Development of a computational mesh generator for the OpenFOAM software environment used at industrial enterprises

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Abstract. The paper is devoted to special features of the development of an application with a graphical user interface to prepare computational meshes (CMs), when performing numerical simulation based on the OpenFOAM software environment (SE), used at enterprises of missile engineering, automobile industry, engine building, shipbuilding and other industries. OpenFOAM, if used, permits successfully conducting numerical simulation in the phase of engineering of finished goods through 3D modelling of deformable solids, investigation of their characteristics, when interacted with liquid and gaseous media, and also study of mechanics of deformable solids that correspond to the models. The paper provides the comparative characteristics of available software with a graphical user interface mainly used to prepare CMs and the revealed drawbacks of the software. The urgency of an issue is highlighted, special features of the development of the new application are given. The study scientific novelty that lies mainly in the enlargement of a list of types of CMs available for preparation through a graphical user interface, and possible operation with any number of mesh models in one OpenFOAM case, is defined. The program has a certificate №2018616380 dated May 30th, 2018 on registration by Federal Institute of Industrial Property.

1. Introduction

The production of multicomponent items such as engines, automobiles, planes, spacecraft, launch vehicles is a complicated technological process that asks for much time and financing. Special requirements to the quality of the result in each phase are specified.

The production of multi-component items involves specialists in different fields, including designers and engineers who govern the final result. Computer technologies used in the production process assist in saving time and financing for making finished goods. In the phase of designing computer technologies permit creating a product model at high precision and avoid further updating.

A computer model is a precise electronic copy of a product on which base the performance of a potential product is identified. 3D models created using modern program complexes open the potential for upgrading both simple and multicomponent products.

The phase of designing of spacecraft, automobiles, engines includes not only definition of the product performance but also study of its behavior, when interacting with liquid and gaseous media. The mentioned above issues are addressed in a discipline of mechanics, physics of
continuum and condensed matter physics, dealing with motion of gaseous, liquid and deformable solids as well as force interactions in such solids. The discipline is also called continuum mechanics (CoM). CoM problems are analyzed on the basis of computer (digital) models created using numerical methods.

In so doing, a number of well-known commercial software made by ANSYS, ESI Group, TESIS are applied. High price of commercial software and its support services impels researchers and engineers to turn to open software, e.g., OpenFOAM. This is the SE with an open source code, highly competitive with commercial software in functional capabilities.

Among the OpenFOAM SE users are famous producers of automobiles (Toyota, Volvo, Audi, Ford), power supply means and fuel (Shell Oil). OpenFOAM is also in wide use by enterprises of shipbuilding and nuclear industry. Makeyev SRC is one of Russian enterprises, where the product starts being implemented.

The OpenFOAM key disadvantage is that it is a console software without built-in graphical user interface. Thus, users should be acquainted with console commands responsible for execution of stages of numerical simulation of CoM problems and features of preparation of internal files with parameters of CMs and CoM problems. The modeling of a CoM problem using the OpenFOAM SE includes preprocessing, solving and post-processing. Special aspects in use of the OpenFOAM environment for solving various CoM problems are presented in [1-5]. During preprocessing a CMs, which defines the accuracy of the final result of simulation and which generation is one of the key process of numerical analysis, is also prepared.

The paper is devoted to features of the development of an application with a graphical user interface to prepare CMs of different types on the basis of utilities built-in the OpenFOAM environment: blockMesh, snappyHexMesh, foamyHexMesh, foamyQuadMesh. The paper continues the research described in [6].

The generation of CMs of the mentioned types require preparation of corresponding utilities and execution of a number of commands. Solving the problems is simplified with the described in the paper application, which is called openfoam_mesh_app, and replaces manual editing of files with parameters of a CMs and activation of commands of generation of the CMs.

2. Urgency of an Issue

The problem of creating an application with a graphical user interface for the OpenFOAM SE was of interest to several foreign companies and resulted in creation of software products Salome, Helyx-OS, Visual-CFD and many others. The specified software found a use at several industry enterprises and were not lacking of drawbacks among which were, first of all, purchasing of services for technical support and consulting. The software products also do not have Russian versions of the graphical user interface and Russian-language documentation.

Table 1. Comparative characteristics of software with a graphical user interface for operation in the OpenFOAM SE.

| Name       | License                  | Technical support       | Support of utilities for generation of CMs                  |
|------------|--------------------------|-------------------------|------------------------------------------------------------|
| Salome     | Open source software     | Not provided            | blockMesh, snappyHexMesh.                                  |
| Helyx-OS   | Open source software     | Provided, to be paid    | blockMesh, snappyHexMesh.                                  |
| Visual-CFD | Demo version for 30 days  | Provided, to be paid    | blockMesh, snappyHexMesh.                                  |
Provision for the program preparation of a CMs is made in each of the given graphical applications, while users have access only to standard utilities for the generation of a CMs: blockMesh and snappyHexMesh.

3. Setting goals and tasks
The purpose of the study described in the paper lies in the development of an application with a graphical user interface (openfoam_mesh_app) for centralized preparation of a CMs based on utilities of the OpenFoam SE: standard CM (blockMesh, snappyHexMesh) and specialized ones (foamyHexMesh, foamyQuadMesh). It is required to develop the application as a desktop version.

The following tasks were formulated for the paper authors to attain the goal:

For the application interface structure:

- The application should have a main window with 5 blocks of a service control panel, a main control panel, CMs parameters editing block, results visualization block, a panel to visualize signal messages;
- The service control panel should have a button to open a window for choosing an OpenFOAM case, for which a CM is to be prepared;
- The main panel should have a button to open a window for choosing the CM type;
- A block for editing the CMs parameters should have a window with a kit of electronic screens to specify parameters of the corresponding mesh model;
- A block to realize the results should have a window to visualize the content of generated internal files with parameters of the CMs;
- A panel for signal messages should have a mechanism to inform users on the status of actions executed by him and to brighten signal messages.

The logics of the application operation should:

- Make provision for preparation of new CM and editing parameters of any existing one;
- Make provision for preparation of any number of CMs for a current case (project of a CoM problem);
- Make provision for preparation of a CMs both with the OpenFOAM utilities and msh-files of the CMs generated in third-party software;
- Check, if input data are of compatible type for control elements of electronic screens, in particular, input fields;
- Check, if each block of the CMs parameters of the chosen type is present, t.i., if corresponding filled-in and saved electronic screens from a set of screens are present.

To execute the formulated tasks the authors examined the OpenFOAM SE official documentation and tutorials.

4. Theoretical part

4.1. Selecting tools for development
The authors of the paper decided to use a high-level programming language Python, version 3.4 for describing the application operation logics. It is one of the most popular programming language along with Java and C/C++ successfully used for creation of desktop software products.

The authors decided to use the PyQt4 framework to describe elements of the graphical user interface. It is able to create conventional window interfaces with attractive design. The authors studied special aspects in use of the Python programming language and PyQt framework based on tutorials [7-8] and official documentation.
The open PyScripter environment with a brightened code, the possibility to start, debug programs and put to standard PEP-8. A full list of required software is shown in table 2.

**Table 2.** A list of required software.

| OS      | Processor | Third-party modules | Software                                      |
|---------|-----------|---------------------|-----------------------------------------------|
| Linux   | Python 3.4| PyQt4               | PyScripter, OpenFOAM 4.0, ParaView (to visualize the results) |

5. **Practical part**

5.1. **Finding**

The study described in the paper resulted in an application with a graphical user interface to prepare a CMs for realization of numerical simulation in the OpenFOAM SE. Figure 1-2 give images of the main window when selecting a CM type and starting visualization of the results using ParaView. The application work was tested using one of training tasks on preparation of a CM of the *foamyHexMesh* type containing in the OpenFOAM distribution kit.

*Figure 1.* The application main window with a loaded window for selecting of the CM type.

*Figure 2.* The application main window, when visualization of the results is launched with the ParaView software.
The developed application expands the OpenFOAM source code, it was registered by Federal Institute of Industrial Property (certificate №2018616380 dated May 30th, 2018).

The application was put in service at Makeyev SRC for numerical simulation of space-rocket projects. The application is universal and can be used by other industrial enterprises that utilize the OpenFOAM SE. The application demo version is available at the GitHub web-service via the link https://github.com/DmitryChitalov/openfoam_mesh_app.

5.2. Scientific novelty

The authors formulated the following statements to justify the scientific novelty:

- The application permits preparing not only typical CMs based on the OpenFOAM utilities blockMesh and snappyHexMesh, but also specialized CMs based on utilities foamyHexMesh and foamyQuadMesh;
- For internal files of CMs of different types there are sets of electronic screens to edit parameters of the meshes. A separate kit of electronic screens matches to each block of parameters of the file. The electronic screens implement the separation of their external appearance (interface) from logics of operation. Hence, the process of further modification of electronic screens and expansion of their functional capabilities is simplified;
- Any number of CMs of different types can be created in one project of a CoM problem (a case). For the purpose the authors realize a mechanism of serialization (packing) and further recovery of packed data using the Python-module Pickle;
- Program launch of the OpenFOAM console commands is realized through a mechanism to create and execute bash-scripts containing OpenFOAM commands;
- It has also a system to protect a user from wrongdoing that simplifies numerical simulation in the OpenFOAM environment.

5.3. Practical relevance

Numerical simulation of CoM problems using the openfoam_mesh_app application gives experts a series of advantages as against traditional approaches that use terminal:

- It saves the working hours for numerical simulation. Each step of preparation of a CM is made through a program with a graphical user interface. A user should not record complex console commands, structure and required parameters of the CMs internal files;
- Minimization of the number of mistakes in numerical simulation. The proposed application has a system to check types of input data and the presence of needed files and CMs parameters included in them;
- It saves the working hours for getting acquainted with the OpenFOAM SE. The openfoam_mesh_app application has Russian user interface with informative description of the interface elements and is supplemented with documentation in Russian.

6. Conclusions

One of urgent tendencies of industrial growth is computerization of a production cycle that supports saving time for production of one item and minimizing the number of fault goods caused by mistakes in the phase of designing and production.

The paper is devoted to a problem of upgrading the OpenFOAM SE to efficiently perform numerical simulation of CoM problems in the phase of designing of multi-component items. The OpenFOAM SE makes it possible to create 3D models adequate to real objects and analyze their characteristics and features of their interaction with different media.

The paper proposes and describes a method used in the development of an application with a graphical user interface to perform one of stages of preprocessing of numerical simulation - preparation of a CM.
The application is based on the Python 3.4 program language and framework PyQt4 for SRC Makeyev’s needs. Moreover, the application is universal and can be used not only at enterprises of space-rocket industry but also in other industries. The application is implemented and successfully applied for numerical simulation in the OpenFOAM SE. Its baseline version is available at the GitHub web-resource.

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