Solar Car Body Design

Course: EML 4451/2, Senior Design

Instructor: Dr. Cesar Luongo

Customer: Dr. Thomas J. Harrison

Team Name: 3DSCBT (3D Solar Car Body Team)

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Abstract

This report explains the tasks completed by the ME Senior Design Solar Car Body Team during the 2001-2002 academic year at the Florida Agricultural & Mechanical University – Florida State University College of Engineering (FAMU-FSU CoE). It begins with an background information regarding the FAMU-FSU CoE's Solar Car Team and the process it uses to construct the mold for a solar car. Next, information regarding the scope and deliverables of the project is presented. The scope of the project involves, using two longitudinal profiles to create the following deliverables:

- 2D latitudes used in creating the plug, or wooden framework of the mold for the solar car
- a 3D CAD model of the solar car's mold
- a step-by-step process for creating 2D latitudes and a 3D CAD model from two longitudinal profiles
- a tangible scale model of the solar car's mold
- a chassis that fits inside of the solar car

Following that is an in-depth description regarding the design constraints, end-product description, and technical approach for each deliverable. The report concludes and is followed by relevant appendices referenced throughout the report.

Introduction

Background

Every year during the month of May, collegiate solar car teams from across the country gather in Topeka, Kansas to compete in the Formula Sun Grand Prix. The Florida Agricultural and Mechanical University – Florida State University College of Engineering's (FAMU-FSU CoE) entry each year is car #30. Recently, Formula Sun, the governing body of the Formula Sun Grand Prix, has changed some of the regulations regarding the car's overall size and chassis requirements. The 3D Solar Car Body Team was formed because of the need express by Dr. Thomas Harrison, FAMU-FSU CoE's Solar Car Team's faculty advisor, to ensure that the FAMU-FSU CoE's new solar car would be compliant with these new requirements. The members of the 3D Solar Car Body Team are all graduating seniors enrolled in Engineering Design Systems I/II, which is instructed by Dr. Cesar Luongo. The 3D Solar Car Body Team's customer is Dr. Harrison.

The process to fabricate the mold for a solar car's body as described by Dr. Harrison is as follows: a wooden framework called a design plug is constructed to represent the general shape of the body. The lateral sections of the plug are called latitudes and the longitudinal section that runs down the center of the plug is called a longitude. Next, pink modeling foam is glued between the plug's latitudes and shaped by sanding it to level of the latitudes and longitude manually until the shape of the car is smooth. The smooth body is then covered with a thin coat of diluted vinyl wall spackling and sanded to create a smooth, easily painted surface. The last step in the mold creation process is sealing the male mold with several coats of paint.

For clarification, the *mold* is the same size as the *body* of the car. However, the mold is filled with foam and wood, while the body is hollow. The terms body, car, and mold are used interchangeably throughout this report.

Problem Statement

Dr. Harrison required five deliverables upon completion of this project. The first is a step-by-step process detailing the creation of a 3D CAD model of a mold for the new solar car's body from two longitudinal profiles. These profiles were developed by students in the solar car class (EEL XXX) during previous semesters using AIRFOIL 4.0 and then exported to the said AutoCAD files. The process should resemble the process for physically creating a full-scale mold as described above. In other words, the team had to develop a way to generate latitudes from the longitudes supplied by Dr. Harrison. Then the body should be created by "filling in the gaps" as outlined above. Currently, the solar car's profile is nearly constant across the width of the car (i.e. if the current solar car was cut vertically in the longitudinal direction at any distance from the edge, the profile would approximately be the same size). The canopy, which is region where the driver's head and shoulders are located, protrudes from the otherwise continuous body, increasing drag significantly. The purpose of generating a more complex shape for the body is to incorporate the canopy more smoothly into the shape of the car to reduce drag. The new solar car's profile changes drastically across the width of the car (i.e. if the new solar car was cut longitudinally at any distance from the edge, the profile would be different).

Dr. Harrison wanted the team to demonstrate that the process developed is valid by sketching the latitudes in an AutoCAD file, which is the second deliverable, and by creating a 3D CAD model in an MDT file, which is the third deliverable, The fourth deliverable is a tangible scale model to show that the computer's representation of the model accurately simulates the results of mold creation process that the Solar Car Team uses.

Finally, Dr. Harrison required that the team design a preliminary version of a chassis to fit inside the new body. The chassis is a metal framework to which components such as the suspension, driver's seat, dashboard, batteries, and body are attached. This fifth deliverable is an MDT file containing the chassis.

Deliverables

Operations Manual

Design Constraints

The operations manual *should* be a step-by-step guide detailing the process of:

- Creating 2D latitudes from an edge longitude and a centerline longitude (AutoCAD format)
- Creating a 3D model based on the 2D latitudes and longitudes (MDT Format)

The operations manual should assume that the user is an engineer familiar with 2D sketching and 3D solid modeling techniques. It *does not* assume that the user is familiar with the process used by the Solar Car Team to create a mold for the solar car and should describe this process.

End-Product Description

The operations manual *is* a step-by-step guide detailing the process of:

- Creating 2D latitudes from an edge longitude and a centerline longitude (AutoCAD format)
- Creating a 3D model based on the 2D latitudes and longitudes (MDT Format)

The operations manual assumes that the user is an engineer familiar with 2D sketching and 3D solid modeling techniques. Additionally, it also describes the process used by the Solar Car Team to create a mold for the solar car.

Note: See Appendix A for the Operations Manual in its entirety

Technical Approach

The Operations Manual was written after completing the processes it describes approximately 30 times. Additionally, screenshots (.jpg files) of each step were taken to increase the user's understanding of the steps described. The paper version of the Operations Manual references the screenshots where relevant and features a CD containing the referenced screenshots.

Note: For a downloadable copy of the operations manual see
www.eng.fsu.edu/ME_senior_design/2002/folder11/3dscb_operations_manual.pdf

2D Computer Model

Design Constraints

The team was required to develop the latitudes using the edge and centerline longitudes supplied by Dr. Harrison. The width and length of the body were specified by Dr. Harrison to be 1760mm and between 4800mm and 4850mm, respectively.

According to Section 6.1.2 of the Formula Sun Grand Prix 2002 Regulations, the solar car must fit inside an imaginary box that is 1.8 meters wide, by 1.6 meters high, by 5 meters long (ISF5000 Standard, formerly NIS Standard).

End-Product Description

The 2D computer model is an AutoCAD file containing all of the steps and iterations used to generate the latitudes.

Technical Approach

Throughout the fall 2001 semester, the team developed a process employing Pro/Engineer (Pro/E) and AutoCAD to generate latitudes. For an in-depth description of this process, see Appendix B.

At the beginning of the spring 2002 the team developed a *superior* process employing AutoCAD to generate latitudes. This process involves using the heights of the centerline and edge at the locations of the latitudes to generate the latitudes. Unfortunately, there is no concise way to describe this process. It is highly recommended that the user see the Appendix A for detailed instructions regarding creating latitudes in AutoCAD.

Note: See the photos and screenshots located at
www.eng.fsu.edu/ME_senior_design/2002/folder11/stage_1.htm

3D Computer Model

Design Constraints

The FAMU-FSU CoE Solar Car team uses 100mm square photovoltaics to collect solar energy. When photovoltaics are laminated into larger sheets to protect them from the weather, their flexibility decreases such that they are not readily bent to a radius of more than 20 inches. As a result of this constraint, the curvature of the solar car's body is something that needs to be assessed. In previous years, the only way for the Solar Car Team to make a qualitative estimation of the body's curvature was to fabricate tangible scale models by hand based on the latitudes.

End-Product Description

The latitudes created by the team have been used to define a loft in MDT, which represents the shape of the new solar car's body. A *loft* is a complex shape that is created through a series of planar closed loops or sections. In this case, the latitudes act as the closed loops. The computer model is an MDT file that serves as a tool for the Solar Car Team to qualitatively evaluate the curvature of the body. Theoretically, such a tool eliminates the time and effort necessary to create iterations of a tangible scale model. The shape of the car can easily be modified by moving existing work planes or creating new work planes to relocate the latitudes as necessary.

Technical Approach

During the fall semester, longitudinal profiles were blended in the lateral direction using Pro/E to make the first computer model of the new solar car. Because the full-scale car is fabricated using latitudes and "blending" (i.e. sanding and shaping) the modeling foam in a longitudinal direction, the team wanted to perform a blend in the same direction using the computer in an attempt to generate an even more accurate 3D model.

The team decided to create a second 3D CAD model using MDT instead of Pro/E because sketching and editing drawings was easier using AutoCAD. Additionally, AutoCAD sketches translate seamlessly to MDT. To create this new solid model in MDT, the team used the *loft* command, which is synonymous with the *blend* command in Pro/E. Recall that the latitudes' locations had been marked using colored vertical lines in the drawing of the centerline longitudinal profile. This profile was used to properly align the latitudes vertically and horizontally in the 3D workspace of MDT. Despite the team's best efforts to use each of the 11 latitudes to create the loft, no single loft could be created. According to MDT's error message, "sections U and V (were) are in the same or opposite directions". The team performed an exhaustive search of the MDT Help File but no solution to this problem was found.

Generally, for "simple" geometries, multiple sections can be used to define a loft. However, despite the simple *appearance* of the new solar car's body, the geometry proved too complex to be generated using the sections to define a single loft. Consequently, three lofts were performed to create the body.

Note: See the Appendix A for detailed instructions regarding the process of lofting in MDT.

Note: See the photos and screenshots located at
www.eng.fsu.edu/ME_senior_design/2002/folder11/3d_body.htm

Tangible Scale Model

Design Constraints

Dr. Harrison stipulated no specific constraint, but stated that the model must be sized sufficiently to be able to make a qualitative assessment of the body's curvature. Dr. Harrison recommended the following method for fabricating the design plug:

1. Plot the full-size latitudes and longitude at a smaller scale
2. Cut them out
3. Glue them to 3mm Birch plywood
4. Cut them out of the plywood using a scroll saw

To complete the model, Dr. Harrison recommended the process of filling and coating the plug as described in the Background section of the Introduction of this report.

End-Product Description

The model is 1:10 scale and accurately represents the curvature as shown by the MDT model. It serves as a tool to qualitatively assess the curvature of the new solar car's body.

Technical Approach

The first step taken in creating the scale model was redrawing the full-size latitudes and centerline longitude drawn in AutoCAD at 1:10 scale and plotting them on white paper. Next, they were cut out and glued to 3mm Birch plywood. Each shape was then cut out using the scroll saw located in FAMU-FSU CoE's Machine Shop. The centerline longitude was cut into two pieces to facilitate plug construction.

Then, the latitudes were glued individually to the bottom portion of the centerline. Once the latitudes were dry, the top portion of the centerline longitude was glued onto the latitudes to complete the plug.

Next, blocks of pink modeling foam were cut and sanded until they fit snugly into the gaps of the plug. They were glued in place to prevent them from dislodging during the shaping process. After the glue was dry, the blocks of foam were shaped by sanding them to the heights of the latitudes. Next, vinyl wall spackling was diluted to the consistency of heavy cream using water and painted over the foam with a brush. Several coats were applied until all of the irregularities disappeared. Once the layers of spackling were dry, the model was sanded until smooth. Finally, several coats of spray paint were applied to enhance the model's appearance.

Note: See the photos and screenshots located at
www.eng.fsu.edu/ME_senior_design/2002/folder11/plug_construction.htm
www.eng.fsu.edu/ME_senior_design/2002/folder11/sanded_foam.htm
www.eng.fsu.edu/ME_senior_design/2002/folder11/coated_foam.htm

Chassis

Design Constraints

The new chassis must fit inside the solar car's new body. The current chassis was designed to accommodate a front suspension consisting of two A-arms and a rear suspension consisting of two L-shaped arms. In previous years, the solar car team noticed that there was significant deflection at the rear portion of the chassis due to the configuration of the rear portion of the chassis. The team discussed a change in suspension from the current system to a system employing 4 A-arms Dr. Harrison. The team reasoned that since no visible deflection had ever occurred at the front of the chassis, the best option would be to design the new chassis assuming the use of 4 A-arms. Dr. Harrison agreed that a suspension system featuring 4 A-arms would be a valid approach to designing the new chassis.

End-Product Description

The new chassis fits inside the solar car's new body and assumes a suspension system consisting of 4 A-arms. The chassis is stored in a MDT .dwg file.

Technical Approach

The first step taken to design the chassis was determining the distance between the suspension's A-arms, which determines the width of the chassis. The distance between the A-arms is a function of two things: spat size and spat location relative to the edge of the car. The size of the spat is related to the maximum turning angle of the front wheels, which is 27 degrees according to the solar car steering team. The team rotated the wheels to 27 degrees in either direction and redrew the spats to accommodate the wheel in either configuration with a clearance of 12mm. The new spats were then located 50mm from either edge of the car, as specified by Dr. Harrison. Next, the A-arms were added to the drawing and the distance between them was measured. This d

Of course, the chassis must not protrude through, interfere with, or touch the body of solar car. To prevent this, a 3D spatial constraint needed to be constructed. To do this, a rectangle the width of the chassis was drawn inside each latitude in AutoCAD. These rectangles were then located in the 3D workspace of MDT. To further ensure that no interference occurred between the chassis and body, these rectangles were offset a distance of 50.8mm.

Upon inspection of the current A-arm assemblies, it was determined that the portions of the chassis to which the A-arms would be attached needed to be horizontal. The 2D drawings of the spat/wheel/A-arm assembly were inserted in MDT to determine the locations where of the horizontal sections. Once the locations and lengths of the horizontal sections were determined, the chassis was drawn. (picture). Originally, the driver's compartment was too narrow in the estimation of the team, so it was widened to accommodate a driver more easily.

The steel tubing of the chassis stands is far less susceptible to failure when the tubing completely in compression or tension. Cross bracing was added to triangulate the compartments of the chassis. Triangulation of chassis compartments serves to transform all forces and moments on the chassis into compressive and tensile forces in the cross bracing.

To give the chassis a more realistic feel, the lines that represent the vertical and horizontal components of the chassis were used as the trajectory for a sweep. A sweep is created by sketching or selecting a trajectory and then sketching a section to follow along it.

<u>Note</u>: See the photos and screenshots located at

www.eng.fsu.edu/ME_senior_design/2002/folder11/swept_chassis.htm

Recommendations

Driver Location

It is recommended that the driver be moved rearward for several reasons. First, moving the driver will accommodate the new cable-based steering assembly. Currently, the driver's legs interfere with the new steering assembly. Unfortunately, this interference could not be helped because the steering team was designing the *new* steering assembly based on the *current* chassis. The chassis's configuration changed as a result of the body's shape changing. Second it will be easier to widen the driver's compartments in the chassis if the driver is moved rearward. The slope of the sides of the car is greater towards the middle of the car, which allows for a wider driver's compartment.

Chassis Width

The width of the chassis is a function of the wheelbase because the wheelbase determines the maximum steering angle of the front wheels. The wider the steering angle, the farther in the location of the wheel/steering/A-arm assembly and the narrower the chassis. The spat width is determined by the steering angle of the front wheels. The outer edges of the spats are located laterally 50mm from the edges of the solar car. The location of the wheel/steering spindle/A-arm assembly is determined by its location within the spat.

Closing Remarks

The 3D Solar Car Body Team was able to create the aforementioned deliverables by using time management, teamwork skills and maintaining close contact with the customer, Dr. Thomas Harrison, and the instructor, Dr. Cesar Luongo. Finally, the 3D Solar Car Body Team gained an more realistic perspective regarding the dynamics of a professional level engineering project upon completion of this course. The team also networked with Russ Lepisto and Eric Guttormson of 3M's AutoCAD Help Desk and with Dr. Yousef Haik and Dr. Pat Hollis of the FAMU-FSU CoE to gain a deeper understanding of the intricacies of MDT and Pro/E, respectively. The team increased its existing sketching and CAD skills as each task was completed during this project. The team used two longitudinal profiles to create the following deliverables:

- 2D latitudes used in creating the plug, or wooden framework of the mold for the solar car
- a 3D CAD model of the solar car's mold
- a step-by-step process for creating 2D latitudes and a 3D CAD model from two longitudinal profiles
- a tangible scale model of the solar car's mold
- a chassis that fits inside of the solar car

References

- Pro/E 2001 Help File
- AutoCAD 2002 Help File
- Mechanical Desktop 6 Help File
- *Race Car Chassis Design* by Forbes Aird

Appendix A: Final Operations Manual (Spring 2002)

See

www.eng.fsu.edu/ME_senior_design/2002/folder11/3dscb_operations_manual_web.pdf

Appendix B: Preliminary Operations Manual (Fall 2001)

See

www.eng.fsu.edu/ME_senior_design/2002/folder11/3dscb_final_report_fall01_web.pdf