

Experimental analysis of dynamic parameters of the robot's drive

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Abstract. Nowadays, can be observe an increase in production velocity due to better use of machines. More and more efficient use of machines requires better knowledge of their parameters, especially dynamic parameters. Incomplete knowledge of the parameters increases the safety factor that must be used to make the machine work safely. It reduces the dynamics of the machine, and in consequence of working time is longer. Reducing working time by up to several seconds in one cycle brings measurable benefits in production. It is possible to experimentally shorten the working time, but it requires a lot of tests that need to be done. The machine must be bought for testing. Testing results in machine wear, tool wear and material consumption. It takes a lot of time and work of specialists in difficult conditions. Even a small error during these tests can result in the destruction of the machine and its surroundings. The use of software in which the models are more accurate not only shortens the time of entering the machine into production, but also enables its better use. It is also possible to carry out more experiments before buying a machine and the machine's behaviour is more predictable.

1. Introduction

The analysis of complex mechanisms is very difficult [6]. Particularly a complex arrangement like a robot. Many parameters affect the results obtained, and it is not possible to determine their impact. The study of such systems is presented in an earlier article [1]. The results obtained were very complex, the models made on them were very complicated. Attempts to simplify the models [3, 9] have proved ineffective so it is necessary to change the method of acquiring parameters.

Replacing a complex system into several simpler subsystems will make the analysis easier. Disassembly of the robot into subsystems, and their analysis may be the only way. The current and voltage measurements [5, 15] of the servo drive will be compared to the angular movement of the robot arm connected to this servo drive. The timelines presented will be analysed. Based on these studies, a mathematical model is made. This model can be used in various programs and can be used to study the behaviour of the robot.





Figure 1. Disassembled robot.

It is very difficult to find the right dynamic parameters of the robot. Better knowledge of the behaviour of the robot improves the simulation [10, 16] and gives more accurate results [11, 14]. The robot's kinematic system is complex, the robot's geometry is also complex and changes during movement. Even measurements and their analysis are difficult and the obtained models are complex and it is difficult to determine the impact of individual components of the system. Therefore, the dismantling of the drive system is necessary for the proper determination of the parameters. Special care during decomposition is necessary. This is especially important to be careful when doing research. It is also problematic to assembly the robot to work properly. Figure 1 shows the dismantled robot servo drive

2. Measurement and analysis.

The equipment based on Labview software was used for the measurement [2]. A series of measurements was carried out after dismantling the engine. The servo parameters were measured at a constant load. Such measurements are not possible without dismantling the robot because each move causes a change in the load. A special program for the robot for measurements was written to ensure the movement of only one axis [8].

Measurements whose results are presented in table 1 were carried out during the servo drive movement at a velocity of 2217 rpm. This velocity corresponds to a velocity of 104.5 degrees per second of the robot arm.

Table 1. The moment and power of servo.

%	clockwise		counter clockwise	
	Power [W]	Moment [Nm]	Power [W]	Moment [Nm]
10	23,5	0,101	46,3	0,201
15	47,7	0,205	71,2	0,306
20	102,8	0,443	125,6	0,541
25	196,1	0,845	219,7	0,946
30	341,2	1,474	363,2	1,566
40	742,3	3,192	767,1	3,311

A load of more than 40% of the power of the dynamometer activated the robot's safety systems. Which made it impossible to carry out tests at higher loads [4]. Although the velocity in both directions was the same, in the direction of motion the servo counter-clockwise is about 23 W higher than in the opposite direction.

Tabular summary of test results does not give a full picture of the servo response to loads. This is the reason for further research and acquisition of time chart. The results are shown in figure 2. These tests are done at servo drive movement velocity - 2071 rpm. This velocity corresponds to a velocity of 103.5 degrees per second of the robot arm.

It is easy to calculate the moment on the robot arm for comparison, the torque values for the servo and robot arm were inserted as the series name.

The servo moment is small and not enough to raise the weight of 0.5 kg on the 1 m arm even when the power is the highest but the velocity of this mass would be 6213 degrees per second. Such robot motion parameters are not suitable for robot tasks. For this reason, a gear is use in the robot. The use of the gear has changed the robot's motion parameters to velocity 103.5 degrees per second and torque 196.8 Nm at 712 W. These motion parameters enable the robot to perform the correct movement.

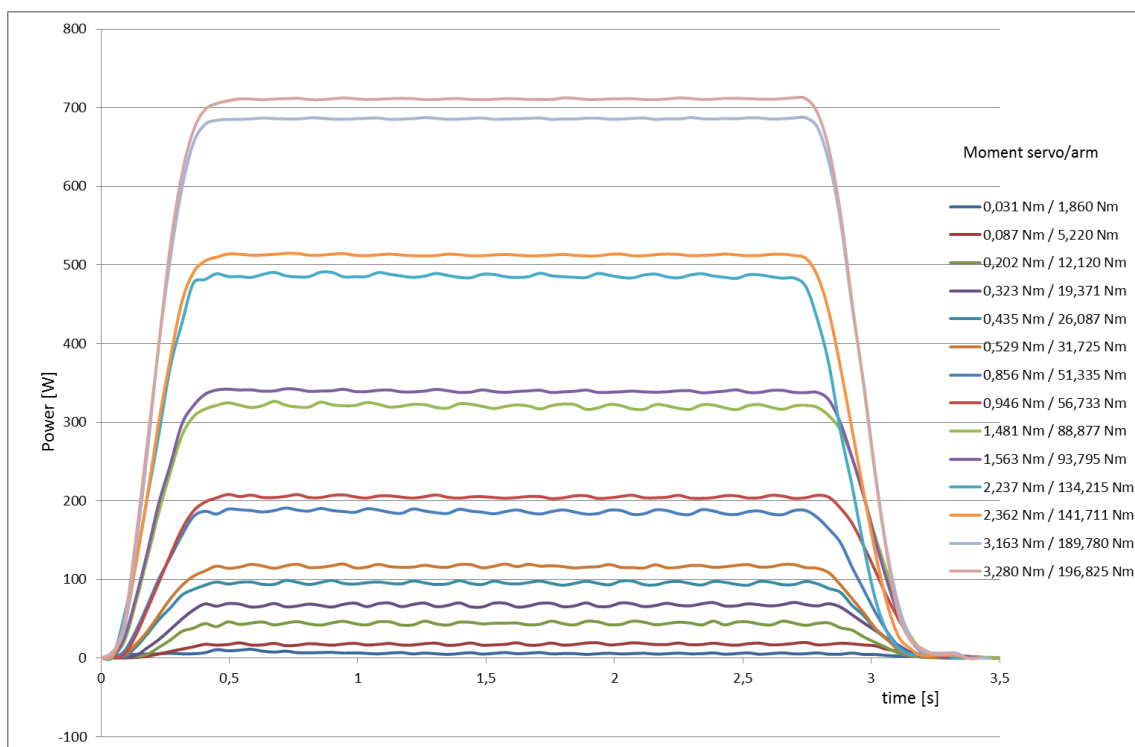


Figure 2. The time trace of mechanical power.

The time course of the robot's movement consists of typical stages of the start-up of the work and braking. The starting and braking time is 0.5 seconds and does not depend on the servo load. Most of the time of the move is work. In this system there are elements with a small inertia, hence small changes in power are visible. This graph has a very gentle traces, no distortion. This is an unusual characteristic of such a dynamic system it is necessary to take a measurement with a shorter time of sampling. Unfortunately, this requires changing the configuration of the measurement system. In the case of measurements presented in table 1 and in the chart in figure 2, the measuring system measured

the torque resistance of the rotational velocity and active power on the dynamometer. The mechanical power is measured.

In subsequent measurements, an additional system measuring the angle, voltage and current will be used. The load is given in the same way by the same device with the same settings. In this case, the electric power is measured.

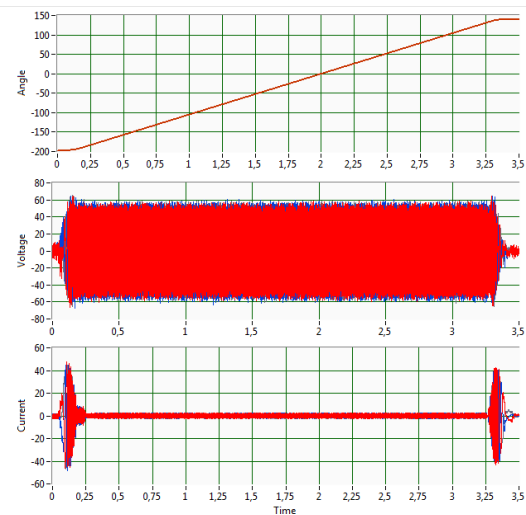


Figure 3. Graphs of changes in angle, voltage and current for load moment 0.087 Nm for servo, 5.220 Nm for robot arm.

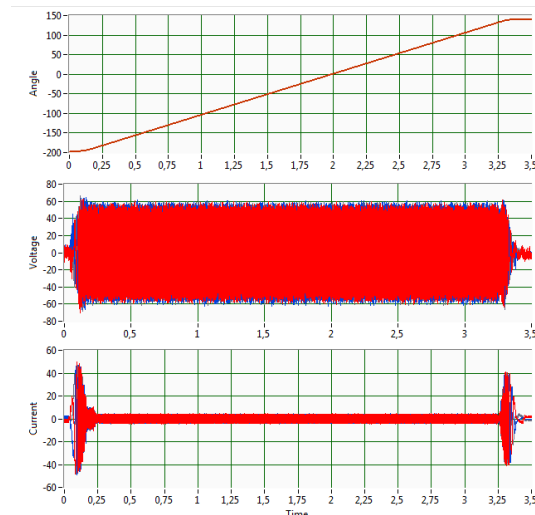


Figure 4. Graphs of changes in angle, voltage and current for load moment 0.529 Nm for servo, 31.725 Nm for robot arm.

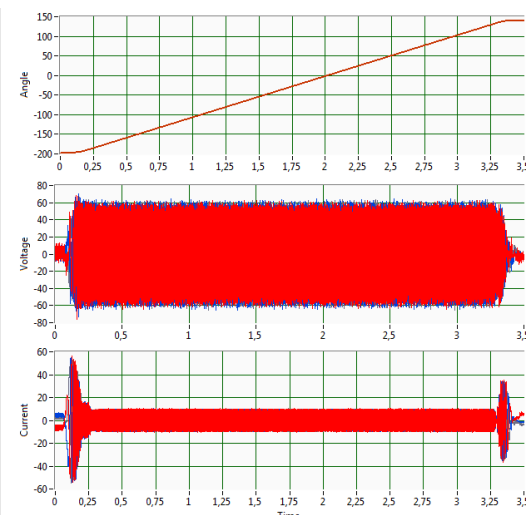


Figure 5. Graphs of changes in angle, voltage and current for load moment 1.563 Nm for servo, 93.795 Nm for robot arm.

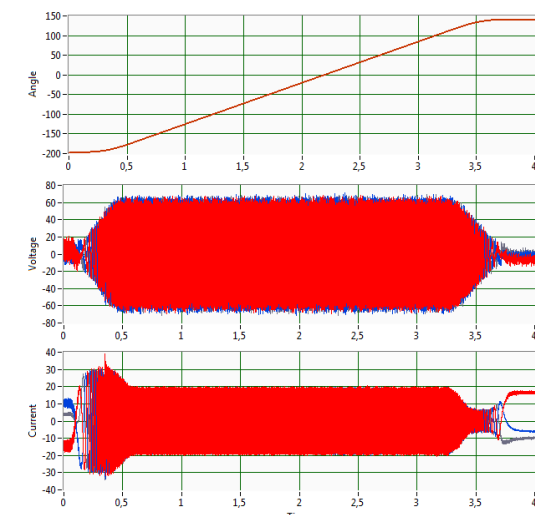


Figure 6. Graphs of changes in angle, voltage and current for load moment 3.280 Nm for servo, 196.825 Nm for robot arm.

Figures 3 - 6 shows the trace of angle, voltage and current for various loads. In these cases, three stages of movement can be noticed - start-up of the work and braking. Starting and braking are shorter than 0.5 s. In most of the results obtained, the trace is very similar except for the largest load.

Not all results are included in the article because they are similar. The graphs do not show any details, therefore graphs from the start, work and braking are shown in figures 7-12.

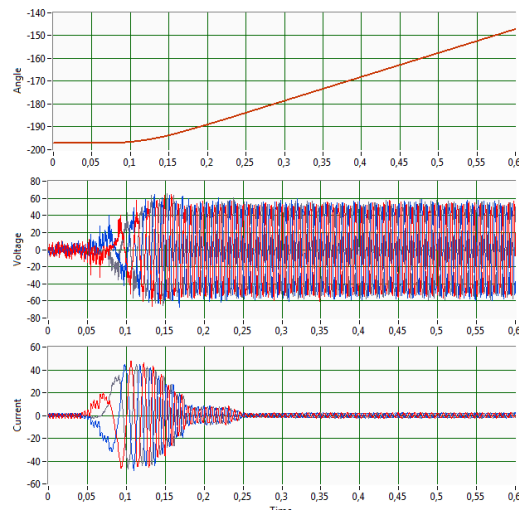


Figure 7. Graphs of changes in angle, voltage and current for load moment 0.087 Nm for servo, 5.220 Nm for robot arm.

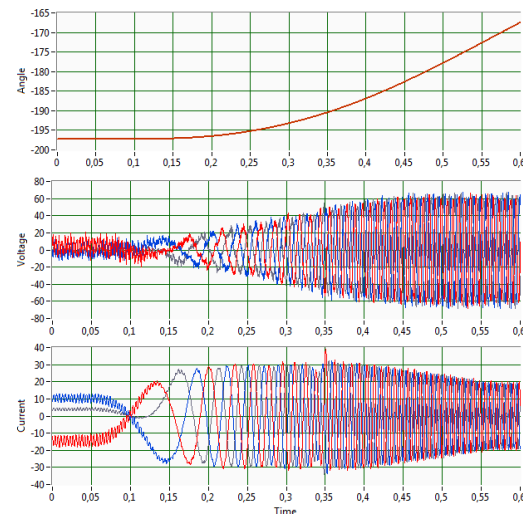


Figure 8. Graphs of changes in angle, voltage and current for load moment 3.280 Nm for servo, 196.825 Nm for robot arm.

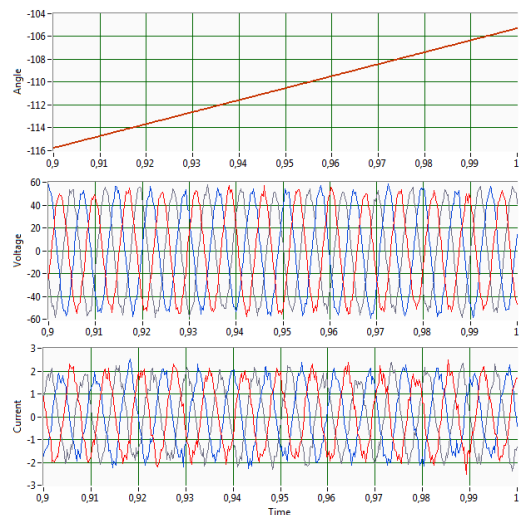


Figure 9. Graphs of changes in angle, voltage and current for load moment 0.087 Nm for servo, 5.220 Nm for robot arm.

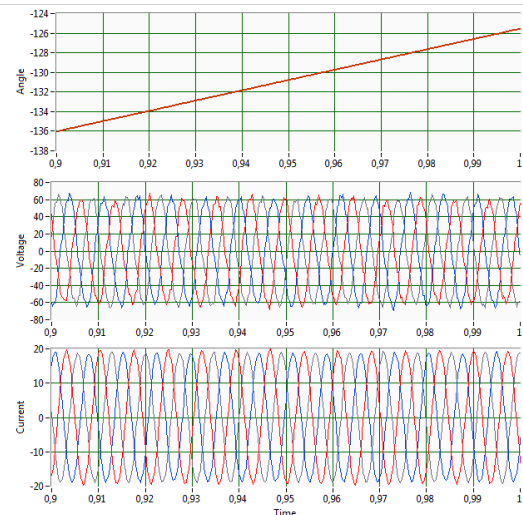


Figure 10. Graphs of changes in angle, voltage and current for load moment 3.280 Nm for servo, 196.825 Nm for robot arm.

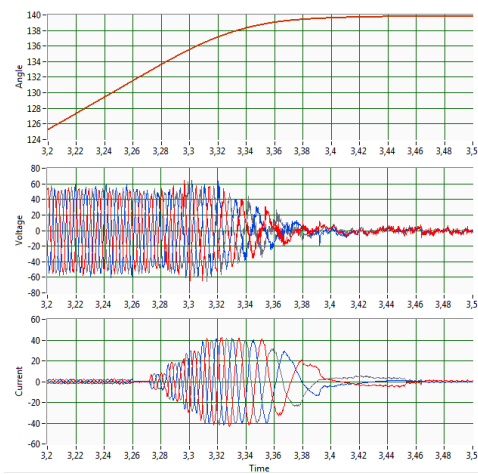


Figure 11. Graphs of changes in angle, voltage and current for load moment 0.087 Nm for servo, 5.220 Nm for robot arm

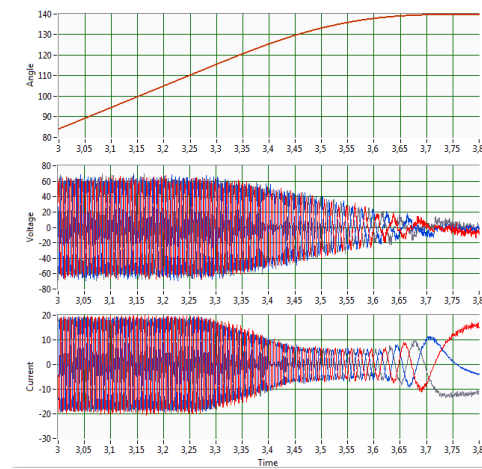


Figure 12. Graphs of changes in angle, voltage and current for load moment 3.280 Nm for servo, 196,825 Nm for robot arm

Figures 7 and 8 show the starting phase, there is a slight increase in voltage and a strong increase in current, as well as a change in frequency. This change in current should be visible in the power graph, especially when the load is small. During operation, the amplitude and frequency of current and voltage are almost constant. Such traces are appropriate for the stable operation of the servo.

The most interesting is the braking because at low load the frequency inverter increases the current amplitude as it was at the start.

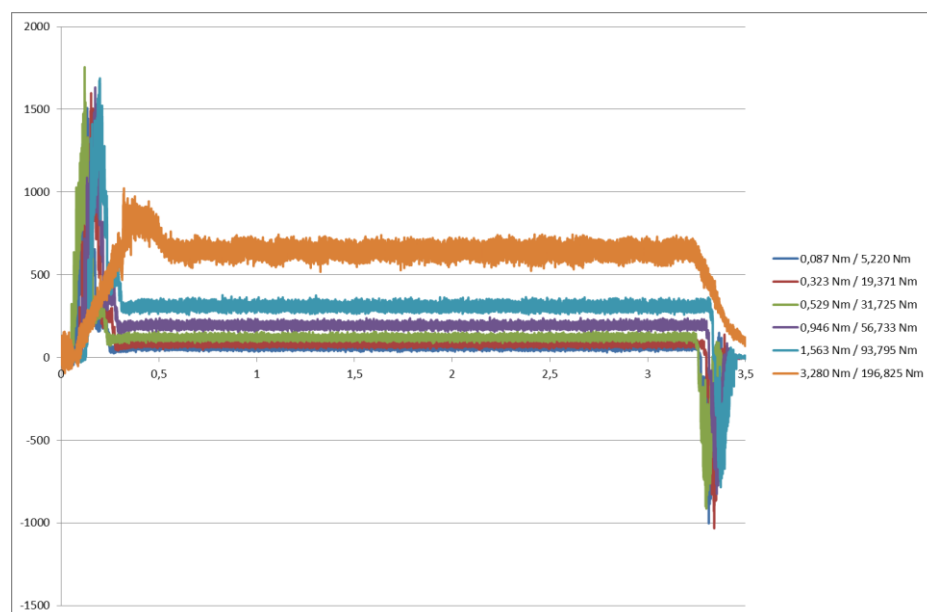


Figure 13. The time trace of electrical power.

The figures in figures 7-12 not clearly show changes of power. The power changes in the graph of figure 13 are much better. This graph was created as a result of the analysis of the measurements shown in figures 3 - 6, and the measurements of which results have not been included in the article. This chart shows the nature of the servo work at each stage. During the start-up, the power peaks up

very sharply so that the servo reaches the set velocity as quickly as possible. At low load, the start is shorter but the peak power is higher. In the case of higher loads, the start-up is longer and gentler. When work gets a servo power load-dependent. During braking, the low-load servo is supplied in the opposite direction. Such braking is very fast. With a heavy load, the trace is milder but the time is longer. There is no servo supply in the opposite direction.

3. Conclusions

Measuring the disassembled drive system is much easier with fewer components reducing the complexity of the obtained results. The electric power supplied to the motor has a different course than the mechanical power received on the dynamometer. Determining the electric power based on the voltage and current traces is complex. For further analysis, it is necessary to integrate power while performing the same motion at different loads and to check the energy consumption of these movements. These tests can be used to build better CAX models [12, 13].

4. References

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