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Numerical modeling of the influence of different options for feeding fuel on the combustion process for turbine profiles

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Abstract. The article presents the results of numerical modeling of the effect of various fuel supply options on the combustion processes behind the turbine profiles. The article considered three options for fuel supply. In the first option, (a) the fuel is supplied to the wide side of the profile; in the second option, (b) the fuel is sprayed directly into the recirculation zone formed between the plate and the profiles; in the third option, (c) the fuel is sprayed from the convex (back) part of the profile. On the basis of the analysis performed, it can be concluded that the profiles of the blades have rather high stabilization parameters. The best performance has the option of supplying fuel from the back of the turbine profile. This option provides the minimum concentration of nitrogen oxides, with all other factors being equal.

1. Introduction

The ANSYS Fluent program was used in the study. When building models, it was proposed that the fuel will flow to a wide part (back) of the turbine profile. Three methods of fuel supply are considered in this article, presented in Figure 2. Experimental studies conducted on corner stabilizers show [1-11] that the method of fuel supply plays a significant role in the formation of the recirculation zone, respectively, and ensuring flame stabilization.

The authors considered three options for fuel supply. In the first option, the fuel is supplied to the wide side (back) of the profile; in the second option, the fuel is sprayed directly into the recirculation zone formed between the lining and the profiles; and in the third option, the fuel is sprayed from the back.

2. General Data on the Modeling Process

An isometric view is presented on the modeling area in Figure 1.



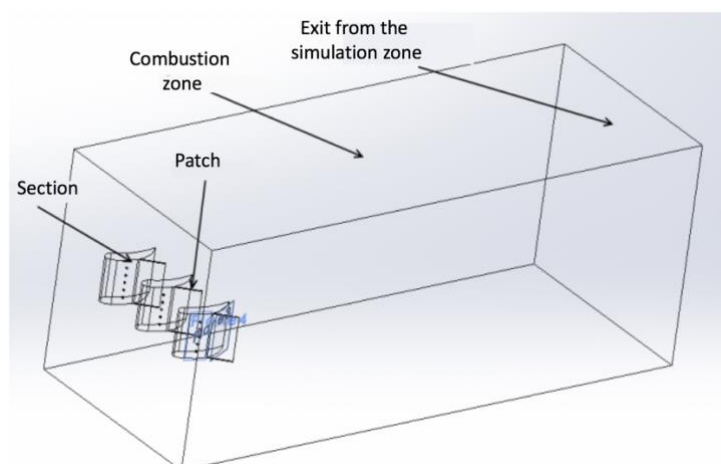


Figure 1. Isometric view of the simulation area.

The modeling area consists of three blade profiles, all of which are involved in the combustion process. Profiles are equipped with adjustable (in this article, adjustment was not considered) lining, the angle of which was equal to 45° from the tangent to the convex (back) side of the profile. The angle was chosen based on past simulation results and [1-10]. The initial parameters are presented in Table 1.

Table 1. Initial Parameters.

Fuel consumption, kg / h	Air velocity, m / s (was taken according to the experimental setup)	ϕ , Excess fuel ratio [1]	Initial temperature of oxidizer (air) / fuel, K	The number of tetrahedral elements in the modeled area
1	10	0,06	300	200000

The k- ϵ realizable turbulence model was used in modeling, which, according to [12], is the most optimal solution.

In view of the fact that only the effect of fuel supply was considered in the article, the speed and value of fuel consumption did not change during the simulation. The excess fuel (air) was calculated according to [1].

Considered fuel supply options are presented in Figure 2. In the first option (a) fuel is supplied to the wide side of the profile; in the second option, (b) the fuel is sprayed directly into the recirculation zone formed between the cover and the profiles; in the third option, (c) the fuel is sprayed from convex (back) part of the profile.

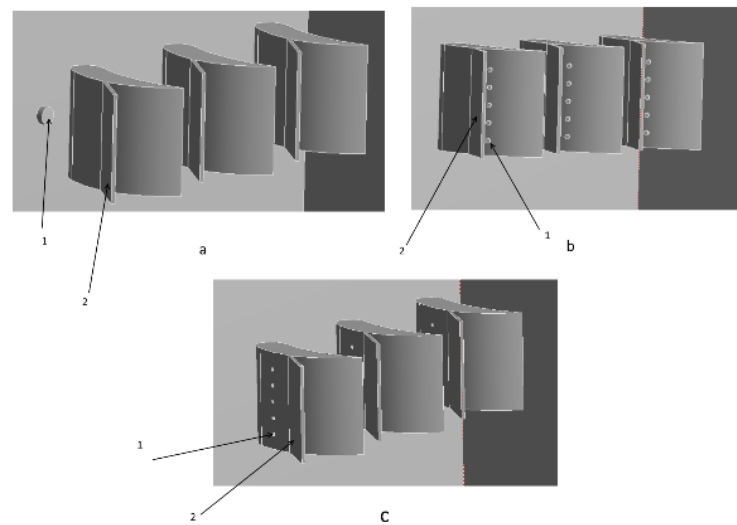


Figure 2. Fuel supply options:

(a) to the turbine profile; (b) to the recirculation zone; (c) from the back of the profile
1 – nozzle, 2 – pad.

3. Results

Temperature contours are presented depending on the fuel supply options in Fig. 2. When the fuel is supplied to the turbine profile (option a), there is a high-temperature zone formed behind the turbine profile where the main part of the fuel burns, and compared to other fuel supply options, the temperature is higher. The lowest temperatures are observed when the fuel is fed from the back of the turbine profile (option c), due to the fact that the fuel reacts earlier with the oxidizer than in other variants, respectively, burn out earlier. It is noticeable that the right profile is exposed to the highest temperatures (option a). This is due to the fact that there are no disturbances on the left side of the profile. When fed into the recirculation zone, the recirculation zone itself is pushed out of the internal space between the cover plate and the profile due to the additional generated flow force of the fuel. From the figure, we can conclude that the maximum temperature load is on the pad with the options (a) and (c); and with the option (b), it is slightly lower due to the fact that the high-temperature zone is located only on one side.

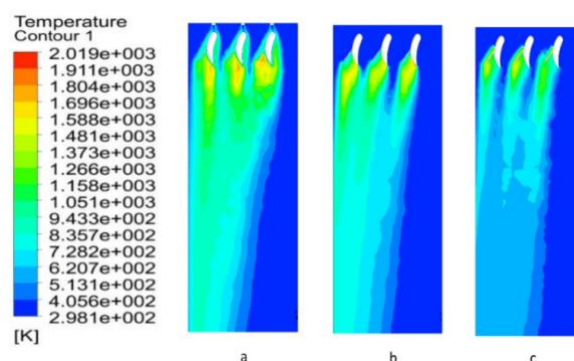


Figure 3. Temperature contours depending on the excess fuel supply.

(a) the option of feeding to the profile; (b) the option of feeding into the space between the profile and the lining;
(c) the option of feeding from the back.

Table 2. Results of numerical simulation.

Fuel supply option	a	b	c
NOx Concentration, ppm	6,8	3,5	1,3
Temperature at the exit from the simulated area, K	358	360	358
Fuel concentration at the outlet, g / m ³	0,058	0,059	0,056
Axial speed at the exit, m / s	11,8	12	11,93

The concentration of nitrogen oxides (NOx) is also considered. The results of the concentration of nitrogen oxides at the exit from the simulated area look very interesting. As can be seen from Table 1, the concentration of fuel is maximum under the option of feeding (a). This is due to the fact that the fuel mixes with air rather “late” compared to other options. Therefore, the concentration of fuel in the recirculation zone is quite high, which can also be seen in Figure 2 at the high temperatures of option a. Direct supply of fuel to the recirculation zone reduces the concentration of nitrogen oxides due to a more uniform fuel supply (see Figure 1). Obviously, splitting the fuel stream into smaller ones leads to faster burnout and lower local temperature, which is the main source of nitrogen oxides.

The option (c) is the most acceptable from the point of view of reducing nitrogen oxides. Uniform supply of fuel along the back of the profile leads to mixing and combustion of the fuel to the recirculation zone, which reduces its concentration. The decrease in the concentration of fuel in the recirculation zone leads to a decrease in temperature, respectively, and the formation of nitrogen oxides.

4. Conclusions

On the basis of the analysis conducted, it can be concluded that the profiles of the blades have rather high stabilization parameters. The option of fuel supply from the back of the turbine profile has the best performance. This option provides the minimum concentration of nitrogen oxides, with all other factors being equal.

Measurement of temperature, velocity, and fuel concentration at the exit from the simulation zone shows similar results.

For a more complete analysis, the authors will conduct research in a wider range of excess air α .

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