February 2013

Simplify the Design of the 980H Medium Wheel Loader

Brendan John McLaughlin
Worcester Polytechnic Institute

Peter Malcolm Wallace
Worcester Polytechnic Institute

Simplify the of Rear Wheel Arch Panel for the Caterpillar 980H Medium Wheel Loader

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A Major Qualifying Project submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of the Bachelor of Science.

Submitted By:

Peter Wallace

Brendan McLaughlin

In partnership with Shanghai University and Partners:

Weiqing Chu

Mengyuan Guo

Chao Xie

Sponsoring Agency:
Caterpillar Inc.

Advisors:
Kevin Rong

Xiuling Huang

Amy Zeng

Shuai Guo

AUTHORSHIP

ABSTRACT……………………………………………………………………….Brendan

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ACKNOWLEDGEMENTS

Our group would like to thank the following individuals for their help and support throughout this project:

Scott Panse, Engineer at Caterpillar

Professor Xiuling Huang, Shanghai University

Kevin Rong, Worcester Polytechnic Institute

Amy Zeng, Worcester Polytechnic Institute

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ABSTRACT

In collaboration with Shanghai University, our project team developed an integrated methodology for simplifying the design of the rear wheel arch panel for all standard 980H medium wheel loaders at Caterpillar's Suzhou Product Group. In addition, we developed a special design configuration that includes a 100mm hole for fire-hose access in case of emergency. Furthermore, we provided lean solutions to some of the problems associated with packaging and transporting the part throughout the facility.

EXECUTIVE SUMMARY

The design that currently exists for the rear wheel arch panel of Caterpillar's 950H and 980H medium wheel loader is extremely complex. The manufacturing process for the medium wheel loaders is timely and requires 10 individual components for assembly. These components are collected from 4 suppliers. The total time for assembly is 30 minutes.

During the manufacturing process some of the components are often damaged and either disposed of or reworked. These parts are extremely heavy and are also over packaged, which adds to the total assembly time.

This project is intended to simplify the design and manufacturing process for the rear wheel arch panel. The overall goals for this project include: using fewer parts in the total assembly which will reduce the overall assembly time, finding an alternate material that is lighter, simplifying the supply chain, reduce material cost, simplify the value stream map for the process and reduce the packaging needed to transport the arch panel. The rear wheel arch panel for the 980H medium wheel loader will also need a new design which incorporates a 100mm hole that will allow a fire hose to enter the engine compartment.

Figure 1: Project Group with 980H Medium Wheel Loader

CHAPTER 1

Background

Caterpillar is the world's largest manufacturer of earthmoving, construction and mining equipment and a major global producer of diesel and natural gas engines, turbines and diesel-electric locomotives. Caterpillar manufacturing began with the establishment of its first foundry in East Peoria, Illinois in 1929 and has expanded outside of the United States now encompassing many manufacturing facilities throughout American, South America, Europe and Asia. Manufacturing lines have become much more efficient and incorporate standard work and processes that are replicated throughout the world. (Caterpillar Company Website)

Before the 1920's Caterpillar's existence began as a construction vehicle and equipment company formerly known as Holt. In 1905 Holt's equipment was first used when their steam traction engine was involved in the modifications of San Francisco's cable car system. A year later this engine helped during Earthquake recovery efforts in the city. In 1908 Holt's track-type tractors were used in an aqueduct project in Los Angeles, California. These same tracks also were used as a supporting role in World War 1 in Europe. This was the first time Holt vehicles were used outside of the United States On June 16, 1919 Holt developed its 5-ton Caterpillar tractor. This tractor was the first ever to navigate 20 miles up Pikes Peak in Colorado. In 1928 A Caterpillar Sixty Tractor pulls the Southern Cross to the runway in Oakland California to start the first ever trans-Pacific flight. In the 1930's Caterpillar machines helped construct the King Albert Canal in Belgium, the Hoover Dam in Nevada and Arizona, the Golden Gate Bridge in San Francisco, the Bonneville Dam in Oregon as well as many other famous Canals and Dams

(Funding Universe). Between the years 1937 and 1980 Caterpillar machines helped build the Pan-American Highway that linked North and South America. Caterpillar steadily expanded across the globe during the 40's and the 50's and its machines were being used throughout Europe, North and South America, Africa, and the Middle East. In 1955 Caterpillar designed military equipment for Operation Deep Freeze 1. In which the United States conducted a series of science research missions in Antarctica. Caterpillar machines were used in Australia to prepare sites for the 1956 Olympic Games. In 1957 Caterpillar D6 Tractor pulled the first undersea telephone cable between the U.S and Hawaii ashore. (University Of Illinois) In 1958 Caterpillar D9 tractors helped the U.S Navy complete its first permanent airstrip on Antarctica. Caterpillar helped push a mountain into the sea in Kobe, Japan as part of the Kobe Bay Reclamation Project and worked on some of the world's largest earthmoving projects in India and Pakistan (Britanica Encyclopaedia).

Caterpillar's projects expanded rapidly in the 70's and 80's as they supported large construction, earthmoving, and hydroelectric projects all across the globe. In 1991 about 700 Caterpillar machines help extinguish one of the largest oil well fires in the world Kuwait. In 1995 Caterpillar's machines worked on the Panama Canal Widening Project. In 2001 Caterpillar machines were used in the relief efforts within hours after the September 11th terrorist attacks. In 2004 Caterpillar machines help built sites for the 2008 summer Olympics in Beijing, China and helped build the infrastructure in Shanghai necessary to host the 2010 World's Fair. (China Caterpillar Site). Caterpillar has an impressive history in aiding with some of the largest engineering, earthmoving and relief projects across the globe. WPI is very fortunate to be able to work with such a reputable industrial sponsor such as Caterpillar. They are able to offer WPI students hands-on business challenges for students to complete in their qualifying projects.

This Project was sponsored by Caterpillar Suzhou—a branch of Caterpillar—, which specializes in manufacturing medium Wheel Loaders, and Motor Graders for markets in Asia Pacific, Russia, CIS, Africa, Middle East and South America (Caterpillar Inc.) "CAT's motor graders and wheel loaders continue their reputation for offering world-class cab and controls, advanced electronics and hydraulics, and optimum productivity to meet your needs in any application" (Shuzhou Product Group)All of CAT products share a pedigree of deep industry insight and cutting-edge technology. The CAT equipment product line consists of more than 300 different machines, setting the industry standard. The innovators at Cat are constantly striving for perfection. They are constantly improving ease of operation and operating time. In addition they strive to increase productivity, improve availability and decreased maintenance time while maintaining the superior quality that defines CAT products.

Caterpillar is sponsoring a project in which students from both Worcester Polytechnic Institute and Shanghai University collaborate to provide innovative solutions to problems facing the organization.

Project Description

This project focuses mainly on the re-design and simplification of the rear wheel arch panel for the 980H Medium Wheel Loader. The current functionality of the rear wheel arch panel is to protect the engine from the outside elements, such as dirt, water, rocks and other debris. There is also a secondary focus of the project, which requires a new design that adds a 100mm fire hose hole to the rear wheel arch panel. This fire hose hole design is per request of a client that uses the 980H medium wheel loader in steel mills, where the machines often reach extremely high temperatures and in certain situations the engine of the machine catches fire. They requested that there be an easy way to insert a fire hose through the rear wheel arch panel to reach the engine and extinguish a fire effectively in case of emergency.

The rear wheel arch panel used on Caterpillar's medium wheel loaders is over-complicated in design. There are 10 different parts that make up the rear wheel arch panel and are acquired from 4 different suppliers. In the facility, the rear wheel arch panel must go through a sub-assembly process on the production line before being installed on the machine. This process takes upwards of 30 minutes. Time on the production line costs Caterpillar a significant amount of money. Not only does this process slow production of their machines, but if a problem occurs during the sub-assembly process the entire production line can come to a halt. The goal of our project team is to simplify the current design of the panel to eliminate sub-assembly all together.

Figure 2: Detailed Location of the Rear Wheel Arch Panel

Project Plan

In order to ensure that our project objective was completed within our given time limit, it was essential for our team to establish a project plan. The purpose of this project plan was to identify what tasks needed to be completed in order to meet our objective within the given time limit. Our group first needed to identify the objective. Once our objective was defined we needed to determine what tasks needed to be completed in order to complete this objective. We needed to create a task list in order to determine the necessary order in which each task was to be completed. Additionally, we needed to determine what group member(s) were responsible for specific tasks. Next, we needed to determine what tools would be necessary to complete each task. This was essential in order to ensure that our group had the necessary resources required to complete each task.

Finally we needed to set deadlines specific to each task. In many cases, one task cannot be started unless a prior task is completed. By setting deadlines for each task, our group was able to define a project plan that would ensure that all tasks would be completed in time to meet our objective with ample time to prepare our final presentation to the Caterpillar Suzhou project group.

Figure 3: Project Methodology

CHAPTER 2

Visit To Caterpillar

In order for our project group to obtain a better understanding of our objectives, we visited Caterpillar's Suzhou Product Group Facility. Upon entering the facility we were first presented with an informational video about Caterpillar and the industries they serve. Next we took a tour of the production facility where we were able to watch the medium wheel loaders in each step of the production process. Specifically we were able to follow the rear wheel arch panel as it was transported through the facility, assembled and installed on various machines.

Figure 5: Picture taken at visit to CAT. Front view of Panel.

Figure 4: Picture taken at visit to CAT. Back View of Panel.

During this process, our project group photographed and video recorded the sub-assembly process, installation process and transportation process.

Defining Our Objective

In order to begin our project, we needed to first define our project's overall objective. After much consideration we determined the objective of our project is as follows:

Simplify the design of the rear wheel arch panel for all standard 980H Medium Wheel Loaders and implement a 100mm fire-hose hole design for a specialized configuration of the 980H to be used in steel mills.

Finalizing Our Task List

In addition to defining our objective, we also created a detailed task list which we would use as a guideline to help gage if we completed our project successfully. In the creation of our tasks, we realized we would have two overall tasks, one would be specifically for the simplified design for all standard 980H medium wheel loaders and the other would be for the specialized fire hole hose design.

The first task was to simplify the design of the rear wheel arch panel for the standard configuration of the 980H medium wheel loaders. This task had seven main steps including:

1. Identifying and eliminating unnecessary parts from the rear wheel arch panel.
2. Determining what materials should be used for the new design.
3. Creating a one-piece simplified model in Pro/E.
4. Determining the ideal thickness for the one-piece design.
5. Attaching the hinge and pin-lock to the design.
6. Comparing the new integrated design with the current design using our constraints.
7. Conducting a stress and strain analysis on our part.

The second task was to create a design that added a 100mm fire hose hole on the specialized configuration of the 980H medium wheel loaders to be used in steel mills. This Task had six main steps including:

1. Determining the ideal location for the fire hose hole.
2. Using Pro/E to create the hole in our integrated design.
3. Creating hole cover design concepts.
4. Determining the parts and materials to use in the cover designs.
5. Attaching the fire hose hole cover the integrated design.
6. Ensuring that the cover is airtight.

These two tasks helped ensure that the project group had an in depth understanding of what we would need to do in order to accomplish the overall goal of this project.

CHAPTER 3

Analyzing Current Design

The first step to creating a new integrated design for the rear wheel arch panel was to analyze the current design of the panel. This would help us identify what aspects of the current panel could be eliminated and what parts we would need to keep and incorporate into our new design.

The current design was made up of three main components. First was the outer panel, which was composed of fiberglass (see Figure 6). This fiberglass panel helps protect the engine from the outside elements such as dirt, dust and other small debris. After thorough research, our group determined that the outer panel is made of fiberglass because it is extremely light in weight and strong enough to withstand the outside elements. The fiberglass cover was 6mm in thickness.

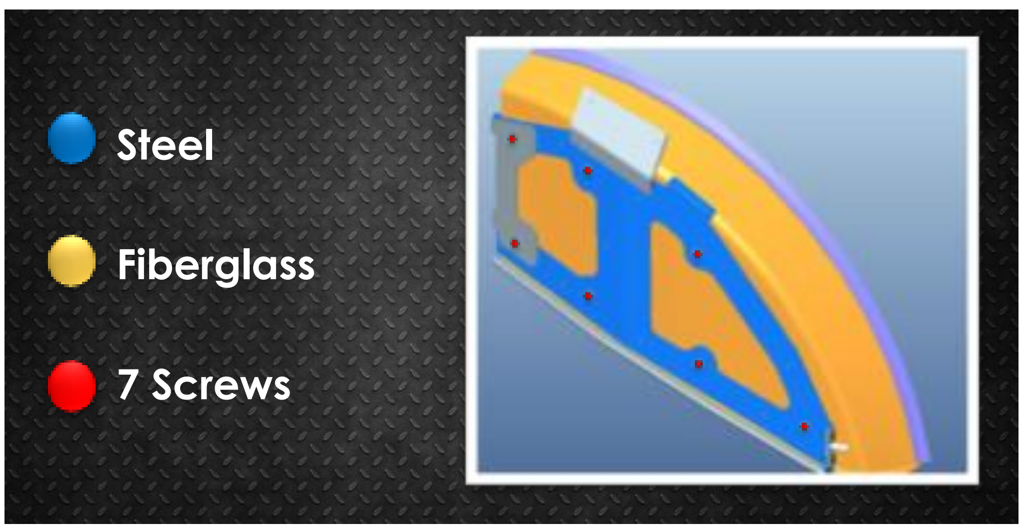

Figure 6: Current Design of Rear Wheel Arch Panel

The rear wheel arch panel also has a steel support (see Figure 6) that is attached to the fiberglass. This steel support provides extra strength to the panel and also is used to attach addition components to the rear wheel arch panel. The steel support is necessary because the fiberglass would not be able to support the panel when attached to the 980H Medium Wheel Loader. The steel support was 4mm in thickness. Lastly, there are 7 screws (see Figure 6) that secure the steel support to the fiberglass.

After analyzing the three main parts of the rear wheel arch panel we then investigated the other components on the panel. These components included the hinges, insulation, lock-part and handle. Each of these components had specific functions.

The hinges (See figure 7) attached the panel to the medium wheel loader and was secured to the steel support by two screws. The hinges also allowed the panel to swing open if needed. The insulation (See figure 7) was a separate piece from the steel support, fastened onto the support by two screws. Its purpose was to protect the fiberglass cover from high temperatures that the engine compartment sometimes reached. The lock-part (See figure 7) locked the panel closed against the machine and endured that the engine compartment remained airtight. Lastly, the handle (See figure 7) provided additional protection to the fiberglass cover.

Although these components were necessary for the current design, our team set out to create a new more simplified design that would eliminate as many of these additional components from the panel as possible.

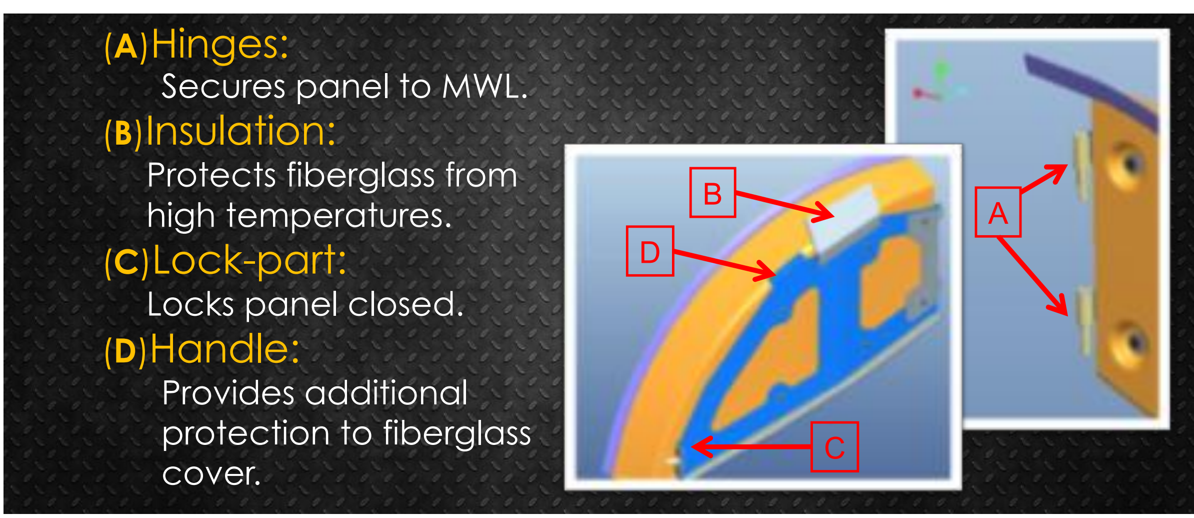

Figure 7: Components of Current Design

Drafting 2-D Sketches

During our group meetings we would discuss our ideas and assumptions for the new design. In order to better visualize our ideas our group drafted 2D sketches of our design concept before developing the 3D model. This way we could obtain feedback from our advisors and industrial mentors before proceeding with the 3D design concept in Pro Engineer.

Our 2D designs begin simple, only including the rough outline of our new integrated rear wheel arch panel. The design was altered and adjusted numerous times. We analyzed the current 2D picture of the rear wheel arch panel, to help determine what the 2D design would be for the new integrated design.

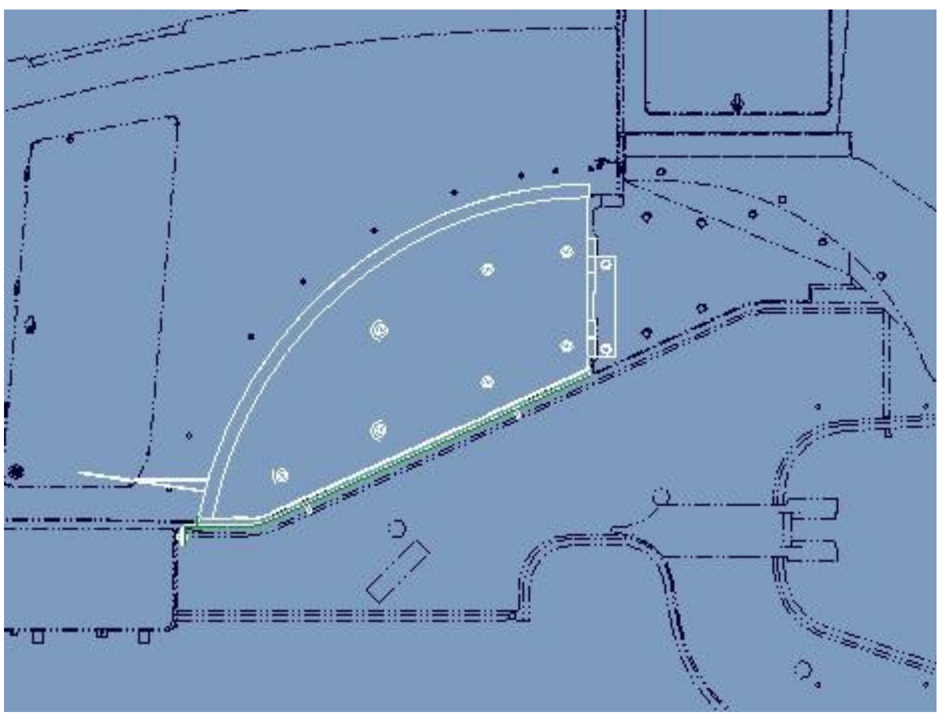

Figure 8: 2D Picture of Rear Wheel Arch Panel

CHAPTER 4

Eliminating Waste Through Design Specification

On our first visit to Caterpillar, we met with project engineers to better understand our problem statement. Upon arrival we discovered the major issue with the current design of the rear wheel arch panel was its over-complications. Before the arch panel can be installed on the medium wheel loaders, it must undergo a 30-minute sub-assembly process. Although the costs of the materials used for the current design are not significantly high, the 30-minute sub-assembly process slowed production of the medium wheel loaders. By developing a new design that did not require sub-assembly, we would be able to eliminate waste from the manufacturing process and speed up the time it would take to produce one medium wheel loader. Essentially—by making the design process more simplified—the production process would become leaner as a result (Ad-Esse).

The first step to eliminating waste was to identify the waste. Our group identified many aspects of design that did not add value to the rear wheel arch panel. Additionally our group identified waste in the flow of materials of the rear wheel arch panel as it travels from raw materials to medium wheel loader. By identifying waste in the process we were able to successfully able to develop a feasible methodology for eliminating waste, thus creating a simplified design and a leaner manufacturing process (Green Suppliers).

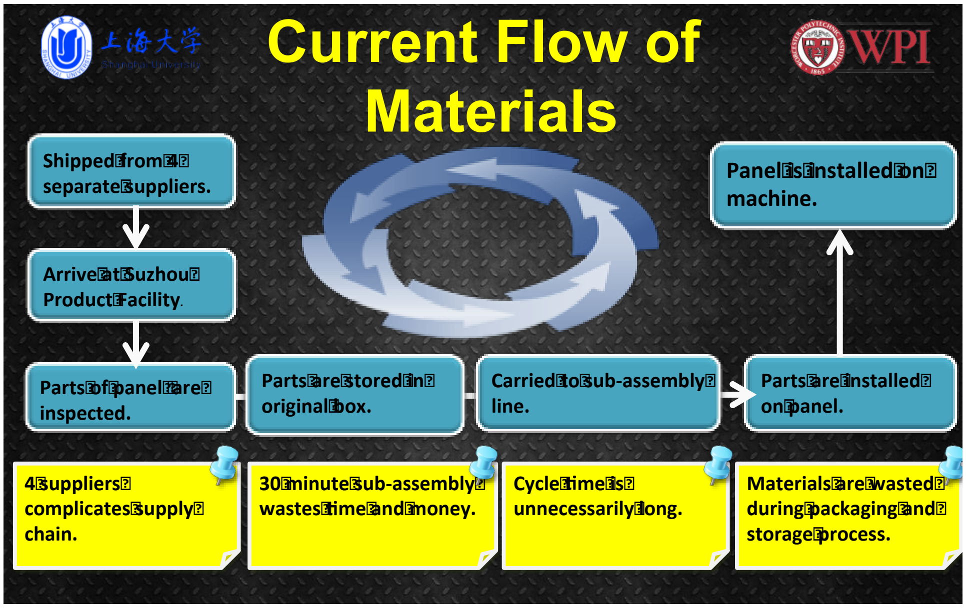

Figure 9: Current Flow of Materials

After analyzing the current design it was evident that it's over complications were very wasteful. Our project team determined which aspects of the design did not add value to the arch panel. Next we developed a practical strategy to create a design concept. First we developed 2D drawings of simplified design concepts for the rear wheel. The purpose of this step was to visualize our ideas for simplified designs. Next we used Pro Engineer (Pro/E) software to turn out 2D drawings into 3D design concepts. We tested the design concepts to ensure that our simplified design would not compromise the integrity of the arch panel. Our simplified design was 2mm thick of low carbon steel allow which was thinner than the current design. Additionally we eliminated the insulation, handle and combined the outer panel and support into a one piece stamped design. This reduced the number of parts by half. Our integrated design could be stamped by a single supplier and shipped to the facility as one part—eliminating the sub-assembly process.

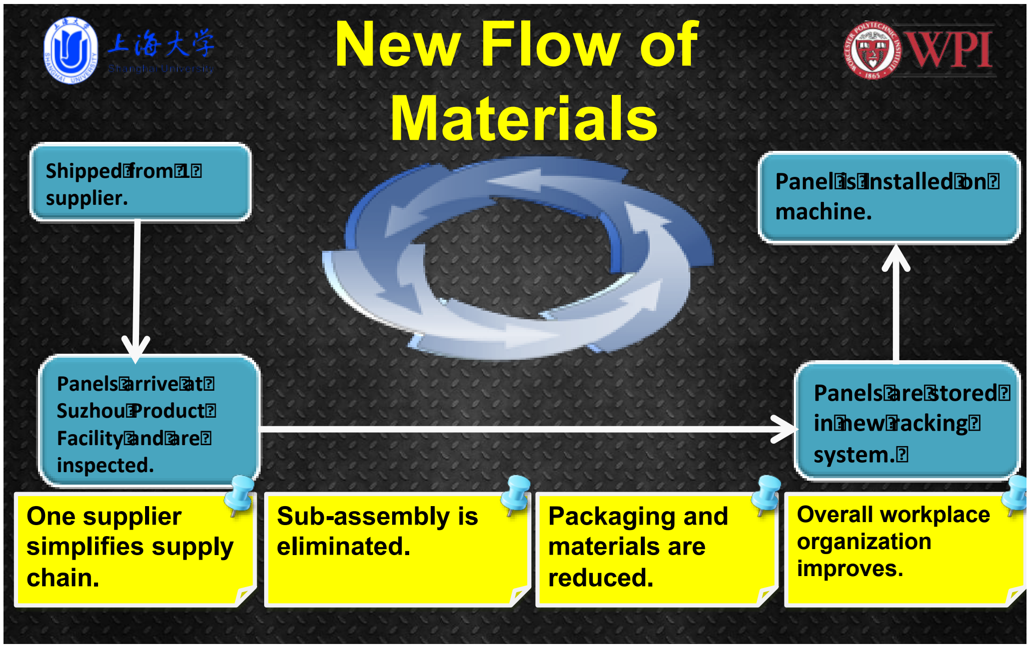

Figure 10: New Improved Flow of Materials

By simplifying the design of our real wheel arch panel we were able to eliminate waste from the manufacturing process—thus simplifying the flow of materials and making the process leaner. After analyzing the current flow of materials we were able to identify waste within the process. Our simplified design was able to eliminate much of this waste. The first complication with the current flow of materials is obtaining materials from 4 separate suppliers—both from the U.S and local suppliers. Our one-pieced stamped design can be sent directly to the facility. The second most wasteful aspect was the packaging. By reducing the amount of parts and the amount of suppliers Caterpillar is able to save on packaging costs. Additionally, our project team designed a new packaging system that was able to eliminate additional materials used in the packaging/storage process. Finally our integrated design was able to eliminate sub-assembly. By doing so Caterpillar is able to reduce cycle time by 30 minutes and save on labor costs since an employee is no longer needed for sub-assembly of rear wheel arch panel. In summation, by simplifying the design of the rear wheel arch panel—we were not only able to eliminate nonvalue adding design aspects—but were able to eliminate waste present in the current flow of materials, making the process leaner.

CHAPTER 5

Creating the 3-D Design Concept

After analyzing the current design and creating the 2-D sketches of the rear wheel arch panel, our team created detailed 3-D designs of the new panel using Pro/Engineer software (M Cad Central). In creating the new integrated panel, our team avoided altering the dimensions of the panel so that the new part could seamlessly be integrated into the current 980H medium wheel loader.

Pro/Engineering software allowed us to remove parts from the panel that were not needed and alter specific characteristics of the panel including: the thickness, material and shape of the panel. After determining what parts could be removed from the panel, we designed the new integrated 3-D model without these parts present.

We first removed the handle part from the panel; this only provided protection to the fiberglass cover, and because our new design would be made completely out of steel, we would no longer need this protection. Secondly we removed the insulation because this also only provided protection to the fiberglass from heat. Lastly we removed the steel support because the new integrated design would be made of steel and support itself. In our new design we reduced the thickness of the steel from 6.00mm to 2.00mm. We did not reduce the thickness of the panel to less then 2.00mm to ensure that the new panel would maintain the same structural integrated as the current panel.

Two parts that we did incorporate into the new 3-D design were the pin-lock and the hinge. These two parts were necessary to ensure that the functionality of the new integrated panel remained the same as the current design.

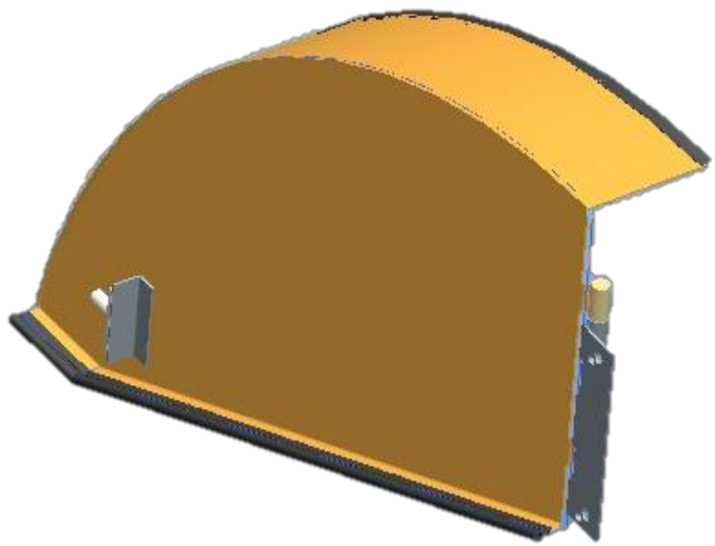

Figure 11: 3-D Model of New Integrated Design of Panel

Material Analysis

The current design of the rear wheel arch panel is composed up of one large fiberglass outer panel and a low carbon steel support. In our new integrated design, we completely eliminated the fiberglass outer panel, and made one large steel panel. Our team determined that it would be most cost effective and efficient to use low carbon steel for the new integrated panel as well. Our new integrated design is significantly thinner then the current design (we reduced the thickness from 6.00mm to 2.00mm), so we needed to preform a stress analysis on the panel to see if the new panel design would maintain the same functionality.

Using Pro/Engineer material analysis software we were able to identify where the highest yield stress occurred on the panel. In both instances the highest stress was seen on the hinge part of the panel. We first tested the current 3-D model of the panel, and the max yield stress seen at the hinge was 41.252 Mpa.

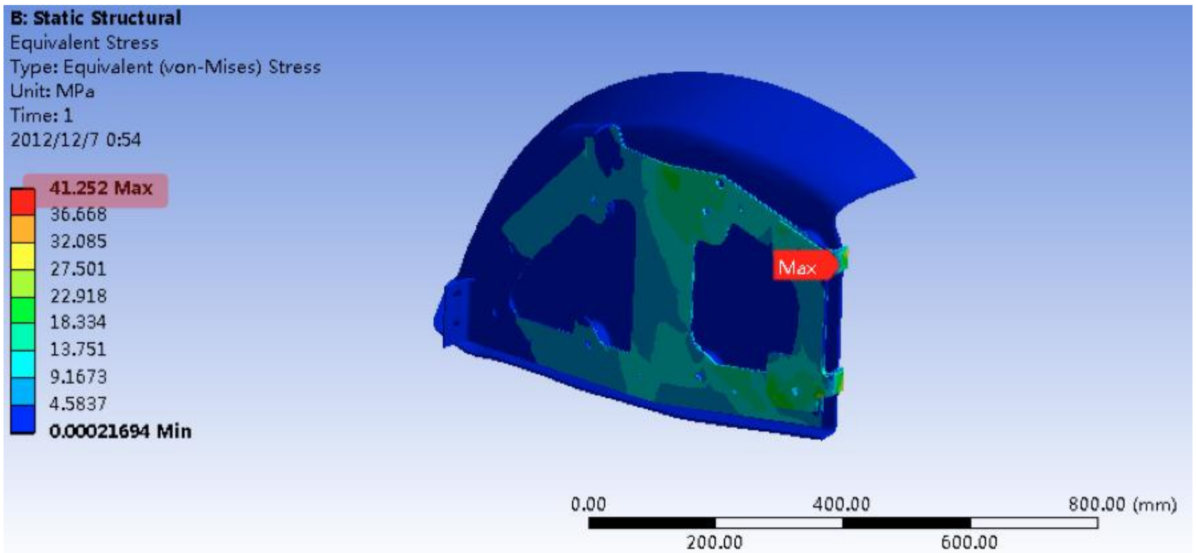

Figure 12: Stress Test Results on Current Design

We then analyzed the 3-D model of our new integrated design of the panel and the max yield stress seen at the hinge was 135.24 Mpa.

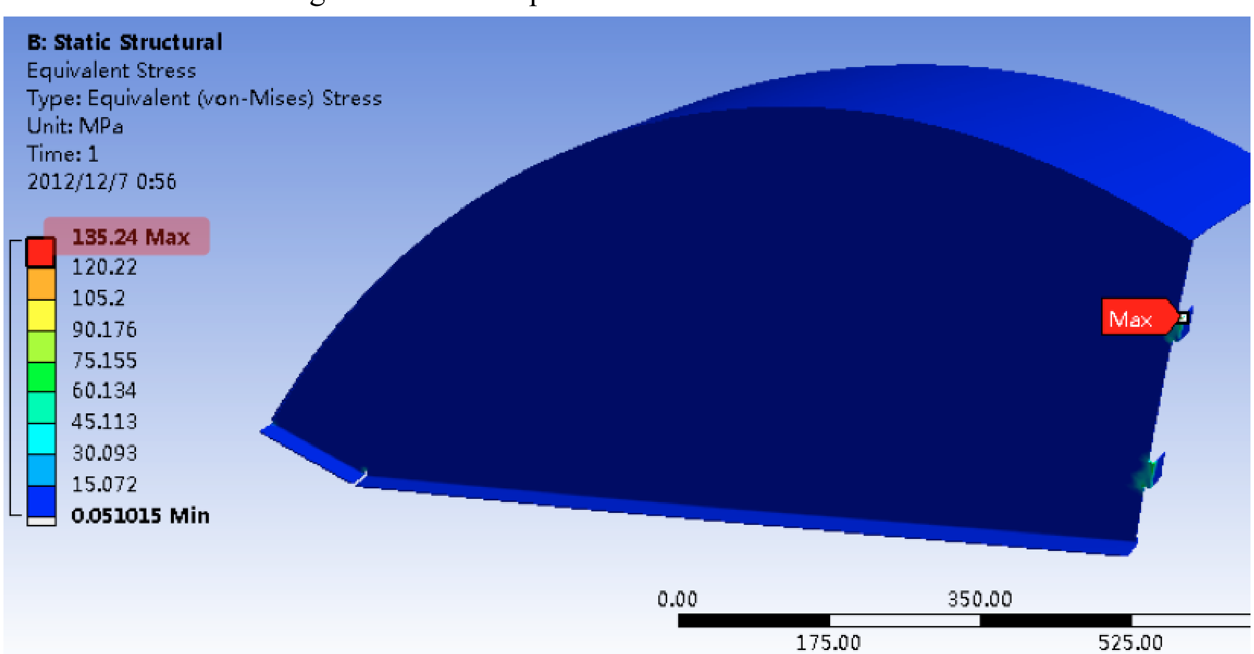

Figure 13: Stress Test Results on New Integrated Design

Although the stress on the hinges in our new integrated design are significantly higher then that of the current design, the max yield stress of low carbon steel is 284.4 Mpa; therefore the hinges will still be strong enough to support the new integrated panel design.

Comparing Current Design to Integrated Concept

A comparison was essential to prove the advantages of our integrated design over the current design. Before comparing our design we defined our constraints. These constraints were measurable values that could be used to compare the two different designs and associated flow of materials and packaging design. Our list of constraints was defined as follows:

1. Number of parts
2. Cost
3. Sub-assembly time
4. Weight of the part
5. Functionality
6. Transportation
7. Packaging
8. Supply Chain
9. Materials
10. Ergonomic Factors

After defining our constraints our project team used these to improve the design of the rear wheel arch panel. Through design simplification we were able to reduce the number of parts by half, cutting it from 10 to 5 parts. By doing so we were able to reduce the cost significantly. The current design costs about 185 U.S dollars. Our estimated cost of our current design would be less than 100 U.S dollars. The weight of the current design is roughly 13kgs. Although we were only able to reduce the weight by 0.3kgs, the weight was still reduced. The reason for such a slight weight reduction despite a significant cut of the parts is because our integrated design is made solely out of steel, which is heavier than the fiberglass outer-panel that was eliminated.

After our design concept was developed we had to prove that our integrated design maintained the functionality of the part. The functionality of the current design is to protect the engine from our elements. After conducting a stress, strain and thermo analysis on our integrated design in Pro/E our group concluded that the functionality would not be compromised.

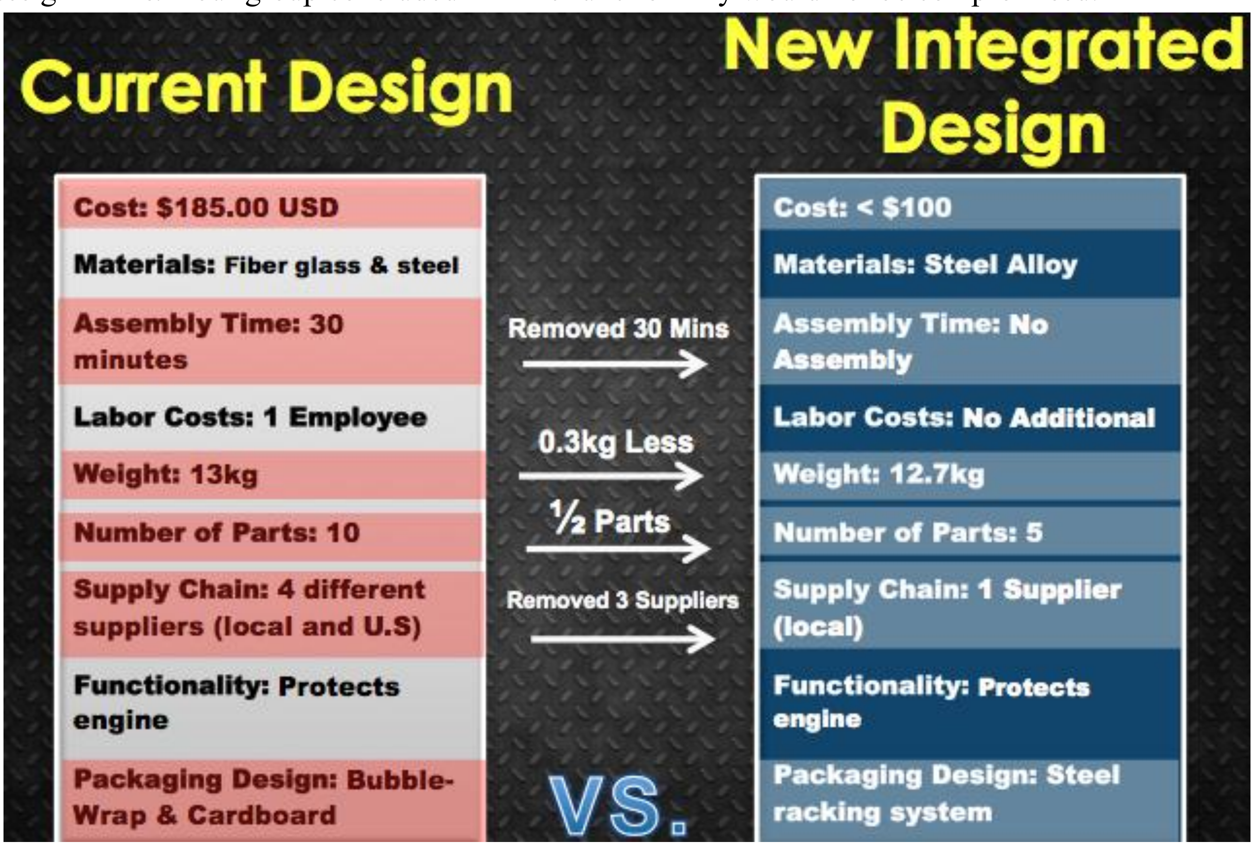

Figure 14: Comparing New Integrated Design with Current Design of Panel

The next aspect of our comparison included an analysis of the supply chain, transportation, packaging and flow of materials. By simplifying our design we were able to reduce the supply chain from 4 suppliers to 1 local supplier. Additionally waste was eliminated from the transportation and packaging and flow of materials associated with the manufacturing process of the panel. Since our part would be used by human operators our group analyzed ergonomic factors in determining fire hose hole location and cover design. Our goal was to provide a design that could be easily and safely accessed by a human operator in an emergency situation. Our project team used these comparisons to showcase the advantages of our integrated design.

CHAPTER 6

Determining Fire Hose Hole Location

Once our integrated design was completed, the next step was to begin developing the special design concept that included a 100mm fire hose. This hole will be implemented per request of a customer that uses 980H medium wheel loaders in steel mill applications (Schaetzl). The purpose of this hole is to allow a fire hose to penetrate through the rear wheel arch panel of this special design in an emergency situation if the engine parts are at risk of catching on fire. Not only will this hole improve the safety of the machine and the workers operating it, but it will add more value to the machine and help assure its longevity. In order to create this specialized design, our group must first determine fire hose hole location.

When determining the fire hose hole location our project team considered safety and ergonomic factors. Safety is held to the upmost importance by Caterpillar standards. Our vision included a fire hose hole location that will allow the operator to be able to access it as quickly and effectively as possible without putting themselves or others in danger. If a fire were to break out within the engine, this could cause an explosion that could potentially inflict damage on the operators or surrounding workers. This fire must be able to be put out quickly and easily to improve safety in emergency situations.

The next factor our project team considered was ergonomic factors. Our project team believes ergonomic factors are important since the operations of all the caterpillar machines are completed by humans. We wanted a human operator to be able to access the fire hose hole in a manner that is both easy and comfortable (Occupational & Safety Heath Administration). We first measured the area of the arch panel that is blocked by the rear wheel. This area would not be ideal for a fire hole location due to the fact that it would be difficult to access. We wanted to place the hole at about arm level for an average height human to ensure that the human operator could comfortably and effectively access the hole during an emergency. Additionally we did not want to place the hole too close to the perimeter of the arch panel to ensure that the strength of the design would not be compromised by hole implementation. Finally our group determined an ideal region to place the hole and implemented it on our integrated design concept using tools on Pro Engineer.

Designing a Hole Cover

Designing a hole cover is crucial aspect for our specialized design configuration. This is necessary to ensure the integrity of design is not compromised. The functionality of the current design of the rear wheel arch panel is to protect the engine from the outside elements.

Improving Safety Without Compromising Integrity of Design

In the creation of this fire hose hole cover we must consider that the implementation of the hole as well as the hole cover could not compromise the integrity of the current rear wheel arch panel. Currently the arch panel helps protect the engine from the outside elements, which includes keeping the engine compartment completely airtight.

In order to ensure that the engine compartment remained airtight our project team knew we would have to install some kind of rubber lining around the fire hose holes to create an airtight seal. We also knew that each design require some sort of locking mechanism, to keep the cover locked on the panel.

Drafting 2-D Sketches

Before we could create the 3D design for our fire hose hole we had to first draft 2D sketches of the where we would locate the hole and how it would affect the overall design of the panel.

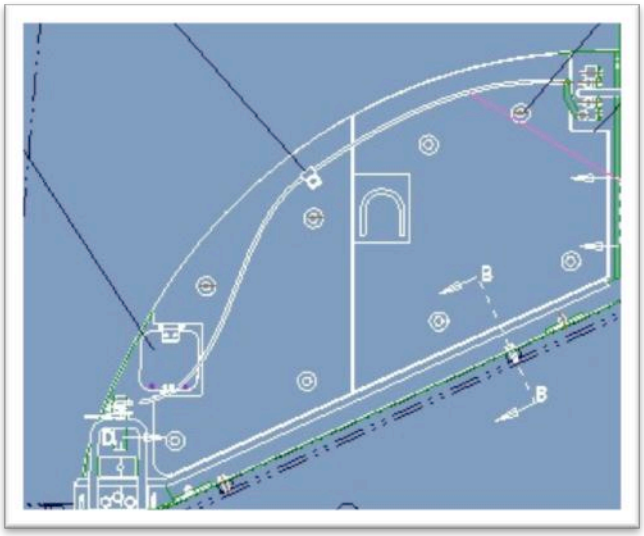

Figure 15: 2D Drawing of Fire Hose Hole & Cover

Creating Hole Cover Design Concept

Caterpillar had requested that our team create more then one design for the fire hose cover, that way they would be able to analyze each design and determine which they think would be best suited. Our project team completed four different designs for the fire hose hole cover.

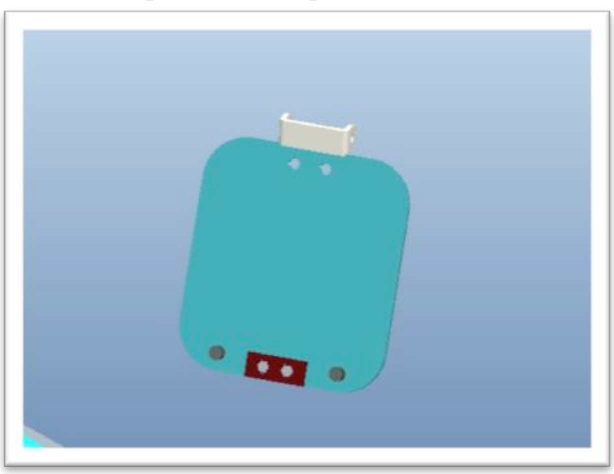

Figure 16: Hole Cover Design A1

Design A1 for the fire hole cover was a steal cover (light blue) that would be secured to the inside of the panel via a hinge (white). This design would be held shut by a small magnet (red) located on the bottom of the cover. There would be a rubber lining around the inside of the hole, in order to keep the engine compartment airtight.

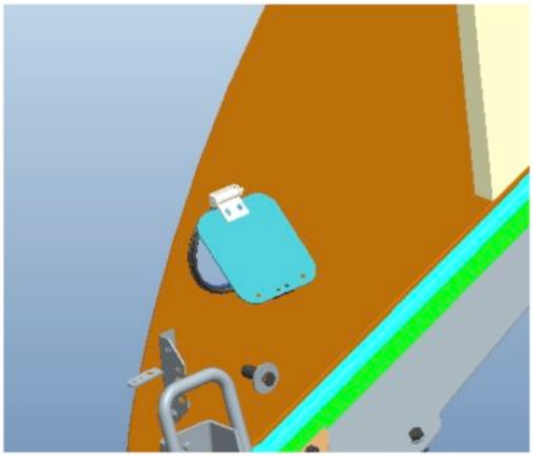

Figure 17: Hole Cover Design A1 Installed On Panel

This design had many advantages over the other three designs. The hinge would hold the cover securely onto the panel even in extreme shaking or vibrations, so there was no worry of the cover falling off of the hole. Also, the magnet would keep the cover locked tightly onto the panel, which would help keep the engine compartment airtight.

Some disadvantages to this design are that if the operator of the fire hose tries to spray the water directly upward, the cover may block the water from reaching the fire. Furthermore, the magnet on this design may attract too much metal filaments from the steel mill, and there could be a large build up of metal around the cover hole.

The second design concept was Design A2; a small adjustment to the Design A1. In this design there is no longer a hinge holding the cover to the panel. Design A2 uses two magnets (grey) to secure a steal cover to the panel.

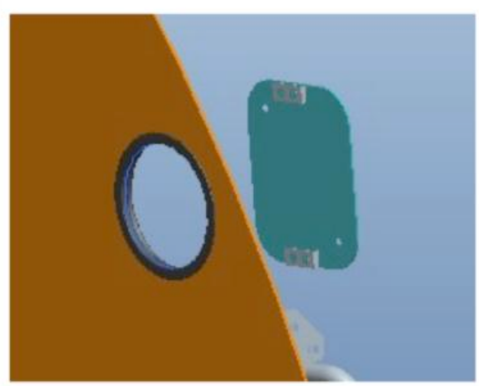

Figure 18: Hole Design A2

The advantages to this design are that the magnets will hold the cover airtight to the panel, but when a fire hose is inserted into the hole, the entire cover will completely detach from the panel. This will allow the fire hose to have full range of motion inside the engine compartment to quickly extinguish the fire. The main disadvantage we see with this design is that there will no longer be a hinge to hold the cover to the panel closed, if the panel starts to shake to violently the magnets release and the entire cover will detach.

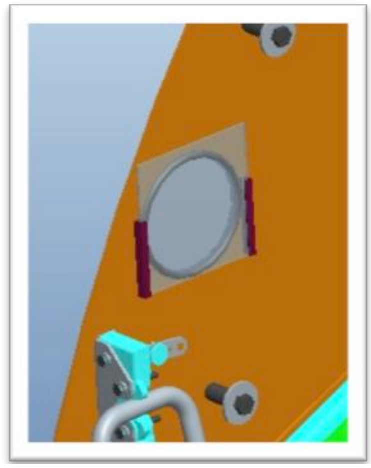

Figure 19: Hole Cover Design B1 Installed on Panel

For Design B1 our team decided we would use a glass cover for the fire hose hole. In this design the glass would be in a rectangular shape, and would be installed on the panel by sliding it into two tracks on either side of the hole.

One of the main advantages to this design was that the machine operator would not need to open the cover in order to access the engine compartment; instead the operator would use the fire hose nozzle to break through the glass cover and then conveniently extinguish the fire. Breaking the glass would allow instant access to the engine compartment and give full range of motion of the water spray from the fire hose.

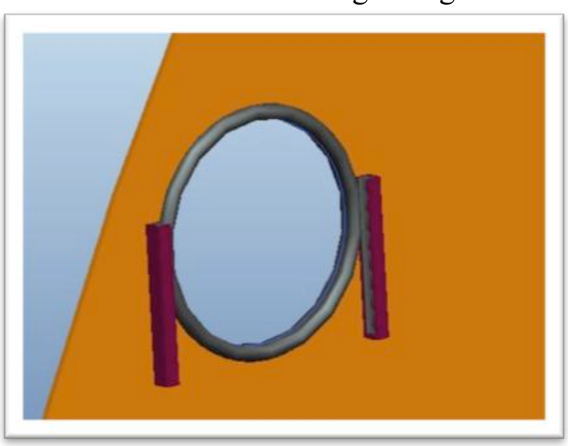

Figure 20: Cover Design B1

Disadvantages of design B1 were that if a small rock or debris hit the cover with enough force the glass may break. Also, buying and transporting the specialized glass piece for the cover would be costly and installation would need to be extremely precise.

Lastly our group created Design B2. Design B2 is very similar to design B1. In design B2 there would be a glass cover installed over the fire hose hole on the panel. This glass cover would be circular in shape, with a small notch at the top of it to help secure it in place. There would be rubber lining around the glass to help ensure that the engine compartment remained airtight. In order to install this cover, the worker would need to use a suction cup to twist the glass piece into place. This cover would be made of tempered glass as well.

The advantages of this cover would be the same as design B1. The operator would break through the glass using the fire hose nozzle, which would give instant access to extinguish the fire inside the engine compartment. The same disadvantages arise with this design B1. Small rocks or debris may break the glass cover and buying and transporting this specialized piece of glass will be costly.

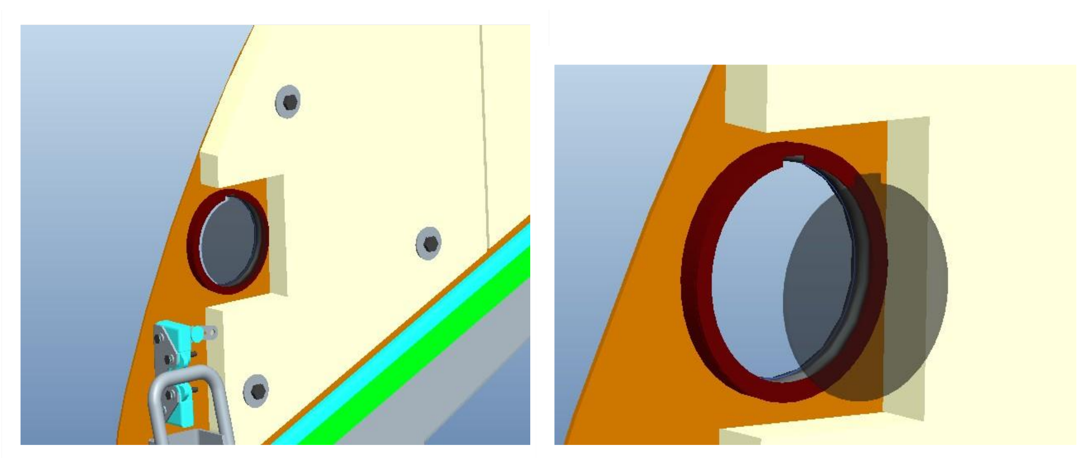

Figure 21: Hole Cover Design B2

CHAPTER 7

Material Analysis for Cover Designs

For every cover hole design our team created, we needed to determine what materials we would use for each design.

We determined cover hole designs A1 and A2 would be constructed out of the same steel alloy as the panel itself. We decided to use steel because caterpillar could get steel from the same supplier and steel would be able to handle the high temperatures of the engine compartment and the outside elements (About.com).

For design A1 and A2 we also had to investigate what type of magnet would be best suited for this application. After researching what types of magnets were available on the market we narrowed the selection down to four specific magnet types, which included: Ferrite, Neodymium, Alnico and Samarium Cobalt magnets.

Our group then created a chart to compare the magnetic strength, resistance to corrosion, temperature tolerance and price of each type of magnet (See Figure 14). (Cool Magnet Man)

Type / Properties	Ferrite (铁氧体磁铁)	Neodymium (钕铁硼磁铁)	Alnico (铝镍钴磁铁)	Samarium Cobalt (钐钴磁铁)
Magnetic Strength	Weak-Mid	Strong	Weak-Mid	Mid-Strong
Resistant to Corrosion	Without plating	Zinc or Nickel plating	Without plating	Without plating
Temperature	80-100°C	80-230°C	450-900°C	250-350°C
Price (Qty 1)	$0.15 ~ $1 USD	$1 ~$10 USD	$16 USD	$13 USD

Figure 22: Magnet Types

After analyzing each specific type of magnet we determined because of its strong magnetic hold, mid-range temperature tolerance and mid-range price, the neodymium magnet would be best suited for design A1 and A2. (K and J Magnet Store)

We calculated the dimensions of the magnet to be 34x14x5mm, which would give the magnet an upward lifting force of 39.98lbs or 17.98 kg. Because in our design the magnet would not be lifting directly vertically, but instead at a 90-degree angle, we would have to take into account the friction force of the neodymium magnet against the steel panel (See Figure 15).

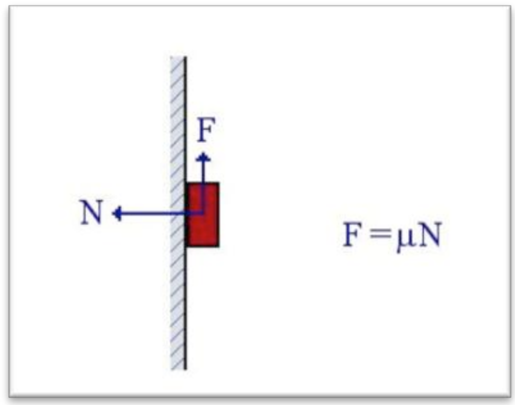

Figure 23: Friction Force Diagram

After taking into account the friction force and weight of the fire hose hole cover itself we then determined the maximum load the magnet would be able to hold would be 35.24N, five times the weight of the cover which is 7.203N. (K and J Magnet Store)

Cover Weight:
0.245kg*9.8N/kg*3 = 7.203N
Coefficient of Friction:
$\mu =$ **0.2**
Max Load:
17.98kg*9.8N/kg*0.2= 35.24N

Figure 24: Magnet Max Load Calculation

Additionally our group needed to investigate what type of glass we would use on our cover hole designs B1 and B2. We looked at three specific types of magnets: annealed, tempered and fire resistant glass. (Glass Of Europe)

Type / Properties	Fire Resistant (防火玻璃)	Tempered (钢化玻璃)	Annealed (退火玻璃)
Strength	Weak-Mid	Mid-Strong	Strong
Breaking Style	Small Round Debris	Small Round Debris	Big & Sharp Debris
Max Temperature	1000°C	700°C	600°C
Price (1m²)	$20.08 USD	$14.08 USD	$9.25 USD

Figure 25: Glass Types

After analyzing each specific type of glass, we determined tempered glass would be the most ideal glass for our designs. Tempered glass is fairly strong, but when hit with enough force can break easily, this is the main reason why our group decided to use tempered glass. In an emergency, the operator of the machine would need to break the glass cover as quickly as possible in order to insert the fire hose and extinguish the fire. Another positive to using tempered glass is that when broken, tempered glass breaks into small round debris, this would help avoid the operator from getting cut or injured from the glass. Also, tempered glass is in the mid-range for pricing and can withstand temperatures up to 700 degrees Celsius. (Ehow)

Because the vehicle operator would be required to use the fire hose nozzle to break through the glass cover, we needed to determine the "breaking force." For tempered glass of those dimensions we determined the breaking force would be 9.17 kg/m^2. The average human can exert over 100kg/m^2 of force with one hand. (Live Science) Therefore, we have determined that the machine operator would indeed be able to break through the glass fire hose hole cover with the fire hose in order to extinguish the fire.

Figure 26: Breaking Force of Tempered Glass

CHAPTER 9

Analyzing Current Packaging Design

In addition to the elimination of waste through design simplification and flow of materials, our project team redesigned the packaging and storage system of the inventory and materials. The purpose of this new design was to eliminate wasted materials, save space within the facility, improve organization and accessibility. Before developing a new packaging design system, we had to analyze the current design.

Currently the outer panel and steel support and stored in the wooden crates they are shipped in. Once they are removed from the crates they are laid flat on a cart where they are covered with bubble wrap and cardboard paper for protection until they are brought to the sub-assembly. Our project team identified waste in many aspects of this packaging design. First off all the bubble wrap and cardboard paper is wasted for protecting each panel. Second space is wasted within the facility due to the size of the wooden crates and carts that they are used for storage. Finally the storage system is unorganized and the parts are difficult to access and ship around the facility occasionally causing the parts to be damaged before sub-assembly. Our project team wanted to design a storage rack system that is more organized, protects the parts, saves space within the facility and reduces wasted materials.

Developing New Storage System

The inspiration for our storage system came from a steel racking system used to store larger parts of the Medium Wheel Loader. Our project team wanted to create a new storage system designed fitted to our integrated design (Reb Steel). We wanted this storage system to optimize space while protecting the parts. The first step to creating this system was to set the initial dimensions for the storage rack. These dimensions were based upon the dimensions of the Rear Wheel Arch Panel. Additionally we needed to incorporate a way to separate the parts individually on the rack so they can be stacked closely together without touching each other. Our design incorporated steel (See Figure 28) and rubber pegs (See Figure 27) that would support the panels from below to hold them in place and protect them from damage. Additionally they were supported by steel support beams on the left and right sides of the racking system to also ensure that the parts are held in place without touching each other. Our project team used Pro/Engineer to design this racking system. We also used the program to create an animated video of 5 rear arch panels being placed on the rack for safe and efficient storage. Images of the steel rack can be seen in the images below.

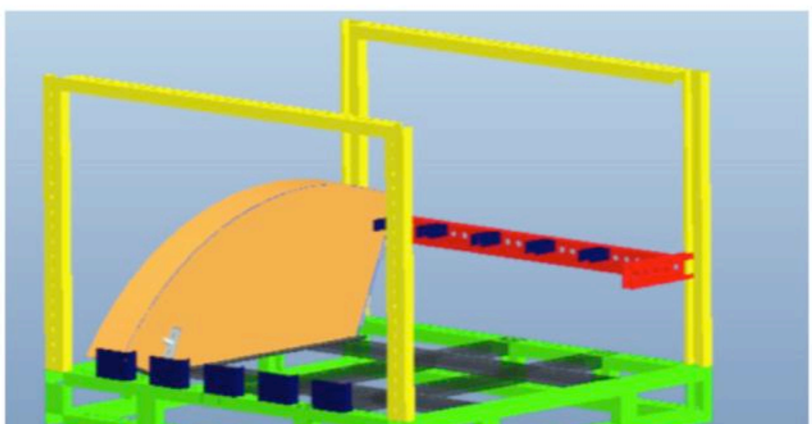

Figure 27: Storage System

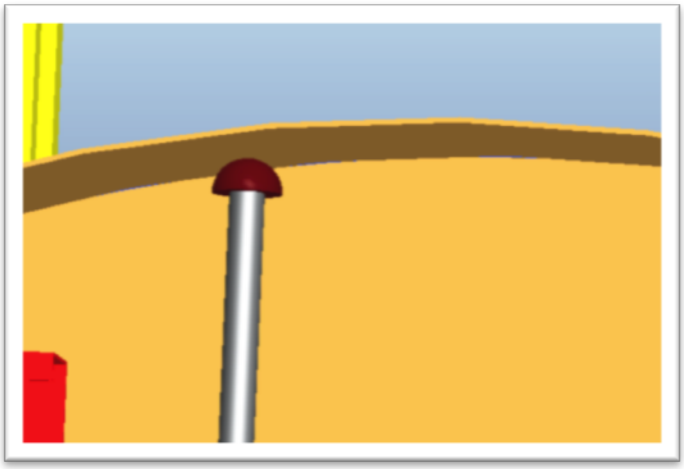

Figure 29: Rubber Pegs

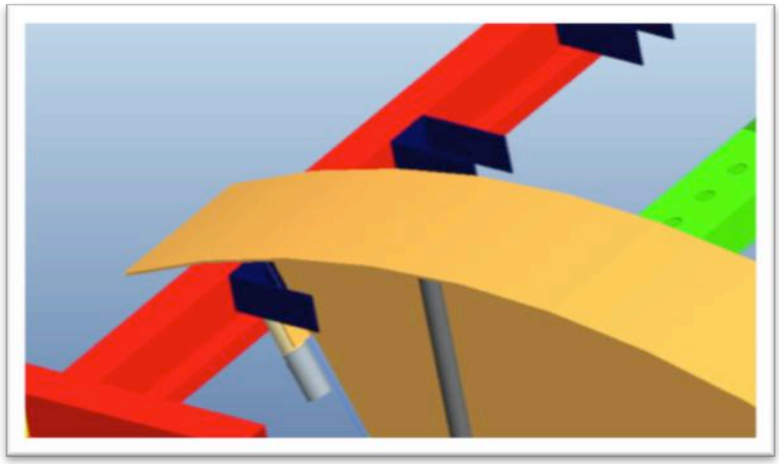

Figure 28: Steel Support

Developing New Packaging System

Our specialized integrated design included a fire hose hole and a hole cover implemented into the design of the rear wheel arch panel. Our project team needed to design a packaging system to ensure that our hole cover could be shipped and transported throughout the facility in a safe, efficient and inexpensive fashion. Since two of our four cover designs included magnets our project team used cardboard to store the hole cover concept designs.

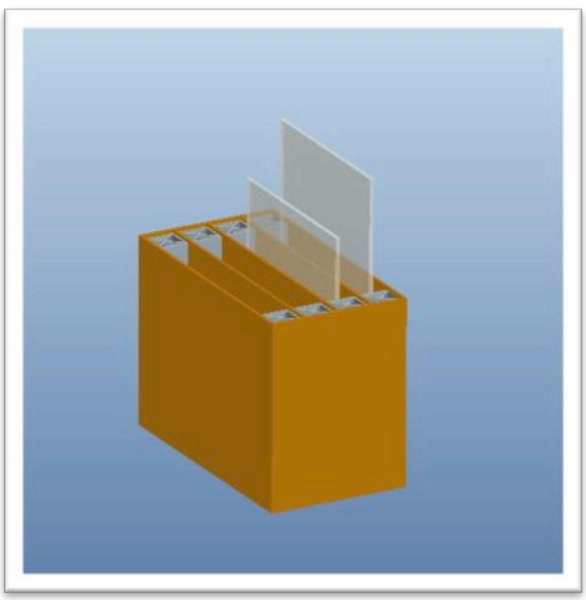

Figure 30: Glass Cover Package Design

Our hole design was created in Pro/Engineer and the dimensions of the storage systems were designed to fit four whole covers close together without having them touch each other. The hole cover packaging design included a cardboard holster with individual compartments to store the covers and cardboard spacers to separate the compartments.

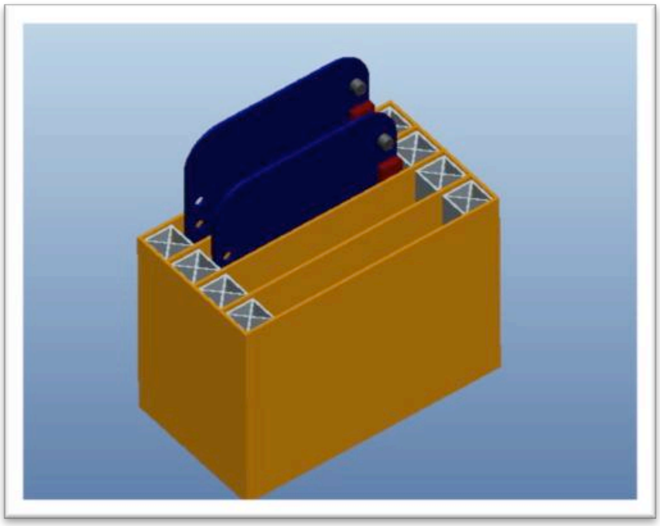

Figure 31: Steel Cover Package Design

CHAPTER 10

Simplification of Value Stream Map through Design

One of the requirements to our problem statement was to simplify the value stream map based on the flow of materials for the rear wheel arch panel from suppliers until they are attached to the Medium Wheel Loaders. Since no actual value stream map existed currently in the facility, our project team showcased the different stages of production where most waste occurred. After identifying and eliminating waste through our simplified design our project team showed the improved flow of materials through a simplified value stream map. Originally the parts are shipped from 4 separate suppliers to the facility in Shuzhou, China. Some of the suppliers are

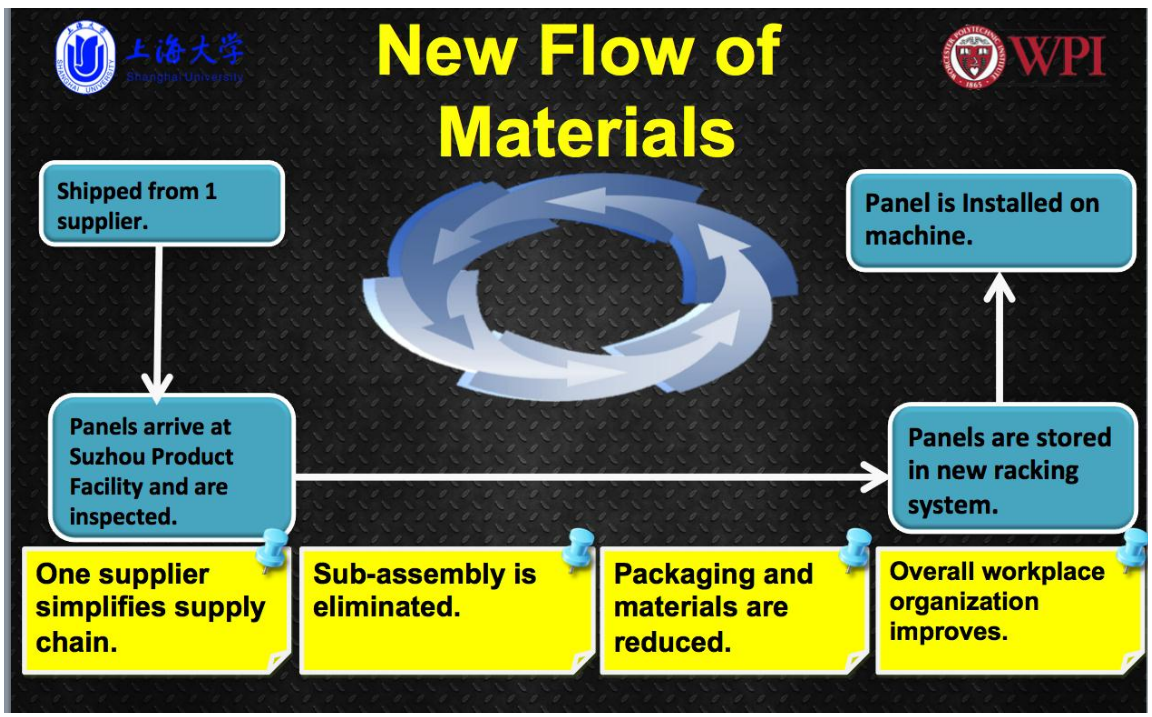

Figure 32: New Improved Flow of Materials

local while others are located within the United States. Upon arrival the parts are inspected and stored in their original carton box. Then the parts are carried to sub-assembly on carts until they are assembled and installed on the machine.

Our new design only calls for supplies from one supplier. Since we have a one-piece stamped design the supplier can be local. This factor alone simplifies the supply chain and eliminates significant amount of waste associated with the shipments of supplies to the facility. The parts are no longer required to be stored in their carton box or on carts with bubble wrap and cardboard paper, or current storage system allows the parts to be neatly and safely stored within the facility and no additional materials will be wasted on protection during the storage parts. Additionally, there is no longer a need for sub-assembly process without integrated design so the parts can be taken directly from storage and attached to the medium wheel loaders. By simplifying the flow of materials our project team was able to reduce cycle times, labor costs, and material costs associated with the manufacturing process of the rear wheel arch panel.

CHAPTER 11

Conclusions

Our project team was successful in our efforts to simplify the design of the 980H medium wheel loader. We created an integrated design for all 980 H medium wheel loaders as well as a specialized configuration to be used in steel mill applications. Per request of the customer, the specialized design included the implementation of a 100mm hole to permit fire hose penetration in case of an emergency. Since the engine components in steel mill applications are at risk of catching on fire, this hole is necessary to improve safety of the machine operators and improve the longevity of the machine. In order to ensure that this hole did not compromise the integrity of the design of the 980H medium wheel loader our project team designed four hole cover concept designs. The purpose of this hole cover was to protect the engine from the elements while simultaneously allowing a human operator to insert a fire hose through the hole to extinguish an engine fire in an emergency situation.

In addition to our concept design work for the arch panel our project team designed a new storage system for the arch panels, a new packaging system, simplified the supply chain and improved the flow of materials within the facility. Our project team designed a steel racking storage system to maximize space within the facility, protect the parts from damage while eliminating wasted materials. Our packaging design allowed us to package the new hole cover designs in an efficient and effective manner. Finally our project team showcased the waste eliminated from the process through our design simplifications. Our project team presented our results to the faculty and staff of Shanghai University and the project engineers and industry sponsors at Caterpillars Shuzhou Product Group.

Recommendations

Our Project team recommends that Caterpillar implements our integrated design for all 980H medium wheel loaders. This will save Caterpillar a lot of time and money on the part itself and on the associated manufacturing process. Additionally, our project team recommends that Caterpillar implements our steel racking design to store the part within the facility. Furthermore we recommend that Caterpillar implements our specialized configuration for steel mill applications with one of the two glass hole cover concepts. We believe that without a proper technical solution and without further testing that it could be problematic when reacting to the large quantities of steel. Our project team also recommends that Caterpillar should explore technical solutions to use magnetic parts on machines designed for steel mills.

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