Mini Robot for Calibration of Stopwatch/Timer

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Abstract. Many industries use stopwatch/timer as instrument for measuring time in production process. To support the quality of product of industries, the stopwatch/timer should measure the time accurately. The accuracy of the stopwatch/timer can be known through calibration to a reference standard. Therefore, a stopwatch/timer should be calibrated first before used as instrument for measuring time. Research Center for Metrology (RCM) - LIPI as National Metrology Institute of Indonesia has responsibility to build measurement traceability in Indonesia, included measurement traceability for time. RCM - LIPI did calibration of stopwatch/timer manually. The operator responses in manual calibration that called as human reaction time contribute to inaccuracy of measurement result. Recently, an innovation for automation of calibration system of stopwatch/timer has been built to eliminate the human reaction time. The automation system has been designed and built using robotic arm and mini robot car. The aim of this system is to increase the efficiency and accuracy of stopwatch/timer calibration. The robotic arm is used to press the button of stopwatch/timer, and the mini robot car is used to press a reference standard universal counter. The measurement result of time from the universal counter and stopwatch/timer are recorded automatically using a camera. The accuracy of the stopwatch/timer calibration has been increased by using the automation system. The system supports the improvement of the quality of industry products.

1. Introduction

Stopwatches/timers are applied to various industries as time measuring instrument. The accuracy of measurement time is required to get high quality products. For that purpose, the stopwatch/timer should be calibrated to ensure its accuracy [1, 2, 3]. The stopwatch/timer is calibrated to a reference standard that has measurement traceability [4, 5]. The stopwatch/timer should be check through calibration regularly [6, 7].

Research Center for Metrology (RCM) - LIPI as National Metrology Institute of Indonesia has responsibility to build measurement traceability in Indonesia, included measurement traceability for time. RCM - LIPI did calibration of stopwatch/timer manually as shown in figure 1. Universal counter is used as reference standard with totalized method [8]. Start/stop button of stopwatch/timer is pressed to start/stop button of universal counter. The both start/stop button must be pressed at the same time to get the accurate measurement result. In the practically, sometimes one of the button is not pressed meanwhile another button has been pressed. For that case, the measurement process must be repeated and it makes the measurements are not efficient.

The manual calibration of stopwatch/timer depends on operator responses; it is called as human reaction time [9, 10]. The human reaction time becomes the most uncertainty source in the
stopwatch/timer calibration [11, 12]. Measurement uncertainty of stopwatch/timer calibration can be calculated using (1) [13]. Measurement uncertainty describes the error of calibration [14, 15]. Therefore, the manual calibration contributes to inaccuracy of measurement result.

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uc = \sqrt{u_s^2 + u_{res}^2 + u_{reap}^2 + u_{HRT}^2}
\]

where:
- \(u_c\) = measurement uncertainty,
- \(u_s\) = uncertainty source from universal counter,
- \(u_{res}\) = uncertainty source from resolution of stopwatch/timer,
- \(u_{reap}\) = uncertainty source from human reaction time.

An innovation for automation system of stopwatch/timer calibration is required to eliminate the human reaction time. Mini robot is one of solution for the problem. The mini robot is used as instrument in the automation system of stopwatch/timer calibration. The measurement uncertainty becomes much smaller by using the automation system. The aim of this system is to increase the efficiency and accuracy of stopwatch/timer calibration that supports the improvement of the quality of industry products.

2. Design

There are two robot that built for this system; a robotic arm for stopwatch/timer and mini robot car for universal counter. The robotic arm and mini robot car are built based on auto push button method in the stopwatch/timer calibration. The robotic arm is design in accordance with the start/stop button of stopwatch/timer. The design of mini robot car is made according to start/stop button of universal counter. The robotic arm pushes the stopwatch/timer with maximum speed, but the mini robot car pushes the universal based on the specific speed that should be tested.

2.1. Robotic Arm for Stopwatch/Timer

Robotic arm has main function to press the start/stop and reset button of stopwatch/timer. Furthermore, the robotic arm is also used as place to put the stopwatch/timer during a calibration process. The robotic arm consists of two main parts, namely automatic button suppressor and auto rotator. Design of a robotic arm is shown in figure 2, the automatic button suppressor is on the left side, and the auto rotator is on the right side.
Automatic button suppressor is used to press the start/stop and reset button of stopwatch/timer automatically. The position of automatic button suppressor and auto rotator can be adjusted in accordance with the size of stopwatch/timer. Automatic button suppressor moves automatically with a certain pattern. The pattern is programmed through a microcontroller that drives a DC motor to rotate the circular disk. The circular disk drives the rod of the robot arm to press a stopwatch/timer. The DC motor speed is adjusted to maximum speed that is 100 rpm. The distance of automatic button suppressor and stopwatch/timer is 4 cm. With the speed and distance, the automatic button suppressor needs 300 ms to push the stopwatch/timer button. Table 1 shows the parameter setting of robotic arm and stopwatch/timer.

| DC motor speed | Distance of robotic arm and stopwatch/timer | Time to push the button |
|----------------|-------------------------------------------|--------------------------|
| 100 rpm        | 4 cm                                      | 300 ms                   |

Auto rotator serves as place for stopwatch/timer, to adjust the position of the stopwatch/timer, and to keep the stopwatch/timer remaining stable. Auto rotator also moves automatically with a certain pattern. The pattern is programmed on a microcontroller that drives a DC motor. The robotic arm pushes the start/stop button of stopwatch/timer based on measurement time, so that the stopwatch/timer starts and stops at the specified time.

![Figure 2. Front view of robotic arm design.](image-url)
2.2. Mini Robot Car for Universal Counter

Mini robot car is used to press the start/stop and reset button of universal counter. Figure 4 shows the design of a mini robot car. The mini robot car works based on instructions from a microcontroller that drives a DC motor with a certain momentum.

Mini robot car is equipped with loads that can be adjusted as needed. The load has function to increase the momentum of the mini robot car so that the start/stop button of the universal counter can be pressed. The harder the universal counter button, the more weight is required. For this case, the load is 2 kg.

The mini robot car pushes the start/stop button of universal counter based on measurement time, so that the universal counter starts and stops at the specified time as stopwatch/timer does. The robotic arm require 300 ms to push the stopwatch/timer, so the mini robot car should push the universal counter in 300 ms to make the start/stop button at the same time between the two equipment. For that purpose, the mini robot car has been tested to get the specific DC motor speed that resulted the time of 300 ms. The distance between of mini robot car and universal counter is 5,5 cm. With the time and distance, the DC motor of mini robot car requires the speed of 65 rpm to push the universal counter button. Table 2 shows the parameter setting of mini robot car and universal counter.

Table 2. The parameter setting of mini robot car and universal counter.

| DC motor speed | Distance of mini robot car and universal counter | Time to push the button |
|----------------|-----------------------------------------------|-------------------------|
| 65 rpm         | 5,5 cm                                       | 300 ms                  |
**Figure 4.** Front view of mini robot car design.

**Figure 5.** Side view of mini robot car design.
3. Result and Discussion

Robotic arm is shown in figure 6. The robotic arm has been used in the calibration process of stopwatch/timer. Start/stop and reset button of stopwatch/timer have been pushed automatically using the robotic arm through the command from a microcontroller.

Mini robot car is shown in figure 7. The mini robot has been used in the calibration process of stopwatch/timer. Start/stop and reset button of universal counter have been pushed automatically using the mini robot car through the command from a microcontroller.

Measurement setup of automation system of stopwatch/timer calibration is shown in figure 8. Both stopwatch/timer and universal counter measure time. A camera records the measurement result from the stopwatch/timer and universal counter automatically.

In the calibration manually, there is time difference between pushing the start/stop button of stopwatch/timer and pushing start/stop button of universal counter. For automation calibration system, the stopwatch/timer and universal counter are pushed at the same time, both for the start and stop process. All instruments are operated using program automation that has been built from RobotC programming. The human reaction time is removed using the automation program. Therefore, the measurement results of stopwatch/timer calibration are more accurate and the calibration process is more efficient. The measurement uncertainty is significantly decreased from 0.061 to 0.015 s. Table 3 shows the advantages of automation system of stopwatch/timer calibration.

![Figure 6. Robotic arm for stopwatch/timer.](image-url)
**Figure 7.** Mini robot car for universal counter.

**Figure 8.** Automation system of stopwatch/timer calibration.
Table 3. The advantages of automation system of stopwatch/timer calibration

| Parameter          | Automation System                                                                 | Manual System                                                                 |
|--------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| Uncertainty source | There is no uncertainty from human reaction time                                  | 75% of uncertainty from human reaction time                                   |
| Measurement        | 0.061 s                                                                           | 0.015 s                                                                       |
| Efficiency of      | More efficient, controlled by computer, only need one click to start measurement   | Not efficient, sometimes the start/stop button of stopwatch/timer are not     |
| measurement        |                                                                                   | pushed at the same time with start/stop button of universal counter           |
| Measurement time   | Quick                                                                             | Longer, because sometimes there are mistake in the measurement (one of button |
|                    |                                                                                   | is not pressed, then need to repeat the measurement)                         |
| Accuracy           | More accurate, there is only slightly difference of measurement result between    | Not accurate, for some case there is a big difference of measurement result    |
|                    | stopwatch/timer and universal counter                                              | between stopwatch/timer and universal counter                                 |

4. Conclusion
Both robotic arm and mini robot car have been worked well. The automation system has been used to calibrate stopwatch/timer. The calibration of stopwatch/timer becomes more accurate and efficient. The automation system of stopwatch/timer calibration supports the improvement of the quality of industry products. Further work is needed to evaluate the measurement uncertainty of the automation system of stopwatch/timer calibration.

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Acknowledgment
The authors acknowledge the financial support from Ministry of Research, Technology and Higher Education of the Republic of Indonesia through the scheme of Incentive Research Program for the National Innovation System (64/P/RPL-LIPI/INSINAS-1/III/2018).