Enhancing Learning Using Interactive Computer Software: Engine Sim Software for Learning Aircraft Propulsion Theory Courses

Ahmed Mamo*

Background:

Defense Engineering College has two programs, one degree and one diploma, in mechanical engineering, specializing in Aviation Power Plant (Aircraft Propulsion Systems). Specifically there are theories and design oriented courses which require certain specific learning skills like visualization, computation, and modeling. Up to now the practices in delivering the courses are demonstration on mockups, models, and real engines, and computing parameters of the jet engine using the formulae studied in the lecture class. These experiences are very much relevant. But for the theoretical courses like. Aviation Gas Turbine Engine (AGTE) Theory I and II (degree) and Fundamentals of Aviation Engine (FAE) (diploma) alternative methods of facilitating the learning by the students is very much essential. This is because students are required to:

- visualize the flow processes undergoing in the jet engine as a whole and its components in particular so as to analyze the thermodynamic and gas dynamic processes;

- compute the main parameters of the jet engine and its components in the varying condition of throttle settings, flight conditions and altitude (engine performance).

- design the geometrical/dimensional parameters of the jet engine and its components for different aircraft types and missions.

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Therefore, as one can see, the contents are more of abstract and that is the reason why we instructors should seek for ways or methods that will enhance students' understanding and self-learning.

It is noted by P. Obanya, J. Shabani and P. Okebukola (2000) that the rapid breakthroughs in new information and communication technologies will further change the way knowledge is developed, acquired and delivered. The new technologies offer opportunities to innovate course content and teaching methods.

Hence the introduction of interactive computer software for teaching the two theoretical courses mentioned above is proposed in this document.

Overview of AGTE Theory and FAE Courses

As per D.E.C catalogue (1997) the description of the courses is as follows:

- AVIATION GAS TURBINE ENGINE THEORY I-MEPT 376 (4-3-3) Pre-requisite: ME 310, MEPT 355, ME 216

  Role of engine in aircraft development, thermodynamic and gas dynamics equations, thrust and efficiency, types, working principle, mathematical analysis, characteristics, regulation, unsteady working conditions and cooling of compressor, gas turbine, inlet and exhaust section of the engine. Main and afterburner combustion chamber: types, combustion process, components and limitations.

- AVIATION GAS TURBINE ENGINE THEORY II -MEPT 471 (4-3-3) Pre-requisite: MEPT 376

  Working process of gas turbine engine, component matching, computation of parameters, performance *curves analysis of the engine and noise reduction methods, design, construction and principle of operation of ram, pulse and combined jet engines, selection of optimum dimensions, parameters and controlling program of an engine for specified flying vehicles.*

- FUNDAMENTALS OF AVIATION ENGINES - MEPT 0276(4-3-3)
  Pre-requisite: ME 0213, MEPT 0254

  Introduction: Power plant progress, classification, basic requirement, background and development; Types variation and application; engine theory two plus two; design of inlet ducts; compressor design, Combustion chamber design; Turbine design, exhaust systems design, methods of thrust augmentation, Fuel system and components; lubricating system, starting system.

The courses take, as a base of the study, turbo jet engine. Turbo jet engine consists of the following components: the inlet duct, The compressor, the combustion chamber, The gas turbine, The exhaust nozzle, the after burner combustion chamber (for military and civilian supersonic aircrafts).

In the first phase of the study the courses deal mainly on analysis of each component: definition of the purpose, modeling of the component, analysis of the flow process, computation of the geometrical and flow parameters of components.

In the second phase of the study the courses consider the jet engine as a system. They deal with components flow and power matching principles, the programs of control and performance of the jet engine, i.e. identification of the main parameters of the engine (specific thrust, specific fuel consumption versus the flying match number, altitude, and the throttle position).

In the third phase of the study the courses focus on the off-design condition of the jet engine (starting, acceleration, deceleration), peculiarities of turboprop, turbofan, turbo shaft engine and ram jet engine.

As one can judge, a lot of abstraction is involved which definitely requires alternative method of learning besides the traditional approaches. For the courses under discussion EngineSim interactive computer software is proposed.

EngineSim INTERACTIVE COMPUTER SOFTWARE

Purpose of the software

EngineSim, an educational computer program developed at NASA's Glenn Research Center, is an interactive simulator that enables students to explore the effects of engine operation on total aircraft performance. This software can be used to illustrate real world application of principles and theories. Using the EngineSim, the student can see how a jet engine works: how changing the temperature in the burner causes an increase in thrust and fuel usage; it shows how improving the compressor and turbine will make a big difference in the thrust and fuel usage; it shows why certain types of materials are used in jet engines, and how engineers use graphs to present information. It also offers the student a simulator that models the design and testing of engines and shows the effects of engine type on aircraft speed and range.

With this software one can investigate how a turbine or jet engine produces thrust by changing the values of different engine parameters. You can also investigate the effects of engine performance on aircraft.

Features of the software

The capability of the software is described below.

Screen

The program screen is divided into four main parts:

On the top left side of the screen is a graphic of the engine you are designing or testing. In the Design Mode, the drawing is a schematic, while in Tunnel Test Mode the drawing is an animation.

On the top right side of the screen are the results of engine performance calculations. The output can be presented as numerical values of certain parameters, graphs of engine performance, or as photos of the engine parts with descriptions of their purpose. Performance results are shown in black boxes with yellow letters. You may select the type of output displayed by using the red choice button labeled "Output Display" on the bottom right panel.

On the lower right side of the screen you will always see the overall engine performance displayed as thrust, fuel flow, airflow, and computed engine weight. You can make choices concerning the type of engine to design or analyze, the type of output to be displayed, and the units to be used in the calculations. To operate a choice button, click on the arrow in the choice box on the right and make your selection.

On the lower left side of the screen various input panels are displayed. You can select the input panel by clicking on the name or the component in the graphic at the upper left. To change the value of an input variable, you can simply move the slider. Or you can click on the input box, select and replace the old value, then hit Enter to send the new value to the program. Upper and lower limits are set for each input variable.

Engine design

You can choose from four different types of engines: a simple turbojet, a jet with afterburner, a turbofan engine, or a ramjet. Selections are made on the graphics window by clicking on the engine name. The chosen engine is shown in yellow.

Design variables include Flight Conditions (airspeed, altitude, throttle), Engine Size (frontal area), Inlet (pressure recovery), Fan (pressure ratio, efficiency, and bypass ratio), Compressor (CPR, compressor efficiency), Burner (maximum temperature, efficiency, pressure ratio), Turbine (turbine efficiency) and Nozzle (maximum temperature, efficiency,). As you choose a different component the part of the engine being affected is highlighted in the graphic by changing from its default color to yellow. If you change the Output Display to Photos you can view an actual photograph and description of each engine part. As the Engine Size changes, the grid background changes in proportion to the change in engine size. The distance between any two-grid lines is 1 foot.

Choices: Mode, Units, and Output Display

The program works in two modes: Design and Tunnel Test Mode. In the Design Mode, you can change design variables including the flight conditions, the engine size, the inlet performance, the turbo machinery compressor and turbine performance, the combustors or burner performance, or the nozzle performance. For a turbofan engine design you can also vary the fan performance and the bypass ratio. When you have a design that you like, you can switch to the Tunnel Test Mode, where you can vary only the flight conditions (airspeed, altitude, and throttle setting). In Tunnel Test mode, you can load models of existing turbine engines for comparison with your design. You can always reload your design to continue testing. In design mode, you can use the existing engine models as good starting points for your design.

The calculations can be performed in either metric or English units. You can always return to the default conditions by pushing the Reset button.

Materials Input

The program will calculate an average weight of the engine that you design. The thrust to weight ratio of the engine is displayed in the numerical output and is a measure of the efficiency of the engine. The weight depends on the number of stages in the compressor and turbine, the diameter (frontal area) of the engine, and the component materials. The program begins with standard materials for the components, but you can change the materials and see the effects on weight of the engine. Just push the blue Materials choice button on any component input panel. You can also select to define your own material by choosing My Material from the menu. Just type in your own values for material density and temperature limit. The program will check the temperature throughout the engine design against the material limits. If you exceed a limit, a flashing warning will occur in the schematic. You can see the temperature limits by choosing Temp Variation in the Output Display. (For the afterburner and the ramjet, the graphical temperature limits are based on the flow temperature, not on the material temperature, and are slightly higher than the material limits. Cooling airflow is often used along the walls of these components to keep the material temperature within limits.)

Graphical Output

The red Output Display menu allows you to change the contents of the output window in the top right side of the screen. You can choose to display output boxes with numerical values of the engine performance, as described below. Or you can display photographs and descriptions of each engine part. You can display the variation of the value of pressure and temperature at various stations through the engine. Or you can also display a T-s Plot or a P-v plot, which are used by engineers to determine engine performance.

To generate your own performance plots; select "Generate" from the graphics window. The input panel will now display some additional buttons and sliders to generate a plot. Choose the variables to be plotted using the pull down menus and then push the "Begin" data button. Set the value of the independent variable by using the slider or the type-in box. Push the blue "Take Data" button and a data point will appear on the graph. Set a new value for the variable and take another data point (up to 25 points in any order). When you are finished, push the "Eng" button and a line will be drawn through your data points. To start a new graph, push "Begin" and your old graph will vanish. When you are finished, push the red "Exit" button and you will return to free stream conditions.

Numerical Output

Numerical Output from the program is displayed on two performance panels. The total engine performance is always displayed below the output panel and includes the engine net thrust, the fuel flow rate, the engine air flow rate, and the engine weight. An additional output panel shows the ratios of these engine performance numbers including the specific fuel consumption, the fuel-to-air ratio, and thrust to weight ratio. The engine pressure ratio (EPR) and engine temperature ratio (ETR), as well as the flight conditions; the free stream Mach number, pressure and temperature are also shown on the numerical output panel.

Exercise:

In addition to the above feature the software gives to the student a lot of exercises. An example of such exercises is given below.

Set the following conditions in EngineSim:

The airspeed should be 0, the Altitude 0, and the Throttle 100. Record the thrust (F net) ____________ and the Fuel Flow ________.

Now go ahead and change the altitude to 10,000ft. and the Airspeed to 350. Did the thrust increase or decrease? Did the fuel flow increase or decrease? Thrust _________ Fuel Flow _____.

What happens when you choose a different engine? Choose a jet with afterburner and record the thrust ______ and the fuel flow ________.

Choose a turbofan engine and record the thrust __________ and the fuel flow _______.

What can you conclude about the effect of an increase in altitude and airspeed on thrust?______________ On fuel flow?______________

Which engine is most fuel efficient?_________________________

How to Get the Software ?

EngineSim runs in a Web browser. It is available on the Aeronautics Software CD or at the Glenn Learning Technology Web site:

http://www.grc.nasa.gov/WWW/K-12/Enginesim/index.htm

Conclusion

As shown above usage of EngineSim interactive computer software in the teaching and learning processes of the courses will enhance the learning by:

- motivating the students to learn giving them the chance to explore through the jet engine from various perspectives using colorful and lively presentation and adding some measure of reality to learning (concreteness);
- giving the students all the opportunities to make mistakes, look for possible reasons of the mistakes and search for alternative engineering solutions to the mistakes on the software (self

regulation and feedback). Expands the possible modalities of learning (redundancy);

- increasing the perceptual scope of the students.

In a nutshell, the software enhances learner-centered approach. Thus, using the EngineSim interactive computer software is recommended for instruction of the aircraft propulsion theory courses.

References:

http://www.grc.nasa.gov/WWW/K-12/Enginesim/index.htm

Defense Engineering 1997, DEC Catalogue,.

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