Use of technology and software in the classroom - Active learning and project-based learning

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ABSTRACT
The work presented in this paper is in continuation of an earlier paper presented at the ASEE2014 NCS Conference held at Oakland University, MI [1] in which analysis of a tile winding machine structure was considered. Math and CAE tools were used for this purpose. The main purpose of this work is to analyze the structure of the same machine to understand the factors contributing to the large deflection of the shaft during operation and to propose a new design. Using the active learning tools mainly in the form of discussions and questions and answers (Q&A) and project based learning, this real life application was assigned as a final project to one of the students group of finite element analysis (elective) course that the second author taught. The students are to analyze the cause of the problem, discuss it using the Q&A sessions and then to look for a solution to redesign the structure. Since cost is also important, they have to propose a low cost device although detailed cost analysis was not required. Some (trial and error) optimization was expected to be carried out. One-dimensional beam and frame models were used and the solution by direct stiffness method is carried out by MatLab, and NX CAE tools. Finally, preliminary calculations were done by mechanics approach using EXCEL. From an observation of the results, a design change of both the function and size of the structural elements is attempted. The learning experience of assigning this real life application as a final project to the senior undergraduate and graduate students is discussed briefly.

INTRODUCTION
In this project, plastic pipe winders used to coil the tile (corrugated hollow pipes) is discussed first. The problem with the original design of the machine was excessive deflection and so was not usable without modification of its design. Students of finite element analysis course were assigned this as a project to analyze the cause of the problem, then to look for a solution to redesign the supporting structure. Since cost is also important, they also have to investigate for different design ideas that reduce the cost of the structure and to redesign it. Students are also expected to discuss among themselves, read literature to obtain data, make assumptions to simplify the complexities involved in the problem and justify those. They should also use a CAE tool such as NX 9.0 to model and analyze the final chosen system and validate some of the critical results by mechanics approach. These requirements promoted active learning

environment after a brief period of resistance to think independently. There are many uncertainties and ambiguities about the assembly connections of the actual machine, and their modeling using the CAE and math tools, as well as obtaining the necessary data for analysis.

Figure 1 shows an example of a tile (or corrugated tube) used just above the ground or underground to move water away from a house in to the field [2]. At the manufacturing and packaging stage of this tube, a machine is needed to wind (coil) it tightly around a spool. Figure 2 shows the example of a commercial winding machine [3]. It contains an integrated wheel on the left with spool or (shaft) that rotate together as one unit, and a removable wheel on the right. However, the right wheel also rotates as one unit with the left wheel. The entire rotating unit of the machine along with the coil can be observed to closely match the support conditions of a cantilever beam.

Figure 1: Commercial corrugated plastic tube [2]

Figure 2: Example of a commercial plastic tube coiling machine [3]

In summary, the requirement in the design of the machine is such that the wheel at free end should be removed easily and quickly so that the fully coiled bundle along with the spool can be removed for packaging and distribution.

Students discussed several alternative modeling methods to model the winding machine for analysis by using mechanics approach as well as by a math and CAE tool. This follows one of the active learning models of teaching and learning that focuses the responsibility of learning on learners. As mentioned in the literature, this model was popularized in the 1990s by its appearance on the Association for the Study of Higher Education (ASHE) report (Bonwell & Eison 1991). In this report they discuss a variety of methodologies for promoting "active learning". They cite literature which indicates that to learn, students must do more than just listen: They must read, write, discuss, or be engaged in solving problems. It relates to the three learning domains referred to as knowledge, skills and attitudes (KSA), and that this taxonomy of learning behaviors can be thought of as "the goals of the learning process" (Bloom, 1956). In particular, students must engage in such higher-order thinking tasks as analysis, synthesis, and evaluation [4 - 6] Active learning engages students in two aspects – doing things and thinking about the things they are doing (Bonwell and Eison, 1991). Some of these principles apply in undertaking the current project based problem.

Machine structure analysis and EXCEL calculation [7]

The winding coil machine composed of the following components: steel frame, shaft, spool, pipe, wheels. However, we only use shaft, spool, pipe, wheels weights and loads to calculate the total deflection at the free end of the coil machine. Standard beam tables available in the literature are used for this purpose.

Based on class room discussions, think-pair-share, collaborative learning and debating to justify one's own findings, the students were able to arrive at rough data to be used for analysis of the machine:

Length of coil: 3.00 meter
Weight of shaft: 425 N
Weight of spool: 1895 N
Weight of left steel wheel of coil: 1550 N
Weight of right aluminum steel of coil: 534 N
Tile (tube) loads: 5560 N

Based on few sample calculations and the formulas for determining the deflection and stress the students were able to estimate the end deflection of the spool using the mechanics approach. The deflection due to the self-weight of the shaft, left and right wheels and spool itself remain unchanged and they do not vary. However, the weight of tile (tube) as it winds up from empty to full condition will change as time goes causing additional deflection. When full, it weighs around 5560 N.

All calculations are based on few assumptions as follows:

1. The frame itself is a rigid body,
2. Material properties are assumed to be linear and elastic,
3. Some weights are concentrated while others are distributed; for example, self-weight is represented as distributed load.

Following data from Table 1 has been inputted in to Excel software. Table 2 shows other dimensions and section property calculations. All values are rounded up and so are not exact.

Table 1: Transferred loads of spool, pipe (tile), shaft, and wheel

	Value	unit
Density of seamless steel shaft	7850	Kg/m^3
Density of aluminum	2700	Kg/m^3
Distributed load on spool	0.672531	KN/meter
Distributed load on pipe	1.972823	KN/meter
Distributed load on shaft	0.22476	KN/meter
Total load including pipe and spool	2.645336	KN/meter
Weight of right aluminum wheel	0.533969	KN
Weight of left steel wheel	1.552465	KN

Table 2: Other geometric and section data of the winding coil machine

	Value	unit
Shaft outer radius	0.03175	meter
Shaft inner radius	0.01905	meter
Length shaft	1.5748	meter
Spool outer radius	0.0381	meter
Spool inner radius	0.03175	meter
Area moment of inertia of shaft	2.89E-13	m^4
Elastic modulus of cold rolled angle iron coiler	2E+08	KPa
L1 (length between left wheel of coiler and bearing house)	0.13716	meter

Figure 3 shows assembly view of the winding machine as the spool is being wound causing variable load on the shaft. Here, the left side wheel and the spool form a cantilever system that is susceptible to excessive deflection, thus necessitating a need for a new design of the support structure on the free end.

Figure 3: Assembly view of the winding coil machine, wheels, and spool [3]

The students performed separate calculations for obtaining total deflection at free end of coil by understanding that they can use the principle of superposition by dividing that task in to four different parts: deflection caused by right aluminum wheel, deflection caused by left steel wheel, maximum deflection from spool and pipe, and maximum deflection from shaft. This activity engaged all students of the group to participate in using the standard beam deflection tables [7]. They did these calculations by hand and by excel first to obtain the end deflection at the right wheel due to individual loading elements. The results are as follows:

Deflection caused by right aluminum wheel only: 0.01655 meter;
Deflection caused by left steel wheel only: 0.000153 meter;
Maximum deflection from spool only: 0.091 meter;
Maximum deflection from shaft only: 0.00129 meter.
Total deflection is nearly: 0.109 meters = 10.9 cm

The students are then engaged in using the direct stiffness method of FEA [8] to formulate the stiffness matrix in bending mode to determine the total deflection at the free end of coil machine. The 1D beam element formulation and solution by MATLAB proved to be tedious and challenging for them as some of them got confused with finding the work equivalent loads due to the distributed loads. Finally, they were able to obtain matching results with Solid Mechanics approach. Subsequently, CAE package such as UG NX 9.0 has been used to validate some of these calculations. Figure 4 shows the CAE model of the winding machine with end deflection computed based on the given displacement and load boundary conditions.

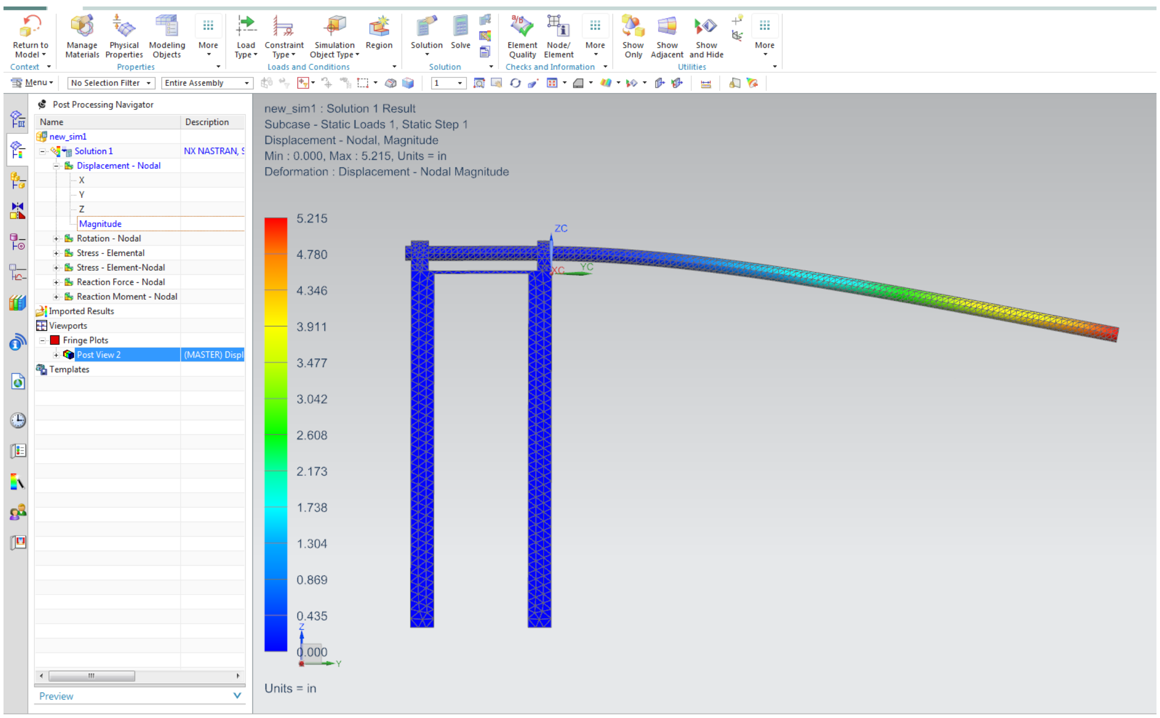

Figure 4: Structural analysis of the unsupported winding coil machine by finite element method NX-Unigraphics 9.0

The CAE results by NX show that the total deflection at the free end of winding coil machine is about 5.215 inch, which is around 0.132 meters; this value is not quite same as the EXCEL/FEA calculation results shown earlier. The main reason for the difference is the one-dimensional (mechanics approach) presented earlier versus the 3D CAE analysis. Additionally, the students understood that proper use of boundary conditions play an important role in obtaining matching results with the 1-D FE analysis. They also realized that the actual support conditions of the real machine use bearings that are difficult to model in FE or CAE analysis.

Redesign for the supported mechanism at free end

The students realized that the support for this machine structure should be safe when disassembled (removed), convenient and needed to be easily reassembled after removing the coil (in less than one minute or so due to the continuous coil manufacturing process). In other words, when the fully wound tile is being removed from the spool, the other machine that produces the tile is still continuously transmitting the finished pipe and that machine cannot be stopped. Otherwise, the hold-on time will cause unnecessary delays and loss to production. So being convenient to remove from the machine and reassembly are very important requirements in the redesign of this machine.

In view of the above situation, the students were engaged actively to brain-storm ideas for design of a new support structure for the machine based on the design requirements as follows:

1. The wheel at the free end should be easily removable and reassembled within one minute,
2. The supported machine structure should be safe to transport and safe for people to operate, and
3. The new support design at the free end of the structure should be cheap.

Several ideas were developed and preliminary analyses done by the students. The final design of the supported mechanism is to use a swing gate. End view of the conceptual design of this idea using NX 9.0 is shown in Figure 5.

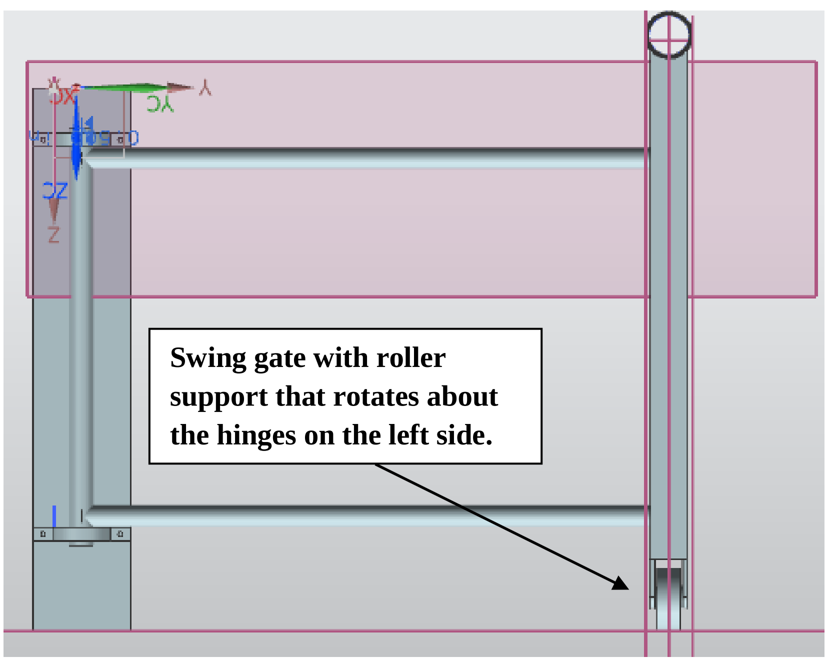

Figure 5: Assembly view of the support mechanism of the machine structure

Figure 5 shows the roller support at the right bottom corner that swings about the hinges on the left. The right support carries the removable wheel at the top. In the redesign of the support structure, the free end of the machine is vertically supported through the rollers that rest on the ground; therefore the deflection at the free end would be zero. The maximum deflection will be shifted to the middle of the spool due to it being treated as a simply supported arrangement. The total deflection after the free end has been supported, from EXCEL calculation came out to be around 0.0095 m (9.5 mm). As expected, the redesigned support system has much less deflection than the unsupported (original design), and it minimizes the stress and damage to the shaft and other fastening systems at the fixed end.

Appropriate bearings (ZB2000) have been selected for the shaft and the right side wheel using the standard catalog [9]. As mentioned before, standard beam deflection tables have been used while calculating the deflection at the free end and at the middle location of the winding machine. Detailed drawings of the redesigned machine have been produced using NX 9.0; however, these are not included in this paper due to space limitations.

Figures 6 and 7 show the side view of the general assembly of the machine showing some details of machine components designed.

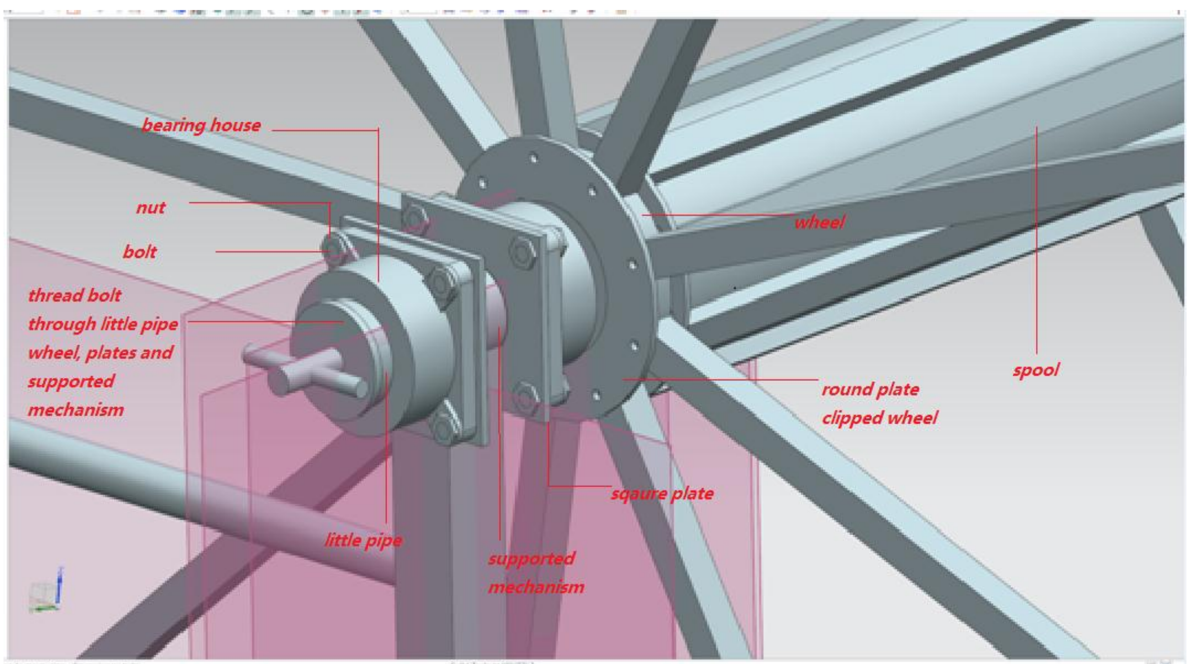

Figure 6: Side view of assembly of round plates, square plates, wheel, little pipe, supported mechanism and thread bolt

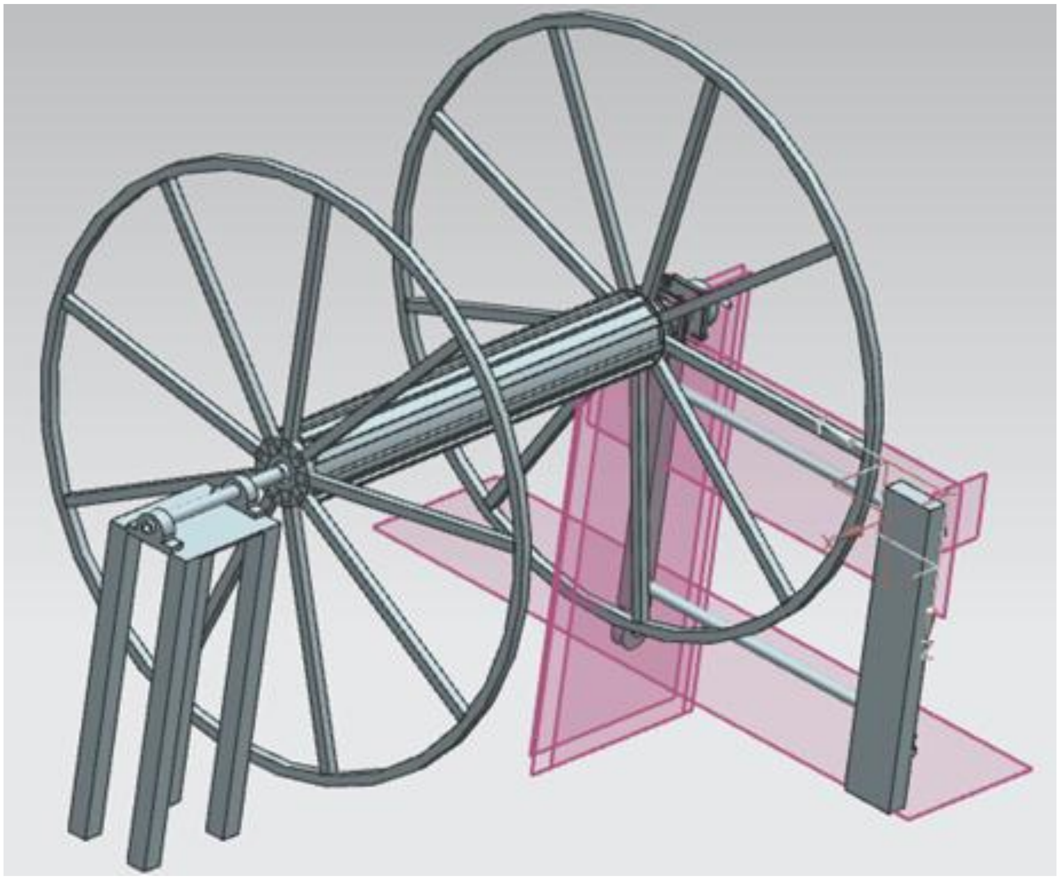

Figure 7: Isometric view of redesigned machine with swinging support at free end

Learning outcomes and conclusions:

In this continuation paper, further studies were made in the redesign of the support structure of a tile winding machine using active learning and project based learning tools. Assigning real life problems for class work is a great way for the students to apply the concepts learned in the classes to solve industry problems in an active learning mode. Group discussions, think-pair-share, presentation of ideas and analysis using math and CAE tools improved their confidence of applying justifiable assumptions to model and to solve real life problems. They also understood the limitations of the assumptions made and their impact on the safety of the design. This way, they further understood that challenging and often ill-defined requirements along with the associated constraints exist inherently in the design and analysis of real life mechanical systems.

Consistent with the course learning objective, namely, modeling a given real-life situation and reducing it to a solvable problem using various engineering judgments and assumptions, it is hoped that the students appreciated and gained more academic experience by undertaking this project. This is also what is expected in project-based learning. Use of math and CAE tools for performing various iterations enhanced the students' understanding of the need to investigate different ideas and to perform different analyses parametrically in order to judge and to arrive at an acceptable final design. The general feedback from the students shows that the amount of effort was lot but the project-based problem solving in an active environment was both challenging and enjoyable.

As an example, one of the student's (the first author's) comments were: "From doing this project, I experienced a process from discovery of problem and EXCEL calculation of damage of deflection to individual design of solution, which offers me a great opportunity of using knowledge learned from school to solve practical problem in real life. I think the most important value I cherished from the project is the constant sprit of developing the capability of independence study. Such a sprit will encourage me in doing more useful individual study, and will help me to pursue higher career achievement in the future."

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