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FLUID FLOW ANALYSIS OF THERMOSTAT IN CAR'S ENGİNE: APPROACH TO STEADY STATE

by
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CERTIFICATE

This is to certify that the Project entitled **"Fluid Flow Analysis of Thermostat in Car's Engine: Approach to Steady State"** submitted by **Umut YUKSEL** in partial fulfillment of the requirements for the degree of **Bachelor of Science** in **Mechanical Engineering** at **Marmara University**.

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INDEX

CONTEXT OF FIGURES

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1. ABSTRACT

The automotive cooling system has unrealized potential to improve internal combustion engine performance through enhanced coolant temperature control and reduced parasitic losses. Advanced automotive thermal management systems use controllable actuators (e.g., smart thermostat valve, variable speed water pump, and electric radiator fan) that must work in harmony to control engine temperature. One important area of cooling system operation is warm-up, during which fluid flow is regulated between the bypass and radiator loops. A fundamental question arises regarding the usefulness of the common thermostat valve. In this paper, thermostat configurations have been examined in the way of technical literature with experimental datas in some conditions.

2. INTRODUCTION

The internal combustion engine has undergone extensive developments over the past three decades with the inception of sophisticated components and integration of electromechanical control systems for improved operation.[1] For instance, stratified charge and piston redesign offer improved thermal efficiency through lean combustion, directly resulting in lower fuel consumption and higher power output.[2] Further, variable valve timing adjusts engine valve events to reduce pumping losses on a cycle-to-cycle basis.[3] However, the automotive cooling system has been overlooked until recently.[4] The conventional spark and compression ignition engine cooling systems can be improved with the integration of servo-motor based actuators.[5] Replacement of conventional thermal management components (i.e., wax thermostat mechanical water pump, and mechanical radiator fan) with updated electric and/or hydraulic versions offer more effective operation.[6] In particular, the main function of the thermostat valve[7] is to control coolant flow to the radiator. Traditionally, this is achieved using a wax-based thermostat which is passive in nature[8] and cannot be integrated in an engine management system.[9] A smart thermostat valve offers improved coolant flow control since it can be controlled to operate at optimal engine conditions.[10]

An electric thermostat valve may be designed with different architectures and control strategies to support a variety of cooling system configurations. For example, a DC motor controlled two-way valve may be utilized at multiple locations in a cooling circuit.[11] Similarly, a solenoid controlled three-way valve offers similar functionality to traditional thermostats but could be electrically controlled by the engine control module (ECM). In general, the valve design dictates its placement in the cooling system since valve geometry contributes to the dynamics of the overall cooling system. It should be noted that the thermostat valve may be located on the engine block with internal passages for coolant flow or external to the block with supporting hoses. The next generation of internal combustion engines should be designed to facilitate advanced thermal management concepts.

A series of automotive cooling system architectures may be created using different thermostat valve scenarios as shown in Figure 1. The valve and radiator baffle configurations considered include: factory mode (Case 1); two-way valve (Case 2); three-way valve (Case 3); valve absent without radiator baffles (Case 4); and valve absent with radiator baffles (Case 5). The factory configuration has the mechanically driven water pump and radiator fan emulated by an electric variable speed pump and fan. The two-way valve operates by regulating coolant flow in either the bypass or radiator branch of the cooling circuit. The three-way valve proportionally directs the flow through either the bypass and/or radiator loop. The proper utilization of a variable speed pump potentially allows the thermostat valve to be removed since the coolant flow rate may be predominantly controlled by the pump. The introduction of radiator baffles in the valve absent configuration provides external radiator airflow control (due to vehicle speed) further enhancing effectiveness.[12]

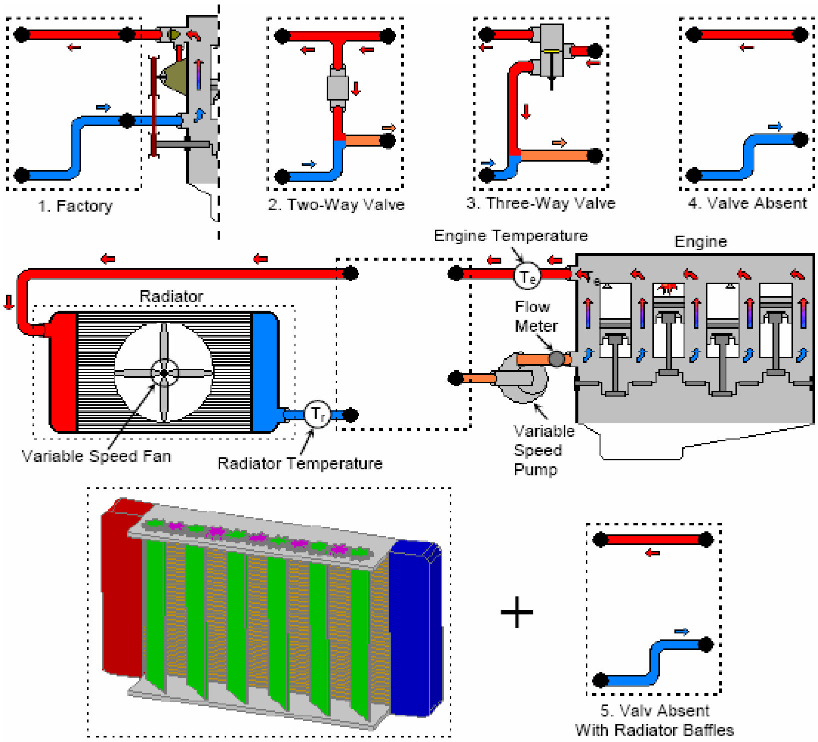

Figure 1: Five valve configurations to enhance fluid flow control

In this paper, thermostatic valve's functionally will be investigated in ground vehicle advanced thermal management system. An overview of the predominant thermostat types and structures will be investigated. Thirdly, cooling system configurations and the thermostatic valve's operation will be discussed. Behind subject is valve design method and its theory, thermodynamics process will be discuss in this part. Finally, faced difficulties at using thermostat will be investigated.

3. THERMOSTAT TYPES AND STRUCTURES

The demand for engineers, less fuel consumption, lower pollutant, reduction weight conversely increase performance, improvement of engine efficiency to be resulted. Different requirements upon reaction speed and mass flow mean the different thermostat versions control the temperatures of the coolant circuit, engine and transmission oll, fuel supply, charge-air and intake air.

In the result of experiments has proved that different requirements allow to control thermodynamic processes in order to achieve maximum performance to be obtained from engine.

The result is the emergence of three thermostat groups have classified as their action with respect to expansion against to temperature.

	THERMOSTAT CATEGORIES		
	Wax thermostats		Electrically actuated thermostats
	Conventional thermostats	Heated thermostats (map-controlled thermostats)	
Type of control	temperature controlled	temperature and map-controlled	temperature independently controlled
Opening temperature	permanently set	variable with limitations	arbitrary
Design criteria	designed for worst case condition	flexible and faster response characteristic	fast response characteristic and highly flexible

Figure 2: Thermostat categories

3.1. Conventional Wax Thermostats

The core of the wax thermostat is the wax element which consists of a pressure-resistant housing that is filled with a special wax which is a remaining from distillation. After the engine has been started the coolant heats up and the wax liquifies at a predefined temperature. This causes the wax in the housing to expand so that it acts upon a pin that serves as a working piston. The pin is pressed out of the housing and pushes against a plate valve that opens the coolant throughput so that the engine is kept within the optimum temperature range. When the coolant drops below the predefined opening temperature a spring pressing against the plate, pushes the pin back into its original position, the coolant circuit is interrupted. The wax liquefaction produces a working range of 12 °C to 15 °C.[13] However, the thermostat can be designed so that the wax element can be adapted to different regulating ranges.[13] By this thermostats with an opening range of 0 °C to 120 °C can be realized.[13] This allows all flowing media to be held in the optimum operating range in various applications reliably and cost efficiently.

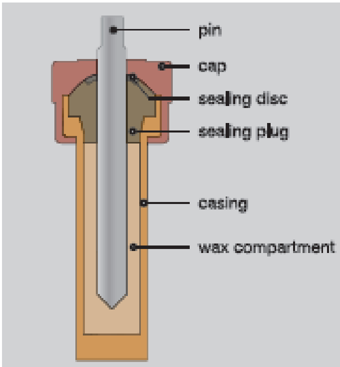

Figure 3: Design wax element

Plate valves reach their engineering limits when large mass flow quantities are regulated, such as in large passenger cars or in commercial vehicle engines. This is where sleeve valve thermostats provide perfect function and control mass flow up to 40 m3/h, independently of the applied pressure differential.[13]

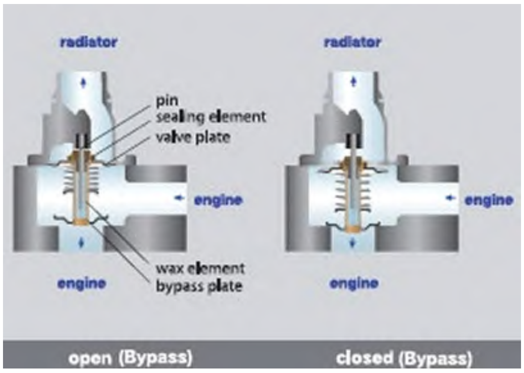

Figure 4: Working principle conventional wax thermostat

Advantages of this type of thermostats are;

- Well proven product
- Little packaging space required
- Production in high volume
- Pre-defined opening temperature
- Cost-efficient product

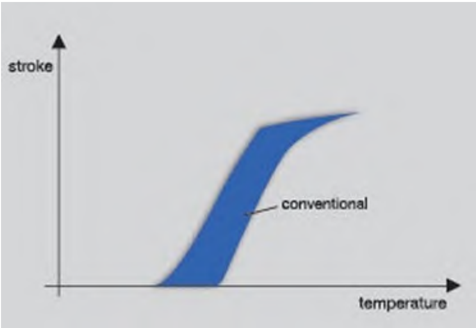

Figure 5: Operating range conventional wax thermostat

3.2. Electrically Heated Wax Thermostat

The cooling capacity in performance-optimized, modern car engines requires thermostats with a wider operating range than that of conventional wax thermostats.[13]

The development provides on the one hand, the continued method of heating the wax by the coolant, and on the other hand its additional electrical heating. In combination it allows the designed temperature differential range to be significantly larger. This means that electrical heating of the wax elements is triggered when the engine is exposed to specific load conditions. These are defined by parameters and stored in a map in the electronic engine management system.

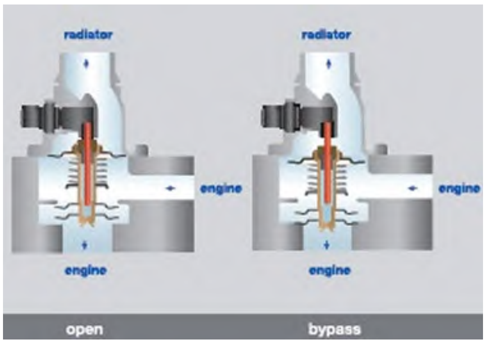

Figure 6: Working principle electrically wax thermostat

Electrical heating opens the coolant circuit earlier in situations of very increased performance requirement. Depending on the present the engine can be operated hotter than previously usual, for instance at approximately 100 ºC to 110 ºC in partial load conditions. This results in a consumption advantage of 1% to 2%. Under full load the temperature is reduced to approximately 80 ºC which allows the performance especially the torque to be measurably increased by approximately 2% to 3%. Virtually a side effect is that the change in the coolant temperature also allows the air conditioning system to be operated in a more favorable temperature range and therefore improve the climatic control in the passenger compartment.[13]

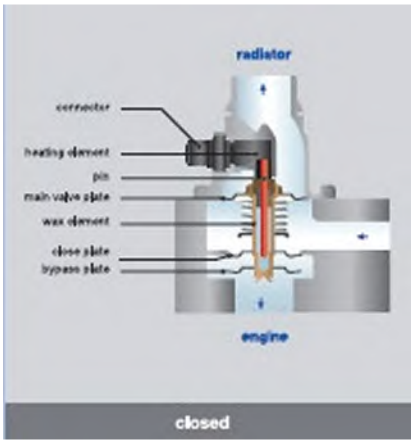

Figure 7: Design principle electrically wax thermostat

Consideration on further reduction of the combustion engine warm-up phase resulted in the idea of a three plate valve in the 1970s. But only the combination with the heated thermostat made suitable reaction times available to prevent local overheating of the overall system.[13]After the engine has been started all coolant flow is initially prevented so that the engine block is quickly brought to its optimum operating temperature. When this is reached the lower plate releases the small coolant circuit stage by stage. As the overall system approaches the defined opening temperature the upper plate also follows the downward movement and opens the large circuit towards the radiator.[13]

A further temperature increase of the cooling liquid causes the lower plate to fully close the bypass channel and route the whole coolant flow through the radiator.[13]

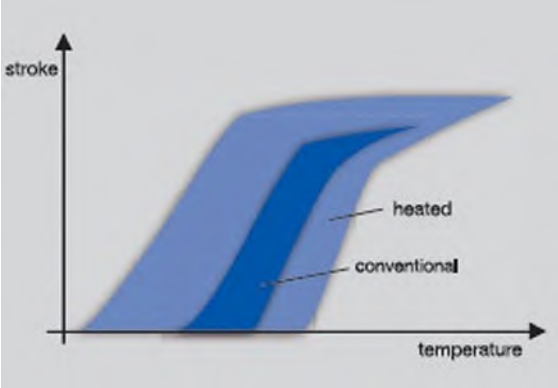

Figure 8: Operating range electrically wax thermostat

Advantages of this type of thermostats are;

- Enlarged operating range through variable opening temperature
- Short response time through optional current feed
- Advanced engine management for better environment protection
- Optimal compatibility to conventional thermostats

3.3. Electrically Actuated Thermostats

Electrically actuated thermostats increase the flexibility of the cooling system to an optimum level as compared to heated thermostats. Because the criteria used to regulate the coolant flow can be selected to meet all requirements.[13]

The coolant temperature can be matched even better to the requirements given by engine cooling and/or vehicle climatic control. The coolant mass flow can be reduced or even stopped in order to reduce the warm-up phase. In the event of an electrical malfunction a return spring ensures that the coolant flow is directed to the radiator and therefore makes sure the engine continues to be cooled.[13]

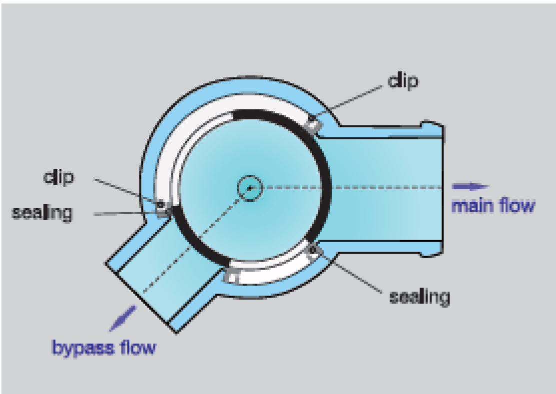

Figure 9: Design principle rotary valve thermostat

The rotary valve design combined with the special sealing concept developed by Wahler allows flexible control of the liquid flow from prevention of engine through-flow right up to continuous control of mass flow in the bypass and radiator operating modes. The special seal ensures that leakage values are effectively and permanently adhered to under all operating conditions.[13]

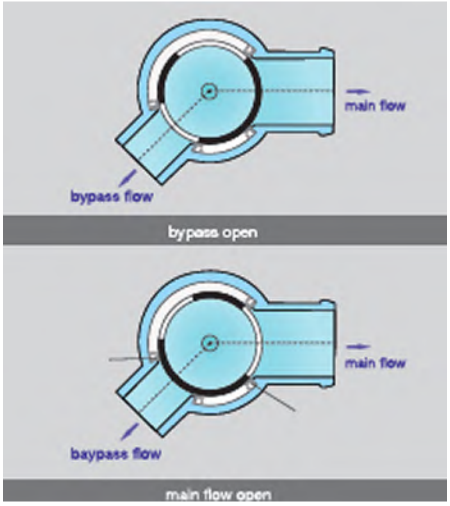

Figure 10: Working principle rotary valve thermostat

Actuation fulfils the highest technical requirements. The non-contact, brushless motor offers maximum resistance to ear. Non-contact Hall Sensors ensure position accuracy and the regulator electronics of the rotary valve can be diagnosed, i.e. the thermostat status can be evaluated via the diagnostics interface. Even here a fail-safe spring ensures that the rotary valve moves to its initial position when electrical current is cut and hence the engine continues to be cooled.[13]

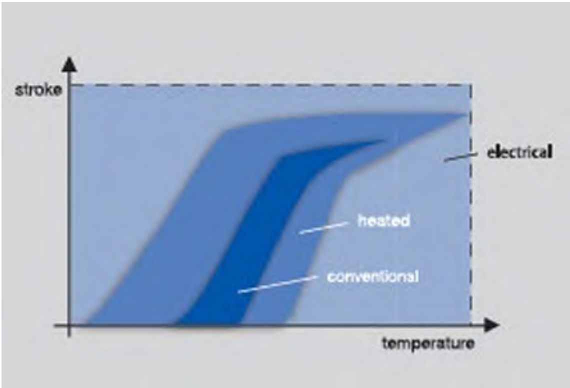

Figure 11: Control range electrically actuated thermostat

Advantages of this type of thermostats are;

- Full control without temperature dependency
- Maximum possible operating range
- Realization of the respectively ideal and freely definable control velocity
- Open for all possibilities of the modern temperature management

4. COOLING SYSTEM CONFIGURATIONS AND VALVE OPERATION

The typical automotive cooling system has two main thermal components: engine and radiator. The coolant flow through the engine loop transports excess combustion heat to the radiator loop which dissipates this heat. Controlling and directing coolant flow between these two loops is the main function of most thermostat valves. This functionality may be accomplished through different valve configurations and system architectures. On this part, these system are going to be investigated and discussed.

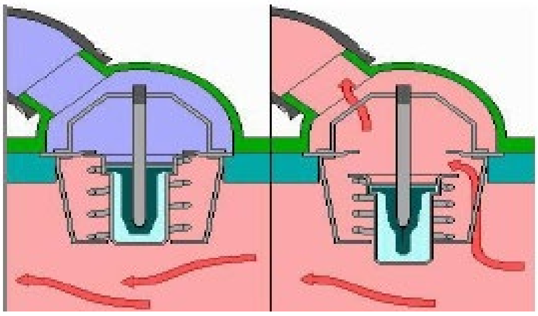

Figure 12: Thermostat valve's move

4.1. Traditional Thermostat Valve Fluid Control

The common cooling system has three key components working to regulate engine temperature: thermostat, water pump, and radiator fan. In operation, when the engine is cold, the thermostat is closed and coolant is forced to flow through an internal engine bypass (usually a water passage parallel to the engine water jackets). Once the coolant reaches the desired operating temperature, the thermostat begins to open and allow coolant to flow through the radiator where excess heat can be rejected. Coolant flowing through the radiator is further cooled by the radiator fan pulling air across the radiator. When the coolant has dropped below the thermostat temperature rating, the valve closes (via spring force) directing the coolant again through the bypass.[14] Traditional water pumps and radiator fans are generally mechanically driven by the engine's crankshaft.

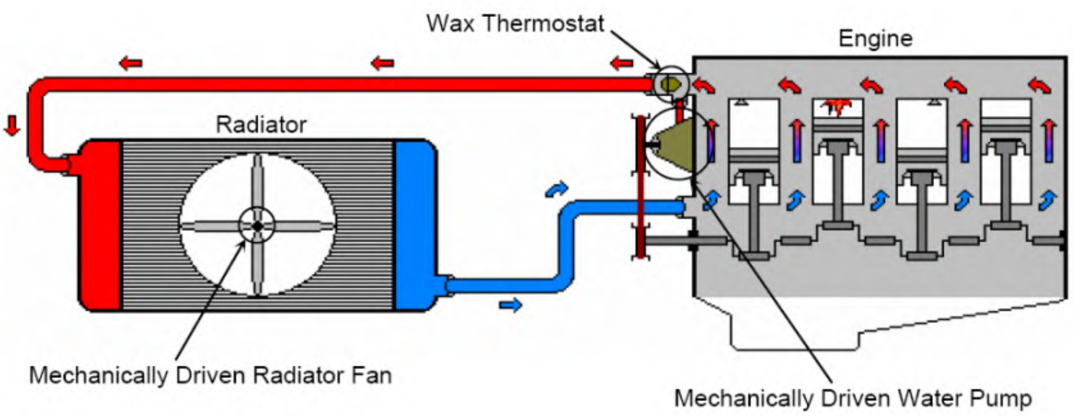

Figure 13: Factory cooling system configuration demonstrating the use of mechanically driven water pump and radiator fan with a wax thermostat

Factory cooling systems typically may face two main problems. First, large parasitic losses are associated with operating mechanical components at high rotational speeds due to their mechanical linkages. This not only decreases the overall engine power, but increases the fuel consumption. Additionally, these parasitic losses are compounded since the traditional cooling system components are designed for maximum (and often infrequent) cooling loads. Second, over/under cooling may occur since the water pump speed is directly proportional to the engine speed (again due to the mechanical linkages). At low engine speeds, the water pump may not be circulating coolant fast enough to properly cool the engine at higher loads. Similarly, the water pump may be circulating the coolant too fast, causing the engine to be overcooled and lose efficiency at higher speeds.[15]

4.2. Without By-pass Valve Fluid Control

A solid wax is placed inside of the thermostat blank which is called valve cylinder. This valve cylinder is fixed to outside body of thermostat. It moves that depends on the temperature increases or decreases. Controlling fluid flow of cold water is a valve which is placed outside of valve track. If a valve cannot open functionally, fluid flow would be cut by valve track. Any increase of temperature on coolant causes that increase volume of wax element. Occupied pressure pushes to valve cylinder, which is fixed to outside body of thermostat, overcomes distributed load concentration. After that, valve track supplies to open valve as going down. When the cooled coolant comes back to the radiator, thermostat' s valve closes. Thermostat controls volume and fluid flow with repeating this operation continuously.

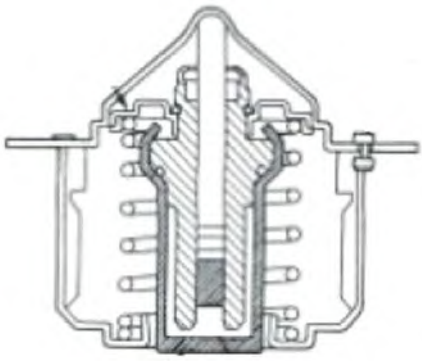

Figure 14: Without by-pass fluid control

Figure 15 shows us how coolant fluid flow realize. If temperature of coolant is low thermostat closes and coolant cannot get in the radiator but coolant is recirculated inside of engine. When temperature of coolant goes up thermostat opens and coolant moves to radiator at the same time.

Figure 15: Fluid flow of coolant

4.3. By-pass Valve Thermostat

When coolant temperature is low, valve would be close and by-pass valve opens. Therefore, coolant doesn't circulate through the radiator. Concurrently, circulation of coolant is controlled in engine with closing by-pass valve. When without by-pass valve opens exactly, not only coolant circulates in radiator but also it circulates in engine. However, coolant is only circulated in engine, when circulation is stopped in by-pass valve.

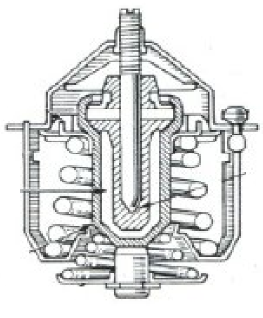

Figure 16: Working principle of by-pass valve thermostat

By-pass valve thermostat checks that circulation of inside of engine as expanding port. Coolant pass through the expanding port and when this type of thermostat compares to classical type, when the engine is cold, fluid flow resistance is reduced that can be observed. In connection with pump which has power would be decreased and power of engine of loss is reduced with this way.

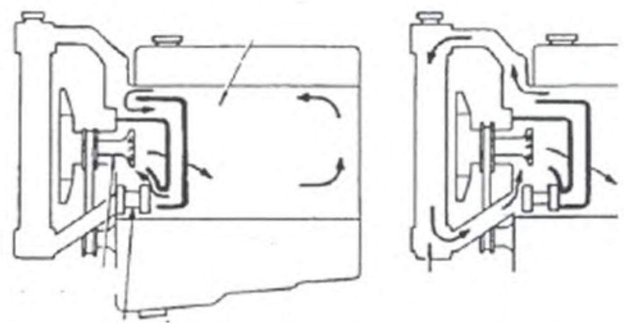

Figure 17: Fluid flow of coolant

5. VALVE DESIGN METHOD AND ITS THEORY

Smart thermostat valve has been developed to control fluid routing at the radiator. For current vehicles, a wax-based thermostat provided the flow control. The thermostat opening characteristics are designed based on a defined cooling system set point temperature. Furthermore, the system action is greatly influenced by the valve's location. For proper modulation of coolant temperature, this unit must observe the highest coolant temperature which occurs by installing the valve close to the engine block. In the proposed smart valve, the system integration constraints are eased with the separation of the actuator control point and its temperature feedback mechanism. Temperature feedback for the actuator was accomplished electronically with temperature sensors such as thermocouples (or thermistors). These sensors can be installed in thermally demanding areas such as the cylinder head and in locations outside the controlled media, such as the engine lubrication oil.

In selecting the valve's diameter, the performance parameters of pressure, flow, speed of response and controllability are considered. Designing the valve required knowledge of the cooling system which the valve will be controlling coolant flow. The main concern is matching the valve size with the cooling system application to ensure proper controllability with respect to the radiator or bypass flow characteristics. If the valve is too large, then insufficient restriction will be offered at a given flow rate and the flow controllability will be diminished. These oversized valves result in small operation ranges (near the fully closed position) which is not desired. In contrast, a small valve will develop a large pressure head, even at fully open condition, negatively impacting the coolant flow control. Proper valve sizing and design is essential to valve function. Accordingly, the prototype valve orifice size is designed to meet the controllability of flow for this specific cooling system application.

The valve's hydraulic performance has been studied using a fluid analysis approach. In the design stage, calculations of the valve's flow area for different positions provide performance feedback. An important design factor includes the effective flow area which requires geometric inspection of the flow passages within the valve. Through the use of solid modeling software (Catia V5), the geometry of the flow area was investigated providing information for a theoretical mapping of the valve where the flow rate, pressure, and valve position are interrelated. This feedback in the design process establishes the basis for the characterization of the valve's orifice diameter. Figure 18 illustrates geometric inspection that produced an analytical valve map, where the relationship between the valve position and the flow area was defined. The valve's cross sectional area, determined by the geometric inspection at various valve 10 positions.

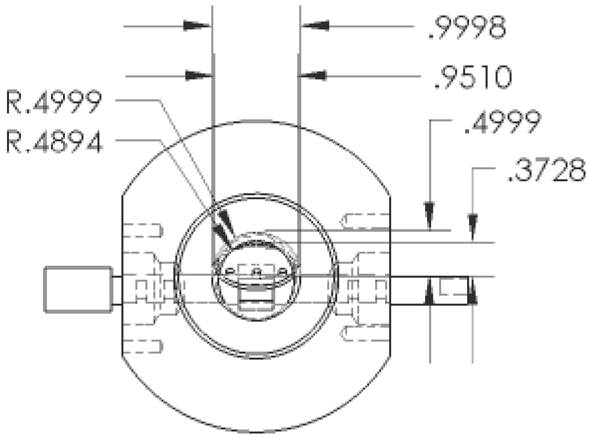

Figure 18: Top view of thermostat valve

The definition of the valve's cross sectional area of flow for various valve positions defines the theoretical valve map. Ideally, the valve's flow rate, Q_v, may be determined using the valve cross sectional area, A_v, and pressure head, P_v, as

$$Q_{v,\,ideal} = A_v\sqrt{2 \cdot \Delta P_v/\rho_w}$$

However, the actual flow rate is less than the ideal this reduction is determined by a correction factor, C, which is a function of the Reynold's number and fluid momentum.

$$Q_{v,actual} = CQ_{v,ideal}$$

A reduced order lumped parameter thermal model may be used to describe the transient response of the engine thermal management system. The thermal dynamics for the engine and radiator nodes, $T_e(t)$ and $T_r(t)$,[17]

$$Ce\dot{T}e = Qin - cpc\dot{m}r(Te - Tr), \qquad Cr\dot{T}r = cpc\dot{m}r(Te - Tr) - \varepsilon cpa\dot{m}a(Te - T\infty) - Qo$$

The coolant mass flow rate through the bypass branch, $\dot{m}_b(t)$, becomes $\dot{m}_b = (1-\varepsilon)(1-H)\,\dot{m}_c$. Note that the parameter $\varepsilon(\Delta p)$ depends on the pressure drop, $\Delta p(t)$, across the radiator and bypass branches. The variable $H(x)$ represents the normalized valve position which is dependant on the actual valve position, $x(t)$. Finally, the overall coolant mass flow rate is $\dot{m}_c = \dot{m}_r + \dot{m}_b$.

The three-way valve dynamics may be applied to evaluate the traditional factory thermostat behavior by adjusting the smart valve's operation. The valve position, $H(x)$, will respond in a linear manner to the coolant temperature so that[16]

$$H=\begin{cases} 0; & Te < Ti \ (bypass\ only) \\ \frac{Te-Ti}{Th-Ti}; & Ti \le Te \le Th \\ 1; & Te > Th \ (radiator\ only) \end{cases}$$

The parameters T_l and T_h represent the temperatures at which the wax in the thermostat begins to soften and fully melt. In an actual wax thermostat, hysteresis occurs while the wax is changing states such that the valve's operation is nonlinear. Hysteresis has been neglected when this formula calculated.

$$H=\begin{cases} 0; Te < Ted - \Delta\mathrm{T} \ (bypass\ only) \\ 1; Te \ge Ted - \Delta\mathrm{T}\ (\text{radiator only}) \end{cases}$$

where ΔT is the boundary layer about the desired engine temperature, $T_{ed}(t)$. The boundary layer was introduced to reduce valve dithering.

The main purpose of the engine's thermal management system is to maintain a desired engine block temperature, $T_{ed}(t)$,while accommodating the un-measurable combustion process heat input, $Q_{in}(t)$ and the uncontrollable air flow heat loss across the radiator, $Q_o(t)$. To achieve this goal, a Lyapunov-based nonlinear controller has been developed so that the engine's coolant temperature, $T_e(t)$,tracks the desired temperature, $T_{ed}(t)$, by regulating the system actuators (variable speed electric water pump and radiator fan) in harmony with each other. The signals $T_e(t)$, $T_r(t)$ and $T_{\infty}(t)$ are measured by thermocouples (or thermistors). The system parameters c_{pc}, c_{pa}, C_e, C_r and ε are assumed completely known and constant throughout the engine's operation. The controller objective is to ensure that the actual engine temperature, $T_e(t)$, tracks the desired trajectory, $T_{ed}(t)$, such that $T_e(t) \rightarrow T_{ed}(t)$ as $t \rightarrow \infty$ while compensating for the system variable uncertainties $Q_{in}(t)$ and $Q_o(t)$.

To formulate the control law, the thermal system dynamics described;

$$C_e\dot{T}_e = Q_{in} - u_e, \qquad C_r T_r = u_e - u_r - Q_o$$

where $u_e(t)$ and $u_r(t)$ are the control inputs, which are defined as

$$u_e = c_{pc}\dot{m}_r(T_e - T_r), \qquad u_r = \varepsilon c_{pa}\dot{m}_a(T_e - T_\infty).$$

A Lyapunov based nonlinear controller can be developed and applied to regulate the engine temperature [17] so that the control law (which establishes a basis to determine the pump and fan speeds) is designed as

$$u_e = -(K+\alpha)[e - e_o] - \int_{t_o}^{t} [\alpha(K+\alpha)e(\pi) + \rho\,\mathrm{sgn}(e(\pi))d\pi$$

In this expression, the final term, $\rho\,\mathrm{sgn}(e)$, compensates for the variable un-measurable input heat, Q_{in} (t). The error, e(t) , is the difference between the desired and actual engine temperatures, T_{ed} (t) -T_e (t) . Finally, the variable, e_o , is the initial temperature error.

6. MAKING CONTROLS AT THERMOSTATS

Thermostats have been made to be opened certain temperature and the degrees. Engines used thermostat which must be started to open between to 60-64 °C and must be completely opened at 77 °C temperature. In today's engines began to open up the thermostat to 80 °C and at 110 °C it is completely opened. Thermostats are used in the engine's operating conditions and selected according to the type of antifreeze.

To check thermostat is gotten a container filled water. Thermostat is hung with a rope or wire will not touch the bottom. After that, container is heated in water. On the other hand, water temperature is controlled with a thermometer which is placed inside the container. When heated water, if thermostat is opened 6-7 °C ago before it needs to be open temperature or if temperature of water is over 6-9 °C needs to be opened temperature, valve not opened, thermostat should be broken up and must be replaced.

7. DESIGN AND ANALYSIS

7.1. Design in CATIA

Thermostat housing, thermostat and thermostat top-lid was drawn in CATIA based on ‘Ford Kangoo‘ thermostat model. All the parts were taken plastic except main thermostat which was considered as aluminum. Design was drawn three parts and assembled after all the process done. Design consists of thermostat housing (figure 19), thermostat top lid (figure 21) and thermostat (figure 23).

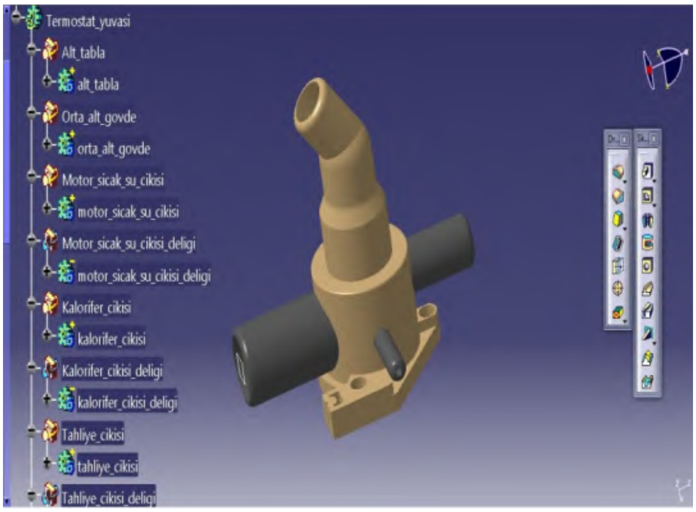

Figure 19 : Thermostat housing

The main part of design was shown in figure 19. The water comes and out from the thermostat housing through the pipe shown different color compare to the main body. It was given different name to the all parts, which create thermostat housing, in order to prevent confliction in their names. The steps of drawing thermostat housing is shown in figure 20.

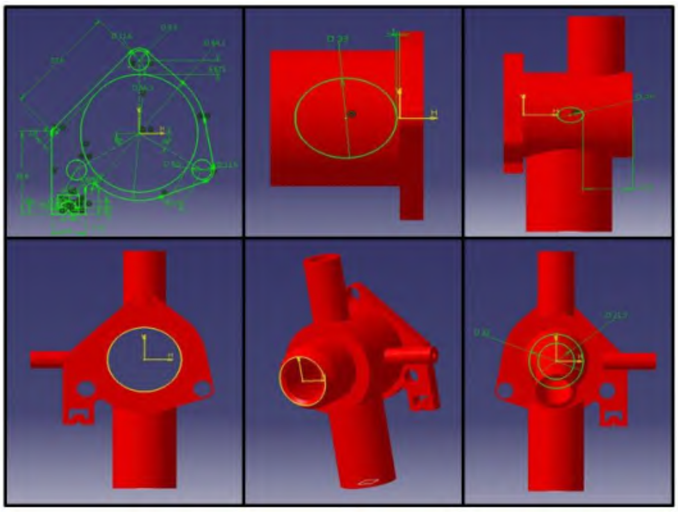

Figure 20: Steps of drawing of thermostat housing

The thermostat top lid was drawn by taking values several times with caliper from the real specimen. In order to obtain the certain values, values were not taken by one person and the number, which was used, determined statistically. The product’s tree shows that all the orders which was used for drawing it. During design process, surface method was used to draw it all. Part’s drawing is below with its values and sketch.

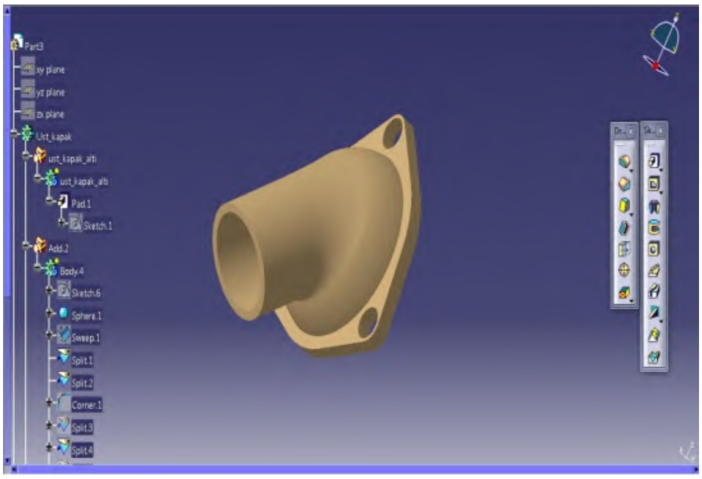

Figure 21: Thermostat top lid

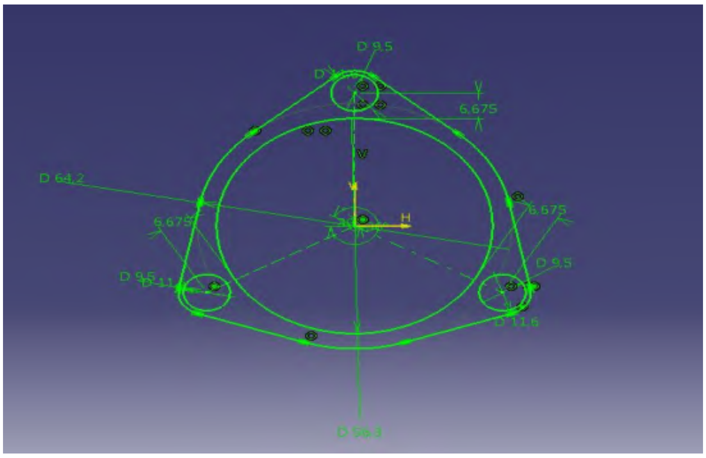

Figure 22: Thermostat top lid’s values and sketch

Thermostat was drawn in CATIA. It was modelled with spring at first. However, It was faced with some surface problem during analysis. The problems were about convergence and divergence. If the part were remained as it was, the number of meshes would increase extraordinarily but the computer technology was insufficient to solve such a this problem. Therefore, spring was represented by increasing diameter of the body which depends on.

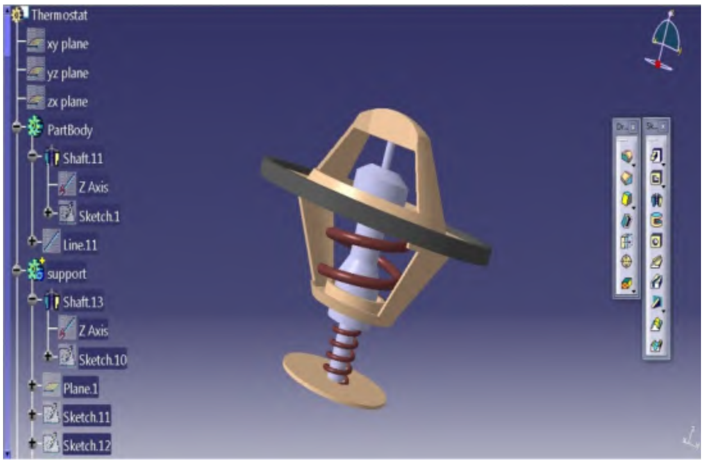

Figure 23: Thermostat body and its spring

All the parts were assembled in order to create fluid flow volume as below. In this thesis, assumed that thermostat was closed in the case examined. Therefore, analysis was just made according to this figure.

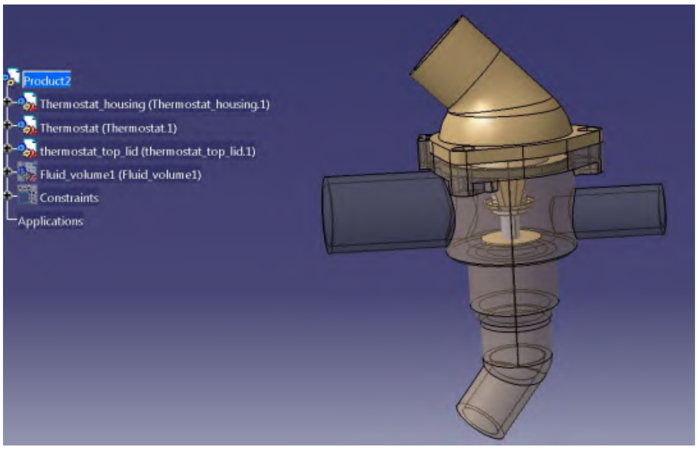

Figure 24: Assembled thermostat

To sum up, all the process was done in order to obtain the fluid flow which is the way water follows when it is inside of this pipe. All analysis was made with this fluid flow.

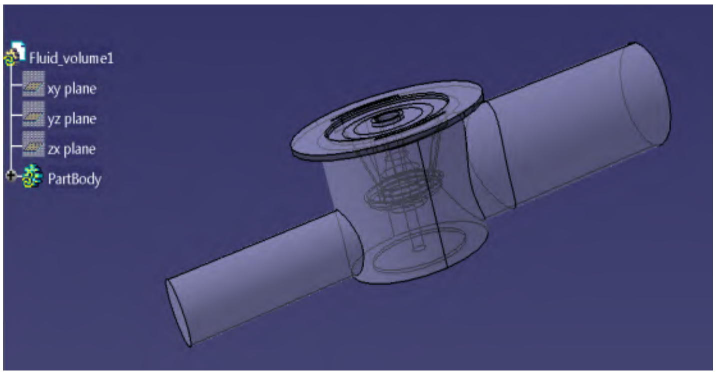

Figure 25: Fluid flow volume

7.2. Fluid Flow Analysis

The fluid part, which was obtained from CATIA drawing program, transferred to the FLUENT analysis program to examine the case was observed on the different aspects to solve the fluid problems out.

In this thesis, fluid flow in thermostat was examined in the view of fluid problems and its solutions when it was about open. The values, which used during analysis, was gotten from the technical paper.[12]

The fluid volume was meshed on ANSYS workbench at first. The mesh had to be clear because its quality would affect easily the results. Therefore, squared mesh was preferred for the analysis rather than triangular mesh. Moreover, the number of elements, which was used, also important for quality of analysis . It had to be on the line which can be ignored if it was increased more. It was tried to increase the number by determining face sizing and refinement tools on ANSYS workbench before it put in fluent analyzer.

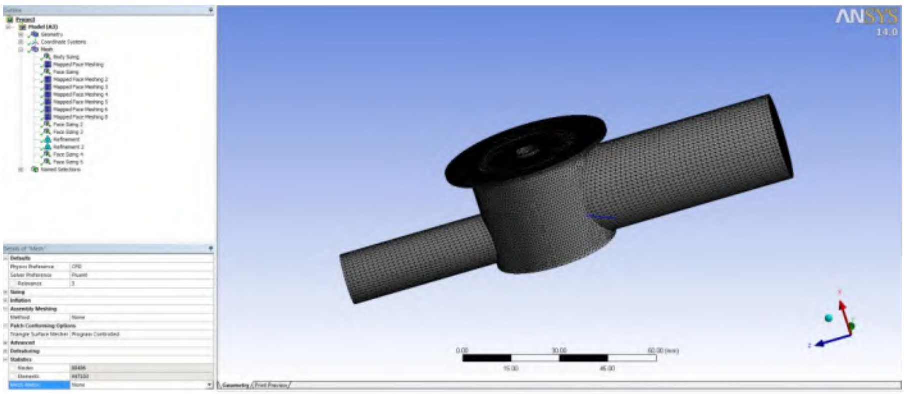

Figure 26: Mesh of Fluid flow volume

Solver type was pressured based with steady-state condition. Model was chosen energy equation with viscous k-epsilon (standard). Material was water-liquid. Residual converge value 1e-06.Moreover, relaxation numbers were as pressure 0.2, density 1, body force 1, momentum 0.5 and turbulence kinetic energy 0.6. Lastly, differential type was second order and the flow character was chosen as turbulent which was the main problem in this state. In the solution state, assuming that mass flow rate in car engine 300 lt/h

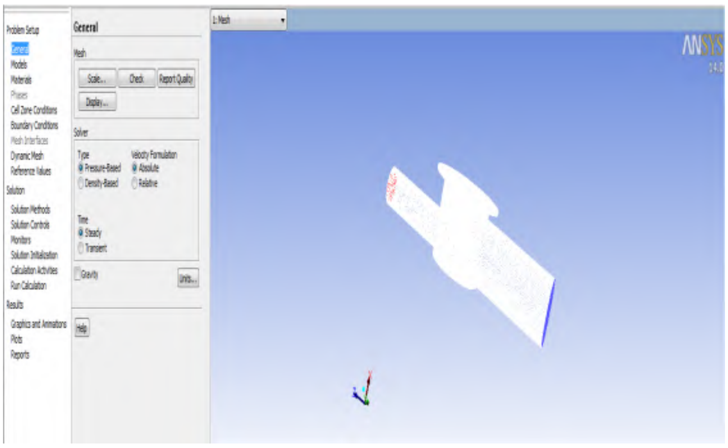

Figure 27: Fluid Flow Volume with Problem Setup

The boundary conditions determined to the real conditions as mentioned before. Inlet velocity was taken 43 m/s and inlet pressure was taken 155 pa.

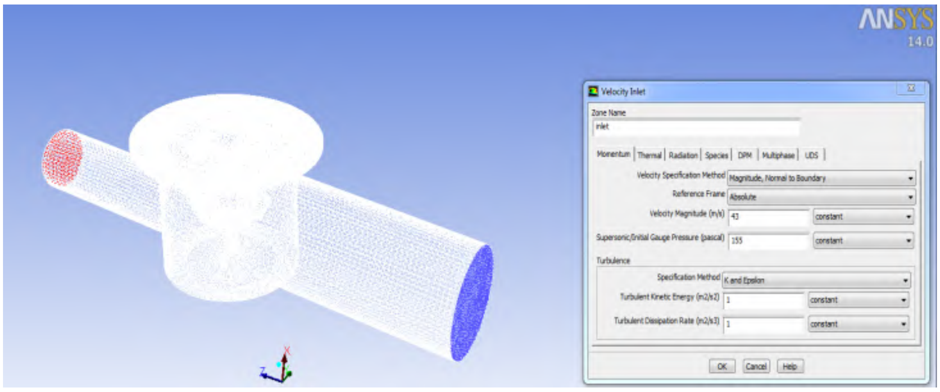

Figure 28: Fluid Flow Volume in Fluent

7.3. Results

The first result is about wall shear which occurs on the inside wall of thermostat pipe. This figure show clearly the deformation when the fluid goes through from the bigger pipe smaller pipe. All values shown in figure is in term of pascal.

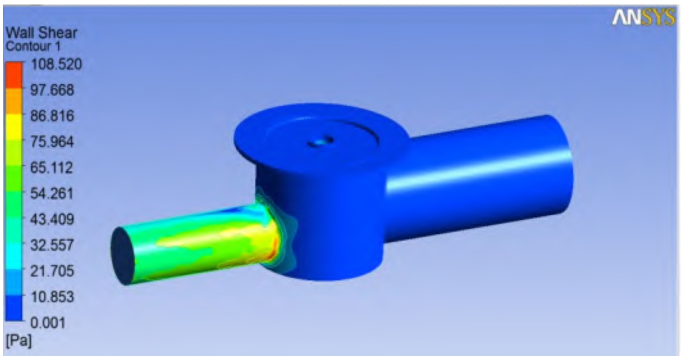

Figure 29: Wall Shear

The second result is about velocity which the water has during pass through the pipe. When the water comes from the bigger pipe, at that time the water tries to get in the smaller pipe. It squeezes itself because of lack of volume. This can cause some deformation at the beginning of the small pipe, also can cause maintenance problem in long term. Moreover, there could be observed serious damage in the engine block, if the water leaks from the pipe to outside of it. There would be insufficient cooling system.

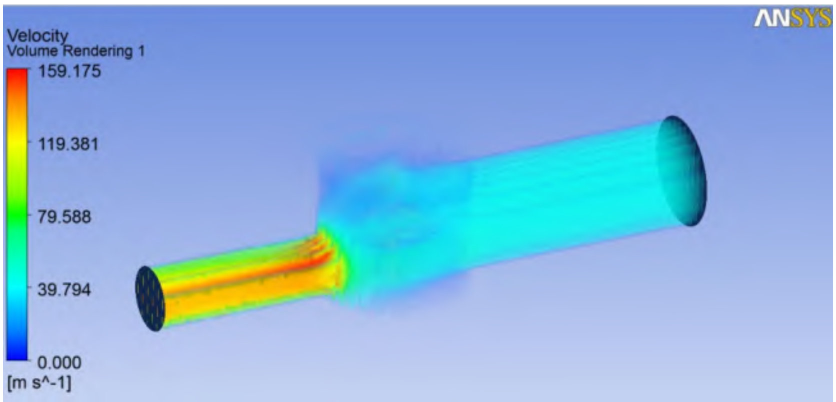

Figure 30: Fluid Velocity in the Pipe

The third result is turbulence kinetic energy which is directly related to velocity in the case. When the velocity increases, turbulence kinetic velocity also increases too. This increment is clearly seen from the analysis. However, turbulence flow is undesirable. When it converts to laminar flow, energy losses could reduce and keep under control easily, also high velocity occurs back flows and swirls which are unnecessary for this system.

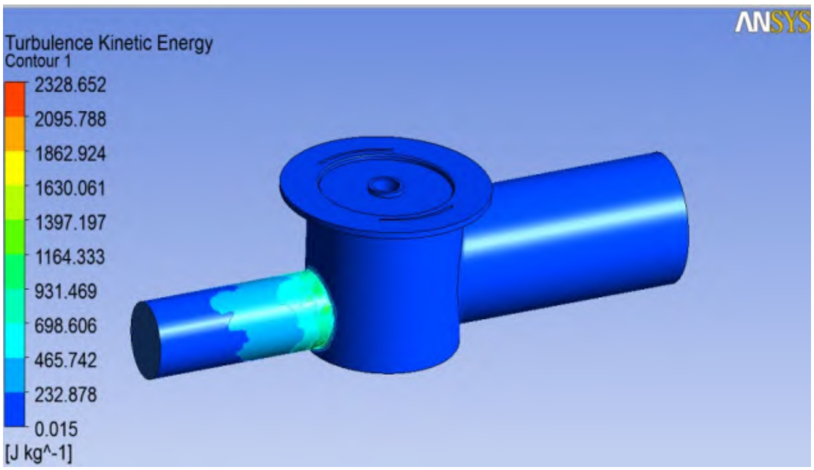

Figure 31: Turbulence Kinetic Velocity

Last result is about streamline which indicates the path water follows throughout its travel inside of the pipe. Squeezing, which occurs because of the water, is extremely observed from this figure at the beginning of the small pipe. Back flows and swirls are observed also.

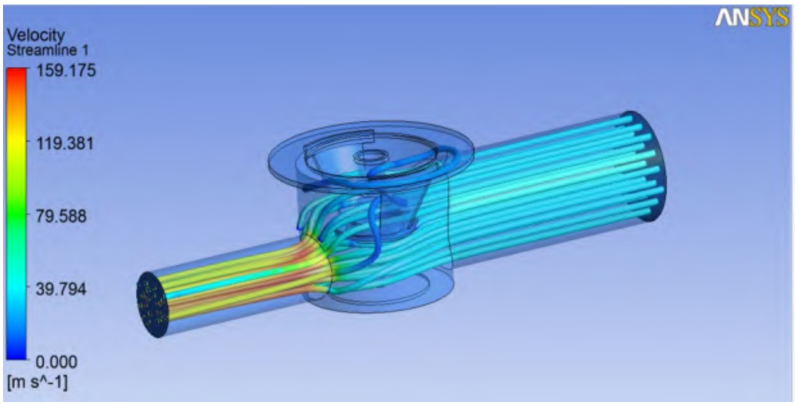

Figure 32: Velocity Streamline

8. CONCLUSION

Advanced automotive thermal management can have a positive impact on gasoline and diesel engine cooling systems. Thermostat valve configuration is an important topic in advanced thermal management systems as it pertains to engine coolant temperature warm-up time.

Heat, high velocity and shear is undesirable quantity in engine block because it might cause serious problems. If the engine could not cool down effectively or high velocity could not keep under control, engine's life will even reduce and may cause high maintenance cost. In order to balance heat of engine, switching thermostat is desirable and it is useful in many aspect for engine. Another suggestion is about heat loss and friction loses can be applied by changing diameters of thermostat housing, also fillet edges could be considerable to reduce friction loses. All these results affect efficiency of engine and power consumption of a car. As a result, it is possible to get some experimental results by using computer-based programs in short time. Computer-based analysis could save time and labor expenses with many materials which use during the process.

9. REFERENCES

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