Paper Details

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Evaluating RANS Predictions of Film Cooling with Shaped Holes and Internal Crossflow Using Thermal and Velocity Field Measurements

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Track 12 Heat Transfer: Numerical Film Cooling

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Session: 12-7 Hole Shape Studies II

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Abstract

Film cooling is a very common technique used in cooling turbine engine components, and hence has been studied extensively experimentally and computationally. Computational studies of film cooling range from more simplistic RANS predictions to high fidelity LES predictions. Generally the accuracy of computational predictions of film cooling is evaluated based on the adiabatic effectiveness measured and predicted downstream of the hole. For this study, a RANS computational prediction was used, but he evaluation of the accuracy of the prediction was based on measured thermal and velocity fields within the coolant hole and immediately downstream. We chose a relatively complex film cooling configuration consisting of a row of 7-7-7 shaped holes fed by an internal channel flow with a range internal crossflow velocities and coolant jet velocities. Previous experimental studies using this configuration showed that at various inlet velocity ratios, the coolant jet becomes biased to one side of the diffusing section of the hole, which degrades performance and can cause ingestion into the hole. For this study we wanted to determine the capability of a RANS computation to correctly predict the flow structures, coolant jet biasing, and film effectiveness for this configuration. Computational results were compared to thermal field measurements made with a micro-thermocouple probe, velocity field measurements made with a PIV, and film effectiveness measurements made with an IR camera. These measurements were made within the coolant hole, at the downstream edge of the hole, and at 5D downstream of the hole. Results from this study show that the RANS computations accurately predicted the flow and thermal fields within and at the downstream edge of the hole, but failed to predict the evolutions of the thermal field and film effectiveness downstream of the hole.

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Reviewer Comments

Reviewer 1:

1) Summarize the goals and outcomes of the paper.
This paper aims at evaluating the capabilities and limitations of RANS codes to predict flow and thermal fields and film cooling performance of shaped holes on a flat plate. Evaluations were conducted by comparing to relevant experimental data within and at short distance downstream of the film-cooling holes. This study showed that RANS, with Reliable k-epsilon turbulence model, could be helpful in evaluating the flow within film-cooling holes and correctly predicting coolant distributions at the hole exit. However, the defect of RANS in predicting the mixing of coolant with mainstream flows is apparent.

2) Comment on the originality, relevance, and long-term impact of the paper.
This work is lack of originality as a number of studies have reported the performance of RANS simulations in predicting film cooling performance. Computation is important in turbine cooling design stage. Some specific aspects of RANS in predicting film cooling have been demonstrated. As a result, this paper is relevance to the gas turbine community. However, in the long term, RANS could be discarded as more advanced and accurate numerical methods would be better choice.

3) Assess the quality and credibility of the work.
The numerical results have been compared to the relevant experimental measurements. It seems that this work is credible. However, there is lack of sufficient details in the description of the computational approach, such as the boundary conditions, the grids used for the CFD, and the choice of turbulence

model. More comments on the missing details are listed in the attached pdf file. Moreover, in a very few sections, explanation of the results is not clear.

4) Comments for author: comments and suggestions to improve the paper. you may also attach a .pdf

Please see the attached pdf file.

5) Minimum Required changes for conference publication (if needed).

There are multiple changes required for conference publication, as noted within the attached pdf.

6) Minimum Required changes for journal, if paper is close to journal.

Not applicable

7) Summary statement of reasons for or against recommendation for conference publication.

The paper requires some major revisions before it is accepted for conference presentation, as many details of the description of the computational methodology are missing. Statement of some important parameters of the experimental test facility should also be included. Besides, there is only background in the introduction but lack of past literature review, at least inclusion of past studies dealing with computational work of film cooling on flat plates.

8) Summary statement of reasons for or against recommendation for journal consideration.

Recommended against journal publication. The paper lacks sufficient originality to merit publication in an ASME journal. The investigation and explanation are also inadequate for a journal quality. Furthermore, there is nothing new in conclusions from the paper, since many past studies have verified the defect of RANS in jets in cross flow.

View Comments 148KB

Reviewer 2:

1) Summarize the goals and outcomes of the paper.

This paper dealt with RANS simulations on the flow in the fan-shaped cooling hole. The calculated results were compared with the corresponding experimental data done by the authors' group published in 2017.

2) Comment on the originality, relevance, and long-term impact of the paper.

It may be useful to know to what extent RANS simulation can work in predicting film cooling performance, however the present paper only showed that the RANS simulation provide poor predictions of adiabatic effectiveness, which is the most important information for turbine cooling designers.

3) Assess the quality and credibility of the work.

This paper includes a lot of errors and ambiguities that should be corrected before publication in the conference. The comments from the present reviewer will be provided in the PDF file.

4) Comments for author: comments and suggestions to improve the paper. you may also attach a .pdf

(empty)

5) Minimum Required changes for conference publication (if needed).

(empty)

6) Minimum Required changes for journal, if paper is close to journal.

This paper is only for the conference publication because it did not provide any new finding.

7) Summary statement of reasons for or against recommendation for conference publication.

This paper is only for the conference publication because it did not provide any new finding, however the accumulation of these kinds of information is useful for further investigation on the improvement of or the limitation of RANS simulation.

8) Summary statement of reasons for or against recommendation for journal consideration.

This paper is only for the conference publication because it did not provide any new finding but the comparison between the RANS simulation and implicit LES.

Reviewer 3:

1) Summarize the goals and outcomes of the paper.

This papers seeks to evaluate the usefulness of RANS with the realizeable k-epsilon model in ANSYS Fluent in predicting film-cooling flow and adiabatic effectiveness by comparing predictions with measurements (existing in the literature) and results from large-eddy simulation.

2) Comment on the originality, relevance, and long-term impact of the paper.

A lot of people have examined the usefulness of turbulence models in predicting adiabatic effectiveness. In this paper, only one turbulence model was examined, and the focus is on the flowfield in the hole. For compound-angle holes, what happens in the hole is important, but not for the problem studied in this paper.

3) Assess the quality and credibility of the work.

Though the CFD appears to be done correctly, the computational domain for the plenum appears too small and the grid quality is poor.

4) Comments for author: comments and suggestions to improve the paper. you may also attach a .pdf

Introduction: - Literature review is incomplete. There are a lot of papers in the literature on the subject. There are also papers that show different turbulence models yield different results. Problem Description: - Good in that the details of the experimental setup are described (albeit done in previous work) since the CFD must reproduce the experimental study. For example, it's great to see the turbulence generator in Fig. 1, which is typically not simulated by CFD studies. How was it simulated in this study? - Operating conditions such as T, P, … not provided. - In this paper, only one turbulence model is examined. For this model, the one-equation model is used in the near-wall region, which the length scales are assumed to behave like that in a standard boundary-layer profile with zero pressure gradient. As a result, it is clearly incorrect about the film-cooling hole inlet and exit. Thus, why was this model selected? Measurements: - Since 100% insulating materials do not exist, how was the heat-transfer that take place accounted for? CFD: - The grid shown in Fig. 4 is of poor quality because it is not smooth when grid changes in grid spacing. - The inlet for the plenum seems quite close to the film-cooling hole. What is the boundary condition imposed at that inlet? Results: - The paper concluded that the adiabatic effectiveness is incorrect due RANS being unable to correctly predict the mixing. But, this is well known and cited in many papers. - But, this study did focus a lot on the in-hole velocity and suggest that RANS can correctly predict this in-hole flowfield. This reviewer is unsure if this is a valid conclusion based on results in Figures 10 and 11, which show fairly significant differences between the CFD and experiment. Maybe, they can get some trends correct, but the magnitudes are off by around 4x, and the in-hole velocity vectors are in opposite directions in many regions between the experiment and CFD. - ASME Paper GT-2015-42771 also looked at the flow field in film-cooling holes for compound film cooling that compared realizeable k-epsilon, SST, and VLES.

5) Minimum Required changes for conference publication (if needed).

Operating conditions such as T, P, … not provided. In this paper, only one turbulence model is examined. For this model, the one-equation model is used in the near-wall region, which the length scales are assumed to behave like that in a standard boundary-layer profile with zero pressure gradient. As a result, it is clearly incorrect about the film-cooling hole inlet and exit. Thus, why was this model selected? This study focused on the in-hole velocity and suggest that RANS can correctly predict this in-hole flowfield. This reviewer is unsure if this is a valid conclusion based on results in Figures 10 and 11, which show fairly significant differences between the CFD and experiment. Maybe, they can get some trends correct, but the magnitudes are off by around 4x, and the in-hole velocity vectors are in opposite directions in many regions between the experiment and CFD. Please explain.

6) Minimum Required changes for journal, if paper is close to journal.

There is nothing that can be done to make this paper a journal paper. Nothing new was presented.

7) Summary statement of reasons for or against recommendation for conference publication.

I do recommend conference publication even though I see very little substance. The experimental part is useful.

8) Summary statement of reasons for or against recommendation for journal consideration.

There is nothing that can be done to make this paper a journal paper. Nothing new was presented - though the experimental data summarized is useful.

Draft Recommendations/Comments

Comments

Two reviewers required Major revisions and one reviewer minor revisions. Therefore, you have to modify your manuscript throughly, and re-submit your new version before the appropriate deadline with a detailed response to ALL of the reviewers' comments.

Status

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