AN EXAMPLE OF USING FEM FOR AIR FLOW ANALYSIS THROUGH AIRCRAFT AREAL INJECTOR

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Abstract. In the article an example of using the Finite Element Method to determine the air distribution that is used in the atomization of fuel by the aerial injector is presented. In detail, Finite Element Method analysis appeared to be helpful in verifying the geometrical parameter of the injector – the two-flow parameter. The Finite Element Method results data of airflow distributions at the end of sections of an aerial injector allows a real geometric parameter to be verified. Full information about this parameter has shown the need to change other geometrical parameters. This work was made within the framework of a research project financed by State Committee for Scientific Research no. 5T12D 027 24.

Keywords: an aerial injectors, atomization, aircraft engines, Finite Element method, Adina system.

Introduction

Since the beginning of the computer revolution, the development of specialized computer software supporting the work of designers has taken place. With the improvement of computational powers, speed of processors and ability to make computer clusters based on Unix/Linux systems came the wide use of analytical software based on the finite element method, boundary element method, and, popular in fluid flow, computer fluid dynamic methods [2].

At present there are a lot of research institutions and scientific centers, which make and promote their own application software. The samples are FLUENT in the area of fluid flows, ANSYS with mechanical, thermal, and fluid flow modules, NASTRAN/PATRAN, TIGER, ADINA, ADPAC, KIVA, etc. Application software is quite often created to solve and simulate an exact technical problem; others are multi-purpose software using existing theories and analytical methods. One multi-purpose created recently is ADINA from ADINA R & D, Inc., which was founded in 1986 by Dr. K. J. Bathe. The main applications for ADINA software are strength analysis, mechanical structure analysis, fluid flows analysis, and vibration analysis both on linear and nonlinear areas. It is based on the Finite Element Method and is a type of analysis that depends on the computational power and memory resources of a computer [1, 3]. The main purpose of this article is presenting an application of the Finite Element Method analysis system to solve various technical issues.

The subject of the FEM analysis

The subject of the analysis introduced in the article is an aerial injector. An aerial injector is a variety of air-pressure injector with swirled flow. The basic working principle of this type of injector is to make use of tangent stresses between thin fluid film and flowing air to intensify the deformation of that fluid film to finally cause vaporization on droplets. During vaporization on droplets, the petrol liquid can have the shape of a stream, thin film, or droplet. From the flowing site, the injector has been designed on three flowing ducts: internal, external, and a fuel gap (Fig 1).

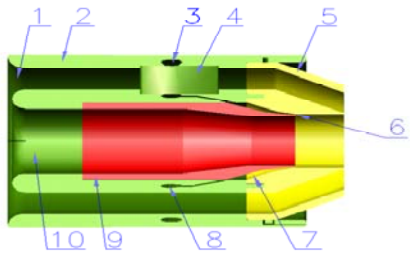

Fig 1. Cross section of aerial injector: 1) external air duct, 2) the main module, 3) the first ring inside external wall to feed of fuel, 4) one of three fairing to feet fuel, 5) module of external swirled, 6) the duct of fuel stream outlet, 7) the feed duct of fuel to outlet, 8) second ring inside internal wall to feed the fuel, 9) module of internal swirled, 10) internal air duct

The relation between the diameter of an internal duct and diameter of an external duct comes from the ratio of flow intensity of that duct. A common characteristic of aerial injectors is the use on the inside site of ducts air an inversed swirled, the main purpose of which is swirling flowing air and aerating vaporized fuel. Swirlers are characterized by equivalent attack angles that influence the quality of atomization.

Preprocessor – The methodology of preparing an analytical model

Making an analysis of flowing air, for example through the aerial injector, requires proper implementation of the problem to the system. For this purpose, the system needs the geometrical parameters of the device analyzed, which can be loaded to the system by *.igs files. That method permits to the creation in the ADINA system of a set of points and lines, on which the user can build more complicated geometrical structures like areas, volumes, or combined elements using Boolean operations. In that case, the set of points and lines composed flat model 2D, which is shown in figure 2.

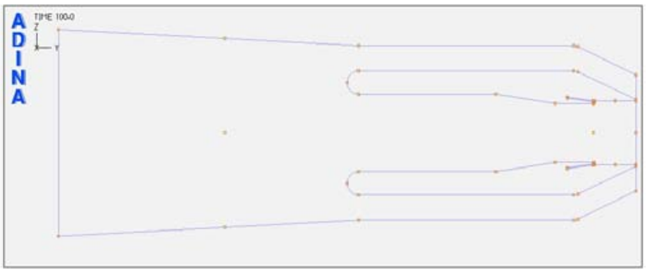

Fig 2. Flat model of geometric of injector

On the next step considering flow area must be divided at which calculations of velocity distribution, pressure, temperature depending on type of analysis will be made. The simplest way to set the mesh of elements is by making them on surfaces. Surfaces can be defined on lines (the "path" method) or on points (the "vertex" method).

Another method of creating flow area is creating one combined line from set of lines and creating on that line surface, which can be divided on proper value of finite elements (Fig 3). After defining of surface, before meshing by finite element, type of finite elements, which in this case was chosen as 2D fluid must be the set.

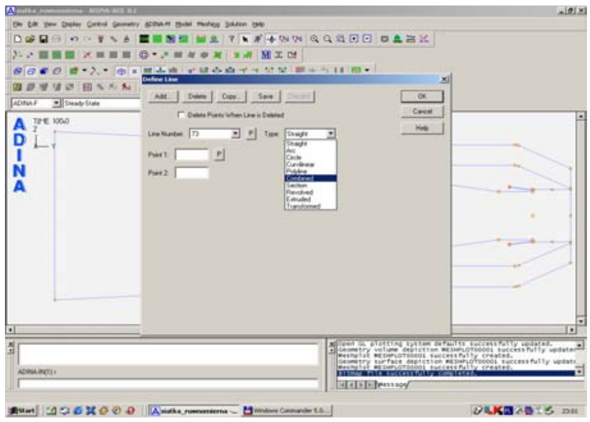

Fig 3. Different methods of defining surfaces

In the analysis, the assumption was made that the model is axsisymmetric. The physical parameters describing properties of air are density $\rho=1.227$ (kg/m^3) and coefficient of viscosity $\mu=4.8*10^{-5}$ (N*s/m^2). Location of the injector assures compatibility of outlet velocity vector with vector of acceleration of gravity. That condition can be defined as an option when defining type of material. In the present analysis, the material is a fluid with the aforementioned parameters (Fig 4).

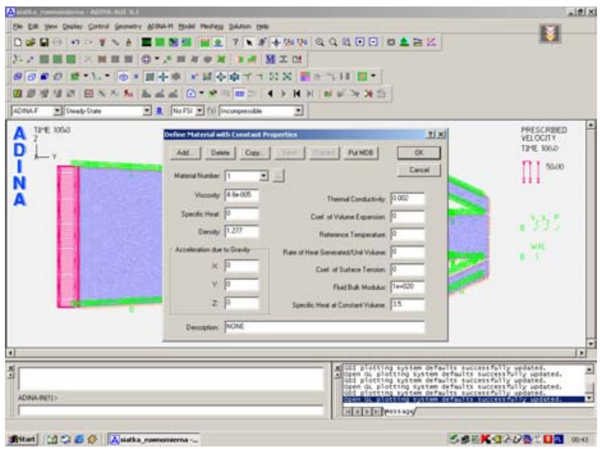

Fig 4. Defining material type and its physical properties

The module of the ADINA system concerning fluid model also allows one to define the physical parameters connected with heat exchange and parameters of stress state on fluid. In the next steps those parameters were not defined, however, because the model of fluid flow does not take into account the case of heat exchange.

After defining type of fluid that is parameter of fluid, the next step is defining the density of the final element mesh. The density of the mesh is defining by division of the face element into elementary segments. For example, dividing the square into 100 elements in two dimensions means dividing generating lines into 100 equal elements, in reality that generated mesh will have 10,000 finite elements if the type of defined elements are 4-nodes. In practice the process of meshing and proper defining of finite type elements require a large amount of experience. A generated finite element mesh with too many elements will affect the length of calculations. In

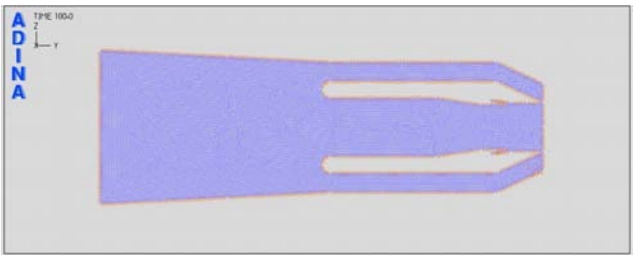

Fig 5. The sample of generated final element mesh on ADINA system

the other hand, a mesh with too few elements will cause to many divergences between results from FEM calculations and experimental results. Generally applying a balance rule of dividing areas and lines of analyzed geometry means that the mesh should be condensed in areas where there is a need of detailed information about parameters.

In the case of airflow through an injector, the most interesting flow area is the outlet section of the injector, so there density of the mesh should be increased. For this application of an aerial injector, mesh densities that were generated are shown on figure 5. When the mesh of finite elements is generated, the boundary condition and type of loading should be selected. It can be point forces, moment of forces, distribution of forces, velocity vectors, distribution of pressure and heat, distribution of temperature, rotational speed, or even electrodynamics force. The setting of boundary condition means applying the special element of type ”wall”. Other boundary conditions that could be applied are elements that conduct the heat by convection or radiation, move elements, free surfaces, contact surfaces of fluid-fluid, surfaces of change phase, or thermal barrier. All that boundary condition could be used to point, line, surface, edge, or sphere. Undoubtedly an advantage of the ADINA system is the possibility of defining the load as a time function and defining the duration of the load. Starting conditions were established as distribution of velocity on inlet section of an injector at value of 50 (m/s) (Fig 6).

The process of defining starting and boundary conditions is the final step of entering the problem into the ADINA system. The next step is to start the solution process.

Adina Solver – calculation of fluid flow model to get solution

ADINA system consists of three main parts: preprocessor – the module for implementing the problem, Solver – calculation module that works without the interference of a user, and post processor – the module to present the results as plots, tablets, lists of data, and so on. The mesh of finite elements that was generated has parameters: 17854 nodes and 34590 fluid elements on axsisymmetric analysis. Solution time depends on density of the mesh, time steps of analysis, and the calculation power of the computer. If we set to solve the problem implemented on 10 (s) in 100 time step, then the time of the solution will be 100 times longer than a problem with 1 time step. The most important factor influencing solution time is the value of the memory RAM on the computer. The results presented in this paper were obtained on a computer with an ATHLON - 1833 Mhz processor with 1024 MB RAM memory. The problem was solved in 13 minutes.

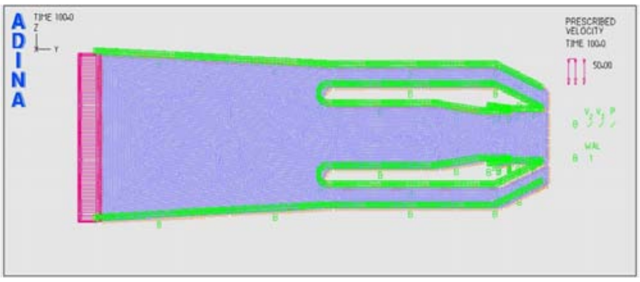

Fig 6. Defining of starting and boundary conditions

Presentation of results

The ADINA system post processor gives wide possibilities for the presentation of results. The system saves results to *.por files, which can be loaded on the Adina-Plot module. The available options for the presentations of results include visualization of velocity distributions, vectors of velocity, Reynolds number distributions, and pressure distributions. Figures 7, 8 and 9 show sample distributions.

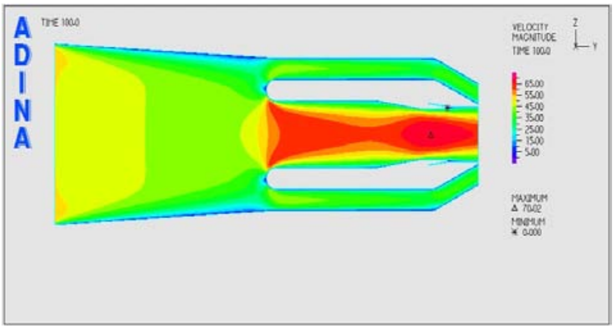

Fig 7. The distribution of air velocity through the injector

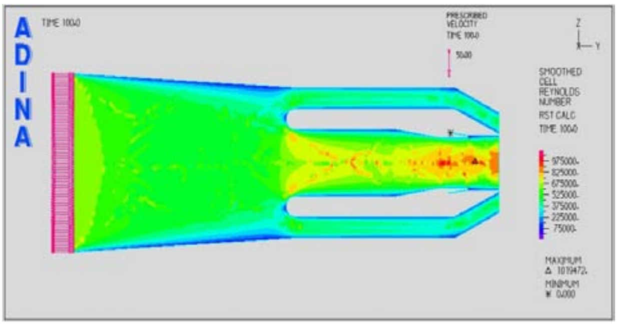

Fig 8. The distribution of Reynolds number of the air flow through the injector

Velocity distribution shown in figure 7, which was obtained from the calculations of the ADINA system, indicates that an external duct takes a small part in the division process of the air stream. The highest value of the stream flows is on the internal duct, where outside velocity is about 60-70 (m/s). Knowing the external and

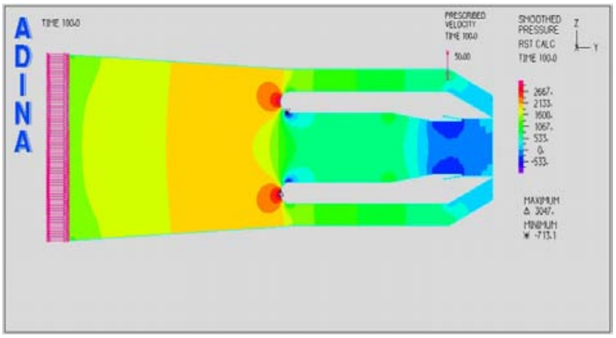

Fig 9. The pressure distribution on walls of injector on the flow of air through the injector

internal velocity distribution and the value of the cross-section allows one to estimate the ratio of the air external flux to air internal flux, which is 1.67. When the injector was designed, the assumption was made that flux flow on the external duct would be 2.5 times more than on the internal duct. The calculation of those values indicates that assumption does not hold true. In reality, real cross-section inside ducts is decreasing by occurring away break of the air on the walls of the injector. To perform that assumption, geometric shape should be changed and new FEM analysis should be executed to check the real value of the division of the air.

Conclusions

It is expected that performing those assumption could have an effect on quality of fluid atomization by air on the real process at the test stand. In this point, one should pay attention to the huge advantage of FEM systems, which can be considered a good tool to verify preliminary assumptions in the beginning steps of designing. The correctness of flow analysis results an earl injector should be compared with research results by laboratory research. By the term of laboratory research we mean the visualization of fluid flow with air by using a CCD camera, visualization of an injection angle and also quality research and quantitative research to define the distribution of circumferential and radial fuel droplets.

At this time the project of this research is executing on Department of Aircraft and Aircraft Engines of Rzeszow University of Technology. Research verification of design still play an important function on design process of machine elements and installations and is inseparable in the case of aircraft engines parts and equipment.

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