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THERMAL PROCESSES CONTROL OF SHIP DIESEL ENGINE BASED ON FUZZY PLC

Abstract. *Object the problem of organization of automatic control the process of heat mass exchange is examined in jacket space of internal combustion engine. The problem of physical realization of device of adjusting is described by the optimal temperature state by this engine. It is suggested to use as this control unit the fuzzy controller adjusted definitely. Supposition is pulled out about creation of device with self-training, which is realizing the functions of optimal comptroller.*

Keywords: *heat mass exchange, optimal temperature state, tuning fuzzy controller*

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УПРАВЛЕНИЕ ТЕПЛОМАССООБМЕННЫМИ ПРОЦЕССАМИ СУДОВОГО ДИЗЕЛЬ-ГЕНЕРАТОРА НА БАЗЕ НЕЧЕТКОГО КОНТРОЛЛЕРА

Аннотация. *Рассматривается проблема организации автоматического управления процессом тепломассообмена в зарубашечном пространстве двигателя внутреннего сгорания. Описана проблема физической реализации устройства регулирования оптимальным температурным состоянием двигателя. Предлагается использовать в качестве данного устройства управления настроенный определённым образом нечёткий контроллер. Выдвигается предположение о создании устройства с самообучением, реализующее функции оптимального контроллера.*

Ключевые слова: *тепломассообмен, оптимальное температурное состояние, настройка нечёткого контроллера*

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УПРАВЛІННЯ ТЕПЛОМАСООБМІННИМИ ПРОЦЕСАМИ СУДНОВОГО ДИЗЕЛЬ-ГЕНЕРАТОРА З НЕЧІТКИМ КОНТРОЛЕРОМ

Анотація. *Розглядається проблема організації автоматичного управління процесом тепломасообміну у засорочковому просторі двигуна внутрішнього згорання. Описана проблема фізичної реалізації облаштування регулювання оптимальним температурним станом цим двигуном. Пропонується використати в якості цього облаштування управління налагоджений певним чином нечіткий контролер. Висувається припущення про створення пристрою з самонавчанням, що реалізовує функції оптимального контролера.*

Ключові слова*:* *тепломасообмін, оптимальний температурний стан, налаштування нечіткого контролера*

Raising of research task. Basic characteristic parameters of process of heat mass exchange in jacket space of engine are four parameters of cooling liquid (CL) : pressure, speed of duct, temperature on an input and on an output from an engine. By a management aim this process is maintenance of CL temperature on an output from the engine of equal set, which will provide necessary for a reliable engine temperature state of piston-cylinder-unit. Pressure and speed of duct remain practically unchanging at influence of revolting influence that in turn can be certain as a moment on the billow of engine or fuel index. The size of these parameters is determined by structural and operating descriptions of the engine. Usually these two parameters do not use for a management the process of heat mass exchange in in jacket space of engine. For weakening of influence of indignation and liquidation of rejection a managing device – three-pass valve set in the by-pass system of cooling liquid by a heat-exchanger is used. A change of position of three-pass valve flap, and as a result change of temperature of water at engine input, is manager by influence is a finishing operation on organization of process of heat mass exchange in jacket space of engine for the achievement of the necessary temperature state of its piston-cylinder-unit.

It is needed to mark that the changes of such parameters of the cooling system are also possible as: pipeline characteristic, pressure descriptions of the pumping stations, change of expense description of jacket space of engine, change of water level in an expansive tank etc. Change of these parameters related to such technological processes as: contaminations of sea chest filter or transition from one sea chest to other, starting or stopping of pumps of the cooling system, change of engine load, and presence of losses in the system etc. It will be considered below, as these changes influence to control quality.

To date for realization of task on automatic control by the temperature state of engine control system usually will be realized on management by exception. And accordingly control unit in these systems is proportional integral (PI) or proportionally integrally a differential (PID) comptroller carrying out a management position of choker of three-pass valve.

Aim of work. Ground of necessity of application of automatic control units by the optimal temperature state of piston-cylinder-unit of combustion engines, that is realized on the base of fuzzy comptroller or device with self-training.

Material and research results. We will consider work of one of such devices on the example of cooling control system operation of main two-stroke engine of HYUNDAI MAN B&W 6C80ME-C of containership ship "Cap Frio" 2013 building year. On this ship a device is realized programmatic in the environment of the alarm and monitoring system "ACONIS 2000" productions of HYUNDAI HEAVY INDUSTRIES CO.LTD and physically on the base of electro-pneumatic comptroller of position of choker of three-pass valve.

On Fig.1 graphs over of change of the described before parameters are brought during ninety minutes of work of ship "Cap Frio" during the maneuver. On a picture: M/E RPM – speed of rotation of main engine shaft; M/E FUEL INDEX – an index of serve of fuel of main engine; M/E J.C.F.W INLET T. – temperature of fresh water of cooling of jacket space on input in a main engine; TEMP. FOR J.C.F.W TEMP CONTROL – controlled temperature of fresh water of cooling of jacket space of main engine; CONTROL FOR JCFW TEMP CONTROL – a reference signal of management by exception by the choker of three-pass valve of management by the temperature of fresh water of the jacket space cooling system of main engine; POSITIONER FOR JCFW TEMP CONTROL – signal of actual position of choker of three-pass management by the temperature of fresh water of the jacket space cooling system of main engine. Control unit reacts on the change of the controlled temperature of fresh water of cooling of jacket space of main engine practically instantly. However the change of this temperature takes place approximately with a three minutes delay after the change of turns of main engine (accordingly, increases of fuel index). On columns evidently, that hereupon control unit is incapable to retain the controlled temperature of equal set. Long, up to seven minutes, deviations of the controlled parameter reach ± 3°C. If the positive deviations of temperature of cooling liquid diminish efficiency of work of cylinder oil, then at negative deviations such phenomenon as "cold corrosion" appear [1]. Both these phenomena negatively affect on a life time of piston-rings and cylinder cover of engine [1, 2, 3].

On Fig.2 graphs over of change of the same parameters are brought, which on Fig.1, but during six hours of work of ship "Cap Frio" in the normal mode. At this mode of operations of ship the change of speed of rotation of crankshaft of main engine was not observed, however in the moment of time 8:25 the change of parameters of the cooling system happened, that resulted in the origin of considerable fluctuations in the managed temperature. It is possible to explain such switch over of the system to such mode that the coefficients of PID controller of management unit are set at editing and debugging of ship's systems and remain permanent at all operational modes. Accordingly for the achievement of higher quality of management it is necessary to change the coefficients of PID comptroller during change both engine operations mode and at the change of any of described before switchovers in cooling water system.

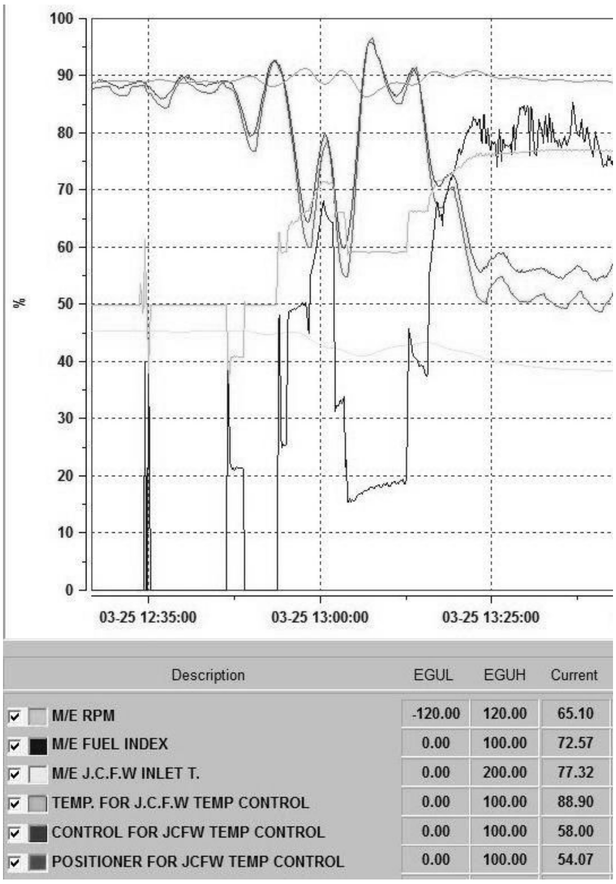

Fig. 1. Graphs of change of parameters of main engine cooling system at the maneuver operations of the ship

In works [4, 5] already talked about the prospect of creation combustion engine's temperature state automatic control system by the indemnification of change of parameters of management object. Usually for realization of control system of such type it is needed to make the mathematical model of process which is necessary to manage. To date the enough mathematical models which describing various processes in a combustion engine are created [6, 7]. However all these models possess have one substantial defect. Further we will consider a few mathematical models of heat transfer from a cylinder to cooling water.

We will consider the example of such mathematical model, in which a cylinder is presented by a limit multi-layered flat wall, made using basic equalization of heat transfer formula:

$$Q_L = \frac{1}{\frac{1}{\alpha_G} + \frac{\delta_{CT}}{\lambda_{CT}} + \sum \frac{\delta_C}{\lambda_C} + \frac{1}{\alpha_B}} \left(T_G - T_B\right) F, \qquad (1)$$

where Q_L – temperature losses from a cycle; α_B, α_G – heat-transfer agent coefficients of heat transfer (working body and coolant); T_G, T_B – temperatures of heat-transfer agent; δ_{CT}, δ_C – thickness of basic and additional layers of wall; λ_{CT}, λ_C – coefficients of heat conductivity of basic and additional layers of wall; F – an area of surface of wall.

An author specifies on that the coefficient α_G can be expected by a few authorial dependences.

Formula of G. Aihelberger:

$$\alpha_G = 7,8\sqrt[3]{C_m}\sqrt{p_G T_G}. \qquad (2)$$

Formula of V. S. Semenov:

$$\alpha_G = 1,1 D^{-0.25}\sqrt{C_m}\sqrt[3]{\rho_G}\sqrt[4]{T_G}. \qquad (3)$$

Formula of Voshy:

$$\alpha_G = 819,5 p_{G.PR}^{0.8}\omega_G^{0.8}D^{-0.2}T_G^{-0.53}. \qquad (4)$$

In the considered equalizations: C_m – average piston speed, p_G – current exhaust gas pressure in a cylinder, T_G – a current temperature of exhaust gas, D – a diameter of cylinder, $p_{G.PR}$ – current pressure in a cylinder at scrolling of crankshaft, ω_G – speed of working body on the different areas of cycle.

Values of coefficient α_B at cooling water flow speed 0,25 ... 1,5 m/s on flat wall cylinder use next statement:

$$\alpha_B = 348 + 2088\sqrt{\omega}. \qquad (5)$$

In [3] specified on that (5) can not apply on universality by reason of solit state of coefficients which can be characteristic only for some cooling system operations mode only. If in details there are riffles forming or channels then, for determination of $\alpha_Ж$ criterion dependences uses, wich taking into account the features of construction and cooling. In the evaluation calculations of the temperature state of details of engine usually numeral values α_g is set and by the results choose the acceptable method of cooling.

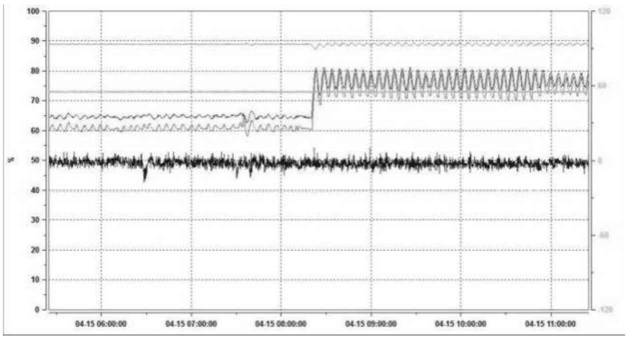

Fig. 2. Graphs of parameters of main engine cooling system at the working mode of ship

In [6] it is suggested to produce the calculation of heat loss in the walls of cylinder through the method of eventual differences on every calculation interval so:

$$\Delta Q_W = 0,5\left[a_{rj}\left(T_j - T_{cyl}\right)F_j + a_{rj+1}\left(T_j - T_{cyl}\right)F_{j+1}\right]\frac{\Delta\varphi}{6n}, \qquad (6)$$

where α_{rj} – coefficient of heat emission from gases to the wall of cylinder; T_{cyl} – average temperature of walls of cylinder; F – surface of cooling of cylinder; $\Delta\varphi$ – a calculation interval is an elementary area of method of eventual differences; n – crankshaft rotation frequency.

For the calculation of coefficients α_r r author used the dependences indicated higher as G. Aihelberger, V. S. Semenov, Voshy, so given below.

Formula of G. Hohenberg:

$$\alpha_G = 0,8201\left(C_m + 1,4\right)^{0,8} p_G^{0,8}\omega_G^{-0,06}T_G^{-0,4}. \qquad (7)$$

Formula of H. Tsapf:

$$\alpha_G = 3,277D^{-0,22}C_m^{\;0,78}p_G^{0,78}T_G^{-0,52}. \qquad (8)$$

Results of comparative calculations of coefficients α_r, given at [6] show that at equal terms the values of this coefficient expected on different methods, considerably differ from each other.

In [7] an author suggests to use the mathematical model of internal combustion engine high-beat by application of method of electro-thermal analogy of processes for description of processes of heat conductivity and heat transfer through the wall of cylinder:

$$\frac{dQ_{in}}{dt} = -\sum_{i=1}^{n-1} g_{in}Q_{nn+1} + g_{nn+1}\left(T_0 - T_n\right), \qquad (9)$$

where $Q_{1n},\ldots, Q_{nn+1}$ – superficial amounts of heat between layers; $g_{1n},\ldots,g_{nn+1}$ – coefficients depending on the parameters of layers of cylinder liner; T_0, T_n – absolute temperatures, being border terms. But an author specifies on that for determination of numerical values of coefficients of $g_{1n},\ldots,g_{nn+1}$, that is used in models, additional independent researchers are needed.

All considered mathematical models describing a the same process, in a combustion engine, possess with the same defect – additional researches of coefficients of heat transfer and heat exchange, that depend on the structural features of concrete engine, are needed. Similarly by the example of imperfection of existent methods and models of calculations of the thermal state of combustion engine, there is a construction of jacket space, of examined engine (HYUNDAI MAN B&W 6C80ME-C). In [8, 9] the main engine operation monitoring results are used by maker for modification of cooling contour of jacket space of cylinder liner of the engine type of HYUNDAI MAN 6S80ME-C. The aim of this modification is lowering of intensity of heat emission in cylinder liner overhead part and as a result minimization of the phenomenon cold corrosion appearance.

Summary. Taking into account, existent lacks of heat transfer processes calculation methods and heat exchange in a combustion engine, task on creation of control unit by the temperature state of the engine adjusted at their help, is impracticable. With the purpose of overcoming of this problem in [10] it is suggested to realize the examined control units on the base of fuzzy controller. For creation of rules of this comptroller application of the special setting is offered. But, maybe, more perspective task is creation of device with self-training.

References

1. Hyundai-MAN B&W Diesel Engine, (2012), *Main Engine Manual*, Volume I-II, *HHI*, 1376 p.

2. Voznickiy I.V., and Miheev E.G. Sudovye dizeli i ih jekspluatacija [Ship's Diesels and their Maintenance], (1971), Moscow, Russian Federation, *Transport*, 192 p.

3. Petrichenko R.M. Sistemy zhidkostnogo ohlazhdenija bystrohodnyh dvigatelej vnutrennego

sgoranija, [High Speed Internal Combustion Engines Liquid Cooling Systems], (1975), Leningrad, Russian Federation, *Mashinostroenie,* 244 p.

4. Gatsuts A.G., and Drankova A.O. Povyshenie jeffektivnosti raboty sudovyh jenergeticheskih ustanovok putem obespechenija optimal'nogo temperaturnogo rezhima. [Ship's Power Plant Operation Effectiveness Increase by Means of Ensuring Optimal Temperature Mode], (2011), *Nauchnoe Izdanie,* Kremenchug, Ukraine, *KNU*, Issue1/2011(1), pp.132 – 133.

5. Gatsuts A.G. O realizacii ustrojstva regulirovanija temperatury ohlazhdajushhej zhidkosti dizel'noj sudovoj jenergeticheskoj ustanovki na osnove nechjotkogo kontrollera [About Realization of Device of Adjusting of Temperature of Cooling Liquid of Diesel Ship Power Plant on the Basis of Fuzzy Comptroller], (2011). *Naukove Vidannia*, Mikolayiv, Ukraine, *IAE NUK*, pp.79 – 81.

6. Varbanets R.A. Vozmozhnosti analiza rabochego processa v raschjotnom module diagnosticheskoj sistemy sudovyh dizilej [Possibilities of Analysis of Working Process are in the Calculation Module of the Diagnostic System of Ship Diesels], (2009), *Vestnik Dvigatelestroenia No. 3. Allukrainian Scientific and Technical Magazine,* Kharkov, Ukraine, *PP "Evromedia",* pp. 46 – 50.

7. Radchenko A.P., Bendakhman Bukhalfa, and Buda Rashid. Stohasticheskaja model' teplonaprjaz-hennosti sudovogo dizel'-generatora, [Stochastic Model of high-beat of Ship Diesel-Generator], (2000), *Ship's Power Plant. Nuch. Techn. Sb.,* Odessa, Ukraine, *OGMA*, Issue No. 5, pp.94 – 98.

8. S903-0050 Replacement of Cooling Pipes. – – *MAN B&W. – MAN Group*. 2013.

9. MAN. Technical letter 08_10_12. – *MAN Diesel & Turbo. – MAN Group.* 2012;

10. Gatsuts A.G. O vozmozhnosti ustanovki po nastrojke nechjotkogo kontrollera v funkcii upravlenija optimal'nym sostojaniem sudovogo dizel'nogo dvigatelja [About Possibility of Setting on Tuning of Fuzzy Comptroller in the Function of Management the Optimal Mode of Ship Diesel Engine], (2013), *Naukove Vidannia,* Odessa. Ukraine, *ONMA.*

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Список использованной литературы

1. Hyundai-MAN B&W Diesel Engine, (2012), *Main Engine Manual*, Volume I-II, *HHI*, 1376 p..

2. Возницкий И. В. Судовые дизели и их эксплуатация / И. В. Возницкий, Е. Г. Михеев. – М. : Транспорт, 1971, 192 с.

3. Петриченко Р. М. Системы жидкостного охлаждения быстроходных двигателей внутреннего сгорания / Р. М. Петриченко. – Л. : Машиностроение, 1975. – 244 с.

4. Гацуц А. Г. Повышение эффективности работы судовых энергетических установок путем обеспечения оптимального температурного режима / А. Г. Гацуц, А. О. Дранкова // Научное издание. – Кременчуг : – 2011. – КНУ. – Вып. 1/2011(1). – С. 132 –133.

5. Гацуц А. Г. О реализации устройства регулирования температуры охлаждающей жидкости дизельной судовой энергетической установки на основе нечёткого контроллера / А. Г. Гацуц // Наукове видання. – Миколаїв : ІАЕ НУК. – 2011. – С. 79 – 81.

6. Варбанец Р. А. Возможности анализа рабочего процесса в расчётном модуле диагностической системы судовых дизилей / Р. А. Варбанец // Всеукраинский научно-технический журнал. Вестник двигателестроения. – 2009. – № 3. – Харьков : ПП «Евромедія». – С. 46 – 50.

7. Радченко А. П. Стохастическая модель теплонапряженности судового дизель-генератора / А. П. Радченко, Бендахман Букхалфа, Буда Рашид. // Науч. тех. сб. Судовые энергетические установки. – Одесса : – 2000.– ОГМА. – Вып. № 5. – С. 94 – 98.

8. S903-0050 Replacement of Cooling Pipes, (2013), *MAN B&W, MAN Group.*

9. MAN. Technical letter 08_10_12, (2012), *MAN Diesel & Turbo, MAN Group.*

10. Гацуц А. Г. О возможности установки по настройке нечёткого контроллера в функции управления оптимальным состоянием судового дизельного двигателя / А. Г. Гацуц // Наукове видання. – Одеса : ОНМА, 2013.

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