AC 2007-304: DEVELOPMENT OF CAE COURSE PROJECT FOCUSING ON DATA MANAGEMENT THROUGH WINDSHIELD WIPER SYSTEM DESIGN

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Development of a CAE Course Project Focusing on Data Management through a Windshield Wiper System Design

Abstract

Computer Aided Engineering (CAE) has been a core course for Mechanical Engineering students at Kettering University. This paper presents an approach to develop a team project for the CAE course. The approach addresses Project Data Management (PDM) through an automotive windshield system design and analysis. The purpose of the course project is to learn how to manage teamwork and share data when working on assemblies and their related parts. Automotive windshield wiper systems are used in vehicles to remove contaminants such as rain, sleet, snow and dirt from the windshield. A typical wiper system consists of an electric motor, a linkage mechanism to transform rotational motion from the motor to oscillatory motion and a pair of wiper arms and blades. Such an assembly is representative in terms of complexity for a mechanical system and therefore ideal for this course project. Each project team sets up a "configured project" including Roles, States, Approval Process, Library and Catalogue. Each team member is responsible for several parts design or analysis. Through data sharing and iteration of all team members, the wiper system assembly is optimized to meet the given technical specifications. Kettering is a member of the Partners for the Advancement of CAE Education (PACE) program, and the CAE team project will be performed in our PACE Laboratory equipped with advanced workstations and CAE software suite.

Introduction

Computer Aided Engineering, often referred as CAE, is the use of computer technology in engineering tasks such as design, analysis, simulation, manufacture, planning, and diagnosis. CAE includes, but is not limited to, the following areas:

- Computer Aided Design (CAD) such as solid modeling and assembly modeling;
- Stress analysis of components and assemblies using Finite Element Analysis (FEA);
- Thermal and fluid flow analysis (CFD – Computational Fluid Dynamics);
- Process simulation in manufacturing such as casting, molding and forming;
- Computer Aided Manufacturing (CAM) such as graphic numerical control and SLA; and
- Optimization of products and /or processes.

The course learning objectives (CLO) of CAE (MECH-300) offered at Kettering University can be described as follows. Upon completion of the CAE course students will be able to:

- Apply the fundamental principles of statics and mechanics of materials;
- Apply modern analytical techniques to mechanical systems;
- Apply computational techniques to mechanical systems; and
- Demonstrate effective communication skills through technical presentations and reports.

During the first three weeks of the 11-week CAE course, students learn solid modeling, sketching, assembly modeling, drafting, parametric design and inter-part modeling. FIGURE 1 depicts an automotive door hinge. Students are required to design the inner hinge, the outer

hinge and the hinge pin. All parts in the assembly have to be mated properly, so that the outer hinge is allowed to rotate unobstructed around the hinge pin by at least 180 degrees. Expressions and control parameters are set at the assembly level so that the whole assembly can be resized automatically based on the outer hinge opening and hinge pin diameter.
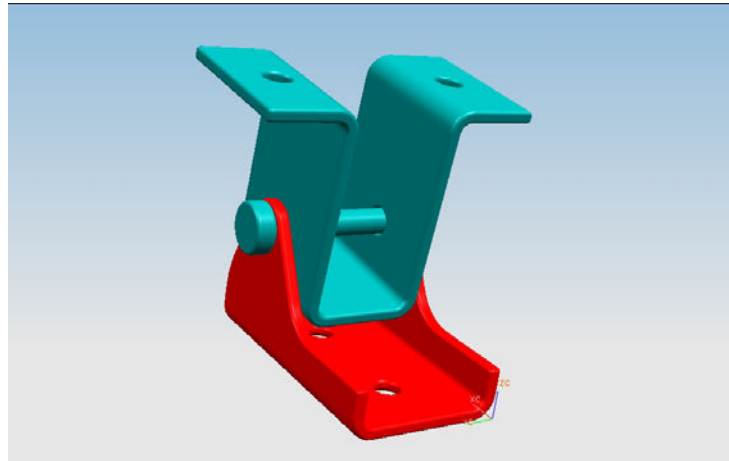

FIGURE 1 – AUTOMOTIVE DOOR HINGE ASSEMBLY

In the following weeks, the main focus is Finite Element Analysis (FEA). The fundamental techniques of FEA are introduced and applied to various structural components. Students in the class perform analytical calculations based on solid mechanics approaches, and compare the solution to the numerical simulations based on FEA. FIGURE 2 shows the stress contour plot of a hook under a load in z-direction. In this problem, one can see that an analytical solution can over simplify the situation when compared to results obtained from an FEA. Similar situations exist in the caster FEA (FIGURE 3) and clamp FEA (FIGURE 4) homework assignments.
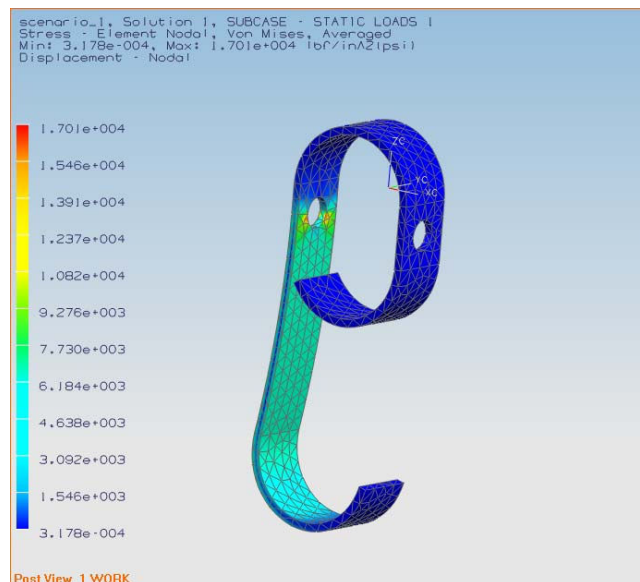

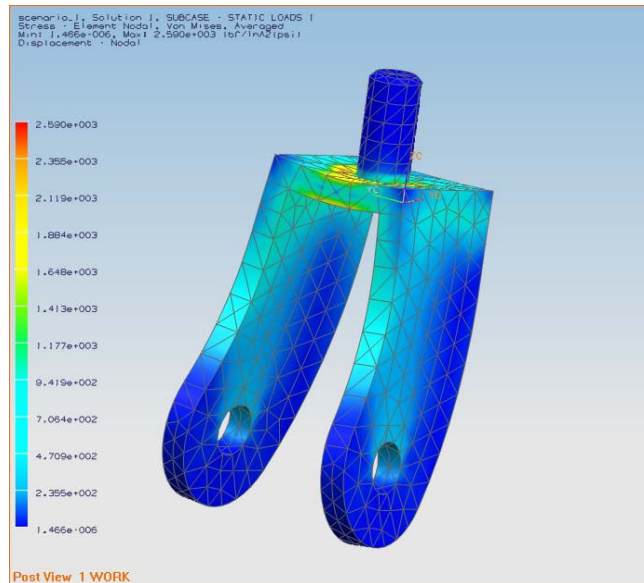**FIGURE 2 – FINITE ELEMENT ANALYSIS OF A HOOK**

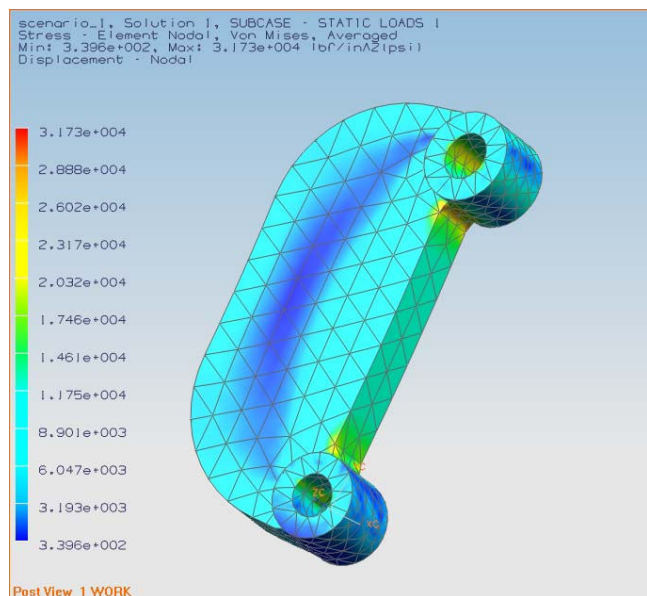**FIGURE 3 – FINITE ELEMENT ANALYSIS OF A CASTER**

FIGURE 4 – FINITE ELEMENT ANALYSIS OF A CLAMP

Currently, an individual student term project is assigned to the class and students work on it from the 5th week all the way to the 11th week. The project is the design and engineering analysis of an "Impeller Assembly". It consists of two parts. Part 1 focuses on solid modeling and is based on UGS training course material [1]. Part 2 concentrates on finite element structural analysis. FIGURE 5 shows the impeller assembly designed by students during the course. The assembly is fully parameterized so students can change,   for example, the size of the housing and the number

of holes in the housing, and the impeller assembly will automatically change in order to accommodate the new requirements for dimensional changes plus the number of bolts and nuts.

FIGURE 5 – IMPELLER ASSEMBLY (WITH EXPLODED VIEW)

FIGURE 6 shows some results for FEA simulations of the impeller assembly shaft. As it can be seen in the figure, students can access the maximum levels of stresses in the parts and make a decision if a design change is needed. If that is the case, they have to decide which change is suitable to the application, such as a dimensional change or a change in material, for instance. Since parametric design is used, the assembly is easily adjusted to the new parameters. The completed project includes initial assembly, analysis, results, changes made and final assembly.
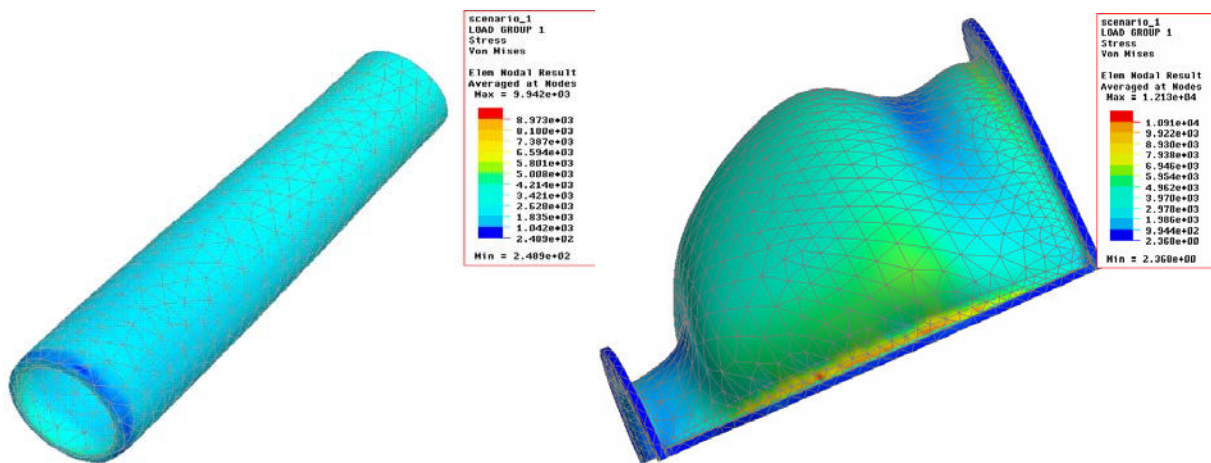

FIGURE 6 – FEA ANALYSIS FOR IMPELLER ASSEMBLY PARTS

The aforementioned *individual course project* has been a great exercise for the CAE students to apply the knowledge gained during the course. Yet, quite often in real world product development situations, engineers have to work concurrently as a team on the same assembly project. This raises the issue of project data management, which is currently not addressed in this course. In order to address this problem a team course project is suggested in the following. The purpose of this proposed course project is to show how to manage and share data when working

on assemblies and their related parts with other team members. Project Data Management (PDM) is used through an automotive windshield system design and analysis.

Proposed New Project

Windshield Wiper Systems

Automotive windshield wiper systems, in conjunction with washer systems, are used in vehicles to remove contaminants such as rain, sleet, snow, and dirt from the windshield. As shown in FIGURE 7, a typical wiper system consists of an electric motor, a linkage to transform the rotational motion from the motor to oscillatory motion, and a pair of wiper arms and blades [2, 3]. The areas of the windshield that must be wiped by the wiper system are mandated by FMVSS 104 [4].
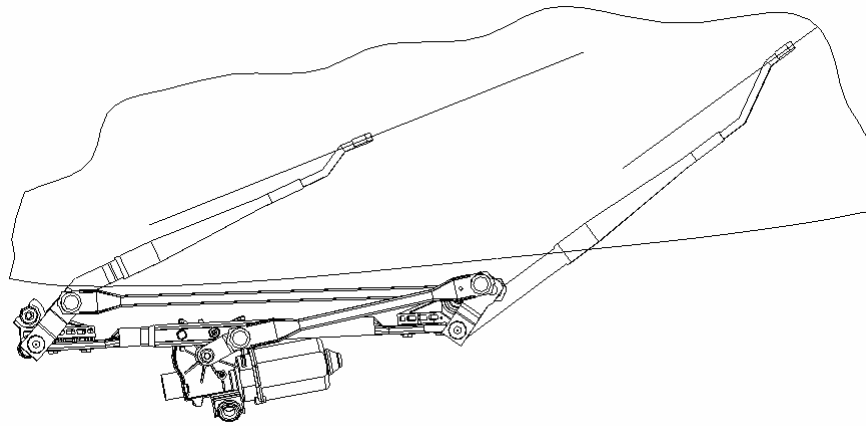

FIGURE 7 – A TYPICAL WIPER SYSTEM

The design of a typical wiper system starts with the technical specifications of the OEM car maker. Given a particular application platform, the geometry of the windshield glass is known. Based on the requirement dictated by FMVSS 104, the lengths of the wiper blades and wiping angles can be determined. Then based on wiping speed and blade-glass frictional loads, the wiper arms and blades can be designed. The linkage mechanism can be designed based on the kinematics, structural strength, wiping angle, and system packaging requirements. The electric motor can be chosen according to the energy required by the wiper system.

Principles of Project Data Management [5] (PDM – using UGS – I-DEAS® [6])

A. Model Files and Bins

All work is done in model files. This includes part or assembly creation, modification, analysis, drafting and checking items into a library (virtual library in the software system). It is easier to use "bins" to manage the contents of a model file. Bins are directories where items are stored. When one wants to remove an item from the workbench, it should be named and then "put away" into a bin, either the default "Main" or a newly created one. When one needs to look at

the item again, one "gets" it from the bin and puts it on the workbench. In summary, the model file is a "private space" and all private data is stored there.

B. Projects, Libraries, and Catalogs

Libraries and catalogs are by definition "shared" resources with the purpose to facilitate and manage team work. When one wants to share data while working on assemblies and their related parts, a project library is selected to store these items. Once this done, the items no longer "belong" to the initial designer and can be modified by anyone who has "permission" to access the project. Items can be checked in and out of libraries.

C. PDM Rules

- There are two kinds of data, namely, shared and not shared. Shared data is in the libraries/catalogs, and non-shared data is in model files.
- Only library data should be shared. Model file data is not to be shared (by copying files back and forth between systems).
- All useful data is to be stored in a library (model files are temporary).
- Only one user can have an item checked out, but many users can reference or copy an item.
- Moving or renaming model files at the operating system level is not allowed.

Steps of Project Data Management (PDM)

A. Project Configuration Setup – Project Manager

For the CAE course, the project team can be set to consist of five members including the project manager. Each member has a role defined as follows:

1. **Project Manager (PM)** - creates the team library and the wiper assembly file;
2. **Project Team Member 1 (PTM1)** – creates and modifies the blades and arms;
3. **Project Team Member 2 (PTM2)** – creates and modifies the linkage members;
4. **Project Team Member 3 (PTM3)** – created and modifies the frame and pivot assembly;
5. **Project Team Member 4 (PTM4)** – creates and modifies motor and packaging interfaces.

The project manager will be responsible for assigning the roles and states of all members, create the assembly file and library for the project, obtain design specifications and participate in every member's design and calculation of his/her respective parts. The overall assembly will be referenced and updated from the library by every team member who will create subassemblies under the overall assembly.

> *PM (procedure):*   *File – import – windshield glass (unit: mm)*
>   *Design the wiping pattern* (FIGURE 8)
>   *Check-In Library: Wiper System Parts (Keep to modify)*
>   *File – Save*
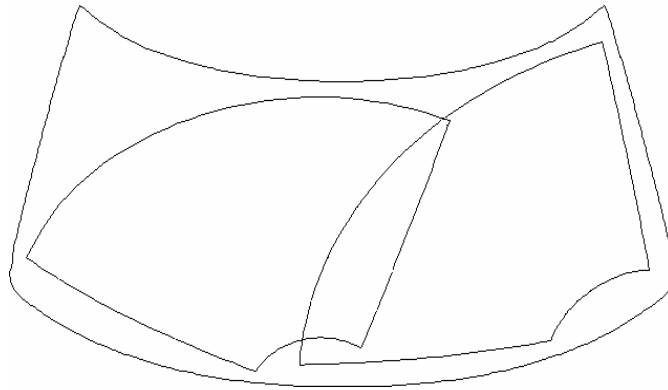>   *Inform other PTMs that they can get started.*

FIGURE 8 – WIPING PATTERN

B. Arms and Blades – PTM1

A typical wiper arm and blade structure is shown in FIGURE 9. The arm head transmits motion from the linkage and the arm retainer/rod provides the blade with a down force (commonly referred as tip force) that controls the pressure between the blade and windshield glass. The claws hold the blade and apply an even pressure distribution. The primary function of the wiper arm and blade is to clean the windshield. As shown in FIGURE 8, the wiping pattern of the wiper system on the glass dictates the wiping angles of wiper arms/blades on both the drive side and passenger side, as well as the lengths of the blades. Based upon the tip loads and frictional coefficient, the arms and blades can be designed.

FIGURE 9 – ARM AND BLADE ASSEMBLY

PTM1 (procedure):   *File – Open: wiper armblade (unit: mm)*
Get from Project Library: Wiper System Parts
Windshield glass (Reference)
Get the Part from Bin into Workbench
Design the arms and blades
Name the parts: driver side arm, driver side blade,
passenger side arm, passenger side blade
Check-In Library: Wiper System Parts (Keep to modify)

C. Mechanism – PTM2

FIGURE 10 depicts a linkage member of the wiper system. The wiper linkage mechanism can be designed based on the kinematics of the system. The "driver" of the linkage mechanism is the crank arm which is mounted on the output shaft of the electric motor. The driver rotates continuously and transmits energy from the motor to the linkages. The "slaves" of the linkage mechanism are the levers that are fixed on the pivot shafts. Therefore the input to the system is continuous motion from the driver and the output is oscillatory motion of the pivot shafts. The linkage mechanism can be designed given the input and output. It includes two levers, one operating link and one motor drive link. The base linkage bar is typically made of steel via a stamping process. The cross-section is commonly designed as a U-shape in order to achieve the desired inertia and structural rigidity. The spherical sockets at both ends of the linkage are over-molded plastic parts to provide for ball-socket joints.

FIGURE 10 – A LINKAGE ASSEMBLY

PTM2 (procedure):   *File – Open: linkage (unit: mm)*
Get from Project Library: Wiper System Parts:
windshield glass (Reference)
driver side arm (Reference)
passenger side arm (Reference)
Get the Parts from Bin into Workbench
Design the linkages and levers
Name the parts: lever1, lever2, operating linkage, motor drive linkage
Check-In Library: Wiper System Parts (Keep to modify)

D. Frame and pivot assembly – PTM3

The wiper arm and the lever are mounted on the pivot shaft that is located in the pivot housing assembly (FIGURE 11). The pivot housing assembly includes grommet, retainer, washer, O-ring, bearings, spring washers, pivot shaft, lever and ball stud. The components in the pivot housing assembly must be able to withstand the load of the wiper system. The wiper system is mounted onto the vehicle though the mounting holes on the pivot housing. Grommets are commonly used to provide a certain level of system compliance under load and reduce noise transmitted to the vehicle.
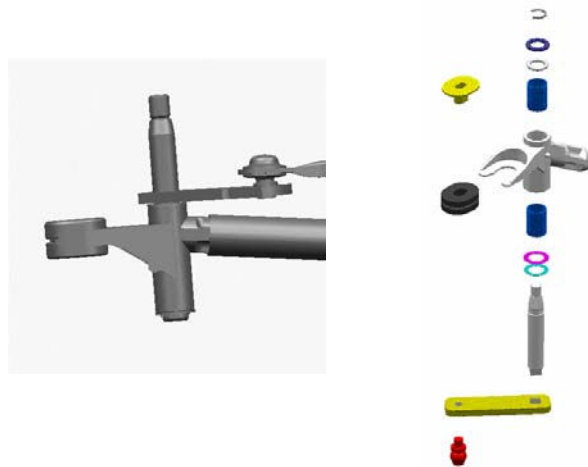
FIGURE 11 – FRAME AND PIVOT HOUSING ASSEMBLY

PTM3 (procedure):	*File – Open: frame (unit: mm)*
	Get from Project Library: Wiper System Parts
	windshield glass (Reference)
	driver side arm (Reference)
	passenger side arm (Reference)
	lever1 (Reference)
	lever2 (Reference)
	Get the Parts from Bin into Workbench
	Design the pivot housings and frame
	Name the parts: pivot housing1, pivot housing2, frame
	Check-In Library: Wiper System Parts (Keep to modify)

E. Motor and Packaging Interface – PTM4

The detailed design of the electric motor is not within the scope of this project. Instead, team member 4 will create a "dummy" motor (the shell) for packaging purposes (as shown in FIGURE 12). A crank arm with a ball stud is mounted on the motor output shaft serving as the driver for the wiper system. Team member 4 is also responsible for the packaging of the wiper system in the vehicle, including clearance check (often referred to D-Spec).

PTM4 (procedure):	*File – Open: motor (unit: mm)*
	Get from Project Library: Wiper System Parts
	frame (Reference)
	operating linkage (Reference)
	motor drive linkage (Reference)
	lever1 (Reference)
	lever2 (Reference)
	pivot housing1, pivot housing2

Get the Parts from Bin into Workbench
Design the crank arm and motor
Name the parts: crank arm, motor
Check-In Library: Wiper System Parts (Keep to modify)

FIGURE 12 – ELECTRIC MOTOR WITH CRANK ARM

F. Assembly Creation

At this point a first version of all wiper system parts is checked in the project library and available for assembly. Some of the parts may still undergo changes, but the library versions can be referenced and the assembly can be updated automatically.

PM (procedure):   *Get from Project Library*
Wiper System Parts: windshield glass, driver side arm, driver side blade, passenger side arm, passenger side blade, lever1, lever2, operating linkage, motor drive linkage, pivot housing1, pivot housing2, frame, crank arm, motor (Reference)
Get the Parts from Bin into Workbench
Switch to the Assembly Task
Use the Hierarchy to Create Top-level Assembly: "wiper assembly"
Check-In Library: Wiper System Parts (Keep to modify)

All PTMs can modify their parts and check the new versions into the project library. Re-designs or new parts should reference the assembly so that one can design parts in the team assembly context. All parts are owned (checked out) by their respective designers. It is good practice to check finished parts back into the library. This procedure allows other users to make design changes.

The PM should check to verify what parts are out of date (using Manage Bins to check the status of the parts and assemblies in the model file) and update the assembly from the library. Note that any versions of parts or assemblies that are out of date will have an asterisk in the status column.

Structural FEA – All team members

All team members need to perform FEA on the major components of the system (for maximum system load). The wiper system experiences maximum load in critical stall conditions where the electrical motor has a maximum stall torque. The boundary conditions can be set by fixing the arms and blades and by applying the stall torque at the crank arm. For a typical application, the electrical motor has a stall torque of 40 Nm.

Conclusions

The proposed team project for the CAE course addresses Project Data Management (PDM) through an automotive windshield system design and analysis. The purpose of the course project is to show how to manage and share data when working on assemblies and their related parts with other team members. Each project team has five members and a set-up with a "configured project" including Roles, States, Approval Process, Library and Catalogue. Each team member is responsible for several parts design and analysis. Through data sharing and iteration of all team members, the wiper system assembly can be optimized to meet given technical specifications. As the project is implemented, archive files and examples will be available at the following website: www.kettering.edu/~amazzei/mech_300_page.htm.

References

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