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COMPUTATIONAL DOMAIN DISCRETIZATION AND ITS IMPACT ON FLOW FIELD AROUND THE SPARK PLUG IN SI ENGINE

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Summary. The discretization of computational domain is a crucial factor influencing the conformity of numerical and experimental research results. The paper presents the comparison of results obtained for the same numerical setup but with different mesh types: hexahedral, tetrahedral and polyhedral mesh. The computational domain was the sector of constant volume combustion chamber with a spark plug. The results presented in the form of velocity and Y^+ contour plots prove that the applied mesh type significantly influences the results and therefore the conformity of numerical and experimental research results.

Key words: spark ignition engine, numerical modelling, mesh type, computational domain discretization, computational fluid dynamics.

INTRODUCTION

The flow field around spark plug impacts the spark discharge in spark ignited (SI) engines [1]. Ignition resulting from spark discharge between spark plug electrodes is a crucial factor which strongly influences the combustion process [2, 3]. As a consequence the flow field around the spark plug significantly affects engine work repeatability and toxic components concentration in exhaust gases [4, 9]. That is why proper modelling of flow field in the vicinity of spark plug is extremely important because it significantly influences results of SI engine work cycle numerical modelling and conformity of numerical and experimental research results [5, 6, 7].

Very often the numerical solution is mesh-dependent, which allows to claim that the discretization of computational domain seems to be one of the key factor, which affects the simulation results. Three mesh types were used to prove the above mentioned thesis. These types are (Fig. 1):

- hexahedral mesh,
- tetrahedral mesh,
- polyhedral mesh.

The hexahedral (HEX) mesh is considered as the most reliable one because its numerical diffusivity is the lowest of all the mesh types describes in the paper. The disadvantage of HEX mesh is the fact, that it is difficult to generate such mesh in case of complicated geometry. On the other hand, tetrahedral (TET) mesh is the most diffusive one but it is relatively easy to generate it even in case of complicated geometry. The polyhedral (POLY) mesh seem to combine the advantages of both HEX and TET mesh as its numerical diffusivity is comparable to HEX mesh and it is as easy to be generated as the TET mesh.

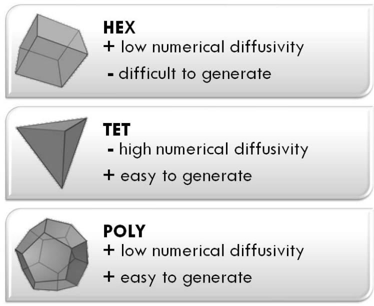

Fig. 1. Mesh types and its basic characteristics

THE COMPUTATIONAL DOMAIN AND BOUNDARY CONDITIONS

The computational domain is a sector of constant volume combustion chamber with a spark plug depicted in Fig. 2. HEX (Fig. 3) and TET (Fig. 4) meshes were generated for the same geometry and the seed setting were identical in each case. The POLY (Fig. 5) mesh was generated automatically on the basis of TET mesh using FLUENT software.

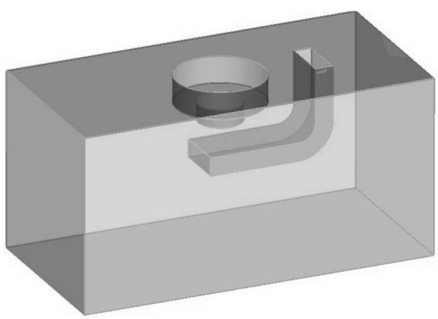

Fig. 2. The computational domain: constant volume combustion chamber with spark plug

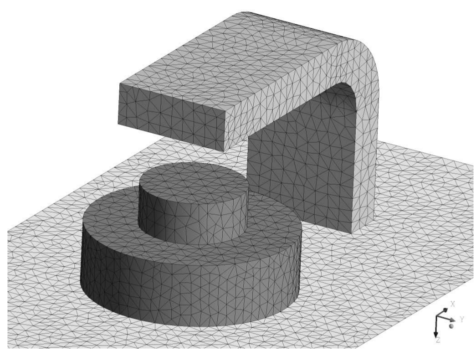

Fig. 3. The computational domain discretization with the use of HEX mesh

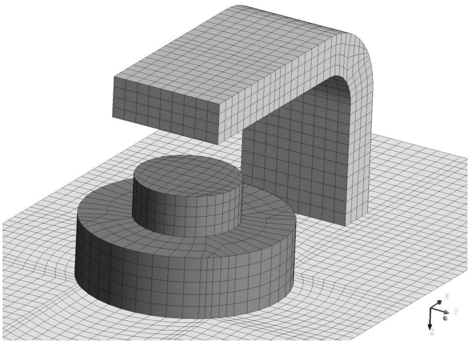

Fig. 4. The computational domain discretization with the use of TET mesh

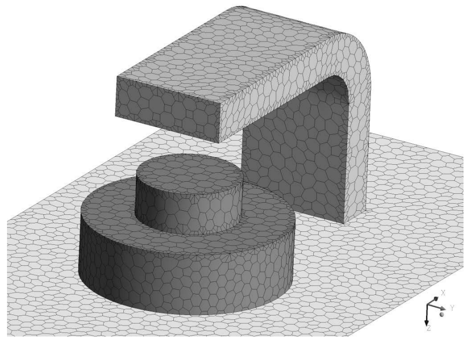

Fig. 5. The computational domain discretization with the use of POLY mesh

The number of elements in case of each mesh type is shown in Fig. 6. Number of HEX elements was almost 11 times lower comparing to TET mesh regardless the fact that the seed settings were the same for each mesh type. Converting TET mesh to POLY reduced the number of elements almost 6 times.

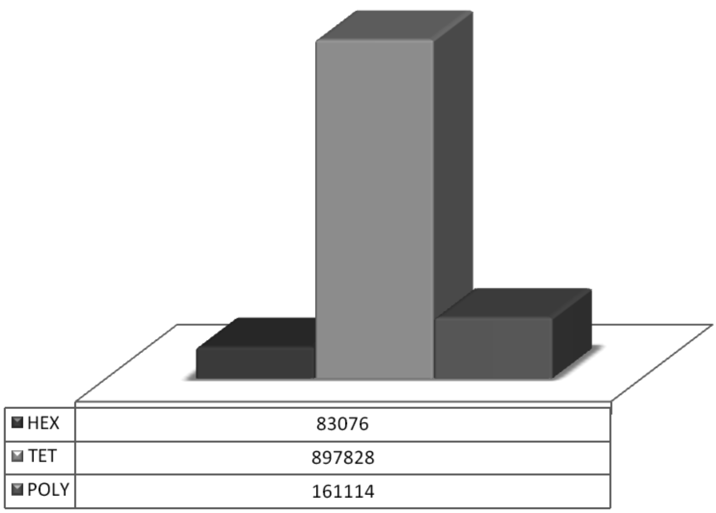

Fig. 6. The number of elements in case of each mesh type

The value of resultant air-fuel mixture flow velocity measured with the use of anemometer located in place of spark plug in S320 engine at the piston position corresponding to ignition moment measured in [8] was determined to be at the level of 8 m/s. Therefore constant and uniform flow field of above mentioned velocity value and direction parallel with the X axis was declared as boundary condition at the borders of computational domain coplanar to YZ plane (Fig. 7).

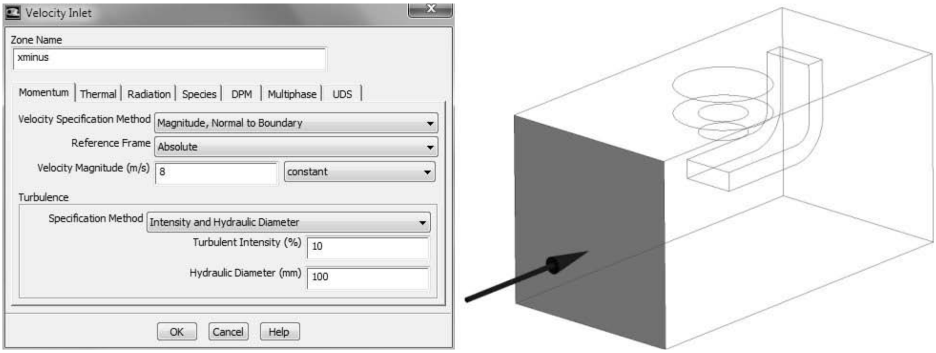

Fig. 7. Boundary condition setup

MODELLING RESULTS

The numerical modelling results are presented as velocity contour plots in the XZ plane (Fig. 8) and Y^+ on the surfaces representing the engine head and the spark plug (Fig. 9) obtained for all three mesh types analyzed in the paper.

The Y^+ is a non-dimensional wall distance from the wall to the first mesh point and can be defined as follows:

$$Y^+ = \frac{U_* Y}{\nu},$$

where:

U_* - friction velocity at the nearest wall,

Y - distance to the nearest wall,

ν - local kinematic viscosity of the fluid.

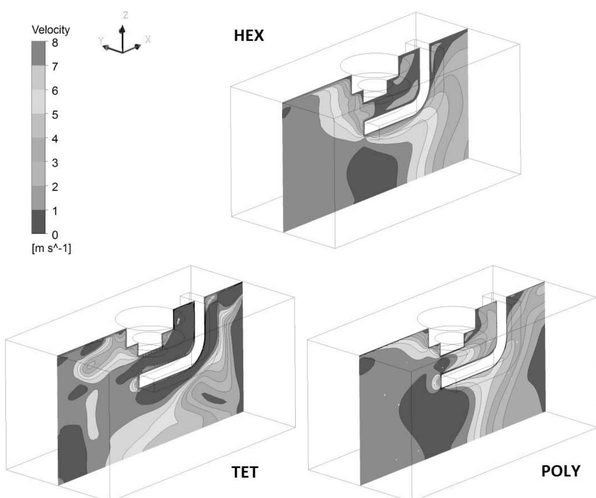

Fig. 8. Velocity contour plots in XZ plane for each of the analyzed mesh types

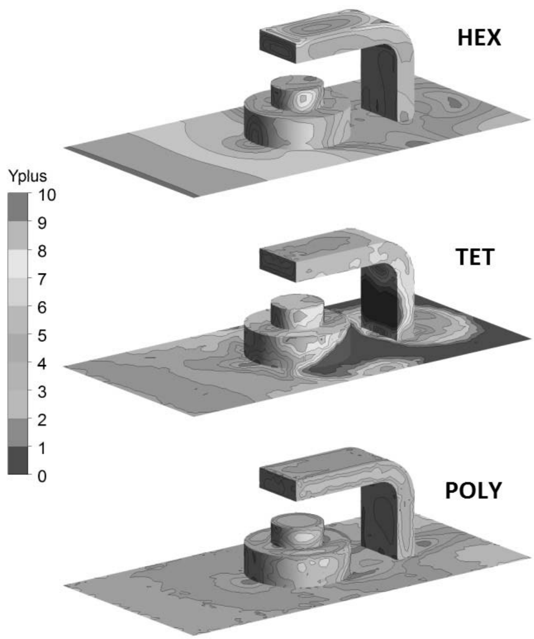

Fig. 9. Y^+ contour plots for each of the analyzed mesh types

CONCLUSIONS

The numerical modelling results presented as velocity contour plots for each of the analyzed mesh types reveal that the velocity distribution in the XZ plane obtained with the use of POLY mesh is more consistent with the HEX mesh than the results obtained for the TET mesh. However differences in the volume between spark plug electrodes are significant even for HEX and POLY mesh.

In case of Y^+ (similarly as for the velocity), acquired results reveal that the distribution obtained with the use of POLY mesh is more consistent with the HEX mesh than the results obtained for the TET mesh. The differences are caused by the local velocity values and the height of the first mesh layer from the wall, which are used to calculated the Y^+.

The results prove that the computational domain discretization significantly influence the numerical modelling results. That is why the mesh type should be wisely chosen for the specific cases and the proper seed size must be declared.

Another issue, which has to be further examined, is the boundary layer. The proper values of Y^+ depend on the kind of solver settings (wall-function or wall-integration) as well as the seed size near the wall. Therefore, the seed size should be chosen separately for each of the analyzed mesh types in order to obtain mesh-independent solution and then the solutions for HEX, TET and POLY mesh should be compared.

REFERENCES

1. Franke A.: Diagnostics of electrical phenomena in gases for the monitoring of spark-ignited combustion, Lund Institute of Technology, Lund University, 2000.

2. Herweg R., Maly R.R.: A fundamental model for flame kernel formation in SI engines, SAE Paper 922243, 1992.
3. Jamrozik Arkadiusz, Kociszewski Arkadiusz, Sosnowski Marcin, Tutak Wojciech; Simulation of combustion in SI engine with prechamber; XIV UKRAINIAN POLISH CONFERENCE "CAD in Machinery Design Implementation and Educational Problems"; Polyana; 2006.
4. Kociszewski Arkadiusz, Jamrozik Arkadiusz, Sosnowski Marcin, Tutak Wojciech: Computational analysis and experimental research into lean mixtures combustion in multi-spark plug SI engine; EUROPEAN KONES 2006, 32nd International Scientific Congress on Powertrain and Transport Means; Warsaw, Lublin, Naleczow; 2006.
5. Sosnowski Marcin: Ignition model and its impact on flame kernel formation in SI engine; Edukacja Techniczna i Informatyczna, 2009.
6. Sosnowski Marcin: Modelowanie i analiza przebiegu wyładowania iskrowego w silniku z zapłonem wymuszonym; Prace Instytutu Lotnictwa, Warszawa, 2009.
7. Sosnowski Marcin: Rejestracja optyczna wyładowania iskrowego przy różnych parametrach przepływowych medium gazowego pomiędzy elektrodami świecy zapłonowej; Edukacja Techniczna i Informatyczna, 2009.
8. Tutak W.: Modelowanie zawirowania świeżego ładunku w komorze spalania tłokowego silnika spalinowego, Praca doktorska, 2002.
9. Tutak Wojciech, Jamrozik Arkadiusz, Kociszewski Arkadiusz, Sosnowski Marcin: The experimental research of the three-dimensional turbulence field in combustion chamber of internal combustion engine; EUROPEAN KONES 2006, 32nd International Scientific Congress on Powertrain and Transport Means; Warsaw, Lublin, Naleczow; 2006.

DYSKRETYZACJA DOMENY OBLICZENIOWEJ I JEJ WPŁYW NA POLE PRZEPŁYWU WOKÓŁ ŚWIECY ZAPŁONOWEJ W SILNIKU NISKOPRĘŻNYM

Streszczenie. Dyskretyzacja domeny obliczeniowej jest kluczowym czynnikiem wpływającym na zgodność wyników badań numerycznych i eksperymentalnych. W pracy przedstawiono porównanie wyników uzyskanych dla tych samych ustawień numerycznych, ale dla różnych rodzajów siatki: siatka sześciokątna, czworościenna i wielościenna. Obliczeniowa domena obejmowała sektor stałej objętości komory spalania ze świecą zapłonową. Wyniki przedstawione w postaci prędkości i obrysów Y^+ dowodzą, że zastosowany typ siatki znacząco wpływa na wyniki, a zatem również na zgodność wyników badań numerycznych i eksperymentalnych.

Słowa kluczowe: silnik niskoprężny, modelowanie numeryczne, typ siatki, dyskretyzacja domeny obliczeniowej, obliczeniowa dynamika płynów.