SSRG International Journal of Mechanical Engineering
ISSN: 2348-8360/ https://doi.org/10.14445/23488360/IJME-V12I3P104

Volume 12 Issue 3, 56-60, March 2025

Original Article

Predicting the Transfer Function and Analyzing a Control System for Recycling Spent Engine Oil using Graphical User Interfaces

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Received: 07 January 2025 Revised: 06 February 2025 Accepted: 05 March 2025 Published: 29 March 2025

Abstract *- One of the most important environmental and financial issues is how to dispose of and recycle old engine oil. The acidic approach, which uses acids to remove pollutants and impurities, is one of the popular methods to recycle used engine oil. The paper addresses the theoretical concepts and the practical applications of identifying the transfer function by the graphical user interface using GUI as a MATLAB toolbox. The transfer function is a pivotal key tool for control system analysis and dissection of the backbone of the control system. The paper's novelty evaluates the control system characteristics such as rise time, peak time, and process time constant for recycling used engine oil. The methodology followed by this paper is the prediction of the control system transfer function in the Laplace domain for controlling the temperature of the process. The viscosity and density of the synthesized oil were monitored and measured. In addition, the characteristics of the control system, like settling time, rise time, and overshoot, were investigated and estimated. The results obtained are the process gain constant, kc = 0.059, and the time constant, ɽp = 13.42, based on the first-order transfer function predicted from the GUI. Moreover, the paper fills the gap in implementing control systems in this era of recycling used engine oil.*

Keywords *- Recycle, Engine oil, Acidic, Transfer function, Graphical User Interphase, Identification, Control system.*

1. Introduction

Stated that studies on the recycling method have demonstrated the potential to get high-quality base oils from spent engine oils, for there are fewer purification steps required in the recycling of wasted motor oil [1]. Referring to [2], the oil produced by the acetic acid-clay technique has no aldehyde, no carboxylic acid, and no fuel residue, according to the FTIR examination. [2] found that there were still some oxidized components in the oil that were generated using the formic acid-clay process. The spectra show alkanes that do not have any fuel residue. This indicates that the acetic acid-clay oil treatment produced superior outcomes compared to the formic acid-clay oil treatment. This study showed that the use of acetic acid and formic acid has more advantages than sulfuric acid, has less impact on the environment, and has no effect on the oil structure besides a higher conversion obtained. [3] stated that the experimental results from this study showed that waste engine oil can be used to produce base oil of high quality at a comparably very cheap cost. [4] concluded that the acid-clay treatment, which employs organic glacial acetic acid and kaolinite, is 95% comparable to fresh oil. Improving the acid-clay modification process has several benefits. According to [4], the modified acid-clay treatment process delivers a high oil yield percentage of 72±3% [5]. "The process parameters were optimized using Central Composite Rotatable Design (CCRD) of Response Surface Methodology (RSM), with the aid of a design expert. [6] used FDM experts to choose lubricant recycling systems via experiments with 17 factors. Also, standardized and objective references were formed. According to [7], laboratory tests were carried out to determine step responses and a mathematical model was developed for the DC motor in terms of the four unknown parameters.

The System Identification and Constraint Optimization Toolboxes in MATLAB were utilized to minimize the root-mean-square error between the experimental step response and the model response, resulting in the parameters. [8] introduced the usage of regeneration procedures to provide a significant reference on the best treatment methods. [9] centered on determining the best optimal circumstances for the process, such as temperature, time, and alcohol-to-oil ratio. [10] the effectiveness of using local clay and activated charcoal was tested, with a remarkable purification efficiency of 72.6% to 70.12%. [11] the study showed that the recycling could possibly be carried out at room temperature and atmospheric pressure by using alum and (khaoh). This article highlights seven of these recycled engine oil recycling approaches that are presently in use all over the globe. They represent a model for the economical and ecologically sound handling of used oils, limiting release into the environment, promoting sustainability and contributing to creating a more sustainable society. The approaches under discussion, as well as other methods for recycling wasted engine oil, are continuously being enhanced to boost the amount of reclaimed oil and the effectiveness of the recycling procedure [12].

The test signal impacting the response was essential to the system design criteria. There is a correlation between a system's response characteristics to a regular test input signal and its capability to deal with real input signals, which justifies applying test signals [13].

A simple method has been developed for PID controller tuning an unidentified process using closed-loop experiments. The proposed method requires one closed-loop step setpoint response experiment using a proportional-only controller, and it mainly uses information about the first peak (overshoot), which is very easy to identify. The setpoint experiment is similar to the classical Ziegler–Nichols [13].

This study's uniqueness concerns the control system implementations for recycling used engines. It evaluates the transient response, rising time, and settling time, every single one of which influences process efficiency, cost-effectiveness, and ecological footprint.

2. Method of Applying Control Systems

To apply a control system for recycling used engine oil. Firstly, the acetic acid method was chosen as a case study to conduct this study and apply the control system. Secondly, formic and acetic acid were chosen as they were shown to be effective in recalcifying acids and safe for environmental impact. The control system starts from experimental data from the literature and is then implanted into MATLAB software to predict the transfer function and further analyze the control system.

2.1. Choice of Acetic Acid Method

The acidic acid method was chosen to apply to the control system via formic acid and acetic acid. This study focused on controlling the temperature of the recycling of used engine oil through acetic and formic acid by measuring the density of oil treated with formic acid and acetic acid and the viscosity of the resulting oil, comparing it with standard oil. The diagram below is utilized to experiment using formic and acetic acid.

Table 1. Shows the experimental results for viscosity and density for treated oil with acetic and formic acid (Hegazi, (2017))

Oil Type	Density, (g/ml)	Viscosity, (cp)
Fresh Oil	0.87	30
Used Engine Oil	0.91	16
Treated Oil with Formic Acid	0.864	30
Treated oil with Acetic acid	0.87	28

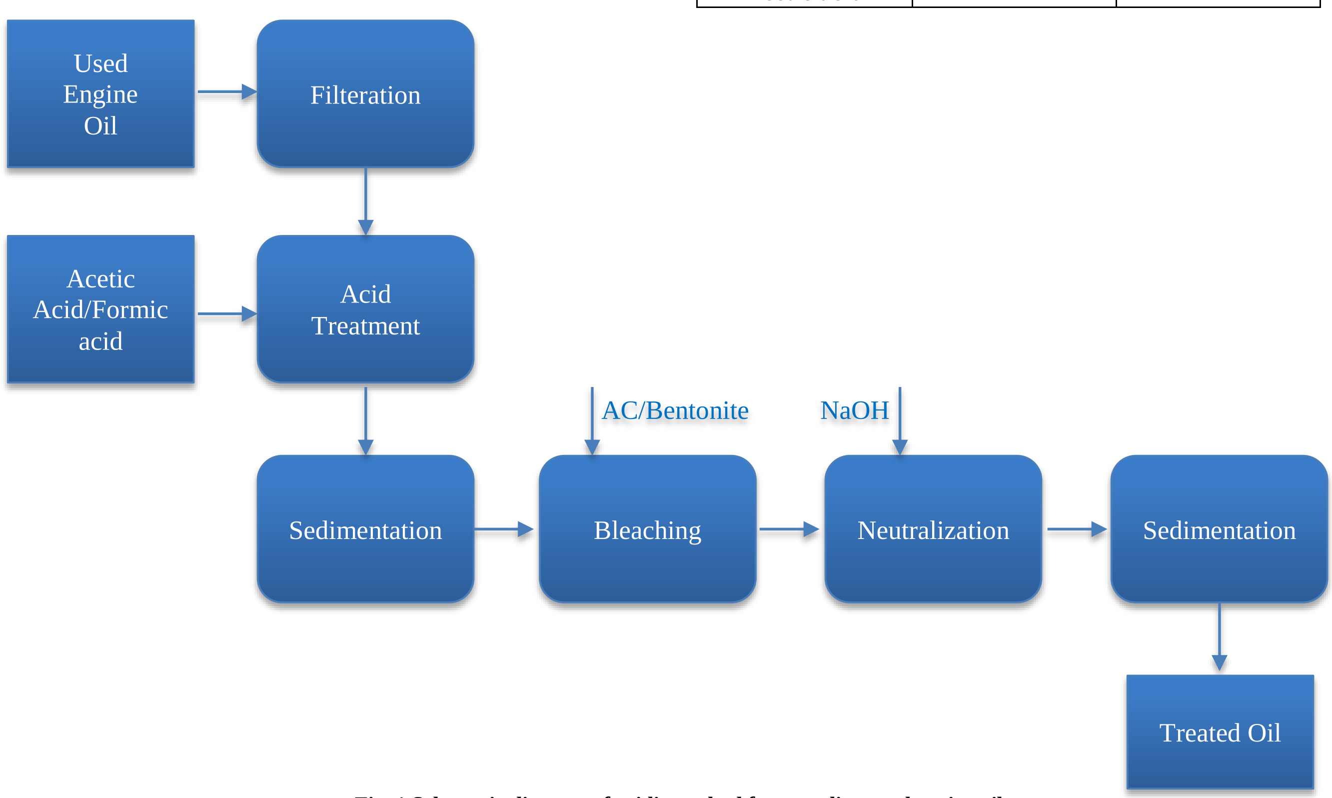

Fig. 1 Schematic diagram of acidic method for recycling used engine oil

2.2. Control the Mixing Temperature for the Acidic Method for Recycling of Used Engine Oil

The approach of adjusting the temperature of acidic acid treatment by using acetic acid and formic acid to obtain the desired treatment leads to an efficient process and fewer impurities in the final product. The optimal temperature range, between 50 and 80 °C, was used in the experiment. This range of temperatures is for this technique. Without causing the desired hydrocarbons to degrade or the oil to evaporate excessively, this range effectively encourages the reaction between the acid and impurities.

2.3. Transfer Function Model Formulation

In control systems, a transfer function represents the relationship between the input and output of a system in the Laplace domain. It is typically denoted as G(s) and defined as the ratio of the Laplace transform of the output (Y(s)) to the Laplace transform of the input (U(s)). The transfer function was predicted by using the GUI after importing the experimental data, which represents temperature as an input and the measured viscosity as an output, illustrated in Figure 1.

Estimates of the transfer function generated after importing process temperature and viscosity data into the MATLAB application using the GUI. The zeros and poles were determined to estimate the transfer function.

$$Gs = \frac{Ys}{Xs} = \frac{0.001817}{S+0.003235} \qquad (1)$$

2.4. Structure of Control System Loop

The PID controller is suggested, and the proposed structure of the control system loop design is to achieve the desired temperature, as shown below in Figure 2.

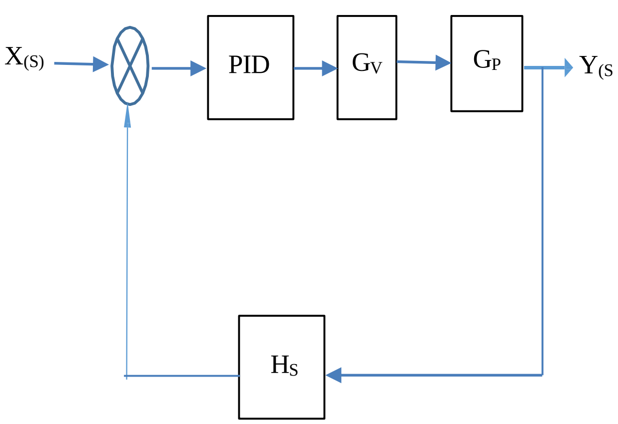

Fig. 2 Elements of control system loop

3. Results and Discussions

GUI was used to predict the transfer function model from the experimental data at Jazan University's chemical engineering department, as shown in Figure 3.

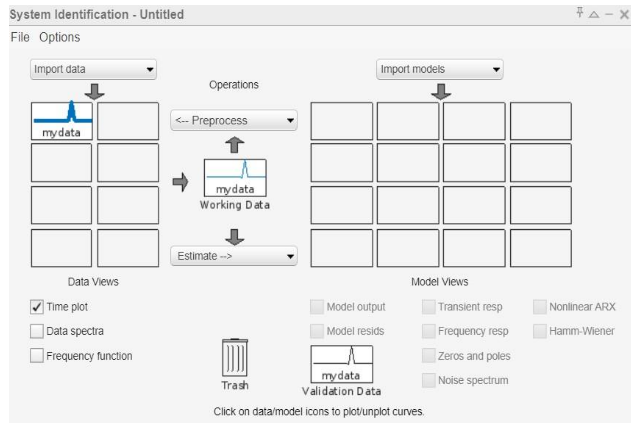

Fig. 3 Data import of experimental data using GUI

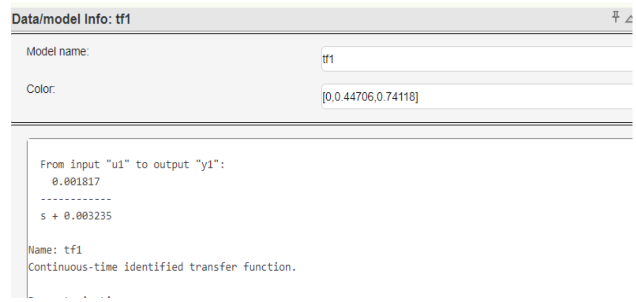

Fig. 4 Estimation of the model transfer function using GUI

The number of poles and zeros was chosen for the transfer function prediction, as illustrated in Figure 4.

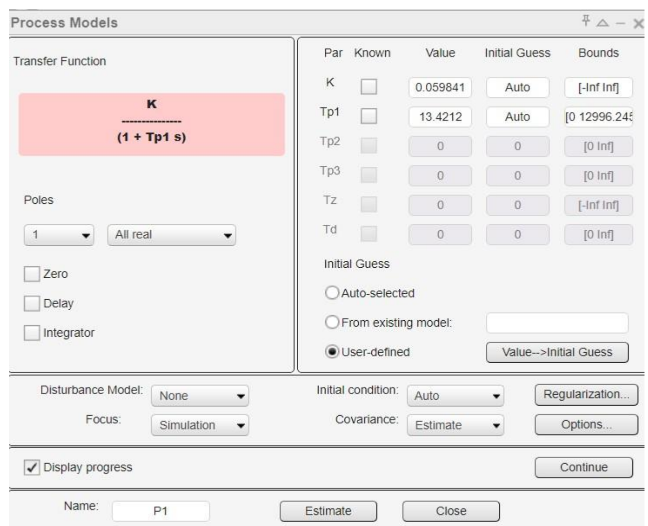

Fig. 5 Process model for parameter estimation

Figure 5 additionally demonstrates that the process gain is 0.059, corresponding to the ratio of the change in process viscosity to the change in process input (temperature and time). Process gain (Kp) is a significant indicator in control loop analysis simply because it quantifies the relationship between the Manipulated Variable (MV) and the Process Variable (PV).

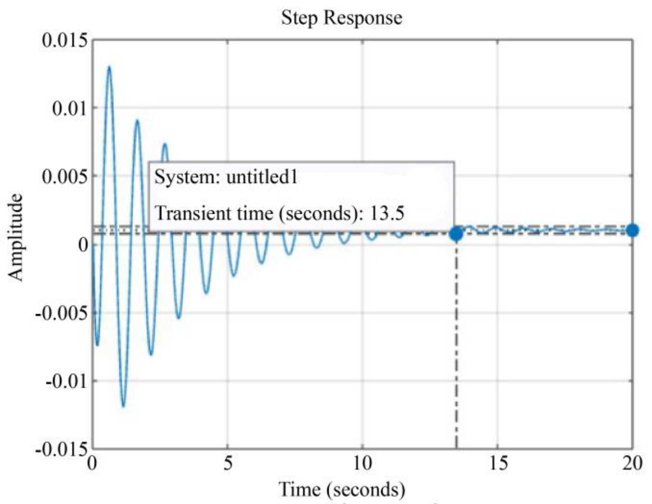

Fig. 6 The transient response of the system

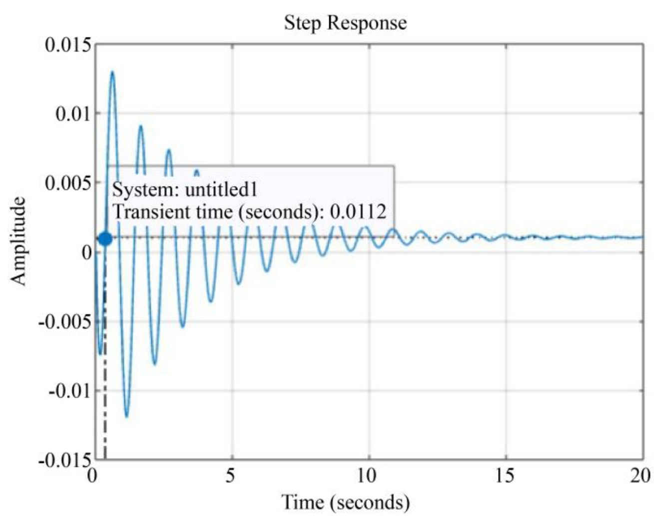

Fig. 7 The settling time of the system

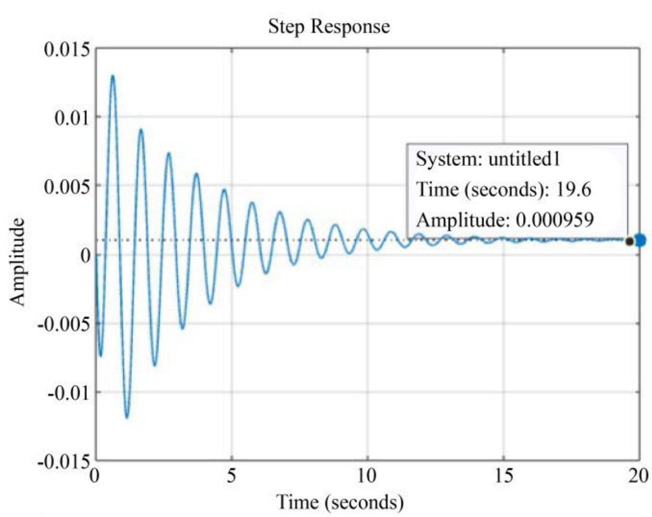

Fig. 8 The rise time of the system

Figure 6 shows a transitory response of 13.5 seconds, which occurs when the input (temperature and time effect) is introduced into the control system, and the output (viscosity) takes some time to reach equilibrium. Thus, before it reaches stability, the resultant property (viscosity) is going to be in transitivity. Transitory time is viewed as an extremely significant criterion that should be governed since it beneficially impacts the environment, cost-effective recycling, and process capacity.

The settling time is estimated as 19.6 seconds, illustrated in Figure 7, showing the time taken for the process to settle and stabilize. The settling time affected the process efficiency, cost-effectiveness, and minimizing environmental impact. The rise time was evaluated as 0.0112 seconds, and this lower time indicates the time required for the system to reach 90% of the final value. This parameter lessens the sedimentation time and boosts the rate of separation. By excluding overheating or prolonged heating times, a well-managed rise time preserves energy waste and saves operating expenses and ecological impact.

4. Conclusion

- The transfer function identification used in the paper provided a valuable tool for understanding the behaviour of the control system.
- The formulation of mathematical modelling and development of control systems enhances the effectiveness of the recycling process.
- The control system transfer function was obtained from the GUI Matlab toolbox; we estimated the recycling process's settling time, rise time, and overshoot.
- The process gain constant was estimated as kc = 0.059, and the time constant is 13.42 for the first-order transfer function.
- A system stability analysis was suggested to analyze the recycling process further.

Abbreviations

GUI	:	Graphical user interphase
Gs	:	Transfer function in Laplace domain
Ys	:	The output of the system
Xs	:	The input of the system
Kc	:	The process gain constant
τ_p	:	Time constant
Sys	:	Refer to the system
Hs	:	Sensor transfer function in Laplace domain
GV	:	Actuator transfer function in Laplace domain
GP	:	Process transfer function in Laplace domain
PID	:	Proportional integral controller
FTIR	:	Fourier transform infrared spectroscopy
CCRD	:	Central Composite Rotatable Design
RSM	:	Response Surface Methodology

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