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DESIGNING OF A BLDC MOTOR BENCH

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Abstract: This paper deals with designing and development of a bench for the test of a brushless DC motor. The bench contains a hydraulic circuit, which provides a controllable load for the motor. The hydraulic system is equipped with a hydraulic pump and choke valve and a manometer. The mechanical connection between the hydraulic pump and the BLDC motor is designed with two clutches and structure of two sheet plates. The bench contains a torque meter, which is built between the two shafts of the motor and pump. The system can determine rotational speed, torque, current and voltage with respect of the load.

Keywords: *BLDC motor, hydraulic circuit, measurement of motor characteristics*

1. INTRODUCTION

Nowadays Brushless DC (BLDC) motors [1] are even used for hobby tools, e.g., lawn and garden devices. The main benefit of this motor that it has not commutator slices, which wear and generate sparks and noises. The commutation is provided by Hall sensors and FETs. The characteristics of the current is varying not with a harmonic function but as a square wave signal. Permanent magnets are mounted onto the rotor and the coils are wired onto the stator. This type of motor even if the voltage source is a battery pack can provide high torques and power.

The characteristics of electric motors are measured usually with such a system, in which the load is provided by another electric motor controlled by computer. This motor is equipped with load cells to determine the torque with respect the rotational speed. The measurement of the voltage and current is performed parallelly.

The authors of this paper have only bench for different type of motors but for small torque and power intervals [2], [3]. Due to this drawback a new measurement system should be designed and developed. Designing of the measurement system for a high-power rate BLDC motor requires caution from engineers.

This paper is organized as: Section 2 deals with the geometrical design process of the clutches and the structure of the sheet metals. Section 3 contains the set-up of the test bench. Section 4 shows the result of a test measurement.

2. DESIGNING THE ELEMENTS OF THE BENCH

Measuring the characteristics of a BLDC motor requires an adjustable load unit, which in our case is a hydraulic pump. A torque measuring cell between the motor

and the pump shafts measures the transmitted torque. The design of the two couplings and the mounting structure required to achieve the mechanical connection. The available items are shown in *Figure 1*.

Figure 1
The existing elements: BLDC motor, torque measuring cell, clutch, and hydraulic pump

Additional machine elements have been designed in Autodesk Inventor 2020 software. The coupling of the BLDC motor and the torque measuring cell clutch requires the design of an intermediate clutch, which is illustrated in *Figure 2*.

Between the hydraulic pump and the torque measuring cell there is also a clutch necessary, which ensures force-locking connection at one side, and at the other side there is a locking groove (see *Figure 3*).

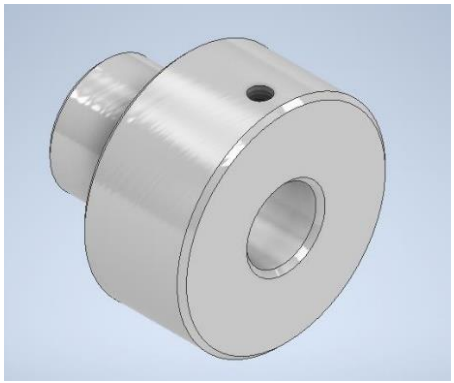

Figure 2
The intermediate clutch

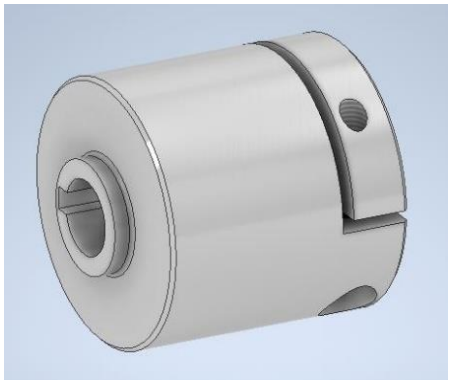

Figure 3
The clutch between the pump and the torque measuring cell

The hydraulic pump and the BLDC motor are mounted on sheet metal structure. The 3D drawing of the pump support element with the corresponding holes is shown in *Figure 4*. The thickness of the plate is 5 mm.

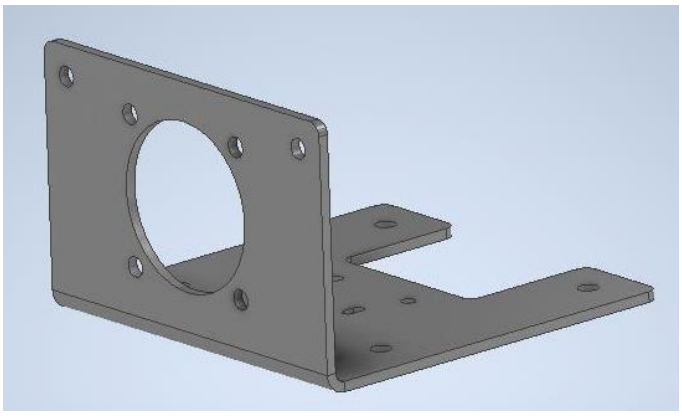

Figure 4
The drawing of the pump supporting sheet metal

A bent plate was also designed to mount on the BLDC motor (see *Figure 5*), which has 3 mm thickness. It is noted that for the sake of mountability, stretched holes are designed for the bolts.

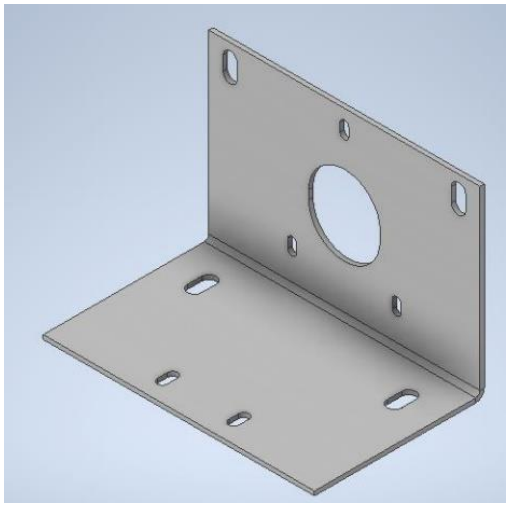

Figure 5
The 3D drawing of the BLDC supporting sheet metal

The designed elements have been manufactured, which are shown together with available ones (see *Figure 6*). The aluminum clutches shown in *Figure 2* and *3* are produced by turning-machine at the Institute of Machine Tools and Mechatronics. The steel sheet metals were formed by laser cutting and edge bending at AR-Robotics Ltd.

Figure 6
The designed and available elements

3. SET UP OF THE TEST BENCH

The picture of the test bench is displayed in *Figure 7*. Standard machine elements are used to fix the metal structure to mount on the hydraulic system.

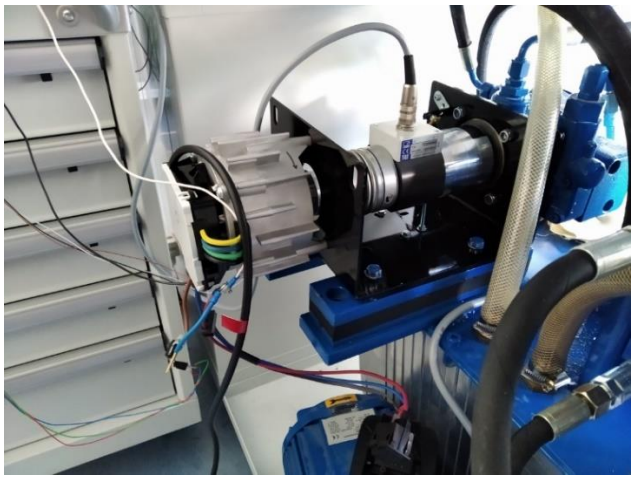

Figure 7
The test bench

The test bench is capable to measure the current, voltage, torque, and rotation speed (RPM). The scheme of the measurement system is shown Figure 8. The measured signals are digitized by an Atmega328 microcontroller, which are transmitted to a Personal Computer (PC). The sampling frequency of the microcontroller is set to 10 Hz. The available voltage source is about 20 V, therefore a voltage divider is required to provide the voltage TTL logic level. The type of the current sensor is ACS758ECB-200B-PFF-T, which has 200 A upper limit. The torque sensor is HBM T22/50 Nm.

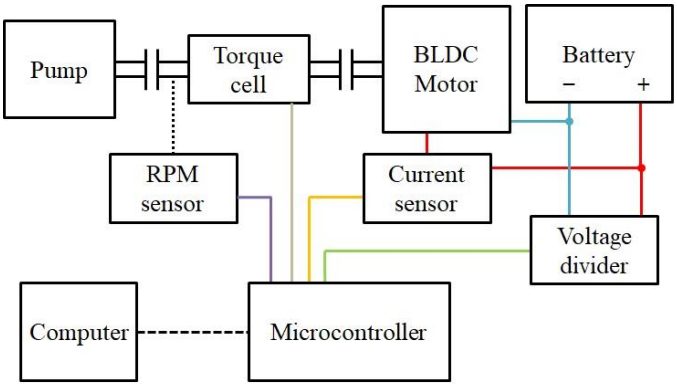

Figure 8
Block diagram of the measurement system

4. MEASUREMENT

A test measurement has been performed for 5 bar load produced by the hydraulic circuit. The signals of one of the measurements are shown in *Figure 9*, where the voltage, the current, the RPM and the torque are denoted by green, purple, red and orange curves, respectively. The vertical axis represents the quantized values between 0–1,023 due to the 10-bit A/D converter, while the horizontal axis shows the elapsed time in ms.

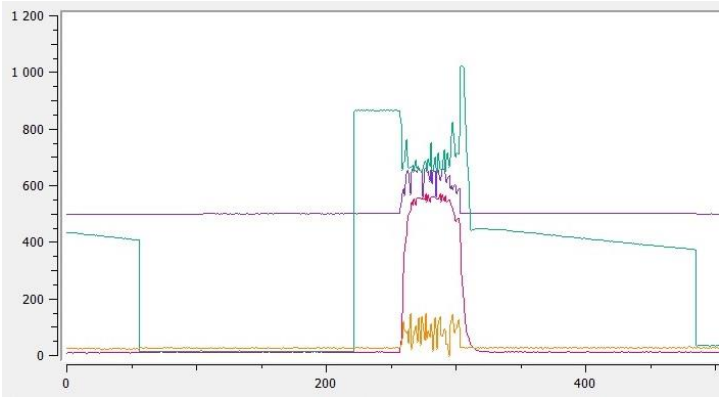

Figure 9
The results of a test measurement

The BLDC motor is started with two pushbuttons, one button enables, while the other actually provides voltage to the system. As *Figure 9* shows, the first button is pressed at 220 ms, i.e., the voltage ramps up, while the second button is pressed at 250 ms when the voltage drops somewhat and shows an oscillating character in

the course of rotation. It can be seen that the current is also showing oscillations at the same time. The operating RPM is achieved suddenly and almost constant during the operation. The measured torque also shows oscillations due to the flexible clutch.

The presented measurement demonstrates that the system works properly but postprocessing the digitized signals need to be postprocessed.

5. SUMMARY

This paper dealt with design of a BLDC motor test bench. The required machine elements were designed in Autodesk Inventor 2020 CAD system. The elements were manufactured, and the system was assembled. A test measurement was performed to demonstrate its functionality. The system can determine the current, voltage, RPM and torque of a BLDC motor controlled under hydraulic loads. The advantage of the system that the load can be adjusted up to 50 bar hydraulic pressure.

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