Mini Car Design Challenge

Introduction

This project will provide you the opportunity to exercise your creativity and utilize the sketching and modeling skills you have developed this semester. You will also get the opportunity to use new and exciting manufacturing technologies to create a prototype.

Using the Design Process, you and a partner will design, document, model, and produce a toy car with interchangeable parts. The design must consist of three parts: body (2), chassis, and wheels (4). Each partner will design their own body for the car but partners must work together to design a single chassis and set of wheels.

To further complicate this challenge, your team's design must be reverse engineered to accommodate a number of requests made by the client. The company you are designing this toy for would like the design to be able to hold coins securely to add weight to the car, allowing kids to race them. The company would also like to use paperclips for the axles of the car. Finally, the company already manufactures a wooden track that they would like your car design to be used on.

Background

This is the final large-scale design challenge I give to my introductory-level engineering students (primarily 9th grade students) for the last several weeks of the class. My classes are block classes so I see my students for 90 minutes everyday for a 90 day semester. The students in this class have already completed a number of activities to familiarize them with concepts essential to this challenge such as: the engineering design process, documentation of the design process in the form of an engineer's notebook, technical drawing and annotation, 3D modeling, as well as statistical and graphical analysis using a spreadsheet software. This activity would be difficult to implement without students having at least some introduction to those concepts, with the exception of the documentation and data analysis (statistical and graphical).

The functional and interoperability analysis pieces of this project are in place as an attempt to have students "reverse engineer" their designs to fit these existing items. For our toy track, we use a knock-off version of the Thomas and Friends® wooden train track. I allow my students to choose which coins they would like their design to hold.

In my school we have access to 5 total, 3D printing machines. 2 of our machines are dual head, dual material printers that we recently purchased and cost nearly $10,000 per machine. We also have 3 MakerBot Mini printers, which are far less expensive to purchase. When I first began using this project, we only had 2 of the MakerBot Mini machines, this was sufficient to be able to run this project.

To test our designs, I created a test track consisting of two parallel lanes of approximately 10 pieces of toy track, placed on an inclined plane.

Equipment

- Engineering notebook (paper or digital)
- Pencil
- Graph paper
- Scale or Triple-beam balance
- Dial Caliper
- Toy train/car track
- Linking cube *(optional)*
- Large paper clip
- Coins: 1 penny, 1 nickel, 1 dime, 1 quarter
- 3D printer

Procedure

Step 1 - Identify the Problem

1. Create a Design Brief for the Mini Car Design Challenge.
    a. If you are not familiar, a Design Brief is a document that identify and defines the problem. Information in this document would include: a statement of the problem, identification of stakeholder groups, and identification of the criteria/constraints for the problem.
    b. Design Criteria:
        - Design must consist of 3 parts: body, chassis, wheels
        - Each partner must design their own body
        - Bodies must share chassis and wheels
        - Car can be no larger than: 3”L x 1.5”W x 1.75”H (assembled)
        - Diameter of wheels must be at least 0.75”.
        - Wheels of the car must fit on wooden tracks.
        - Car must use large size paperclip for axles.
        - Car must securely hold at least 3 coins.

Step 2 - Research and Brainstorming

Research

1. *(Optional)* Perform a functional analysis on a Linking Cube. Be sure to pay close attention to the function of the product’s connectors.
    a. Create an isometric pictorial of the product and label the individual components. If you are not sure what a particular component is called, then make a logical guess.
    b. Create a scaled multi-view sketch of the product.
    c. Use a dial caliper to inspect the components of the product.
    d. Add necessary dimensions on your multi-view sketch.

2. Perform a function analysis on the toy train/car track.

    a. Create an isometric pictorial of the product and label the individual components. If you are not sure what a particular component is called, then make a logical guess.
    b. Create a scaled multi-view sketch of the product.
    c. Use a dial caliper to inspect the components of the product.
    d. Add necessary dimensions on your multi-view sketch.

3. Interoperability analysis.
    a. Use a dial caliper to find the diameter of the wire used to make a paperclip.
    b. Use a dial caliper and scale or triple-beam balance to find the diameter, thickness, and weight of the coins listed on the Equipment list.

4. Tolerancing Information
    a. Include the information provided by your instructor about tolerancing axle holes, connectors, and cavities

Brainstorming

1. Create concept sketches for car body, chassis, and wheel designs.
2. Brainstorm ways to secure coins and connect body and chassis.

Step 3 - Select a Solution

1. Meet with design team member to develop chassis design.
2. Create annotated, detailed technical sketches (multi-view) of car parts.
    a. include section views where necessary
3. Create final design sketch of Mini Car design.
    a. can be drawn as exploded assembly if necessary

Step 4 - Model and Construct a Prototype

1. Create part models in Inventor for your car body, chassis, wheel, and axle.
    a. don’t forget to make an axle
    b. export part files as .STL files for 3D printing (except axle)
        i. put desired print color in .STL file name
2. Create and annotate multi-view drawings of each car part in Inventor.
    a. dimension drawings to the best of your ability
    b. Must include at least 1 section view drawing
    c. Must include at least 1 detail view drawing
3. Create assembly and exploded assembly models in Inventor.
4. Create a Bill of Materials drawing
5. Generate .PDF of multi-view drawings and BOM.

6. Submit all Inventor files to instructor for grading.
7. In your Engineer's notebook, keep track of modifications you make to your final design. Each modification should include:
    a. A written description and justification of the modification
    b. Annotated sketching of the modification when necessary
8. Also in your Engineer's notebook, include a printed Exploded Assembly from Inventor and a printed picture of the assembled car. Take this photo of the assembled car in an isometric view using your phone. Prints should be in color.

Step 5 - Test and Evaluate your Solution

1. Assemble pieces of Mini Car.
2. Perform time trial testing on test track.
    a. Load car with 3 different weight combinations (coins) and time car with each combination at least 5 times. Weigh the car with the coins in it for each of the 3 combinations.
    b. Record time trials in Excel.
3. Find statistics related to test data to include the following:
    a. Mean, median, mode, range, and standard deviation of the time trials for the first weight combination.
    b. The mean of the time trials for the second weight combination.
    c. The mean of the time trials for the third weight combination.
4. Using Excel, create a scatterplot and find a trend line for the relationship between *weight combination* (independent variable) and the *average time trial* (dependent variable). You will have three data points: (1- average time trial for first weight combination), (2 - average time trial for second weight combination), and (3 - average time trial for third weight combination).
5. Use the equation of your trend line to answer the following questions.
    a. Predict the time trial for your car if it were weighted with <u>55 grams of coins</u>.
    b. Predict the amount of coin weight of a car with an average time trial of .75 seconds
6. Create a final write up containing the following items:
    a. Explanation/Justification of design
    b. Testing results and interpretation
    c. Modifications and redesign

Step 6 - Present your Solution

1. With your partner, prepare a 3-5 minute presentation for your Mini Car design to include the following:
    a. Introduction of challenge
    b. Reverse Engineering
    c. "Sales" Pitch
    d. Brainstorming
    e. Inventor Models

f. Testing and Redesign