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From: FMC Wheelchair

Date: 9/11/2020

Subject: ERs and TPs revamp memo

Introduction：

This memo content specifically introduced FMC wheelchair's customer needs and engineering needs, focused on analyzing key engineering needs ERs, and listed target values and tolerances. The team did not make major changes to the customer needs and engineering requirements of the previous semester. At the same time, this memo designed 2 different Testing Procedures for the team's project. They are maximum torque testing and calf pad comparison test. The goal for the tests is to check the damper's stability and find the desired calf pad with more comfort and safety factor.

1 Customer Requirements (CRs)

Table 1: Customer Requirements

Customer Needs	Customer Weights
High safety	5
Comfort	4
Low cost	4.5
Easily cleaned	3.5
Long durablity	4
Good adustability	4.5
Slowdown effect	4.5
Light weight	4

The customer needs is shown in figure , because wheelchairs are provided to patients with mobility impairments, their safety occupies the highest weight, and the adjustability of leg support occupies the second highest weight (4.5), because the client's requirement is that the leg

pads need to be removable and both horizontal and vertical Can move freely. Of course, price is also a factor that consumers must consider, so price also has the second highest weight (4.5). After discussion with the sponsor, the team also set its weight ratio at 4.5.

The change made by the team is to add slowdown performance to customer needs, because when the patient uses a wheelchair to pass a steeper slope, the brake performance needs to be considered. So the team positions it as 4.5.

2 Engineering Requirements (ERs)

This part is the key engineering requirements formulated by the team. The target values and tolerances of the engineering requirements are formulated through customer requirements and some wheelchair standards, and the reliability and durability of the engineering requirements are discussed.

2.1 ER #1: Size of FMC Wheelchair

2.1.1 ER #1: [size of FMC wheelchair] Target = [283*170*245 mm^3]

Because the team's current task is to make a model and then test some key parts, the professor set the size ratio of the model required for the study to 1:4 due to cost and manufacturing difficulty considerations. Compared with the size of the previous semester, this size requirement allows the team to focus more on the key parts of the project, such as the overall design of the leg cushions and the design of the anti-theft system.

2.1.2 ER #1: [size of FMC wheelchair] Tolerance = [(+/- 2mm]

The team needs to use PVC pipes for modeling. Through communication with the merchants, when the tolerance of these pipes is 2mm, it will not affect the establishment of the final model.

2.2 ER #2: [Torque when braking]

2.2.1 ER #2: [*Torque when braking*] Target = [14.83 N*m]

The braking performance of a wheelchair largely represents the safety of the wheelchair.At the same time, torque is generated due to friction. The value of torque when braking when braking is very important. According to the information, the normal speed of a manual wheelchair is 1.08m/s, the speed is 0m/s in 0.5s when the brake is activated, and the acceleration is -1.76m/s^2. According to Newton's second law, F = ma, the available friction force is 34.3N. According to the torque definition T=F*r, the size of the torque is 14.83 N*m

2.2.2 ER #2: [*Friction force when braking*] - Tolerance = [(+/- 3N*m)]

Generally speaking, the braking performance of the wheelchair reflects the sensitivity of the brake. After the user uses the brake, the value of torque from the brake should not fluctuate too much, so the tolerance is set to 3N*m is the most reasonable.

2.3 ER #3 (changed from fall): Cost under $1,500

2.3.1 ER #3: Cost under $1,500 - Target = $1,250

Table 2: List of cost of all parts

small-scale prototype cost summary					
Part Name	Number	Price per part ($)	Total Pr:	Responsb:	Source
Leg Support	2	59.99	119.98	Haoran	https://www.engineeringtoolbox.com/
Anti-theft system	1	149.99	149.99	Simen	https://www.engineeringtoolbox.com/
Disc Brake	2	79.99	159.98	Simen	https://www.engineeringtoolbox.com/
Dampers for rotary joints	4	73	292	Zhenkai	https://www.engineeringtoolbox.com/
Calf support	2	51	102	Jialan	https://www.engineeringtoolbox.com/
Leg support attachment	2	19.99	39.98	Zhenkai	
Total Cost			863.93		

The client was able to increase the overall budget to $1,500 from the $1,000 that was set last semester. The team believes the cost should not exceed $1,250 based on the current Bill of Materials. Currently, we consider the BOM compared with last semester, we decided to build a 1:4 scale test and present a model for the first presentation.

For the first presentation, we decided to mainly use PCR pipe, it can be cheap, light and environmental friendly compared with other materials. The following is the new BOM for ¼ scale model.

Table 3: Bills of materials

1/4 Scale Model Bill of Material				
Part name	Quality	Price ($)	Total Price ($)	Source
3/4 in. PVC Sch. 40 Pipe(2ft)	1	1.6	1.6	homedepot.com/p/VPC-3-4-in-x-2
3/4 in. Furniture Grade PVC 3-Way Elbow in White (8-Pack)	1	14.91	14.91	homedepot.com/p/Formufit-3-4-i
3/4 in. Schedule 40 PVC 90-Degree Elbow	10	0.48	4.8	homedepot.com/p/3-4-in-Schedul
3/4 in. Furniture Grade PVC 4-Way Tee in White (8-Pack)	1	16.8	16.8	homedepot.com/p/Formufit-3-4-i
3/4 in. Furniture Grade PVC 5-Way Cross in White (8-Pack)	1	28.2	28.2	homedepot.com/p/Formufit-3-4-i
1 in. x 10 ft. PVC Schedule 40 Plain-End Pipe	1	3.97	3.97	homedepot.com/p/1-in-x-10-ft-P
3/4 in. FPT Black Iron FPT Floor Flange	2	4.6	9.2	homedepot.com/p/3-4-in-FPT-Bla
samll cardboard	1	1.29	1.29	Walmart
Amazon Brand - Rivet Casual Striped 100% Cotton Bath Towe	1	12.9	12.9	https://www.amazon.com/Rivet-C
		Sum	93.67	

2.3.2 ER #3: Cost under $1,500 - Tolerance = +/- $250

The maximum cost for this project is now set at $1,500, but the team is set to design towards only using $957.6 to allow a contingency of 542.4. However, some manufacturers' fees haven't been considered due to the policy for the Homedepot. They can provide some free manufacturing service. That can help us save money.

3 Testing Procedures (TPs)

A test method is a method used in the science or engineering of tests, such as physical experiments, chemical experiments, or statistical tests. This is the definitive procedure for producing test results. To ensure accurate and relevant test results, the test method should be "clear, clear and experimentally feasible.", as well as effective and reproducible.

Think of a test as an observation or experiment that determines one or more characteristics of a given sample, product, process, or service. The purpose of testing includes determining the expected observations in advance and comparing them with actual observations. The results of the test can be qualitative (yes/no), quantitative (measured value) or categorized, and can be derived from personal observation or the output of precision measuring instruments.

Usually, the test result is the dependent variable, which is the response measured according to the specific conditions of the test or the level of the independent variable.

3.1 Testing Procedure 1: Maximum torque test in joints

3.1.1 Testing Procedure 1: Objective

As one of the core parts of this advanced wheelchair design, ratchet joints with damper function both as dampers and joints. It is indispensable for the team to test the endurance of the joints in terms of maximum torque that they can bear. The main engineering requirements that constrain the testing procedure are friction force when braking and maximum loading weight. Joints have maximum torque restriction. Thus, loading weight on the leg support would be considered an essential factor that generates torque. What's more, when the wheelchair drives at a constant speed, no friction force or resisted force are exerted on the leg support. However, under conditions that the wheelchair is about to start up or stop, a friction force will be applied on it and more torque damper or joints will need to get over the force. So, the testing processes involve torque tests under several conditions, in these processes maximum loading weight will be tested to check whether the wheelchair could meet the standard of walking safely and stably.

3.1.2 Testing Procedure 1: Resources Required

The equipment involves

- Two 6kg iron blocks that could be tied on the leg support, the two iron blocks could serve as the real human leg in the test
- At least two types of rotary dampers for testing, they can be obtained from TOK, team could choose the better one either in consideration of maximum loading or cost

Figure 1: Iron block

In the testing process, team need to tie these iron blocks into the leg supports. Record the status of leg support walk in different velocity to see whether leg support has the trend to fall or break. Meanwhile, more operating situations like suddenly start or stop may also be taken into account. Finally, team could make an assessment of whether the joints are appropriate or not.

3.1.3 Testing Procedure 1: Schedule

Testing procedure will be done very soon. Since the CAD model of the ratchet joints have been designed. After the team gets approval from the professor, the team could do such tests as soon as the team's work on a full size product. This procedure urgently needs to be done because such joints that applied on wheelchairs are kind of a new invention. Team needs to figure out how to make the perfect joints with dampers by tons of failure.

3.2 Testing Procedure 2: Humanize Calf pad

3.2.1 Testing Procedure 2: Objective

What team has already done to stable the calf pads during the falling process is adding more back support to them. Team increased the surface area of the back support plate to make the whole pad stabilized. Besides, team appropriately decreased the surface area of the calf pad without having too much influence on comfort. The main constraints and objectives are safety factor and comfort degree. These engineering requirements are also the standards of whether advanced calf pads are satisfied or not. Finding the appropriate back support area and cald pad area would be the goals of this test.

3.2.2 Testing Procedure 2: Resources Required

Testing Equipment:

- Four different modes of calf pad that could be assembled on the leg support. The modes should be divided as
  1. Maximum surface area, minimum back support area
  2. Minimum surface area, maximum back support area
  3. Smaller surface area, moderate back support area

4. Moderate surface area, moderate back support area

- Iron block that used to tied on the leg support, which served as weight of human leg
- Four testers that actually sit in the wheelchair

Testing process:
For each mode of calf pad, team needs to record the status of calf pad and leg support on condition of iron block tied. This process is to test the stability of the calf pad by checking whether it will move after shaking or other motion. What's more, four testers will actually sit in a wheelchair to record which mode of calf pad is most comfortable. Finally, team would choose the best mode with both good quality of stability and comfort.

3.2.3 Testing Procedure 2: Schedule

Team would make several sketches with different modes of calf pad. These sketches could be done in 1-3-1 method or bio-inspired method and choose four different area designs. Then, the team would try to build actual models of them by the end of September. Afterwards, team would assemble calf pads and do above tests to find desired calf pad.