Motors in Theory and Real Life

Deniz Uzun[1], Cem Yurdusev[2]

Hisar School, Turkey[1,2]

Abstract

In 9th grade we learned about work power, energy; in 10th grade we learned about electricity and magnetism and in 11th grade we will learn about force and motion [1]. When we examined our current textbooks and the textbooks we'll be using in the following years, we couldn't obtain any information on the transfer of power produced by an electric motor to a mechanical system [2]. While building robots for our extracurricular activities, although we achieved some success by using the trial and error method, as a part of the elective mechatronics course we're enrolled in, we had to prove that a system we designed would work scientifically, before physically building it. So, we designed a system that lifts a cap with a mass of 0.335 kg and places it on a 60cm tall pole.

To prove that this system will work; first, the force required to lift a cap was measured by using the torque formula. Then, the power was calculated by measuring the current of the system and multiplying it by the potential difference. Next, the speed in the form of m/s was found. Afterwards, the circuit was supplied with a battery powerful enough to create a force that satisfies the torque formula. The force exerted was calculated by knowing the perpendicular distance and torque (torque is constant), by using trigonometry.

The arm rotates from 0 to 60 centimeters. The force exerted on the system in each interval of the rotation until it reached 60 centimeters in altitude was found by determining the perpendicular distance of the arm in key positions. Then, the torque formula was applied to find the force required to lift the object at those positions. The calculations showed that the system should have been able to lift the cap, but tests showed otherwise.

After some research, we came to the conclusion that this was a result of energy loss during the transfer. So we attached the arm to a system with a gear reduction of 5/2 and tested the minimum amount of force required to lift the cap. The arm started to lift after a greater force than what we had calculated was applied. By doing this, we managed to calculate the loss of energy due to the friction between the two gears.

Keywords: *Power, Torque, Energy Transfer, Force.*

1. Introduction

Since physics is mainly based on concepts, some students struggle with comprehending the different intellects. This is usually due to the lack of daily life cases which the students can use to form solid ideas. Therefore, application based learning is crucial in physics classes. Application-based learning aims to show students how the things they learn in class are relevant by providing them context to the content they learn [2] [6]. This is done by demonstrating examples of the subject in daily life, rather than constantly using theories and imagination. Robotics is a great example of application based learning since it is a hands-on activity where many aspects of physics can be demonstrated.

2. The case

In an assigned case, we were required to build a robotic arm that would lift a 335-gram cap on top of a pole of 60 centimeters. For this section, we always had to rebuild the system because the motor could not produce enough force. We decided to take a professional approach rather than using the trial and error method when building our system. We wanted to calculate the required force to lift the cap.

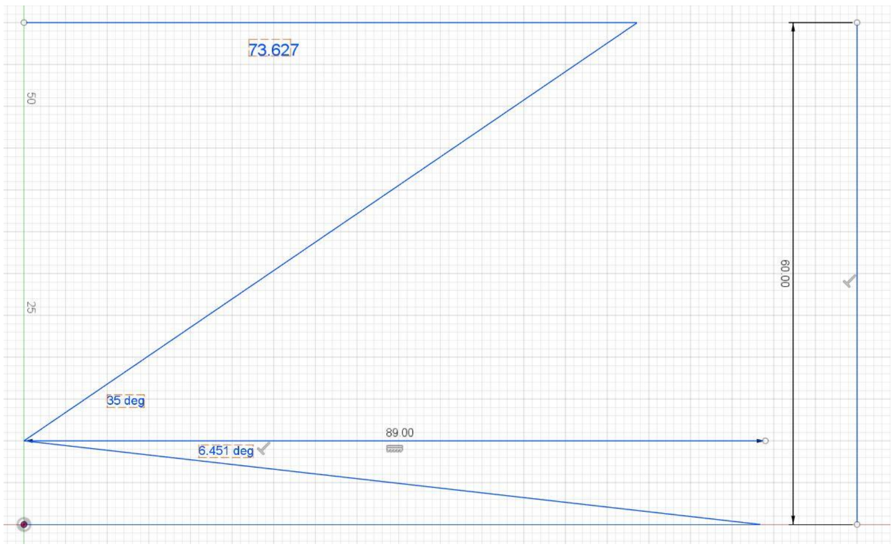
3. The Procedure

To take a more professional approach to the problem, we used the 'SPARK' process [2] which is a system used in engineering in order to exhibit an efficient and attitude while constructing builds or doing research. It is a model suggested by the REC Foundation’s VEX EDR and demonstrated in an activity that students can conduct.

3.1 Seek

In the first step of this process, 'Seek', we were to discover new opportunities to further our understanding of the problem [2] [6]. So, instead of directly starting to build the mechanical arm and eventually finding the gear ratio over trial and error, we decided to use the method of calculating the required force to lift the cap, in order to achieve the ultimate goal of finding the correct reduction ratio.

To achieve this goal, we used trigonometry to find the necessary angle.



The arm is 89 centimeters long. As a result, the hypotenuse is 89 cm. By using the arcsin function, we were able to find the angle of rotation required by inputting the values we have. But this does not indicate how much we need the arm to rotate. The reason for that is that the arm's initial position is on the surface, which is 10 centimeters lower than the "X-axis". To derive the necessary angle, the sine function was of great help once again. With the arcsin function, we derived the total angle of rotation (See analysis 1.) Next, we wondered if the force the motor exerts on the arm is going to be sufficient. To test that, we derived the real torque from the stall torque of the motor. First, the real current was derived. Then, the real torque was derived using the real current of the motor. (See analysis 2.)

While deriving force out of the torque of a motor, the perpendicular distance should be considered, rather than the actual distance. And that value changes over the position of the arm. We took the point where the perpendicular distance is the farthest for reference since if the system was able to operate at that point, it would be able to produce enough force to operate at any point. The resisting force is due to the cap on the arm. The force exerted on the arm by the motor can be derived from the torque value. Since the torque is a constant that consists of perpendicular distance and force exerted, it is possible to find the other variable if one variable is given. After the calculations (See analysis 3.), 1.73N was left as the force exerted. This much of force is not enough to lift a cap that exerts 3.35N of force downwards. We attached a 2/1 reduction system that consists of gears to the arm Theoretically, the force produced should be enough to lift the cap at that time. (See analysis 4.).

3.2 Play

For the second step of the 'SPARK' process, 'Play', we were to test our build and observe how it functioned [2] [6]. During our test, we saw that the arm could not get past the position where it was parallel to the surface and was unable to perform the task although we had used the results which our calculations had yielded.

3.3 Apply

For the third step, 'Apply', which is the step where problem-solving skills and accumulated knowledge are used in order to solve the issues in the design [2] [6], we used the trial and error method to figure out a reduction system proficient enough to lift the cap. Then we tried a 3/1 reduction system. It did work, but the force required practically was more than the force required theoretically.

3.4 Rethink

For the fourth step, ‘Rethink’, where more efficient ways to solve the problem are thought of, research on the topic is done and new solutions are considered [2] [6], we tried to figure out what the exact issue of our calculations, which in theory should have worked flawlessly, was by thinking about what we had left out. During this step, we realized that the friction between two gears caused some of the energy produced by the motor to turn into heat energy. Which means that the energy left was less than what was needed since the results to our calculations only worked in perfect circumstances.

3.5 Know

Finally, for the ‘Know’ step, where the core ideas and knowledge gained are understood and reviewed so that they can be reflected to the solutions of different problems, we decided to write a paper on the issue and the solution we came up with [2] [6]. Keeping the data and procedures for how the problem was solved, helps other people acknowledge the same details.

4. Analysis

1. Calculating the angle of rotation by using geometry. Since the arm rests 10 centimeters above the surface, the opposite side should be 50 centimeters, the arm has a length of 89 centimeters.

$$\sin^{-1}\left(\frac{Adjacent}{Hypotenuse}\right) = x\circ$$
$$\sin^{-1}\left(\frac{50}{89}\right) \simeq 35\circ$$
$$\sin^{-1}\left(\frac{10}{89}\right) = 6.451\circ$$
$$35\circ + 6.451\circ = 41.451\circ$$
$$41.451\circ = Angle\ of\ Rotation$$

2. Finding the real current, then deriving the real torque from it. The real torque turns out to be 1.54Nm[4]

$$I_{Stall} = I_{Real} + I_{Free}$$
$$4.8 - 0.37 = 4.43$$
$$\frac{\tau_{real}}{\tau_{stall}} = \frac{I_{real}}{I_{stall}}$$
$$\frac{\tau_{real}}{1.67} = \frac{4.43}{4.8}$$

$\tau_{real} = 1.54Nm$

3. Deriving the max force required by calculating the max force required by taking the point where the perpendicular distance is at most and manipulating the torque formula. Force applied by the motor turns out to be 1.73N

$$\tau = N \times m$$
$$1.54 = N \times 0.89$$
$$N_{applied} = 1.73N$$

4. Construct a reduction system that will have the motor produce sufficient force. A 2/1 gear ratio should be sufficient to make the system work [3]

$$F_{opposite} = F_{applied} \times Reduction\ Coefficient$$
$$3.35N = 1.73N \times Reduction\ Coefficient$$
$$\frac{3.35}{1.73} = Reduction\ Coefficient$$
$$1.936 \simeq \frac{2}{1}$$
$$\frac{2}{1} \simeq Reduction\ Coefficient$$
$$2 \times 1.73 > 3.35$$

5. Discussion

After some research, we came to the realization that the issue was not a calculation error. Friction was the cause of the deflection of the results. Realizing that friction had an important role in the calculations done, was a discovery that couldn't have been made on paper, however, it played an important role in comprehending conceptual physics. The issue was that naturally, the theory does not apply to real life completely. The friction caused the kinetic energy to transform into heat energy, causing an energy loss. The results which helped achieve this goal were found by performing calculations and experiments which were not a part of the official school curriculum.

6. Conclusion

Application-based learning has many benefits as the case above demonstrates. Not only does this learning approach help students engage in their physics classes more, but it helps promote the students' understanding. While participating in hands-on activities [1] and solving problems which can be addressed as daily life examples, students learn to use different methods, such as the 'SPARK' system [2] [6], which they can later incorporate into other aspects of their daily lives. A variety of schools use robotics and other application based learning activities while creating their curriculums. However, these projects are not a part of the official curriculum in many countries (for example, Turkey or China) [5]. In an era where technology has a large impact on the world and the development of the society as a whole, neglecting to update the school curriculum to match the new standards and innovative teaching methods is a huge loss which shouldn't be omitted by any country.

References

[1] “Application-Based Learning: Making Education Fun!” *Cyber Innovation Center* cyberinnovationcenter.org
[2] VEX Robotics Inc. *Gravity Rush. 04/30/2019.* (retrieved from) education.vex.com.
[3] VEX Robotics Inc. *8.4: Gear Ratios*. Curriculum. (retrieved from) vexrobotics.com (2019).
[4] McGraw-Hill Education.*Glencoe Physics: Principles & Problems, Student Edition.*USA.McGraw-Hill Companies (2005).
[5] 孟令君. “More Schools May Look to Offer Robotics.” *China*, www.chinadaily.com.cn
[6] VEX Robotics Inc. *STEM Lab Guide.* (retrieved from) ducation.vex.com