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Thermal Simulating of Poppet Valve of XUM Motor and its Support in Order to Estimating of Contact Heat Transfer Coefficient: A Numerical Study

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Abstract— The functionality of inter combustion engines is depend on good management of fuel, air, spark and cooling process in order to get assurance from optimum performance of engine, pollutant amount and fuel consumption. The cooling of poppet valve by thermal contact of poppet valve and its support is very important. In this study, the thermal simulating of poppet valve of XUM engine and its support is performed by numerical method and using Ansys CFX software. Firstly, a simplified problem of end contact between two rods is analyzed to assure the accuracy of selected software and results of the solution are obtained. Then, the three dimensional geometry of engine cylinder head is input to the software and using the presented boundary conditions the problem is solved in static contact condition and its results including temperature of contact position between poppet valve and its support is used as initial condition for periodic case. Afterwards, the periodic case in low revolutions of engine and using the input warm air is considered. The obtained results in both cases of static and periodic contact are compared with the results obtained from experimental work on the test model of XUM engine in IPCO Corporation. In addition, the conditions of engine functionality in higher revolutions and using combustion products as input are evaluated. Finally, the contact heat transfer coefficients are estimated in two high revolutions of engine.

Index Terms— Poppet valve, Thermal simulating, Contact heat transfer coefficient, Numerical study, XUM motor, Ansys CFX software, IPCO Corporation

1 INTRODUCTION

Poppet valve is used to removal of smoke and products of combustion after working of engine and is accounted for as mobile elements of cylinder head [1-8]. Poppet valve is of elements that must be designed so accurately to be able to work correctly since it is subjected to high thermal and mechanical stresses [9-19]. Another part of cylinder head which is in relation with poppet valve is the support which cooling the poppet valve by transferring the contact heat between them in addition to supporting the poppet valve [20-23]. The support of poppet valve should be has an enough resistance against high temperature and corrosiveness of passed gases through it. The support is a ring with rectangular cross section which one of its internal corners is conical so that the poppet valve can sit on it [24]. The poppet valves should be resistance against mechanical loads, combustion pressure and temperature and it should be dyke between combustion chamber and exit pipe when it is closed [25-31]. In addition, it should be stable in millions of cycles and these issues should be considered in design of poppet valve [32, 33].

The high temperature distribution of poppet valve is very important from material point of view, in addition to high thermal stresses induced by high temperature gradient [34]. It should be noted that the first step in study of poppet valv is its thermal analysis which includes the finding of temperature distribution in the poppet valve so that the selection of suitable material becomes possible [35-43]. However, the role of support in temperature distribution of poppet valve also should be considered and in addition to considering the poppet valve in thermal analysis, the contact heat transferring between them also is of critical importance [44]. When poppet valve is closed, heat majorly transferred to support and then to cooling system of cylinder head and when it is open, leg of poppet valve is the major path to heat transferring [45]. Due to contact of poppet valve and its support and high temperature of poppet, they may be burned and deformed [46]. During time and due to continuous contacts, this deformation is mainly led to rupture in support and or gullet of poppet valve [47, 48].

In previous studies of thermal simulating of poppet valve, the most attention have been focused on the temperature distribution and thermal flux which is mostly in condition of engine function with combustion and as a result, there has been need to modeling of combustion in numerical analysis [49]. In addition, most of these studies are either in initial steps of engine function prior to reach a stable condition or in long times after initiating of engine function and hence, in stable conditions [50]. Another important note is the lack of study about

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the static contact condition between poppet valve and its support (without move of crank) which has been not considered in most of previous studies [51]. Moreover, the reduction of contact heat transfer coefficient with increase of engine revolutions is an issue that frequently ignored and it has been considered as a constant during the cycle of engine [52]. Among the important issues which are ignored in recent studies is the estimation of contact heat transfer coefficient in various conditions of engine and different revolutions [53].

In addition to those mentioned above, the exact determination of presented boundary conditions in cylinder head, such as displacement heat transfer coefficient of cooling water (composition of water and antifreeze) and condition of engine function in cold case (without combustion phenomenon) and effects of input air and revolution of engine on temperature of poppet valve have been less considered by researchers and studying of engine function in low revolutions and temperatures is seldom [54]. Recent investigations are mostly focused on simulating of a part of cylinder head and or combustion chamber and sometimes in larger studies, the simultaneous moving of poppet valve and piston has been considered by researchers but less attention has been paid to cylinder head and especially its governing boundary conditions including displacement heat transfer coefficient of cooling liquid of engine [55, 56].

The study of both static and dynamic temporary condition of engine function prior to reach a stable condition and or in stable function of engine have been the subject of recent studies and it is increasingly developed which is the indication of its high importance in practical applications and it is a developing field of study in recent years [57, 58].

At now, there is not a comprehensive and suitable model for predicting the rate of heat transfer from poppet valve and its support in static and cyclic contacts in internal combustion engines [59]. Hence, the study of contact heat transfer coefficient and its important effective variables is necessary. Regarding that the most of this heat transfer during connection of the poppet valve and its support is by conduction, estimation of contact heat transfer coefficient and its effective important quantities are one of the main challenges in design of internal combustion engines [60]. The contact heat transfer coefficient is so that it is not directly measureable or calculable; this parameter is only estimated by experimental thermal data and numerical analysis [61]. Hence, thermal analysis of poppet valve in order to obtain a temperature distribution and also studying of contact heat transfer are of the most important subjects in analysis and evaluating of internal combustion engines [62, 63].

Among the important questions and problems in the subject of contact heat transfer study in internal combustion engines which is happened between poppet valve and its support, the estimating of contact heat transfer coefficient in high revolutions by numerical simulating is very important [64-76]. In addition, it is a big question that if the thermal studying of poppet valve and its support can lead to determining of the coefficient and also if these obtained results is in good accordance with experimental results on an internal combustion engine model in true conditions of engine function [77-83]. In fact, a part of the current study is aimed to answer these questions that would be helpful for future studies in addition to thermal study of poppet valve [84].

2 Research Purpose

In the current study, the thermal simulating of poppet valve and its support is performed using synthetic method of finite element and finite volume. This analysis is performed in two cases of static and periodic contact and the contact heat transfer coefficient between poppet valve and its support is considered as an important parameter. The thermal analysis consists of finding the temperature distribution in the poppet valve and its support on the contact zone in low revolutions and temperatures of function of internal combustion engine which is considered without the combustion phenomenon in cylinder and to validate the obtained results from numerical analysis, experimental results of a XUM engine model in IPCO Corporation is used. In the next step, using the simulating in low revolutions and temperatures, the contact heat transfer coefficient in higher revolutions is estimated which has been rarely perfirmed in previous studies. In addition, the case of exit of combustion products (rather than warm air) also is studied which in fact, it can play the role of combustion phenomenon in the engine and hence, the analysis is considered both of warm air effect passed over the poppet valve and its support and the effects of hot gas exited from cylinder that is produced after combustion.

3 Research Method

In the current study, the research method is use of commercial software. The poppet valve and its support in XUM engine simulated and thermally analyzed in ANSYS CFX software in two cases of static and periodic contact and the temperature in the contact point of these two parts of engine obtained and compared with experimental results. Then, the contact heat transfer coefficient between the poppet valve and its support in higher revolutions obtain by results of the software.

4 Results and Discussion

Most of numerical studies performed on the contact heat transfer between poppet valve and its support have been considered the combustion phenomenon in engine and hence, they have been performed in high temperature regions. In addition, both of diesel engines (compression ignition) and flash ignition are studied in this regard.

In these studies, the temperature distribution, thermal flux and thermal stresses in static and dynamic states in poppet valve and or piston by simulating the cylinder head and combustion chamber and piston movement are of great importance. It can be seen that considering of combustion as two region model in such studies is led to better and more accurate results. The evaluation of engine performance in case of engine function without combustion (cold) in studies is considerably lower than engine function with combustion. In addition, vortex formation in combustion chamber and studying of turbulence are recently got attention by researchers. In newest studies, use of methods such as simulating of great vortexes in this field is under study. In addition to evaluating the poppet valve without any sediments, the effects of carbon sedimentation on the poppet valve surface and its support and also the position of formation of these sediments on the performance of poppet valve have been investigated in recent studies and apart from temporary performance of engine in initial cycles, reaching to the stable performance condition also has been considered. The resistor – capacitor method along with clogged parameter method and use of coding software such as MATLAB and also widespread use of commercial software such as ANSYS, CFX and FLUENT are of cases that can be seen in recent studies.

About the estimation of relationships in relation to the displacement heat transfer coefficient of hot gases excited from cylinder, there are numerous recent studies which investigate the heat transfer in cylinder and cylinder head. The investigation about the poppet valve guide and the presented clearance between guide and poppet valve and also in the combustion chamber, evaluating the crest of piston and its rings all are among the subject studies in recent investigations.

5 CONCLUSION

In the current study, the thermal simulating of poppet valve and its support in low revolutions of engine and without forming of combustion in cylinder was considered. The input gases to the engine were considered as warm air that has not been considered in previous researches. Another subject in this study was the importance of the contact heat transfer coefficient between poppet valve and its support that is also has not been widely considered in previous studies. In addition, there has not been any numerical study regarding the XUM engine and its cylinder head and the experimental results obtained from a model engine in IPCO Corporation has not been used to validate any numerical study and this work is the first in this field. Moreover, the effects of engine revolutions and air temperature on the temperatures of poppet valve and its support along with the evaluation in high revolutions and estimation of contact heat transfer coefficient in such revolutions also were considered.

6 SUGGESTIONS AND FUTURE STUDIES

Among the subjects that will be studied in future is the considering of combustion phenomenon in numerical studies along with the study of warm air effect on the engine. In addition, evaluating the problems such as corrosion and erosion of poppet valve and stress distribution in poppet valve and its support will be considered in future studies. Regarding the distortion of support which causes to non-uniformity in thermal distribution of poppet valve will be very useful in future studies since due to such condition, thermal shocks will be result which finally will be lead to rupture in poppet valve. In addition to the case of temperature, the resulted bending stresses and dropping in power of engine also are of problems induced by distortion of support which show the importance of this subject for future studies.

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507.