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TITLE:
A Rapid Method for Modeling a Variable Cycle Engine

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SUMMARY:
Here, we present a protocol to build a component-level mathematical model for a variable cycle engine.

ABSTRACT:
The variable cycle engines (VCE) that combine the advantages of turbofan and turbojet engines, are widely considered to be the next generation aircraft engines. However, developing VCE requires high costs. Thus, it is essential to build a mathematical model when developing an aircraft engine, which may avoid a large number of real tests and reduce the cost dramatically. Modeling is also crucial in control law development. In this article, based on a graphical simulation environment, a rapid method for modeling a double bypass variable cycle engine using object-oriented modeling technology and modular hierarchical architecture is described. Firstly, the mathematical model of each component is built based on the thermodynamic calculation. Then, a hierarchical engine model is built via the combination of each component mathematical model and the N-R solver module. Finally, the static and dynamic simulations are carried out in the model and the simulation results prove the effectiveness of the modeling method. The VCE model built through this method has the advantages of clear structure and real-time observation.

INTRODUCTION:

Modern aircraft demands bring great challenges to the propulsion system, which need more intelligent, more efficient or even more versatile aircraft engines[1]. Future military propulsion systems also require both higher thrust at high speed and lower specific fuel consumption at low speed[1-4]. In order to meet the technical requirements of future flight missions, General Electric (GE) put forward the variable cycle engine (VCE) concept in 1955[5]. A VCE is an aircraft engine that can perform different thermodynamic cycles by changing the geometry size or position of some components[6]. The Lockheed SR-71 "Blackbird" powered by a J58 turboramjet VCE has held the world record for the fastest air-breathing manned aircraft since 1976[7]. It also proved many potential advantages of supersonic flight. In the past 50 years, GE has improved and invented several other VCEs, including a double bypass VCE[8], a controlled pressure ratio engine[9] and an adaptive cycle engine[10]. These studies involved not only the general structure and performance verification, but also the control system of the engine[11]. These studies have proven that the VCE can work like a high bypass ratio turbofan at subsonic flight and like a low bypass ratio turbofan, even like a turbojet at supersonic flight. Thus, the VCE can realize performance matching under different flight conditions.

When developing a VCE, a large amount of necessary verification works will be carried out. It may cost a large amount of time and outlay if all these works are performed in a physical way[12]. Computer simulation technology, which has already been adopted in developing a new engine, can not only reduce the cost greatly, but also avoid the potential risks[13,14]. Based on computer simulation technology, the development cycle of an engine will be reduced to nearly half, and the number of equipment required will be reduced dramatically[15]. On the other hand, simulation also plays an important role in the analysis of the engine behavior and control law development. For simulating the static design and off-design performance of engines, a program called GENENG[16] was developed by the NASA Lewis Research Center in 1972. Then the research center developed DYNGEN[17] derived from GENENG, and DYNGEN could simulate the transient performance of a turbojet and the turbofan engines. In 1989, NASA put forward a project, called Numerical Propulsion System Simulation (NPSS), and it encouraged researchers to construct a modular and flexible engine simulation program through the use of object-oriented programming. In 1993, John A. Reed developed the Turbofan Engine Simulation System (TESS) based on the Application Visualization System (AVS) platform through object-oriented programing[18].

Meanwhile, rapid modeling based on graphical programming environment is being used gradually in simulation. The Toolbox for the Modeling and Analysis of Thermodynamic Systems (T-MATS) package developed by NASA is based on Matlab/Simulink platform. It is open source and allows users to customize built-in component libraries. T-MATS offers a friendly interface to users and it is convenient to analyze and design the built-in JT9D model[19].

In this article, the dynamic model of a type of VCE has been developed here using Simulink software. The modeling object of this protocol is a double bypass VCE. Its schematic layout is shown in **Figure 1**. The engine can work in both single and double bypass modes. When the Mode Select Valve (MSV) is open, the engine performs better at subsonic conditions with a relatively large bypass ratio. When the Mode Select Valve is closed, the VCE has a small bypass ratio and a better supersonic mission adaptability. To further quantize performance of the engine, a double bypass VCE model is built based on component-level modeling method.

PROTOCOL:

1 Preparation before modeling

1.1 Obtain design point performance.

1.1.1 Open **Gasturb 13**. Select **Variable Cycle Engine**.

1.1.2 Click on **Basic Thermodynamics**. Select **Cycle Design**. Open **DemoVarCyc.CVC**.

1.1.3 Obtain the engine design point performance. These are shown on the right side of the window.

1.2 Obtain component maps.

1.2.1 Open **Gasturb 13**. Select **Variable Cycle Engine**.

1.2.2 Click on **Off Design**. Select **Standard Maps**. Open **DemoVarCyc.CVC**.

1.2.3 Click on **Off Design Point**. Then select **LPC**, **IPC**, **HPC**, **HPT** and **LPT**; thus, all components maps are obtained.

2 Model each component of the VCE[20-22]

2.1 Model a single component of a VCE. Take the high-pressure compressor as an example.

2.1.1 Open **Matlab**. Click on **Simulink**. Double click on **Blank Model**.

2.1.2 Click on **Library**, and place function to model.

2.1.3 Double click on **Function**. According to the working principle of the compressor, the thermodynamic equation of the compressor is described. Then describe the equation with the **MATLAB function**.

2.1.4 After finishing the **MATLAB function**, obtain the input and output of the compressor.

2.1.5 Use **Subsystem** to mask the module. Then rename it with “compressor”. Thus far, a subsystem module called “compressor” is established.

2.2 Use the same steps to get the subsystems of all components including inlet, fan, duct, core driven fan stage(CDFS), bypass mixer, compressor, burner, high-pressure turbine, low-pressure turbine, mixer, afterburner and nozzle.

2.2.1 Combine output of each component with input of the next component.

3 Solution of the whole model

3.1 Construct dynamic co-working equations of whole model.

3.1.1 Construct dynamic co-working equations. Construct the following 6 independent co-working equations.

3.1.2 Determine the flow balance equation for inlet and outlet of burner:

$$W_{g44} - W_{a3} - W_f = 0$$

W_{a3}: compressor outlet section air flow, W_f: burner fuel flow, W_{g44}: high-pressure turbine inlet gas flow.

3.1.3 Determine the flow balance equation for inlet and outlet of low-pressure turbine:

$$W_{g44} - W_{g5} = 0$$

W_{g44}: low-pressure turbine inlet section gas flow, W_{g5}: low-pressure turbine outlet gas flow.

3.1.4 Determine the flow balance equation for inlet and outlet of nozzle:

$$W_{g7} - W_{g9} = 0$$

W_{g7}: nozzle inlet gas flow, W_{g9}: nozzle outlet gas flow.

3.1.5 Determine the static pressure balance equation for inlet of rear mixer:

$$p_{s163} - p_{s63} = 0$$

p_{s163}: static pressure of main outer bypass outlet, p_{s63}: static pressure of inner bypass outlet.

3.1.6 Determine the flow balance equation of fan inlet and outlet:

$$W_{a2} - W_{a21} - W_{a13} = 0$$

W_{a2}: fan inlet air flow, W_{a21}: CDFS inlet air flow, W_{a13}: sub-outer bypass inlet air flow

3.1.7 Determine the flow balance equation of CDFS outlet:

$$W_{a21} - W_{a125} - W_{a25} = 0$$

W_{a21}: CDFS inlet air flow, W_{a125}: CDFS bypass inlet air flow, W_{a25}: compressor inlet air flow.

3.1.8 The above 6 independent equations constitute the following equations.

$$\begin{aligned}
&W_{g44} - W_{a31} - W_f = 0 \\
&W_{g45} - W_{g5} = 0 \\
&W_{g7} - W_{g9} = 0 \\
&p_{s163} - p_{s63} = 0 \\
&W_{a2} - W_{a21} - W_{a13} = 0 \\
&W_{a21} - W_{a125} - W_{a25} = 0
\end{aligned}$$

3.2 Use the **N-R iteration solver** in TMATS to solve the above equations.

3.2.1 Before using the solver to solve the co-working equations, set the N-R iteration solver. According to the modeling process, select the following 6 initial guesses: component map auxiliaries line of fan, CDFS, high-pressure compressor, high-pressure turbine and low-pressure turbine β_1, β_2, β_3, β_4, β_5, sub-outer bypass inlet flow.

REPRESENTATIVE RESULTS:

In order to prove the validity of the simulation model, several typical performance parameters selected in static and dynamic simulations are compared with the data in Gasturb.

In a static simulation, we compare several key performance parameters of the model with these parameters in Gasturb to verify the accuracy of the static model. **Table 2** shows the result of the comparison at the design point with H=0 m, M_a=0, W_f=0.79334 kg/s under a double bypass operating mode. According to the comparison, the maximum error of performance parameters between the model and Gasturb is the EPR (engine pressure ratio), which is below 2%. **Table 3** shows the result of the comparison at the off-design point with H=0 m, M_a=0, W_f=0.91032 kg/s under a single bypass operating mode. Under this condition, the maximum error here is the rotational speed of low-pressure shaft, which is just below 4%. The performance parameters of both models are almost the same. Thus, the two comparison results prove that the model is accurate, and the protocol is effective at the design point.

In a dynamic simulation, with the purpose of verifying the correctness of the transition state model, we simulated two typical dynamic processes including acceleration/deceleration simulation and mode switching simulation. The acceleration/deceleration simulation are processed under a double bypass mode with H=0 m, M_a=0. **Figure 2a** shows the input of the fuel flow. **Figure 2b, Figure 2c,** and **Figure 2d** show the response of the rotational speed, air flow and temperature before the turbine, so the model is able to perform acceleration/deceleration simulation. A mode switching simulation is carried out from the double bypass mode to the single bypass mode with H=0 m, M_a=0. As shown in the **Figure 3**, the VCE operating mode is switched from the single bypass mode to the double bypass mode at 5 s. In order to prevent the engine from exceeding the limited speed during the switching process, a single-variable closed-loop control is applied to the rotational speed of high-pressure shaft. **Figure 3b** shows that the rotational speed of high-pressure shaft is nearly unchanged during switching. Similarly, **Figure 3a**, **Figure 3b**, **Figure 3c** and **Figure 3d** show the response of the fuel flow, rotational speed, air flow and temperature before the turbine. During the two-dynamic simulation, the model can run correctly.

FIGURE AND TABLE LEGENDS:

Figure 1: Schematic diagram of overall structure of variable cycle engine. A VCE contains a fan, a CDFS, a compressor, a burner, a turbine, a mixer, an afterburner and a nozzle. The fan and CDFS are driven by the low-pressure turbine. The compressor is driven by the high-pressure turbine. The numbers in **Figure 1** represent the cross section of the engine. The definition of each cross sections is shown in **Table 1**.

Figure 2. Acceleration/deceleration simulation of VCE. This figure presents acceleration/deceleration simulation. The fuel flow input is shown in **Figure 2a**. The responses of main performance parameters are shown as below. **(b)** The response of the high-pressure speed and the low-pressure speed. **(c)** The response of the air flow. **(d)** The response of the turbine inlet temperature.

Figure 3. Mode switching simulation of VCE. This figure presents the mode switching simulation. **(a)** The response of the fuel flow input. **(b)** The response of the high-pressure speed and the low-pressure speed. **(c)** The response of the air flow. **(d)** The response of the turbine inlet temperature.

Table 1: Definition of all cross sections. The cross-section definitions of the variable cycle engine adopted in this protocol are shown in **Table 1**.

Table 2. Comparison of the design point of the double bypass. Several key performance parameters of model are compared with those parameters in Gasturb at the design point with H=0 m, M_a=0, W_f=0.79334 kg/s.

Table 3. Comparison of the off-design point of the single bypass. Several key performance parameters are compared at the off-design point with H=0 m, M_a=0, W_f=0.91032 kg/s.

DISCUSSION:

Based on a graphical simulation environment, a VCE component-level model can be built rapidly through modular hierarchical architecture and object-oriented modeling technology. It offers a friendly interface to users and it is convenient to analyze and design the model[19].

The main limitation of this method is the execution efficiency of the model. Because the model is written in scripting language, the model needs to be recompiled every time it runs. Thus, the execution efficiency is not as good as the system language. In view of this limitation, the next key research point is how to improve the execution efficiency of the model. Another limitation is that the initial value of the N-R iteration should be considered strictly in the model, because the N-R iteration is convergent only in a small range of deviations.

A critical step in the protocol is how to obtain the component maps accurately and use the appropriate algorithm to interpolate. Whether in Gasturb or another existing engine test data, accurate component maps are helpful to build model more accurately.

In the graphical object-oriented modeling of aeroengine, whether it is the whole engine model object, the component model object or the parameter model object of each component, it is built as an independent and encapsulable module. The connection among all component modules constitute the main part of the model framework. The internal model design of each component module is for the purpose of generality, highlighting the features of easy modification and visualization of the component model. The method presented in this paper can be used not only for VCE but also for other gas turbines[23].

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DISCLOSURE:

We have nothing to disclose.

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Figure1

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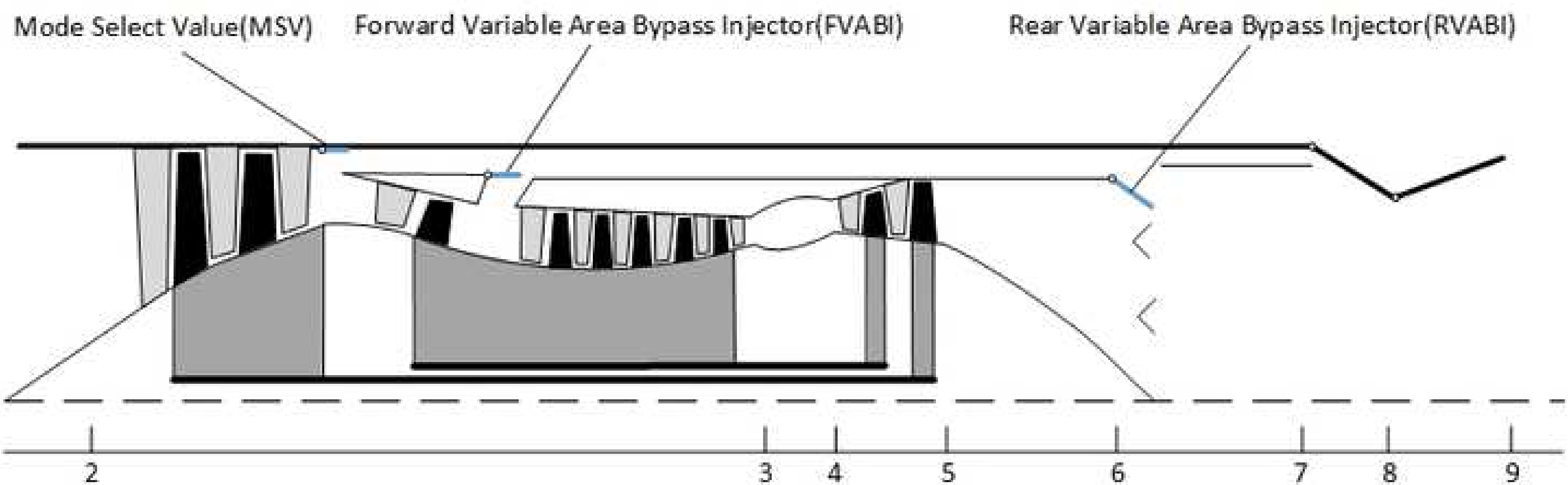

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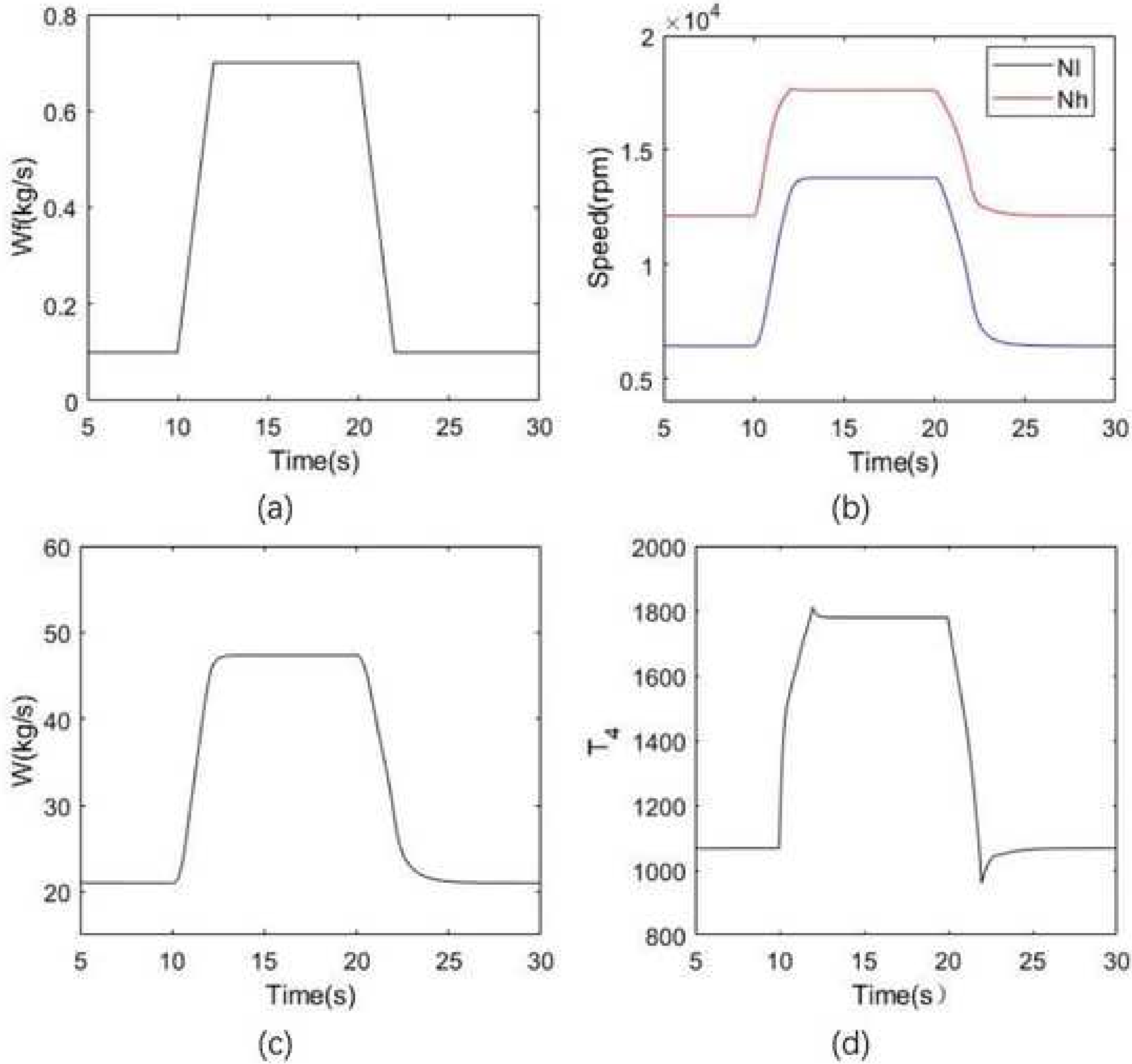
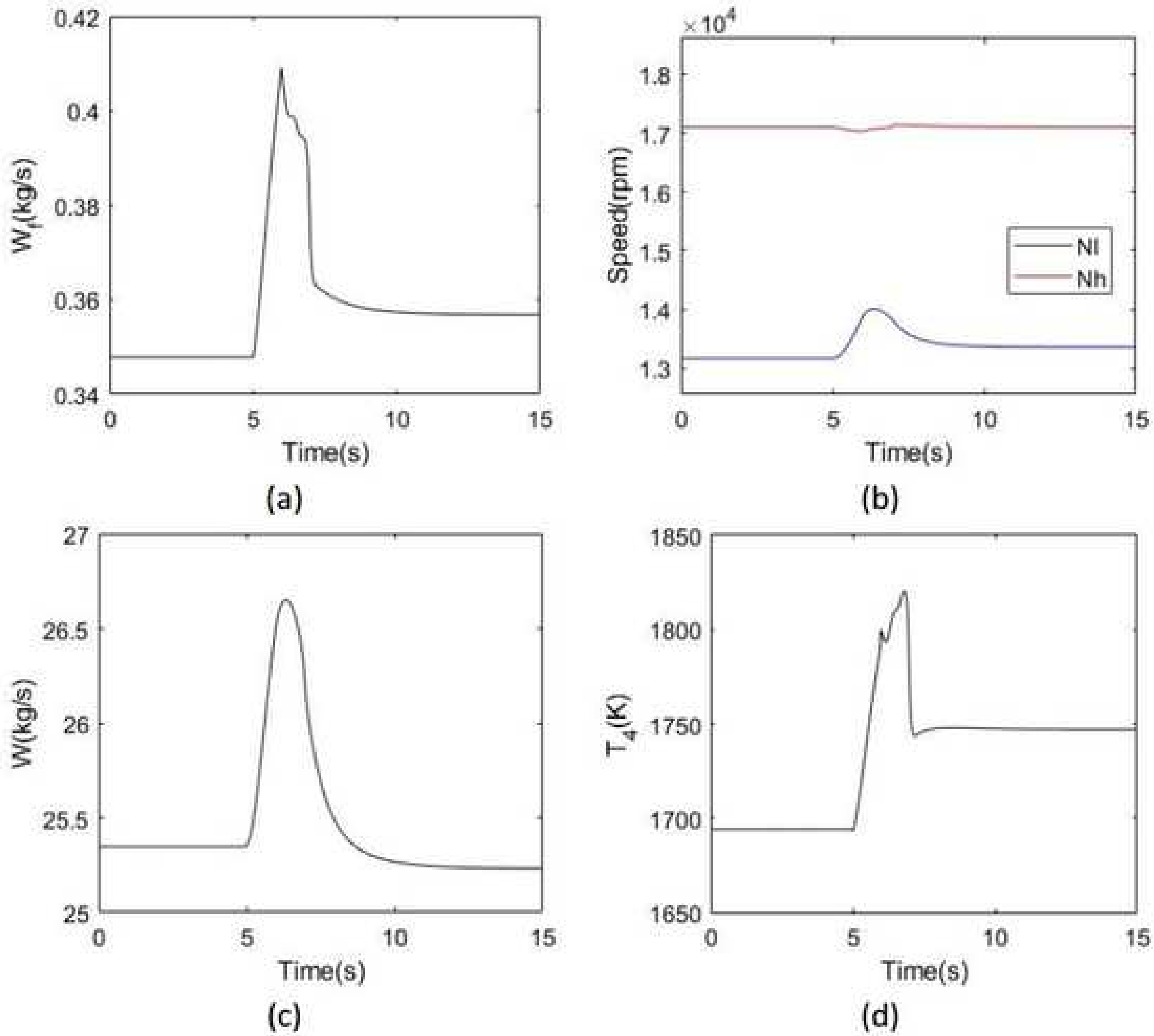


Figure3



(a) (b) (c) (d)

Numbe of cross section	Definition
2	Fan inlet
3	Compressor outlet
4	Burner outlet
5	Low-pressure turbine outlet
6	Mixer inlet
7	Afterburner outlet
8	Nozzle thought
9	Nozzle outlet

Parameter	Model	Gasturb 13	Error(%)
Nl(RPM)	14711	14600	0.76
Nh(RPM)	18060	18000	0.33
T4(K)	1866	1850	0.86
FN(KN)	38.18	37.98	0.53
EPR	4.1653	4.2436	1.85

Parameter	Model	Gasturb 13	Error(%)
Nl(RPM)	15544	15033	3.4
Nh(RPM)	18123	18000	0.68
T4(K)	2036	2002	1.7
FN(KN)	41.23	40.68	1.35
EPR	4.2419	4.2894	1.11

Name of Material/ Equipment	Company	Catalog Number	Comments/Description
Gasturb	GasTurb GmbH	Gasturb 13	
MATLAB	MathWorks	R2017b	
TMATS	NASA	1.2.0	

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CORRESPONDING AUTHOR:

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Article Title: A Rapid Method for Modeling a Variable Cycle Engine
Signature: Bing Yu
Date: Sept. 26. 2018

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Dear Editors,

We have studied comments carefully and have made corrections which we hope meet with approval. Thanks again for your valuable comments.

We tried our best to improve the manuscript and made some changes in the manuscript. These changes will not influence the content and framework of the paper.

We appreciate for Editor/Reviews' hard work, and hope that the corrections will meet with approval.

Once again, thank you very much for your comments and suggestions.

Sincerely,

Bing Yu

Dear Editors and Reviewers,

Thank you for your letter and for the reviewers' comments concerning our manuscript entitled "A Rapid Method for Modeling a Variable Cycle Engine (JoVE59151R1). Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researches. We have studied comments carefully and have made corrections which we hope meet with approval. The main correction in the paper and the point to point responses to the editorial and reviewers' comments are as following:

Response to editorial comments:

1. Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammar issues. The JoVE editor will not copy-edit your manuscript and any errors in the submitted revision may be present in the published version.

Response: Thank you for your comment. We have proofread the manuscript thoroughly.

2. Please provide an email address for each author.

Response: Thank you for your comment. We have provided all authors' email address.

3. Please provide at least 6 keywords or phrases.

Response: Thank you for your comment. We have added several keywords.

4. Please rephrase the Short Abstract/Summary to clearly describe the protocol and its applications in complete sentences between 10-50 words: "Here, we present a protocol to …"

Response: Thank you for your comment. We have rephrased the Short Abstract.

5. Please revise the Introduction to include all of the following:

a) A clear statement of the overall goal of this method

b) The rationale behind the development and/or use of this technique

c) The advantages over alternative techniques with applicable references to previous studies

d) A description of the context of the technique in the wider body of literature

e) Information to help readers to determine whether the method is appropriate for their application.

Response: Thank you for your comment. We have revised the Introduction to include the above.

6. Please remove all commercial language from your manuscript and use generic terms instead. All commercial products should be sufficiently referenced in the Table of Materials and Reagents.

For example: MATLAB, SIMULINK, Gasturb 13, etc

Response: Thank you for your comment. We have tried our best to reduce the frequency of those commercial language. While in some steps of protocol, they are necessary. We are sorry that they can't be removes completely.

7. Please ensure that all text in the protocol section is written in the imperative tense as if telling someone how to do the technique (e.g., "Do this," "Ensure that," etc.). The actions should be described in the imperative tense in complete sentences wherever possible. Avoid usage of phrases such as "could be," "should be," and "would be" throughout the Protocol. Any text that cannot be

written in the imperative tense may be added as a “Note.”
Response: Thank you for your comment. We have revised some the statement in protocol.

8. Please revise the text to avoid the use of any personal pronouns in the protocol (e.g., "we", "you", "our" etc.).
Response: Thank you for your comment. We have deleted all personal pronouns in the protocol.

9. JoVE policy states that the video narrative is objective and not biased towards a particular product featured in the video. The goal of this policy is to focus on the science rather than to present a technique as an advertisement for a specific item. To this end, we ask that you please reduce the number of instances of "SIMULINK" within your text. This can be introduced once in the introduction.
Response: Thank you for your comment. We have tried our best to reduce the number of instances of "SIMULINK" and other commercial language.

10. The Protocol should contain only action items that direct the reader to do something.
Response: Thank you for your comment. We have revised the protocol to make it direct the reader to do something.

11. Please add more details to your protocol steps. Please ensure you answer the “how” question, i.e., how is the step performed?
Response: Thank you for your comment. We have added details of steps. Such as how to build compressor model.

12. 1.1. is this open access? If not, we cannot have commercial terms in the manuscript. Please move the commercial term in the table of materials.
Response: Thank you for your comment. This manuscript is not open access. We have move the commercial term in the table of materials.

13. 2.1.3: What is MATLAB function in this case. Unclear what is being done. What is the working principle of the compressor? Do you run any script in MATLAB?
Response: Thank you for your comment. Every MATLAB function describe the working equation of corresponding component. Taking compressor for example, the input of MATLAB function include air flow, temperature and pressure of inlet, and the output include air flow, temperature and pressure of outlet. Yes, we run script language in MATLAB.

14. 2.1.4: What is the input and output of the compressor? How is this obtained? Please provide details.
Response: Thank you for your comment. As I said above, the input include air flow, temperature and pressure of inlet, and the output include air flow, temperature and pressure of outlet. The input is the output of the front component. We have added more detail to the text.

15. 3.1 How is this done. Do you use any software for this?
Response: Thank you for your comment. 3.1 include all co-working equations obtained based on

analysis for working principle of each component. We don't use any software, these equations can be obtained easily from references.

16. Please include at least one paragraph of text to explain the Representative Results in the context of the technique you have described, e.g., how do these results show the technique, suggestions about how to analyze the outcome, etc. The paragraph text should refer to all of the figures. Data from both successful and sub-optimal experiments can be included.
Response: Thank you for your comment. We have provided Table 1 and Table 2 to show the outcome of the method. We describe and analyze two tables to show the effectiveness of our model.

17. Please include some protocol and result for validating the model as well.
Response: Thank you for your comment. We have added some verifications results for model. Those are shown in Table 1 and Table 2.

18. Please also include some results/discussion on how this is better as compared to C.
Response: Thank you for your comment. We have added some content compared with C in Discussion.

19. Please include a title and a description of each figure and/or table. All figures and/or tables showing data must include measurement definitions, scale bars, and error bars (if applicable). The Discussion of the Figures should be placed in the Representative Results. Details of the methodology should not be in the Figure Legends, but rather the Protocol.
Response: Thank you for your comment. We have remove all figures and tables from the manuscript.

20. Please include all the Figure Legends together at the end of the Representative Results in the manuscript text.
Response: Thank you for your comment. We include all the Figure Legends together at the end of the Representative Results in the manuscript text.

21. As we are a methods journal, please revise the Discussion to explicitly cover the following in detail in 3-6 paragraphs with citations:
a) Critical steps within the protocol
b) Any modifications and troubleshooting of the technique
c) Any limitations of the technique
d) The significance with respect to existing methods
e) Any future applications of the technique
Response: Thank you for your comment. We have revised the discussion to cover the above.

22. Please remove the embedded figure(s) from the manuscript. All figures should be uploaded separately to your Editorial Manager account.
Response: Thank you for your comment. We removed all figures from the manuscript. And we upload those to our Editorial Manager account.

23. Please remove the embedded Table from the manuscript. All tables should be uploaded

separately to your Editorial Manager account in the form of an .xls or .xlsx file.
Response: Thank you for your comment. We removed all tables from the manuscript. And we upload those to our Editorial Manager account.

24. For the table of materials, please include the name, company, and catalog number of all relevant materials in separate columns in an xls/xlsx file.
Response: Thank you for your comment. We have refresh the table of materials and upload it to the Editorial Manager account.

Response to reviewrs' comments:
Reviewer #1:

1. Nomenclature is missing. For example What is MSV?
Response: Thank you for your comment. We are sorry that we miss some nomenclature due to our negligence. Based on this, we have added the missing nomenclature.

2. The author/s claim that "simulation results verify the effectiveness of the modeling method". How did you define effectiveness? It is not clear from the figures because there are no error calculations between the calculated component parameters and the real values of engine in figures and also there are no calculations that show time savings.
Response: Thank you for your comment. We are sorry that we didn't make clear definition of effectiveness in the manuscript. We have added the error calculations between the calculated component parameters and the real values of Gasturb in new manuscript. The results are shown with Table 1 and Table 2 in the manuscript.

Parameter	Model	Gasturb 13	Error(%)
Nl(RPM)	14711	14600	0.76
Nh(RPM)	18060	18000	0.33
T4(K)	1866	1850	0.86
FN(KN)	38.18	37.98	0.53
EPR	4.1653	4.2436	1.85

Table 1

Parameter	Model	Gasturb 13	Error(%)
Nl(RPM)	15544	15033	3.40
Nh(RPM)	18123	18000	0.68
T4(K)	2036	2002	1.70
FN(KN)	41.23	40.68	1.35
EPR	4.2419	4.2894	1.11

Table 2

Here, we define effectiveness from two aspects. Firstly, the static parameters calculated by model are approximately equal to the parameters of Gasturb under the design point. Then, the model can work from one static point to another static point by changing fuel flow. While Gasturb can only calculate the steady-state point, and can not show the dynamic process.

3. Introduction is weak. In the literature, there are many gas turbine mathematical model examples constructed on MATLAB/Simulink platform. They should be added to the introduction. Number of references is not enough.

Response: Thank you for your suggestion. We have revised and added introduction and references based on your suggestion. Such as：

Loftin, Laurence K. "Toward a Second-Generation Supersonic Transport." Journal of Aircraft 11(2012).

Tsoutsanis E , Meskin N . Dynamic performance simulation and control of gas turbines used for hybrid gas/wind energy applications[J]. Applied Thermal Engineering, 2018.

Kurzke, J., Halliwell, I.Propulsion and Power: An Exploration of Gas Turbine Performance Modeling. (2018) Propulsion and Power: An Exploration of Gas Turbine Performance Modeling, pp. 1-755.

Reviewer #2:

1. The body of the manuscript has not clearly demonstrated the procedures of the analysis.

Response: Thank you for your comment. We are sorry that we didn’t clearly demonstrated the procedures. Based on your comment, we have revised some steps to make them more clearly.

2. The results discussions and validation needs to be presented in the body of the manuscripts along with response plots.

Response: Thank you for your comment. The figures are required to be presented alone in the end of the manuscript according to the format of journal. We are sorry to bring you poor reading experience.

2. The appendices needs to be as brief as possible.

Response: Thank you for your comment. We are sorry that we can’t fully understand the meaning of your comment. There is no appendices in our manuscript. If you mean the figures in the end of the manuscript, we have revised the format.

Reviewer #3:

1. Although the model is not highly sophisticated you should acknowledge the need for model validation and verification if this model is to be used for engine model tuning, control, diagnostics etc.

Response: Thank you for your comment. We have incorporated your comment by added validation and verification. We build the model based on the data of Gasturb, so we compare the parameters of model with parameters of Gasturb. We have added the error calculations between the calculated component parameters and the real values of Gasturb in new manuscript. The results are shown with Table 1 and Table 2 in the manuscript.

Parameter	Model	Gasturb 13	Error(%)
Nl(RPM)	14711	14600	0.76
Nh(RPM)	18060	18000	0.33
T4(K)	1866	1850	0.86
FN(KN)	38.18	37.98	0.53
EPR	4.1653	4.2436	1.85

Table 1

Parameter	Model	Gasturb 13	Error(%)
Nl(RPM)	15544	15033	3.40
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T4(K)	2036	2002	1.70
FN(KN)	41.23	40.68	1.35
EPR	4.2419	4.2894	1.11

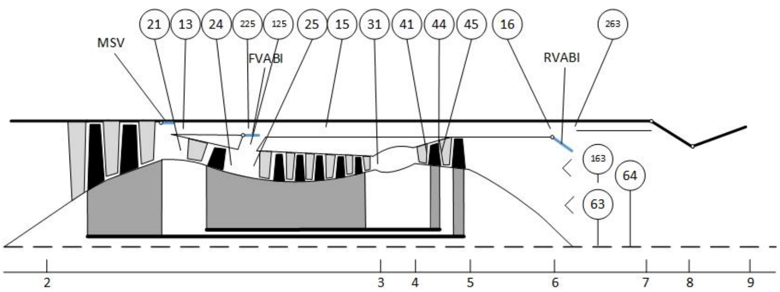
Table 2

2. Number all the equations used.

Response: Thank you for your comment. According to the format requirement of the journal, there is no need to number equations.

3. Provide a schematic layout for the engine.

Response: Thank you for your suggestion. We have added a schematic layout of the VCE, so the readers can understand the model and the modeling method better. The schematic layout of the VCE is as follows.



4. Update your list of references with studies that have used MATLAB/simulink and GasTurb.

Response: Thank you for your suggestion. We have added some references with studies that have used MATLAB/simulink and GasTurb.

Thanks again for your valuable comments.

We tried our best to improve the manuscript and made some changes in the manuscript. These changes will not influence the content and framework of the paper. And here we did not list the changes but marked in the revised paper.

We appreciate for Editor/Reviews' hard work, and hope that the corrections will meet with approval.

Once again, thank you very much for your comments and suggestions.

Sincerely,
Bing Yu

Dear Editors,

Thank you for your letter concerning our manuscript entitled "A Rapid Method for Modeling a Variable Cycle Engine (JoVE59151R3). Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researches. We have studied comments carefully and have made corrections which we hope meet with approval. The main correction in the paper and the point to point responses to the editorial comments are as following:

Response to editorial comments:

1. Please note that there continues to be issues that prevent the acceptance of your manuscript. We need representative results text that shows the efficacy of the protocol and a discussion of these results. The paragraph text should refer to all of the figures. Data from both successful and sub-optimal experiments can be included.

Response: Thank you for your comment. In latest revision, **Figure 2** and **3**, **Table 2** and **3** verify the efficacy of the model.

2. We need definitions of all abbreviations especially those in Figure 1.

Response: Thank you for your comment. We definite all abbreviations in **Figure 1**.

3. **Figure 1a** is referenced and there are no panels to **Figure 1**.

Response: Thank you for your comment. We are sorry that there is a mistake. Actually, it should be **Figure 2(a)**. We have corrected it.

4. Please include panel labeling in **Figure 2 and 3**.

Response: Thank you for your comment. We are sorry we don't understand the meaning of "labeling". We consider it as legends.

5. What does **Table 1** reference now?

Response: Thank you for your comment. **Table 1** show the cross section definitions of variable cycle engine.

Thanks again for your valuable comments.

We tried our best to improve the manuscript and made some changes in the manuscript. These changes will not influence the content and framework of the paper. And here we did not list the changes but marked in the revised paper.

We appreciate for Editor/Reviews' hard work, and hope that the corrections will meet with approval.

Once again, thank you very much for your comments and suggestions.

Sincerely,

Bing Yu