Thermostat Influence Simulation During Warm-up Period In SI-Engine Cooling System

by Ary Syahriar

Submission date: 27-Nov-2020 08:30AM (UTC+0000)
Submission ID: 1458015893
File name: a46-AMR_03_Tarigan.pdf (702.25K)
Word count: 2399
Character count: 12442

Thermostat Influence Simulation During Warm-up Period In SI-Engine Cooling System

Elroy FKP Tarigan
1)Department of Meister -Bachelor Professional
Politeknik Manufaktur Astra
2)Swiss German University
Jakarta, Indonesia
elroy.fransiskus@polman.astra.ac.id

Ary Syahriar
1)Department of Electrical Engineering
University Al Azhar Indonesia
2)Department of Mechanical Engineering
Swiss German University
Jakarta, Indonesia
syahriar@uai.ac.id

Yohanes Climacus Sutama
Department of Automotive Engineering
Politeknik Manufaktur Astra
Jakarta, Indonesia
yohanes.csutama@polman.astra.ac.id

ABSTRACT

This study shows the simulation of thermostatic valve in the cooling system of Spark Ignition (SI) Engine and the behavior of warm up period for difference ambient temperature. There is a condition in the field if there is malfunction on thermostat the fastest solutions to do is to remove it. This study result shows that the simulation without thermostat have 3 time longer than a system with thermostat to reach the working temperature. If the time to reach the optimal temperature last longer, the combustion process becomes inefficient. The experimental data will be used to calculate new equation for difference ambient temperature and the result shows the recommendation to fix the cooling system with new thermostat rather than remove it.

CCS CONCEPTS

•Computing methodologies~Modeling and simulation~Model development and analysis~Model verification and validation

KEYWORDS

Spark Ignition, Cooling System, Modelling, Thermostat Valve, OBD-II

ACM Reference format:
Elroy FKP Tarigan, Ary Syahriar, and Yohanes Climacus Sutama. 2020. Thermostat Influence Simulation During Warm-up Period in SI-Engine Cooling System. In proceedings of international conference on Engineering and Information Technology for Sustainable Industry (ICONETSI 2020), September 28-29, 2020, Tangerang, Indonesia. ACM, New York, NY, USA, 6 pages.

ICONETSI, September 28–29, 2020, Tangerang, Indonesia

ACM ISBN 978-1-4503-8771-2/20/09…$15.00
https://doi.org/10.1145/3429789.3429836

1 Introduction

Heat is one of the impacts on the process of energy converting. In an engine the chemical energy converted into mechanical energy to drive a vehicle. This heat comes from the combustion of fuel mixture and the friction of engine components against each other.[10] Economical direct injection diesel engine can only utilize at most 43% of the energy stored in the fuel and for Spark-ignition engine it only shows one third of overall energy (Fig 1). The primary functions of the cooling system in internal combustion engine are:

- To reach the operating temperature of engine as soon as possible.
- To remove excess heat due to the process on the engine.

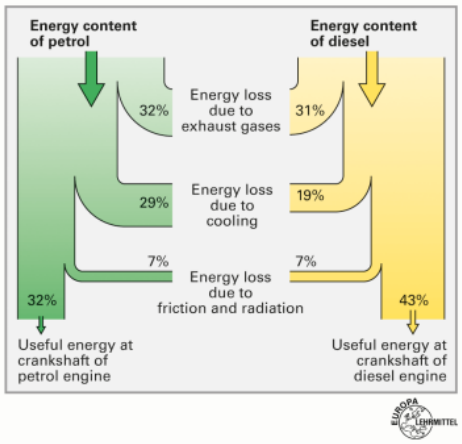

Figure 1: Sankey Diagram [5]

In an automotive engine, the heat comes from the friction of engine components and the combustion itself. This rising temperature must be managed to prevent the failure in engine mechanical system. This failure comes from overheating oil film between the mechanical components and also make a failure in metal components itself. With maintain the engine temperature we can also maintain the bad impact such as : high fuel consumption, low engine efficiency and poor exhaust emission [7][6][4].

The cooling system in an automotive engine consist of sub system such as: radiator, Radiator Fan, Water Pump and Thermostatic valve. On traditional engine cooling system, the mechanical connected fan and wax type of thermostatic valve are used. Latterly the development of cooling system technology, the wax thermostatic valve replace with electric controlled thermostatic valve and mechanical fan drive replaced with electric fan [3][11]. Figure 2 shows the schematic system of engine cooling, the function of thermostatic valve is to open and close the valve that allows coolant to pass the radiator or direct through bypass.

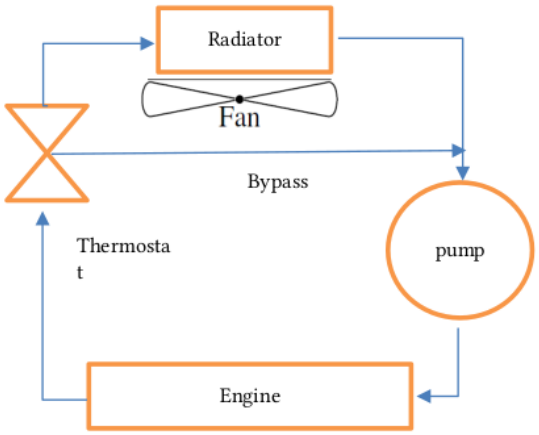

Figure 2: Schematic of Cooling System [2]

Thermostat in vehicle known as 'engine cooling control valves', is a part located in the engine cooling system and control the engine's temperature. This temperature consists of warm up period and operating temperature. In normal condition the engine need only partial part of coolant and in the full load condition the engine need the maximum flow of coolant. The difference amount of coolant must be controlled by engine cooling system. In warm up period, if the coolant flows through the radiator, the engine will be too cold, and the time to get the optimal operating temperature is too high. The thermostat sense the temperature and react with the opening valve. With this system, the optimal temperature will be achieved with short time. It will be closed in cold temperature and will be open in opening temperature. In this paper the thermostatic valve will be open at 80°C, this temperature has been determined by experimental result. This temperature means the thermostat has started opening. Another thermostat behavior has been researched by Arici et al, the opening temperature is 88°C (fig 3).[1] When the thermostat open, the coolant flows through the radiator, so the temperature will be reduced and the electric fan will be activated in certain temperature to help the coolant absorb the heat.

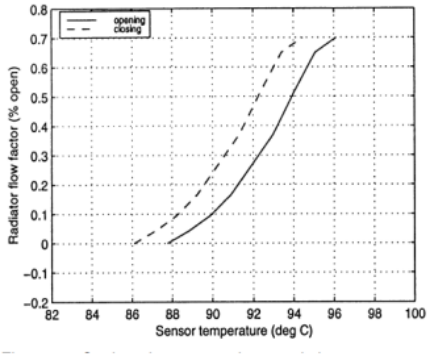

Figure 3: Thermostat characteristic [1]

2 Method

The method consists of 3 steps. The first step is data collecting. It was an experiment with a temperature measuring tools. The second step is a simulation. It was simulated using Simulink® software. The last method is mathematical calculation that be calculated with exponential equation. The equation used is based on the plot of graph.

2.1 Data Collecting

The experiment using a Sport Utility Vehicle (SUV) 1500cc with Spark ignition (SI) engine as a test vehicle. The coolant temperature data can be retrieved using standard OBD-II scanner device. The main menu of OBD-II scanner consist of: error read/erase, actuator activation and data stream. The function of OBD-II for this purpose is "Data Stream". This function allow user to get the actual data of engine such as: Temperature of coolant, temperature of air intake etc. The block diagram of data collecting shows on figure 4.

2.2 Simulations

Simulink® is used to make simulations, all of data parameter are used to make the simulation closer to reality. The data subsystem consists of: Thermostat, Radiator, Water Pump and Engine. The important data has been filled. The data are opening valve temperature (353,15 K), the coolant volume and the physical dimension of the sub system. The other parameter which are not examined in this research, filled using the parameter values in the simulation

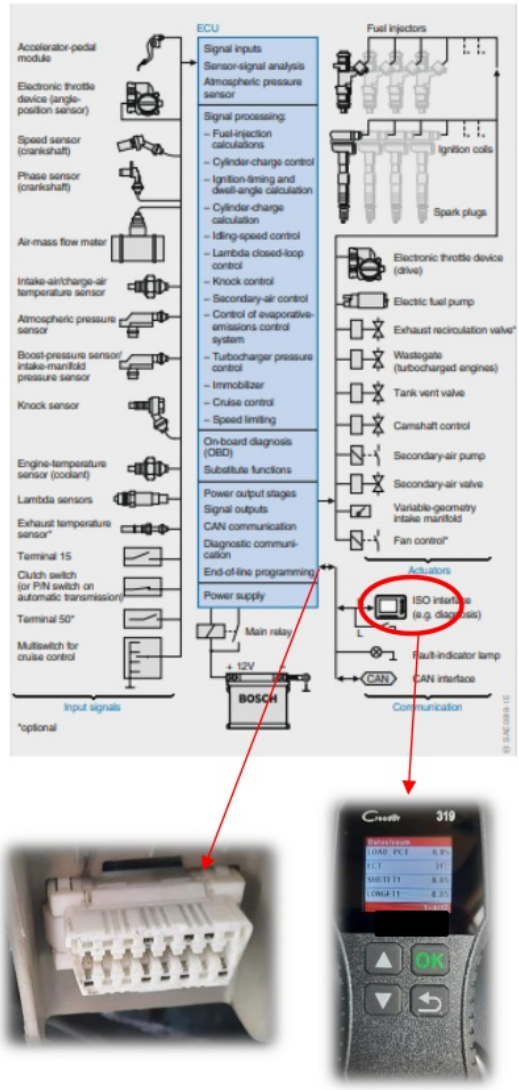

Figure 4: Automotive OBD-II Components [9]

2.3 Mathematical Analysis

The temperature graph has been analyzed with mathematical equation. The formula of the graph has been determined. This formula could be used to make the mathematical analysis in future work.

3 Simulations and Experimental

The simulations is used to examine the time to reach the working temperature. The method that has been used in this simulation is elimination model. The eliminated subsystem is Thermostat. The first simulation using a thermostat and the second simulation does not used thermostat.

Figure 5 and 6 shows a simulation created using Simulink. There are 2 model of simulation such as: with thermostat and without thermostat

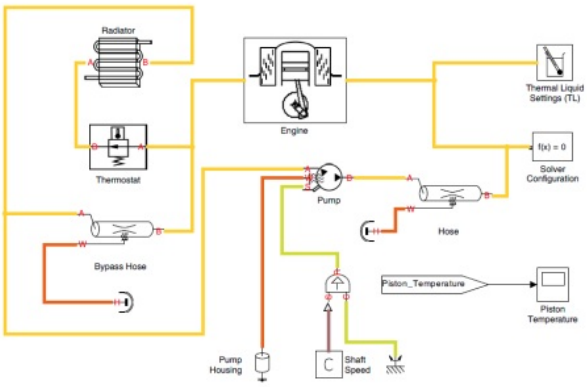

Figure 5: Simulation of Engine Cooling System

There are many sub system of engine simulation, in this case the simulation using a necessary detail according to the cooling system (Fig.5)

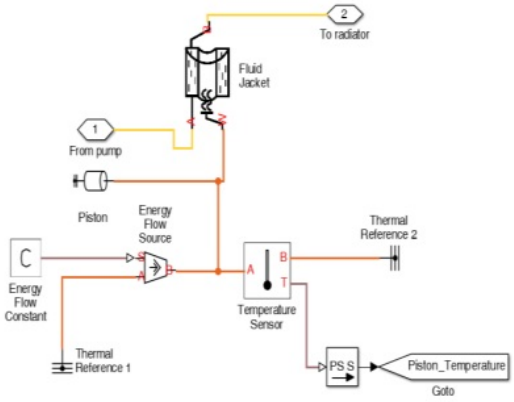

Figure 6: Detail of Engine Sub System

4 Result and Discussion

Fig 7 shows the result of temperature simulation with thermostat and without thermostat. Without thermostat the temperature need more time to reach working temperature

The function of thermostat is to regulate the water flow through the radiator. The opening temperature of thermostatic valve from our test vehicle is 80° C or 353,15 K.

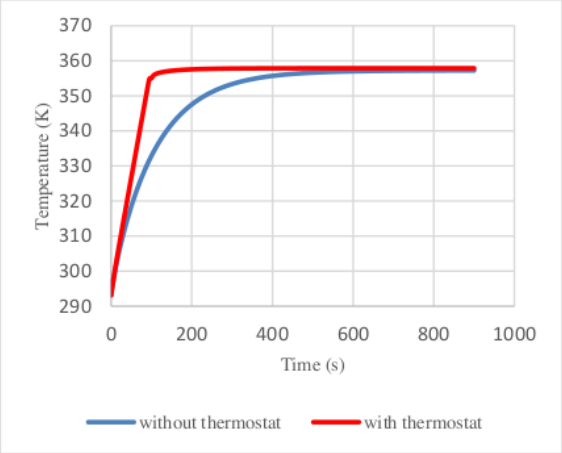

Figure 7: Result of Simulations with and without thermostat

As shown on figure 7, The system with thermostat need 91 s to reach the 353 K temperature. The system without thermostat need 291 s to reach the 353 K temperature. longer time to reach the working temperature make inefficiency of engine. This efficiency will be examined on next project.

To prevent the uncontrolled temperature rising, the engine equipped with a fan. The radiator fan are using the mechanical system or mechanical system. Figure 8 shows the experimental result of engine coolant temperature in complete period until fan motor activated. The graph shows the warm up period, the opening time of thermostatic valve that caused the flat graph and the rising temperature until fan motor active (98°C) and inactive (95°C). The system of temperature reading and motor fan actuation control the engine coolant temperature between 98°-95° C

Figure 9 shows the experimental data result of engine coolant temperature in warm up period with different ambient temperature 29°C and 31°C. according to this graph the formula of time and temperature could be written as exponential function [8]:

$$y = be^{mx} \quad (1)$$

$$m = \frac{1}{x_2 - x_1} \ln \frac{y_2}{y_1} \quad (2)$$

$$b = y_1 e^{-mx_1} \quad (3)$$

y = *Temperature (Kelvin)*
m = *gradient*
x = *time (second)*
b = *ambient temperature (Kelvin)*

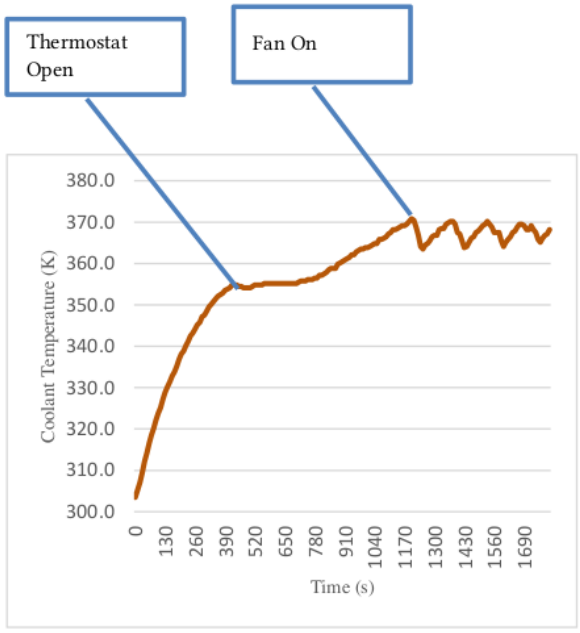

Figure 8: Result of Experimental Data in complete period

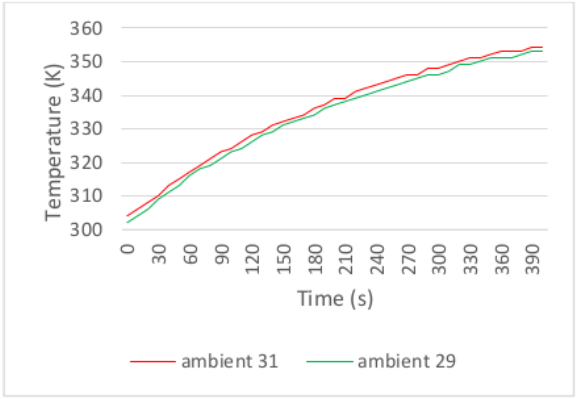

Figure 9: Result of Experimental Data in in different ambient temperature

The calculation of average graph as sampling data has been developed (figure 10). The average data using the result of 29°C and 31°C temperature. this average data has been used to determine the new formula of warm up behavior.

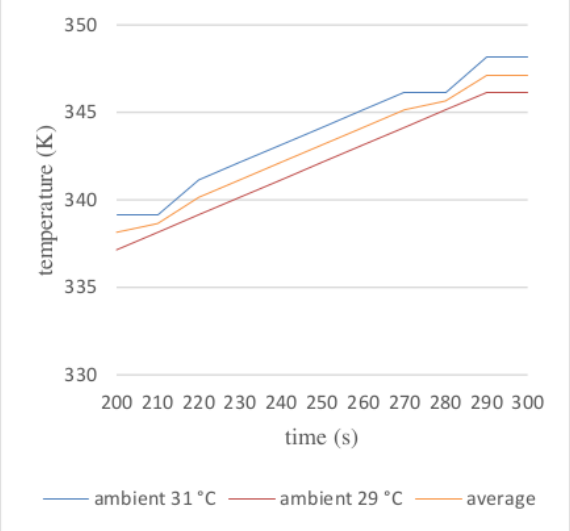

Figure 10: Average Data for calculations

According to equation (1), (2), (3) and figure 10 datasheet, we make a new equation to calculate the warm up behavior. This new equation are:

$$m = \frac{1}{(360-0)} \ln \frac{352,15}{303,15}$$

$$m = \frac{1}{360} \ln 1,16 = 4,16E-4$$

$$b = 303,15\ e^{-5,46*10^{-4}*0} = 303,15$$

$$y = 303,15\ e^{4,16*10^{-4}*x} \qquad (4)$$

The plot has been developed to validate the equation 4. Figure 11 shows The graph of equation (4) :

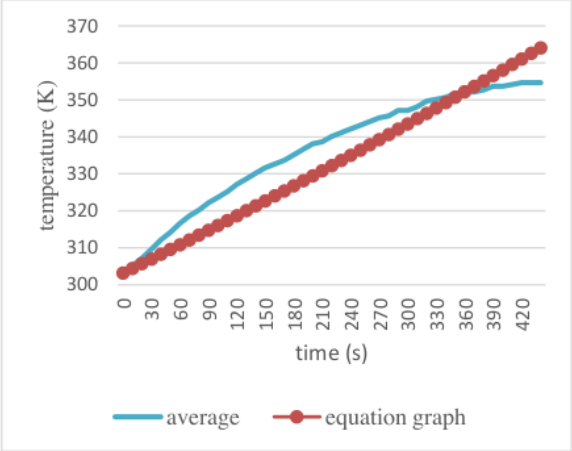

Figure 11: Average Data for calculations

The number of 303,15 comes from ambient temperature, with this equation, the new calculation of difference ambient temperature could be calculated as shown on figure 12. For example for new ambient temperature in 41°C.

$$y = (41 + 273,15)e^{4,16*10^{-4}*x}$$

$$y = 314,15\ e^{4,16*10^{-4}*x}$$

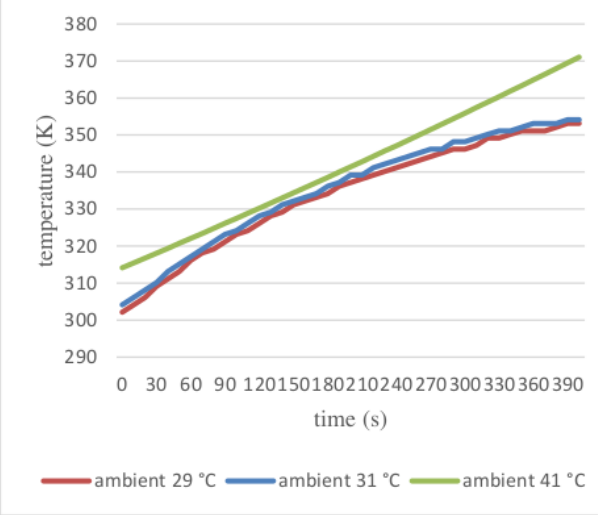

Figure 12: Graph of Equation

5 Conclusion

The Simulation to shows the engine coolant temperature has been made with simulink®. It shows that the system without thermostat have more than 3 times longer than the system with thermostat, to reach the working temperature. The experimental data has been take from vehicle using an OBD-II device. The ambient temperature difference of 2°C has a little effect to graphic result. But in an extreme condition the ambient temperature could affect in wide range. The equation of warm up behavior have been developed.

REFERENCES

[1] Oner Arici, John H. Johnson, and Ajey J. Kulkarni. 1999. The vehicle engine cooling system simulation part 1 - Model development. *SAE Tech. Pap.* 724 (1999). DOI:https://doi.org/10.4271/1999-01-0240

[2] Saif Siddique Butt, Robert Prabel, and Harald Aschemann. 2014. Robust input-output linearization with input constraints for an engine cooling system. *Proc. Am. Control Conf.* (2014), 4555–4560. DOI:https://doi.org/10.1109/ACC.2014.6858647

[3] Teresa Castiglione, Francesco Pizzonia, and Sergio Bova. 2016. A novel cooling system control strategy for internal combustion engines. *SAE Int. J. Mater. Manuf.* 9, 2 (2016), 294–302. DOI:https://doi.org/10.4271/2016-01-0226

[4] Roberto Cipollone and Davide Di Battista. 2015. Sliding vane rotary pump in engine cooling system for automotive sector. *Appl. Therm. Eng.* 76, (2015), 157–166. DOI:https://doi.org/10.1016/j.applthermaleng.2014.11.001

[5] Richad et al Fischer. 2014. *Modern Automotive Technology* (2nd ed.). Haan-Gruiten.

[6] Koorosh Khanjani, Jiamei Deng, and Andrzej Ordys. 2014. Controlling variable coolant temperature in internal combustion engines and its effects on fuel consumption. *SAE Tech. Pap.* 2014-Novem, (2014). DOI:https://doi.org/10.4271/2014-32-0064

[7] Franz W. Koch and Frank G. Haubner. 2000. Cooling system development and optimization for di engines. *SAE Tech. Pap.* 724 (2000). DOI:https://doi.org/10.4271/2000-01-0283

[8] William J Palm III. 2017. *System Dynamics* (3rd ed.). Mc Graw Hill, New York.

[9] Konrad Reif (Ed.). 2015. *Gasoline Engine Management*. Springer Vieweg.

[10] Konrad Reif and Karl-Heinz Dietsche. 2014. *Automotive Handbook* (9th ed.). Robert Bosch GmbH, Karlsruhe.

[11] X. Zou, J. A. Jordan, and M. Shillor. 1999. A dynamic model for a thermostat. *J. Eng. Math.* 36, 4 (1999), 291–310. DOI:https://doi.org/10.1023/A:1004587425961

Thermostat Influence Simulation During Warm-up Period In SI-Engine Cooling System

ORIGINALITY REPORT

10%	8%	9%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	arxiv.org Internet Source	6%
2	Ji-jiao Jiang, Xiao Yang, Ming Yin. "Cooperative Control Model of Geographically Distributed Multi-teamAgile Development Based on MO-CSO", Proceedings of the 2nd International Conference on E-Education, E-Business and E-Technology - ICEBT 2018, 2018 Publication	1%
3	jeneza.com Internet Source	1%
4	Aliriza Kaleli, Galip Kaltakkiran, Ahmet Dumlu, Kagan Koray Ayten. "Design and control of intelligent cooling system for IC engine", 2017 International Conference on Engineering and Technology (ICET), 2017 Publication	<1%
5	Rusdianasari Rusdianasari, Yohandri Bow, Tresna Dewi, Ahmad Taqwa, Lin Prasetyani.	<1%

"Effect of Sodium Chloride Solution Concentration on Hydrogen Gas Production in Water Electrolyzer Prototype", 2019 International Conference on Technologies and Policies in Electric Power & Energy, 2019
Publication

6	dspace.lboro.ac.uk Internet Source	<1%
7	Pavel Gurevich, Eyal Ron. "Stability of Periodic Solutions for Hysteresis-Delay Differential Equations", Journal of Dynamics and Differential Equations, 2018 Publication	<1%
8	Teresa Castiglione, Sergio Bova, Mario Belli. "A Model Predictive Controller for the Cooling System of Internal Combustion Engines", Energy Procedia, 2016 Publication	<1%
9	J.C. Chipman, W. Houtz, M. Shillor. "Simulations of a thermostat model I: Approach to steady states", Mathematical and Computer Modelling, 2000 Publication	<1%
10	arrow.tudublin.ie Internet Source	<1%
11	E A Wibowo, T Sukarnoto, Y T Wibowo. "Research of Injection Molding Parameters with	<1%

Acrylonitrile Butadiene Styrene Composition Recycled Against Mechanical Properties", Journal of Physics: Conference Series, 2019
Publication

12 Te-Yi Chen, Sheng-Yuan Chu, Shih-Jeh Wu, Yung-Der Juang. "Effects of Strontium on the Dielectric and Piezoelectric Properties of Sm-Modified PbTiO 3 Ceramics", Ferroelectrics, 2011 <1%
Publication

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		