
View – 1



View – 2



View – 3



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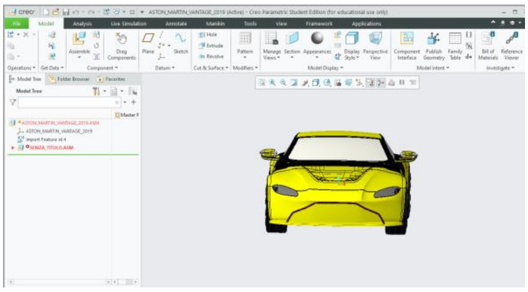

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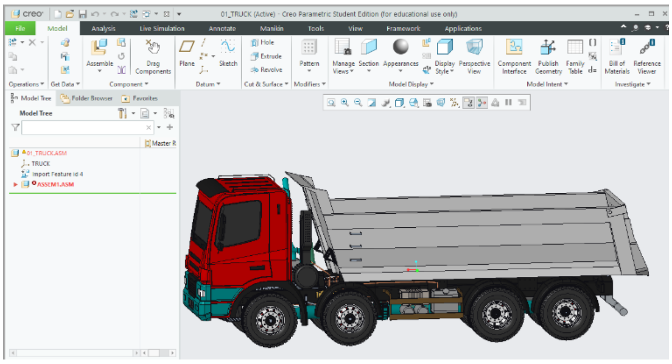

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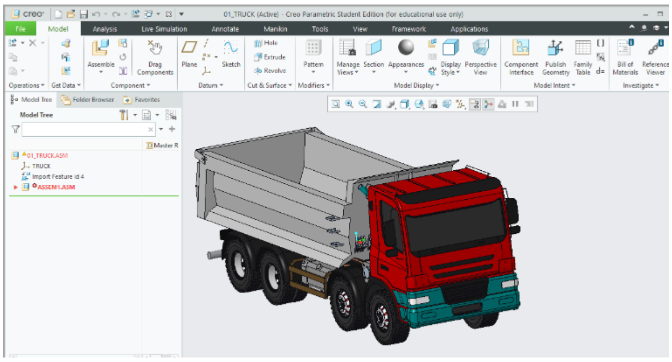

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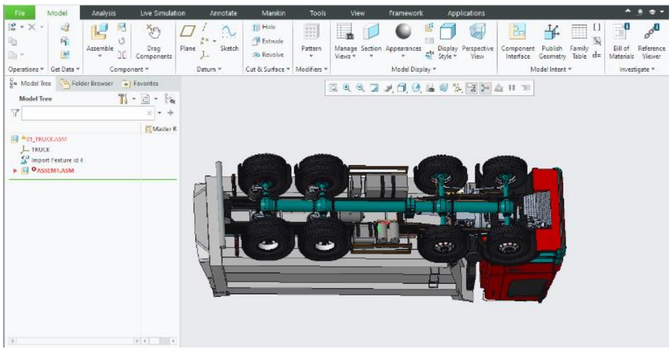
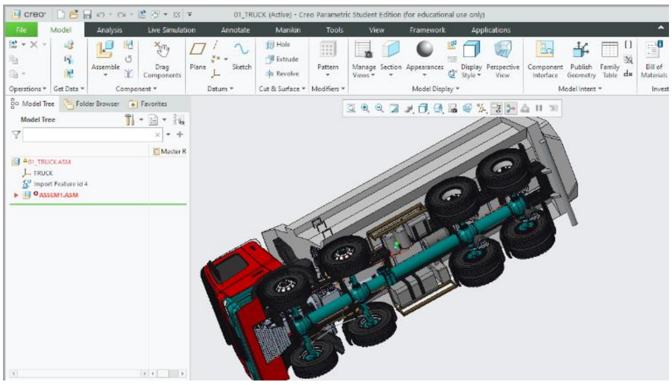


View – 4



VI. CONCLUSION

Presented is a 1D unsteady model varied against experimental data and supported with parallel 3D simulations. It contains predictive models of aero engine, cooling system, oil circuit and utilizes a temperature dependent model of aero engine friction losses. The 1D transient model has been validated by comparison of simulated results with measurements from a dynamometer test. Satisfactory consistencies between computed and measured readings for coolant and oil temperatures were reported.

Results from 3D CFD simulations were used to calibrate a 1D model of the cooling system with non-uniform temperature and flow boundary dentition on the inlet of the cooling package. The implementation of the non-uniform boundary strategy did not result in any measurable increase in simulation accuracy, but the analysis confirmed that validated 3D CFD methods can be used to calibrate 1D models of the underhood air path with excellent results in the absence of data from physical measurements.

Models of the engine, cooling and oil systems were coupled with a temperature dependent engine friction model. A series of complete vehicle simulations of a cold start drive cycle at different initial oil temperatures were performed in order to evaluate the influence of reduced warm-up phase on fuel consumption

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