

Research methodology simplification for teaching purposes illustrated by clutch automatic control device testing

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Abstract. The paper proves that simplified, shorter examination of an object, feasible in laboratory classes, can produce results similar to those reached in scientific investigation of the device using extensive equipment. A thorough investigation of an object, an automatic clutch device in this case, enabled identifying the magnitudes that most significantly affect its operation. The knowledge of these most sensitive magnitudes allows focusing in the teaching process on simplified measurement of only selected magnitudes and verifying the given object in the positive or negative.

1. Introduction

To determine the characteristics of the operation of a given car mechanical subassembly it is infrequent to employ multichannel measurements. Their purpose is to properly characterise and describe the subassembly operation, determine its time and power characteristics to finally connect the magnitudes and parameters that identify the object. To achieve this it is necessary to design a relevant plan of tests and experiments, often time-consuming and requiring advanced apparatus for the measurement and recording of signals, and eventually processing the results with error analysis. Once the detailed investigations identify the parameters of the subassembly operation and its functionality (including merits and weaknesses of its operation), it is possible to distinguish the properties and physical magnitudes that are essential for the role of this subassembly in the car. This enables, within the framework of teaching process, select the physical magnitudes most important for the proper functioning of the subassembly as well as simplify tests performed in time-limited laboratory classes in order to – without neglecting the aim of tests– measure and analyse only the parameters that will enable (even only in terms of quality and roughly) verifying (positively or negatively) the test object during the laboratory classes.

2. Test object – Polish clutch automatic control device CEBRON

The automatic clutch [1] is a device enabling driving a car without using the pedal. It is designed for disabled persons after amputation of the left or both legs or suffering dysfunction of these.

The working element of the self-engaging clutch is a vacuum servo-motor, shown in figure.1, interacting with three or four sensors and valves. It is divided into two chambers, left –vacuum chamber and right – compression chamber. The vacuum chamber is connected with vacuum tank by an electromagnetic valve, while the compression chamber is connected with the atmosphere by:

- return valve delivering air to the compression chamber,



- release control valve responsible for removing air from the compression chamber only in the first phase of the piston movement,
- release mechanical valve controlled by throttling valve,
- release electromagnetic valve controlled electronically.



Figure 1. Vacuum servo-motor of automatic clutch [2].

The working medium is negative pressure in the suction manifold.
 For the tests a relatively small, cheap passenger car shown in Fig. 2 was used.



Figure 2. Test vehicle with automatic clutch [2].

Specification of the test car [2] :

- VIN	KLY3S11BDWC491576
- engine cubic capacity	796cm ³
- maximum power	30kW (41KM)
- rotational speed at maximum power	5500 rpm
- maximum torque	59 Nm
- rotational speed at maximum torque	2500 rpm
- friction, single-plate, dry clutch with compression spring and torsion damper.	

The tests on the automatic clutch were done by the author of this paper within the framework of his doctoral research and the details are given in [2]. The results are quoted in the paper for comparison.

The testing equipment used for advanced investigations [2] included:

- a telemetric set with bridge foil strain gauges (measurement of torque on half-shafts)
- potentiometric sensor (measurement of throttle angular displacement and measurement of clutch lever angular displacement), Figs 4 and 5,
- CORREVIT contactless head (measurement vehicle velocity), Fig.3,
- rotational speed impulse converter (measurement of wheels rotational speed) Fig.5,
- all the data were processed and recorded using a processing system shown in Fig 7.

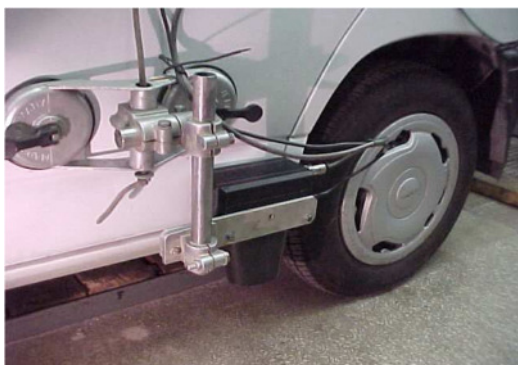


Figure 3. Correvit head [2].



Figure 4. Clutch lever angular displacement [2].



Figure 5. Throttle angular displacement converter [2].



Figure 6. Wheel rotational speed converter [2].



Figure 7. Data processing system [2].

Figure 8 presents the results of tests on vehicle running-up with automatic clutch disengaged. The aim was to compare the behaviour of the vehicle during running-up from rest with automatic clutch engaged and disengaged. The driver operates the clutch in such a way as to start from rest fast and smoothly, avoiding sharp jerks.

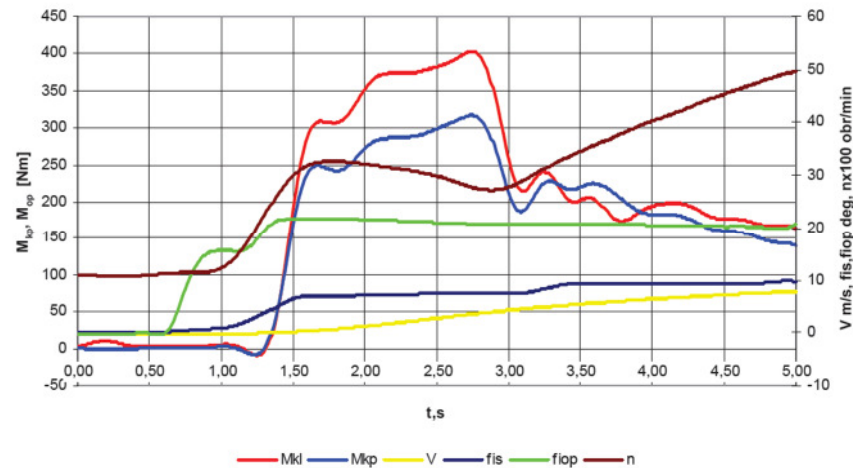


Figure 8. Results of running-up a vehicle without automatic clutch [2].

Notation in the diagram:

- M_{kl} – torque on the left half-shaft [Nm],
- M_{kp} – torque on the right half-shaft [Nm],
- ϕ_s – clutch lever angular displacement [°],
- ϕ_{op} – throttle opening angle [°],
- V – vehicle velocity [m/s],
- n – engine speed.

The highest values of driving torque on half-shafts occur at clutch full engagement the duration of which is ca. 3 seconds. The engine rotational speed drop is then observed. As can be seen in the diagram, there is a time relationship between the throttle opening angle and clutch lever angular displacement, and torque drop on half-shafts typical of vehicle running-up from rest, after engine speed and clutch shaft speed become equal.

Figure 9 presents the results of tests on running-up a vehicle with automatic clutch engaged.

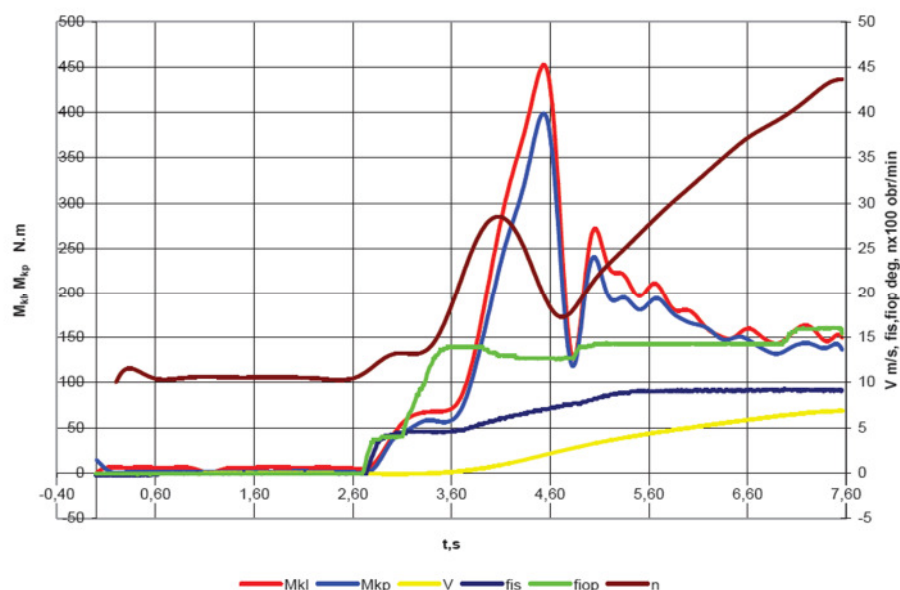


Figure 9. Results of tests on running-up a vehicle with automatic clutch engaged [2].

Notation in the diagram:

- M_{kl} – torque on the left half-shaft [Nm],
- M_{kp} – torque on the right half-shaft [Nm],
- φ_s – clutch lever angular displacement [$^{\circ}$],
- φ_{op} – throttle opening angle [$^{\circ}$],
- V – vehicle velocity [m/s],
- N – engine speed.

With the automatic clutch engaged higher values of torque are observed than in the case of running-up the vehicle with the clutch disengaged. The same is true for engine speed. The total time of clutch engagement was reduced compared with the previous test.

The analysis of errors indicate the occurrence of standard deviation in the measurements of the random variables, which are the measurement results biased with error. Mean value was calculated.

Table 1. Measurement devices errors [2].

Value measured	Measurement device	Unit	Measurement accuracy
Vehicle velocity	CORREVIT contactless head	m/s	0,1 m/s
Clutch lever angular displacement	Resistance converter	1°	0,5 $^{\circ}$
Throttle opening angle	Resistance converter	1°	0,25 $^{\circ}$
Half-shaft torque	a telemetric set with strain gauges system	Nm	0,1 Nm
Rotational speed	Impulse converter	rpm	1/60 rpm
Range (measurement section)	Ruler	mm	1 mm

The road tests were run on a dry road surface. The measurements of the parameters shown in table 1 were recorded by means of processing and digital recording apparatus. For each parameter standard deviation and mean value were calculated. The diagrams below show the values of torque on half-shafts with standard deviation and clutch lever angular displacement with standard deviation.

Notation in the diagrams:

- M_{kl} – torque on left half-shaft [Nm],
- M_{kp} – torque on right half-shaft [Nm],
- φ_s – clutch lever angular displacement [°],
- σ – standard deviation,
- w_{sr} – mean value.

The left half-shaft torque curve (figure 10) shows the standard deviation to be minor since its value does not exceed 6% at the highest torque. It can be concluded that the accuracy of the tests was satisfactory.

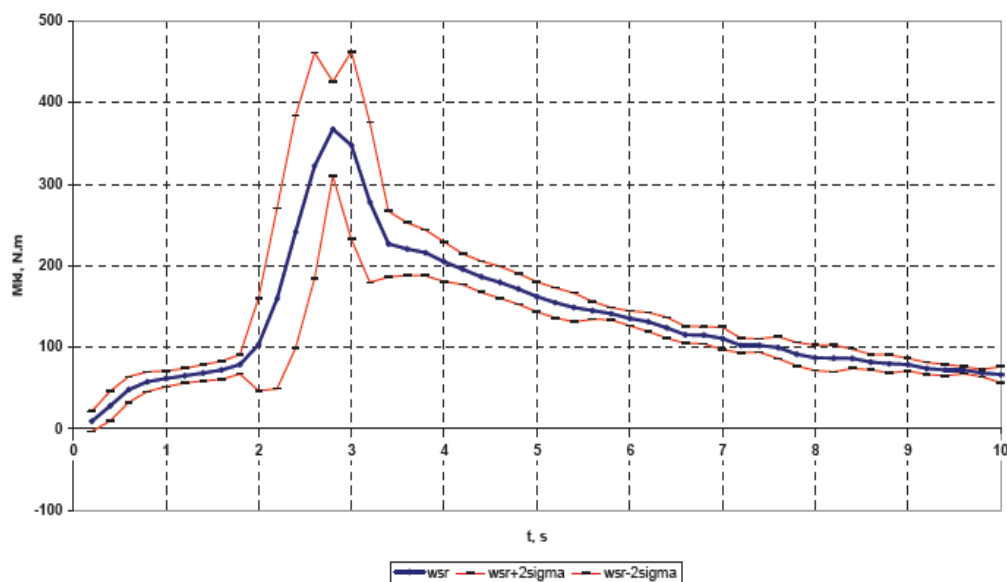


Figure 10. Torque on left half-shaft with standard deviation when vehicle starts moving.[2].

The curve for the left half-shaft is similar right shown in figure 11. The value of standard deviation does not exceed 7% of the mean value of torque.

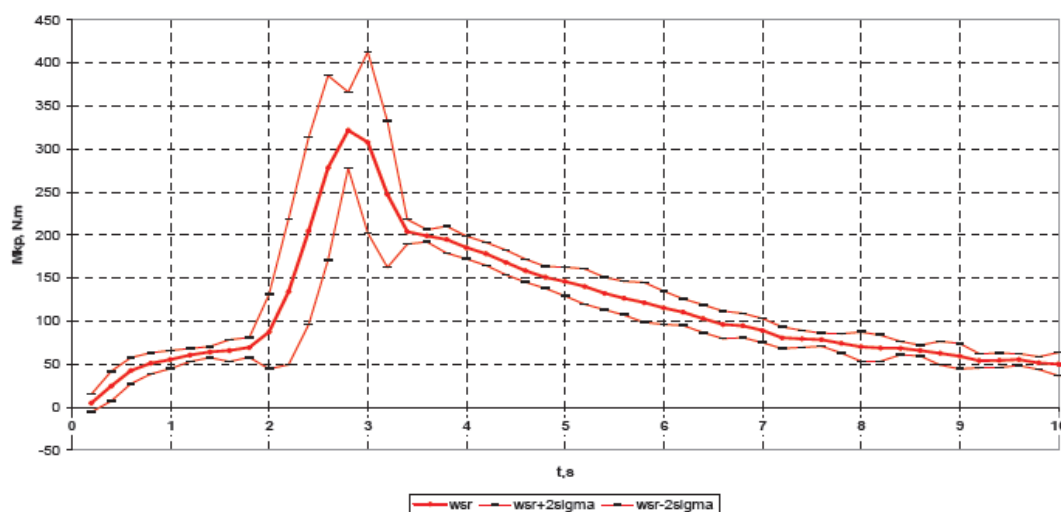


Figure 11. Torque on right half-shaft with standard deviation when vehicle starts moving [2].

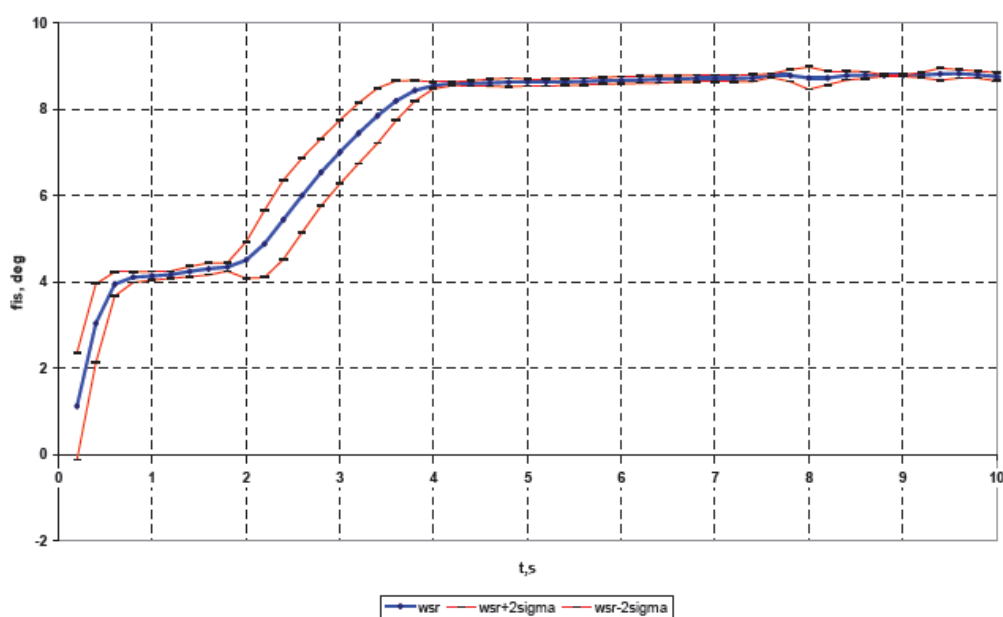


Figure 12. Clutch lever angular displacement with standard deviation [2].

The clutch lever displacement angle curve shown in figure 12 also indicates a minor percent of standard deviation from the mean value, which is a satisfactory result. To sum up, in the performed tests the values of standard deviation were close to one another.

The analysis of error for both simplified and thorough tests proves that the tests were performed correctly, and their results are close and relatively easy to interpret. They confirm the proper execution of the intentions of the designer of the device. The device operates correctly.

3. Simplified tests

The tests were performed on a dry asphalt surface on the test section of 50m. The task of the driver was to run up the test car from rest fast and smoothly on the test section, in other words to operate both the accelerator and clutch pedals in such a way as to limit the phenomena (e.g. jerking) adversely affecting the measurements. In total 24 time measurements were taken, eight for each configuration, that is:

- with disengaged clutch,

- with engaged clutch in the city mode,
- with engaged clutch in the road mode.

The results of time measurements of the ride were recorded with a mechanical stop-watch. The watch was switched on at the moment of starting from rest and switched off when the front wheels of the car crossed the measurement section end line.

Table 2. Running-up time of vehicle with automatic disengaged and engaged clutch [5].

Measurement number	RUNNING-UP TIME [s]		
	Clutch DISENGAGED	Clutch ENGAGED ROAD MODE	Clutch ENGAGED CITY MODE
1	8,3	9,0	18,0
2	10,6	11,0	14,8
3	10,5	10,1	15,1
4	9,6	9,4	16,2
5	10,6	10,9	14,6
6	9,8	10,1	15,4
7	8,6	8,8	17,7
8	8,6	8,9	16,9
t_{sr}	9,575	9,775	16,0875

As can be seen, the automatic clutch “imitates” the driver in the road mode, while in the city mode it works similarly but with the application of “driving on half-shaft”[5].

When the automatic clutch is disengaged and when engaged in the road mode the running-up times are similar, almost identical. This indicates that the clutch works correctly, there is no adverse effect on the clutch operation and comfort. Its operation is different in the city mode. The running-up times for the city mode are significantly longer due to slower engaging the clutch. Adjusting the automatic clutch in the city mode results in slower running-up time due to reduced jerking movements while starting, which is also an intended effect for the city traffic.

Below (Table 3) vehicle velocities calculated on the running-up time are tabulated.

Table 3. Vehicle velocities calculations [5]

Measurement number	Velocities [m/s]		
	Clutch DISENGAGED	Clutch ENGAGED ROAD MODE	Clutch ENGAGED CITY MODE
1	6,02	5,56	2,78
2	4,72	4,55	3,38
3	4,76	4,95	3,31
4	5,21	5,32	3,09
5	4,72	4,59	3,42
6	5,10	4,95	3,25
7	5,81	5,68	2,82
8	5,81	5,62	2,96
V_{sr}	5,27	5,15	3,13

4. Conclusions

In the road tests of a vehicle for disabled persons, equipped with an automatic clutch, during starting from rest the running-up time was determined, during the specific tests – also the time characteristics of velocity and torque on half-shafts.

The tested automatic clutch fixed in cars correctly controls the clutch operation. The test results indicate how close to each other are the running-up times of a car with automatic clutch in the road mode. This confirms the correct operation of the clutch controlling device, no adverse effect of the device on clutch operation was observed.

In the city mode, however, the device behaves differently. The running-up times in the city mode differ from such values during running-up times of a vehicle without the automatic clutch. This is caused by slower engaging the clutch by the device to avoid jerking movements during start (different regulation adjustment is employed than for the road mode). It is a favourable and intended effect improving the comfort of starting from rest.

During vehicle work with the automatic device engaged a larger torque on half-shafts and higher rotational speeds are observed.

References

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