FSU-FAMU College of Engineering

TECT POWER 68K Blade Process Handling

Concept Generation and Selection

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Introduction

TECT Power, a turbine part manufacturing facility, currently processes a multitude of turbine blades of varying sizes and dimensions. They currently have a need to remove manual lifting from their processing of their 68K blade which weighs about 45lbs before machining. Their machining fixtures, however, are set in such a way that it is often difficult to place the bulky blades into the machines without straining oneself. Last year a cart was designed to transport the blades from storage to machine 1, a horizontally-oriented mill. However, the design only considered one of many machines. Each of the following machines requires the blade to be reoriented either horizontally or vertically with some angular twist.

This project's focus is to design a modification to the current cart (or cart design) such that the orientation and 3D position of the blade can be adjusted so that the blade can be loaded and unloaded into the machines down the production line. The new design will focus upon two main sections of the overall design: the arm apparatus responsible for moving the turbine blade into and out of position and the clamping mechanism responsible for holding the blade.

Existing Apparatus

Last year, a 2012 Senior Design team was able to construct a cart responsible for transporting 68K turbine blades to and from storage and load them into machine 1, a horizontal milling fixture. (See Figure 1 for an image of the constructed cart prototype.) Their design, however only worked for machine 1, not any of the multiple machines to follow. However, due to their diligence and the budget placed into the previous project, salvaging their design and prototype seems to be both efficient and frugal.

Figure 1 – The existing cart prototype designed by the 2012 Senior Design group.

The design consisted of a metal cart with the ability to lift and lower in the vertical position. It features a tray capable of sliding in the horizontal position and has the capacity to hold four 68K blades comfortably. Also included in the design is a wooden box frame that the blades would be able to rest in as they are transported. This frame is usable on machine 1, but not the future machines. As such, this part of the design may very well be disregarded for this project. Regardless, the remainder of the design is sufficient enough, with modification, to be the base of the new design.

MODIFICATIONS NECESSARY

CART STABILITY

Because the new design requires that the 45lb blades be hoisted over objects in some cases and be extended far from the cart in others, the worry that a large moment may be exerted on the cart, resulting in the cart tipping over. The further the weight is supported from the cart, the greater the moment, and therefore the greater the chance that the cart will tip. This can be countered by added support struts, similar to those on construction machinery (Figure 2), to keep the cart at balance. If the cart were to tip, it would tip onto the struts and be kept upright. These would have to be retractable so that the cart can maneuver throughout the facility.

Figure 2 – Retractable support struts on a crane performing construction in a church.

Another option for stability and support may be balancing the center by adding additional weight to the base of the cart. This would result in a larger modification of the cart to incorporate either a base ballast or even, with its carrying ability being kept in-mind, a carousel that could bear additional blades, held upright, that could be free to rotate about the base of the cart. This idea is being kept as an option for future expansion, but is not particular design criterion for this year's design.

ATTACHMENT OF THE NEW APPARATUS

Because the new design requires that the blades be placed vertically into a broaching machine’s repository which is about four feet high, the addition of the new apparatus was thought to be best implemented by mounting the new device to the top of the cart. This would allow the apparatus to access anything on the tray as well as be tall enough such that it can carry the three-foot long blades over the broaching machine’s repository and then gently lower the blade’s tip onto a centering pin.

The attachment of the device must be rigid so that there is no chance that the device might accidentally disconnect, but also removable so that the entire fixture can be removed if repairs or maintenance are necessary. As such, a simple mount can be implemented on the top of the cart to attach the fixture. Currently, the design of the cart consists of bars on the top to hold two blade sheaths on either side of the center bar (see Figure 1); this, however, seems erroneous and a simple fix to this would be to remove the bars and replace them with a mounting plate that can either be welded into place or screwed into place using the metal mesh.

PART 1 – ARM APPARATUS

DESIGN 1 – BALL-JOINT ARM

This design was inspired by robotic arms such as those used on autonomous assembly lines for sorting and assembling. (Figure 3) However, due to budget constraints, the design has been voided of all mechatronic systems. As such, the system is being modeled as two rigid arms connected by a ball joint. The arms will also be connected by a dampening device which can be pinned to a collar on both arms to allow the arms to rotate around.

Figure 3 – a robotic arm sorting glass pebbles.

This device can be modeled as a basic dampener (the green section in Figure 4), but needs to support a force, yet be able to be moved by human interaction with ease. Options for the device include:

- A spring with a stiffness such that the force applied by the weight of the blade onto the arm is nearly the force being applied by the spring.
- A power screw – a power screw is a screw (worm gear) that is capable of bearing an axial load and can be adjusted by the use of a motor to turn the screw to adjust a threaded surface parallel to the axis of the screw along the length of the screw.
- A hydraulic damper that uses a pressurized canister to support the weight of the blade.

This design is useful because it allows for a large degree of freedom while still being capable of lifting the desired load of 45lbs. It can also reach below itself and extend outwards. (Figure 4)

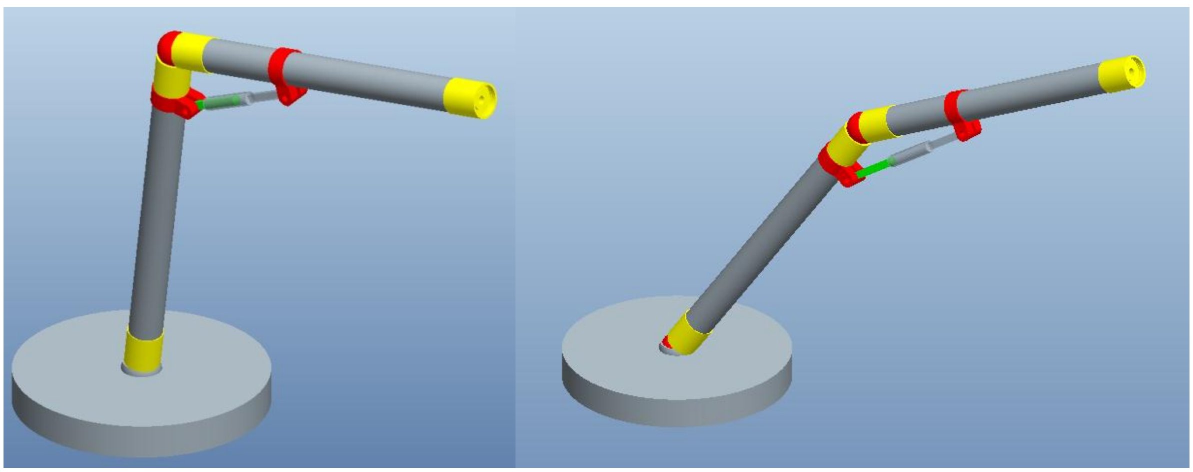


Figure 4 – Design 1 concept extending to a greater reach.

Pros	**Cons**
• Capable of large reach • Capable of reaching below itself • Natural design (human arm-like) • Easily adjustable • Compactable	• Potentially expensive components • Low durability • May not reach certain positions • May be difficult to calibrate • Replacement of parts

DESIGN 2 – PULLEY SYSTEM

The second design of the arm apparatus was inspired by crane mechanisms that are able to lift heavy objects and transport them from location-to-location whether at the level or above or below the level that they initially started. This design uses a simple pulley system to generate mechanical advantage (Appendix 1) and consists of two or more cable tracks which at one end can be controlled by levers or cranks and at the other serve as mounts for the grips. The entire "crane" would be able to rotate about on an axis perpendicular to the ground as well as translate down a track allowing it to reach further distances than the arm alone allows. The track on which the apparatus transverses upon can be designed in such a way that it is retractable and storable so that it is not cumbersome or in the way of the workers.

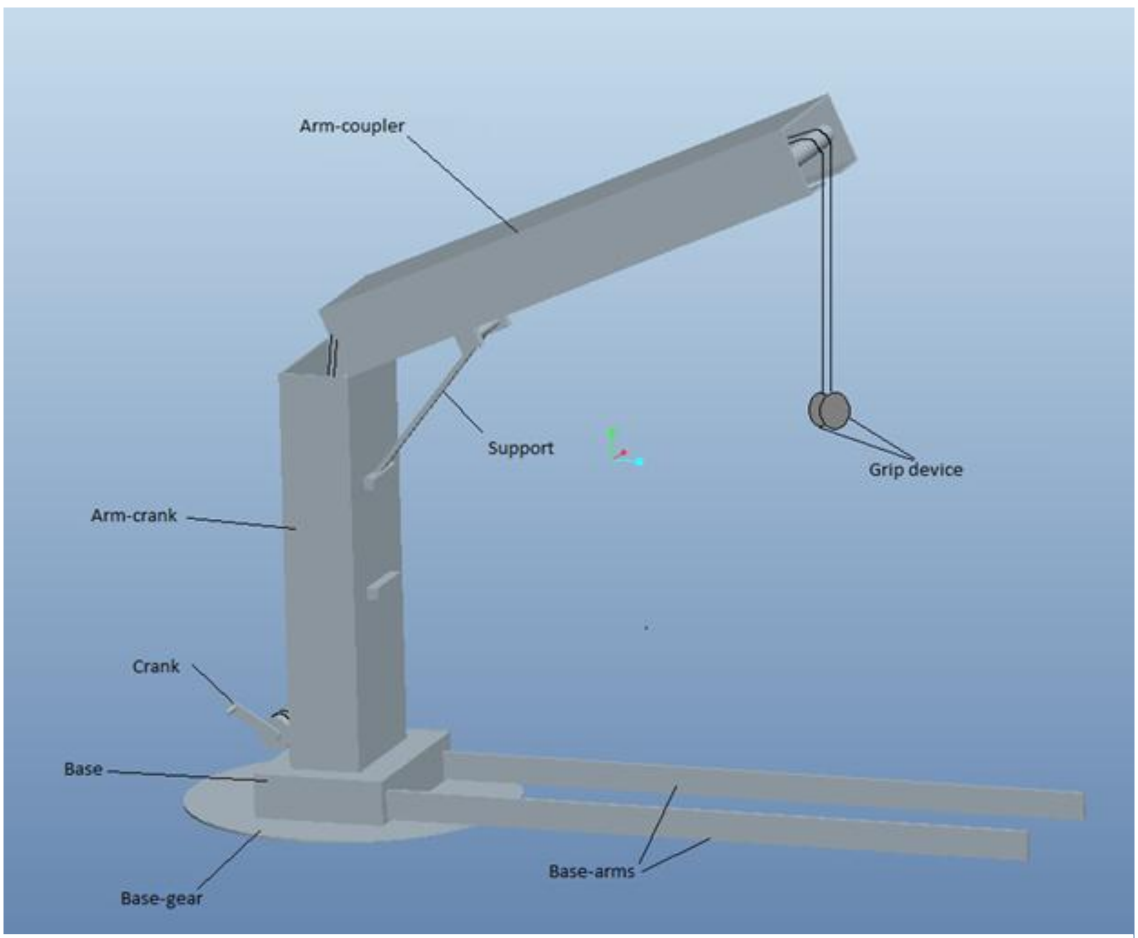
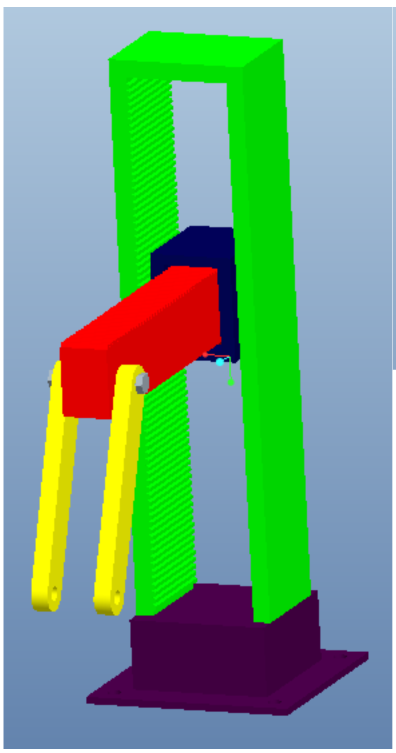


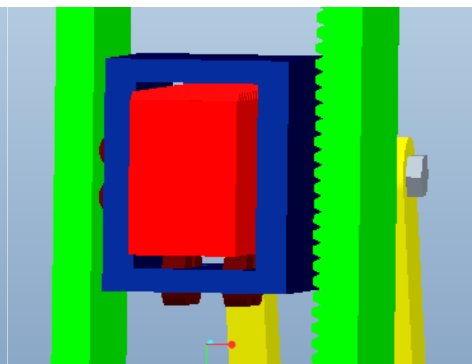
Figure 5 – Design concept 2 modeled in ProEngineer consisting of the crane and its track. Note that the "Arm-crank" section would contain a pulley system. With a mechanical advantage great enough so that the 45lb blade can be cranked with ease.

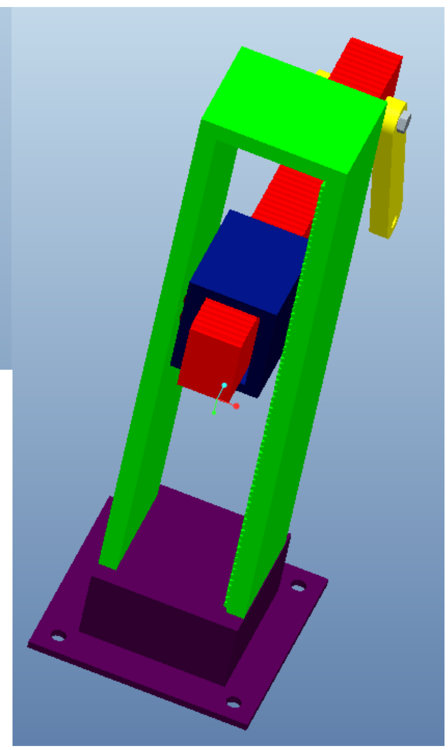
Pros	Cons
• Mechanical lifting mechanism-Cost • Durable • 4 degrees of Freedom • Can lift blades from floor	• Fairly slow lifting process • May not be able to easily mount gripping devices to the design • Two-worker teams may be necessary without electrical components

DESIGN 3 – THREADED TRACK

The third design features two bars, one horizontal and one vertical, with gear-threaded tracks running perpendicular to each other. A box housing acts as a junction between the two bars and contains gears which run along either gear threaded track. By turning either gear, the bar moves relative to the box housing in the direction of the turn. The base of the vertical bar is mounted upon a turntable allowing it to rotate perpendicular to the floor. The horizontal bar contains an attachment on which the grips would be mounted and the blade could hang.







<u>Left</u>: front view, grip attachment in yellow.
<u>Right</u>: Back view: box housing in blue contains gears to allow it to travel along the vertical (green) track or move the horizontal (red) track.
<u>Above</u>: A close-up of the box housing. Note the burgundy rollers.

Figure 6.1,2,3 – Design 3

Pros	Cons
• Ability to lift turbine blades vertically • Structurally strong • Purely mechanical with electrical capability • Capable of moving blades over oil bays	• Bulky and incapable of compressing in size • May be difficult to maneuver into certain machines • Maintenance and cleaning may be regular • Heavy, solid design

PART 2 – GRIPS

Because the blades are of a unique shape, about three feet long with a slight twist down its major axis and varying thickness with a meeting fin on either side, it becomes critical that there be a way to grip the blades effectively. However, this becomes difficult as many of the machines need to access different parts of the blades and also limit the exposure to other parts. Often times the blade will need to be placed at an angle such that gripping components will not be able to hold the blade at one universal spot every time due to this angle and the shape of the machining fixture and its surroundings. As such, there is a need for grips that are capable of gripping the blade at varying locations, without compromising the stability of the blade in the grip, so that the blade can be adjusted as needed for each individual machine.

The following concepts are ideas for differing ways to model grips for the blades that are able to move along the length of the blade as well as support the blade by its root (the thicker end) for loading into the broaching machine.

CONCEPT 1 – FORM-FITTED

Because of the unique geometry of the blades, it may be difficult to grip the blades with a standard bar or plate due to the possibility of slip. As such, the grips on the blade must fit the geometry of the blade nearly exactly so that the blades have a minimized chance of slipping out of the grips during processing. The possibility of form-fitting grips becomes an interesting solution to this necessity. Though this concept will still rely on pressurized grips, the pads placed on the plates will be able to form to the blade. This can happen in a few different ways:

PREFORMED NEGATIVE CAST

By using a cast of the forged blade, a negative can be constructed such that it is able to grip the forged blade along its geometry. This would be advantageous because the grips require no electricity nor require a vacuum seal as seen in the upcoming concepts. However, the implementation of grips of this sort would require multiple interchangeable plates to be created so that they can be placed at different spots along the blade as well as on the forged and machined root. Also, it should be noted that when gripping the machined roots, the grips would need to have a protective buffer such as carpeting so that the grips do not scratch or knick the machined surface.

MALLEABLE SURFACE

By using a surface on the plates that can change shape and adjust its own geometry to create a virtual negative (much like in the Preformed Negative Cast concept) dynamically, it no longer becomes necessary to create multiple plates. Cornell University, Chicago created a universal gripper that uses vacuum-packed sand inside a flexible membrane. The bag of sand is first shaped over the surface or edge or object that is desired to grip or form to while the air is still in the sand by simply pressing the bag over the object, then the air is removed from the sand, packing the sand, and making the bag into a virtual solid in the shape it was molded to. This process is similar to instantaneously creating a mold for the blade each time the air is vacuumed from the sand. Strips of these membranes can be placed along wide fingers of grips that would then be able to grab the blade along its length.

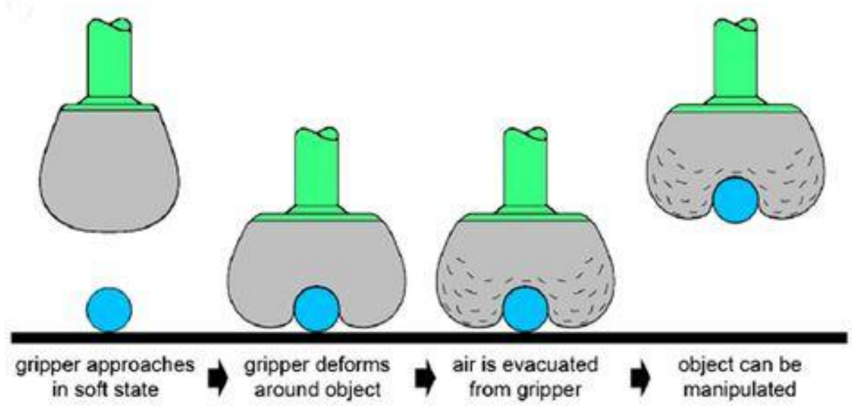


Figure 7 - The concept developed and prototyped by Cornell University.

Though this process seems like an end-all-beat-all way to grip surfaces, it is not used in industry, and research on this process only finished two years ago. Replication of this process may be difficult and possibly expensive. Also, the addition of an electrically-powered vacuum system will also add an electrical component to the system and additional tubing

Concept 2 – Vacuum-Forming Suction Cups

Many industrial applications for transport of large surfaces include the application of suction cups to grip the surface along its flat, planar surfaces. By having a polymer or elastomer washer compress on a surface, internally sealing it, and removing the air from the sealed volume created with the surface of the turbine blade, a vacuum is formed which is capable of exerting a pressure difference strong enough to support the weight of the blade.

Figure 8 – An industrial-strength suction cup. This would be much larger than required for the design as multiple cups would be used to provide support to the blade on either side and limit the degrees of freedom

Suction cups are also a great alternative to other gripping devices because they are relatively cheap, especially for those that are rated for low loads, which the 68K blade is considered to be within that range at only 45lb. One concern about these blades, however, is the chance of the blade slipping along the surface for the blades are cooled and cleaned during machining with oil that remains on the blade throughout the machining process. Also, the rough surface of the forged bladed may not create a workable seal for some suction cups. These constraints must be considered before choosing this option.

DECISION MATRIX

PART 1 – ARM

Arm Concept	Cost	Maneuverability	Effectiveness	Efficiency	Safety	Durability	Maintenance	Practicality	Compactability	Machinability	Total Score
1	3	4	3	3	4	1	3	2	4	3	**30**
2	5	3	3	2	4	2	3	2	3	4	**31**
3	3	2	2	2	3	4	2	3	1	2	**26**

Figure 9 – The decision matrix used to select the design

PART 2 – GRIPS

The grips in the design will be chosen later, and may be possibly kept as simple clamp grips for this year's design. As of right now, with current budget constraints in mind, the primary focus will be on the ability to create an apparatus to move the blades into multiple positions: the type of gripping device should not affect this task, but will alter how it is performed. As such, this part of the design may be considered in the future of this project but if not can be considered as a new selection for a future Senior Design project. Because of this, an effective gripping system will be chosen during the cost analysis of the system.

FINAL SELECTION

Concept 2, the pulley design, was the final selection by group discussion and construction of the decision matrix. (Figure 9) Because of the design's low cost, ability to maneuver throughout the machines with relative ease, and its simplicity, it was the top choice. The design itself also has much room for modifications and design improvements if desired. Because it is a purely mechanical system, and a very simple one requiring little input by the user, it prevailed over the other designs which may have required electronics or even mechatronics – because of the relatively limited cost and the possibility of having to redesign the cart from the previous year if modifications are not sufficient enough to adapt the cart to the new task, keeping the cost low without having to use electronics is desirable.

With our final design concept in-mind, more mathematics and a more highly designed model with machine drawings can be created and vendors for raw materials and any parts required can be selected on a basis of price and part effectiveness. Also, any modifications needed for the design can be added as needed: this includes the modifications necessary to the cart and any modifications needed for the arm design. Additionally, after these modifications are planned, the grips can be selected based on the new additions to the arm and the remaining budget.

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APPENDIX

Mechanical Advantage using pulley system

$mass := 45lb = 20.412\,kg$ $\qquad g = 9.807\,\frac{m}{s^2}$

$force := 45lb \cdot g = 200.17\,N$

$n := 9$ number of pulleys

$h := 3ft$ height mass is lifted

$me := \frac{force}{n} = 22.241\,N$ Mechanical Advantage

$s := \frac{h \cdot me}{N} = 20.337\,m$ lengh of rope to be pulled at force F

Appendix 1: Design 2 for the arm calculating the mechanical advantage and the length of rope needed for a pulley system with 9 pulleys.