Optimization of a Hood Latch System

A Major Qualifying Project

Submitted to the Faculty

Of

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

By

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Acknowledgement

We would like to thank Professor Lee and Professor Kim for their support and assistance during our stay at Kyungbook National University. Furthermore we thank our sponsor, the ACS group of the Pyeonghwa Company, for giving us this opportunity to work on a real world project. Lastly, we thank our T.A. Zhe Hao Yin for helping us to obtain the results that were necessary for the analysis of our designs.

Abstract

The use of hood latch systems is vital to all automotive companies that produce cars, trucks or other vehicles. The design of such part needs thorough investigation of professional engineers to make sure that it is safe to use as well as safe for holding the hood to the chase. Since this is a product needed in every car, the automotive component specialists, like ACS, have a hard competition for which one is the better product. In this project the given concept design of a hood latch system was used in an optimization process.

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1. Background

1.1 Company Background

The ACS group was founded in 2002 as a distributor of automotive parts. Their products are mainly actuators, latches, and torque converters. Some of the latches they distribute are hood latches, tail gate/trunk LID latches, and seat back latches. They produce door actuators as well as fuel filler openers, which open the fuel filler lid electronically. They use a press stamping system in order to produce their torque converters. Lastly, they also have a plastic injection line, for the many gear parts needed for their other products.

The ACS group follows a three-stage procedure for their designs. First is the concept stage, which includes the following steps: contract review, CFT, develop review, benchmarking, and the design. Next is the prototype stage, which has the following steps: prototype FMEA and design, CAE analysis, prototype control plan, prototype, prototype part review, and prototype valuation. Their last stage is production. In this stage they have the following steps: design FMEA, process FMEA, production valuation, production control plan, productibility review, and quality planning sign off followed by management support.

The company originally asked us to work on their current hood latch design and to optimize the weight. The important factors to realize when working on a hood latch is the many factors involved in its use. The hood latch system must keep the hood securely locked, with a catching hook for safety, be easy to open, while being able to maintain reliability under any possible conditions. It must also be simple and easy to close and lock the hood. It must also be able to withstand temperature conditions as well as be dimensionally structured to fit into the chase.

1.2 Technical Background

The hood latch system is a vital component in every automotive. It is located behind the grille, directly under the hood striker, which is on the hood. The hood latch has many important functions. As the engine of the car is many times referred to as the "heart" of the car, it is necessary to keep the engine covered and protected. The hood latch system ensures that the hood stays locked, therefore protecting the engine and the many other parts that reside within the hood of the car.

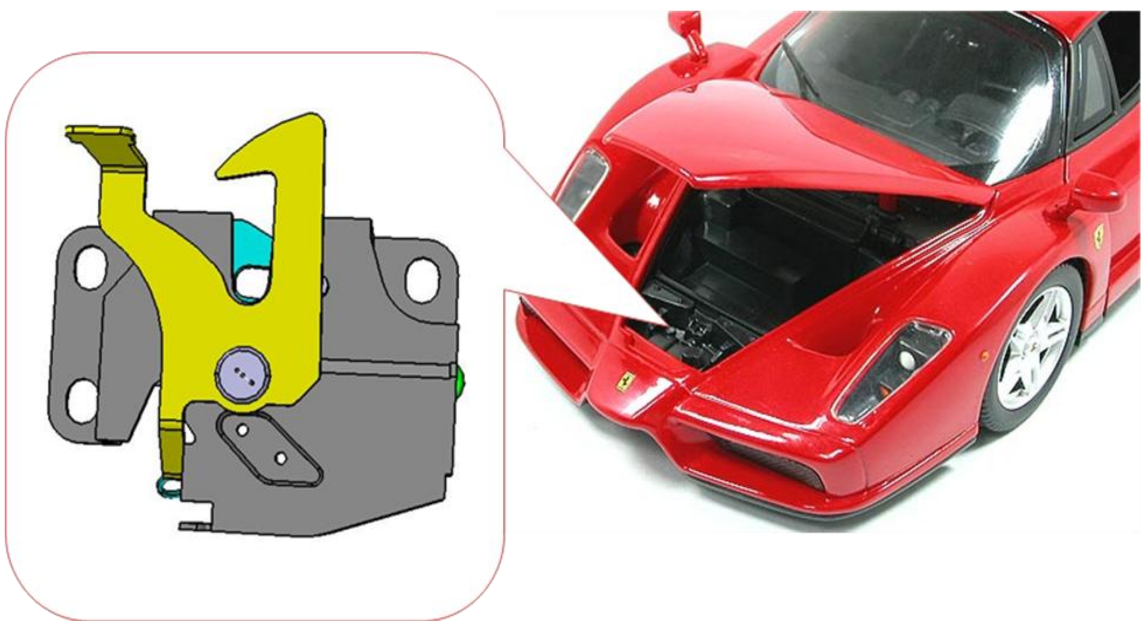

Figure 1 Location of Hood Latch System[1]

[1] http://cafe.naver.com/choy1978

The hood latch system must be able to catch the striker of the hood upon closing and instantaneously, as well as automatically, lock. Once in the locked state, it must remain locked and only unlock upon the operator’s control. Even once unlocked, the hood should not swing open at once, and therefore, a safety hook must be present to catch the unlocked hood and keep it closed. The hood latch must then be easy and safe to open, once caught by the safety hook.

The following figures show the concept hood latch system we were given to work on. There are many components to this assembly and therefore it is important to know the functions and responsibilities of each.

The first is the latch (1). It is responsible for the locking and unlocking of the striker. Second is the base (2). The base keeps all the components mounted on to the car and to each other. Third is the safety hook (3). The safety hook is responsible for catching the striker upon unlocking (3a), as well as opening the hood (3b). Next is the plate (4). The plate keeps both the latch and the pawl from rattling and moving. The spring-latch (5) and spring pawl (6), keep the latch and the pawl from rotating in any unwanted direction as well as causing them to return to the original position upon rotation. Simply, they keep the pawl and latch working properly. The striker (7) is a representation of the hood. It is attached to the hood and is what needs to be locked in order to keep the hood itself locked. Lastly, the pawl (8), can either keep the latch locked or block the latch from unexpectedly unlocking. We have narrowed down to three components to focus on, as they deal with the majority of the forces involved, as well as have the most immediate responsibilities in the locking, unlocking, and opening of the hood. The three components are the latch (1), the safety hook (3), and the pawl (8).

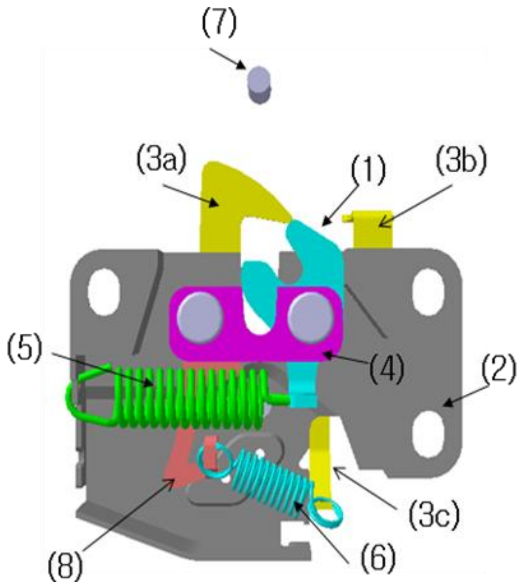

Figure 2 Open Hood Latch Design

(1)Latch (2)base (3a,b,c)safety-hook (4)plate (5)spring-latch (6)spring-pawl (7)striker (8)lever-arm

The company gave us a specified maximum load value of 550kg on the latch/pawl and 270kg on the safety hook. This means that the latch and pawl are expected to withstand a minimum of 550kg of force, and the safety hook must withstand a minimum of 270 kg of force in order to ensure proper use and reliability. Because they receive the majority of the stress loads, they must also be the most efficient. This means shaving off unnecessary sections and redesigning them for better production cost and lighter weight. It is too risky to try to alter the base of the model, since we are not sure of the dimensional qualifications the part must have, nor is it easy to try to modify the springs, because there are many potential and internal forces at work within the springs.

The ID is a concept design from the ACS Company which we will use as starting point for this project. The characteristics of this design are also used to measure the improvements of our new designs. This means, that in the procedure of designing our new ideas we are trying to receive better designs than the ID. Better, for the purposes of this project means lower cost, lower weight, while maintaining acceptable, satisfactory, or high performance capabilities. We will talk about what is an acceptable performance later on in the paper.

In order to manipulate this design we need to understand every separate component and its function in the system. The major parts in the system are the latch, the pawl and the safety hook. These are the parts that hold the striker in its locked position. The base is the plate on which the other parts are mounted on and which is fixed to the chase. The base (1) and the plate (4) can easily be remodeled to fit modified latch, pawl and safety hook. The springs can be selected in various sizes and strengths. For these reasons we decided to keep our main focus on modifying the three major components: the latch, the pawl and the safety hook. In return, this assumption was confirmed by the Professors, the T.A. and the ACS.

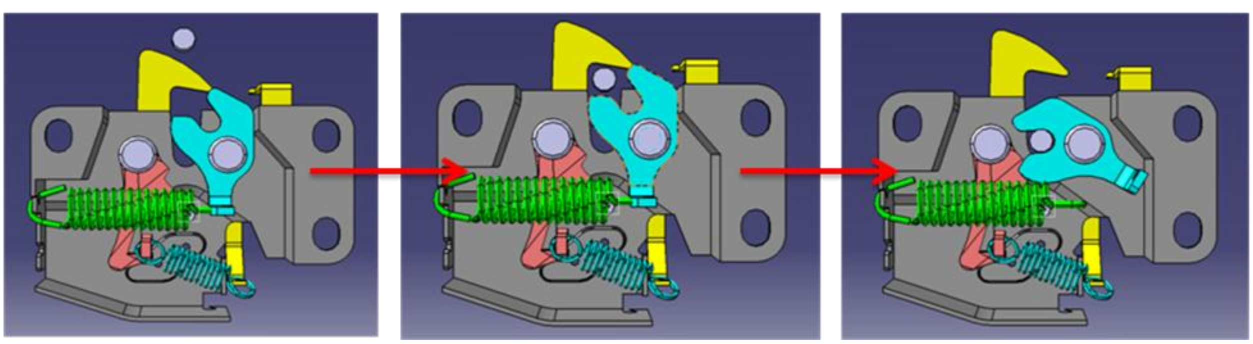

Figure 3 Operations of the ID

Figure 3 shows the operation steps for closing the hood latch and is explained below. The striker is bound to a vertical motion only; it cannot move to the side or rotated in any direction. From the open position shown in Figure 2 the striker starts to move downwards. It hits the safety hook forcing it to rotate counter clockwise until the striker passes its tip at which point the hook snaps back to lock the striker in. the striker continues to move down reaching the mouth of the latch. At this point the force of the striker on the latch forces it to rotate counter clockwise. During this motion the latch will hit the pawl forcing it to rotate clockwise. Both, the latch and the pawl are suspended by springs that create forces acting against the rotations of both components as seen in Figure 2. This motion continues until the latch reaches the locking position in which it interlocks with the pawl. This position is depicted in Figure 4 below.

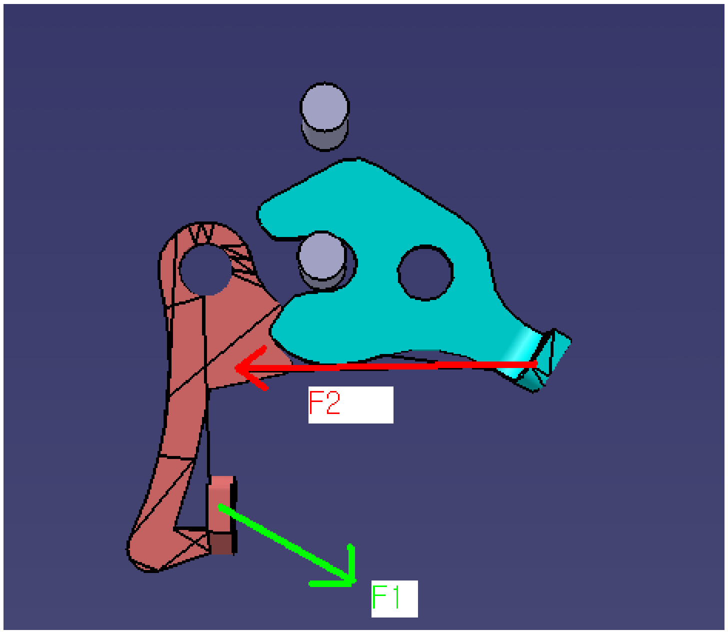

Figure 4 Latch interlocks with Pawl

Figure 3 also includes the forces, F_1 and F_2 which continue to act on the latch and the pawl while interlocked. F_1 is the force created by the spring-pawl (6) and F_2 is the force created by the spring-latch (5). These two forces are important in the locking mechanism, because they keep the latch and the pawl from rotating back and releasing the striker. They create the connection between the latch and the pawl to keep the system in the locking position.

Figure 3 shows the system with all components in the locked position. At this point the hood is securely shut. How to open the hood again will involve either manual operated mechanisms or electronically. In general there are two mechanisms: the first one is to rotate the pawl clockwise in order to allow the latch to rotate clockwise. This rotating motion will force the striker upwards until it reaches the position between latch and safety hook. At this point the second mechanism needs to be handled. This is to rotate the safety hook counter clockwise to release the striker entirely from the system.

As I said before, the mechanisms can be manual or electronically operated. The mechanism that operates the pawl is located in the interior of the car. It is in form of a handle that needs to be pulled back by the operator. The motion is transferred to the latch system by cables that pull the pawl back (to the left in Figure 4). In higher class vehicles an electronic, more expensive version replaces the manual handle in the interior.

The second mechanism involves the movement of the safety hook. Here, the operator needs to be in front of the car and manually rotate the safety hook using its handle (3b in Figure 2).

These mechanisms are standard use in vehicle operations, but for this project we focused in the mechanisms and information that we received from the ACS Company.

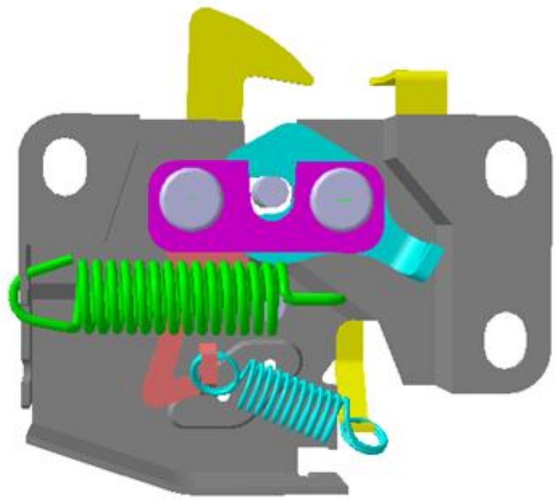

Figure 5 Locked position of ID

The safety hook is the second important mechanism which needs thorough analysis. The safety hook, as the name indicates is a mechanism that will prevent major accidents in case the latch and pawl mechanism fails to hold the hood in place.

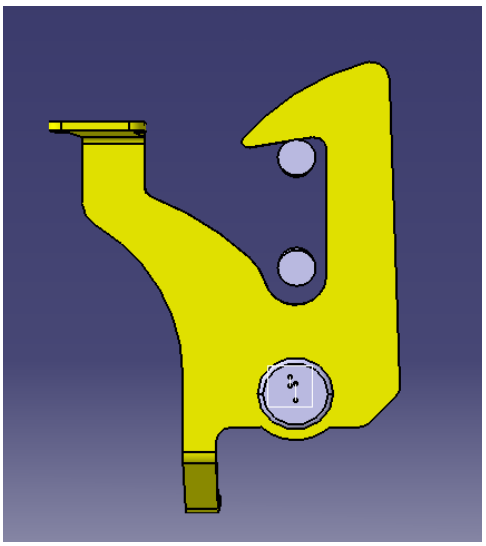

Figure 6 Safety Hook to ID

As you can see in Figure 6 above the safety hook is a handle that will allow the operator of the vehicle to manually open it. This motion will release the striker from its secured position.

1.3 Software Background

The use of CAD (Computer Aided Design) software was necessary in order to visualize and modify the original model and its components, as well as in order to create new components and assemblies. We were supplied with CATIA for use as our primary CAD software. We were accustomed to other CAD software such as Solidworks or Pro-Engineer, but never used CATIA before. We needed to familiarize ourselves with the given software, and therefore needed to do tutorial exercises as well as create sample components. Applying our previous knowledge of the other CAD software, we were quickly able to perform simple operations and steps in order to get the desired results. We would create a 2D sketch of the desired component using an array of lines, circles, curves, and angles. After checking to see that the sketch is complete and accurate, we needed to extrude the part into 3D. After a few simple modifications to the extruded part, we were able to add more details, such as shells, ridges, holes etc. Lastly, we could add material properties to the part or color-coordinate the part as desired. This is the process we would go about using in CATIA for all of our project-related designs.

After finishing the CAD file, we would need to analyze the parts. Therefore, it was also necessary to use FEA/FEM (Finite Element Analysis/Finite Element Modeling) software. We were supplied with ABAQUS to use as our FEA software. With ABAQUS one is able to perform many different types of analysis, such as: stress analysis, thermal analysis, noise analysis, etc. For use the stress analysis was the application that we needed to use. We are able to get results by going through several steps. Property is the first step, in which we assign the part with specific properties, such as physical properties or material properties. Assembly is the next step, in which we assemble the parts together and make sure they are all complete. The next step is called step, in which you create stages for the part to undergo, such as static or dynamic. Interaction is where you would apply the interactions within the assembly between the components, such as friction. Load is for the boundary conditions as well as the external forces involved. Using the boundary conditions we were able to allow it certain ranges of freedom or completely stop any translational or rotational movement. Mesh is for the element size, mesh size, and basically choosing how accurate or how rapidly you want data. Job is the simulations to get the stress distribution and for analyzing the results through graphs, tables, contours, etc.

2. Problem Statement

The hood latch system is a very important mechanism in a vehicle and there are many different designs on the market produced by different companies. The importance of this part lies in its security; that means that it is safely secured to the chase of the car and has a functional mechanism. The hood should not fly open when the draft of the wind is pulling on it. Neither should it be too hard to open or close if the operator needs to get to the engine or other components of the car that lie underneath it. For this to apply a simple, but strong mechanism is needed to hold the hood in place.

The problem description that was given to us initially stated briefly, that this project intents to optimize the weight of a concept design from one of ACS's hood latch systems. In the duration of our preparation for this project we established that this will incorporate the overall reduction of the manufacturing cost. This was confirmed by the ACS Company. While visiting the company and the manufacturing sight we discussed with the representatives, that the optimal design would be one that is remodeled, has a better stress distribution, costs less and uses less components in the mechanism. For design specifications we received minimum load applications on the latch and the safety hook, these are 550kg and 270kg respectively. To clarify for future sections and graphs in this report we used Newton's Second Law to convert kg to Newtons.

$$F=m*g$$

where m is the mass (either 550kg or 270kg) and g is gravity. For the gravity we used an approximate value of $10m/s^2$. From this we receive the two forces 5500N and 2700N.

Our goals to successfully solve the problem in this project is to create three alternative designs that will have the attributes of less weight, less cost, and if possible will need less number of springs or components. The cost of the system will depend on the weight, the number of springs and the number of components in the system. Hence this factor is more of a result of the modification of the other variables, e.g. the weight or number of components. In order to achieve these goals we will need to use several computer programs to modify and analyze the designs. At KNU we will use CATIA, a Computer Aided Design program to modify and create new designs. The data received from our CATIA designs will be fed into a finite element method computer program to analyze the stress distribution in the designs. The FEM program that is available to us at KNU is ABAQUS.

3. Development of New Designs

In this section we begin to discuss the concept designs that were created in CATIA. We came up with three variations of designs that focus on different aspects of the hood latch system: One is a simple weight reduction design (WRD) a second is a simple mechanism design (SMD) and the third is a structural reinforced design (SRD).

3.1 Weight Reduction Design (WRD)

The WRD is a basic idea for optimizing the weight of the initial design. In this design, the idea was to keep the latch and the pawl and their function in the hood latch system mostly unchanged. This system is probably the simplest one of our alternative designs that we came up with. One reason for this assumption is that it leaves out the remodeling of a new mechanism. In the WRD the locking mechanism is very similar to the ID where the latch and the pawl interact in such way that they can close in the striker. The main difference is that the pawl interlocks with the latch and not the latch in the pawl like in the ID. In Figure 7 shown is a picture from the WRD modeled in CATIA. The similarities are clear to see; it has the same set up and orientation of the latch and pawl, the extended portion on which the springs will be attached are in similar locations. On the other hand one can see how the interlocking position is different.

The opening and closing mechanism for this design undergoes the same motion than the ID. In order to open this system to release the striker the pawl needs to be rotated clockwise around the centered hole until the latch is free to snap open. The latch and the pawl are suspended by springs at the ends similar to where the springs are located in the ID. F_1' and F_2' indicate the forces that the springs exert on both parts the latch and the pawl in this design.

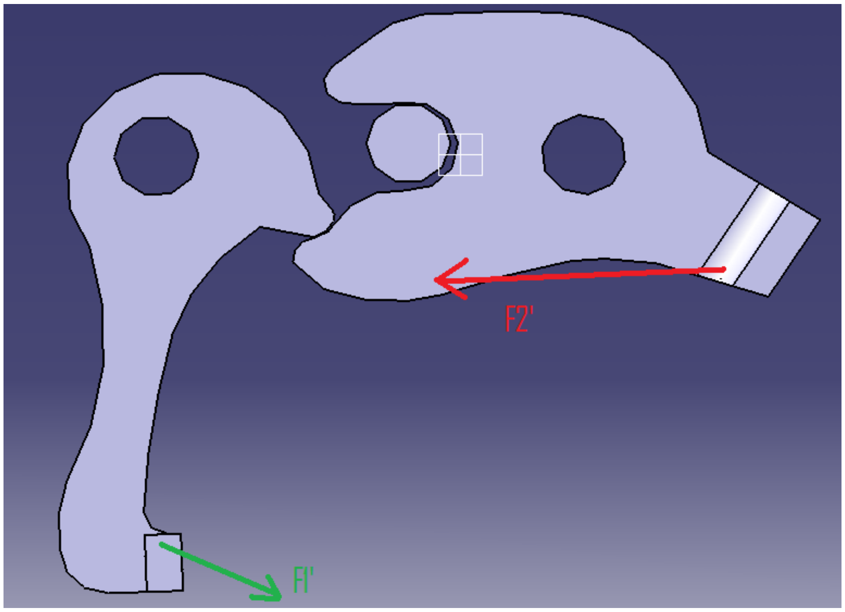

Figure 7 WRD locked position with forces

As you will see, this design is slightly different from the one that was used in the FEA for the WRD. This is only due to the modification of minor portions that will not have significant impact on the stress distribution. One thing that should be mentioned here is, that the base plate has a stopper for the pawl. This stopper prevents the pawl from rotating too far in the counter clockwise direction. The stopper is located to the right of the elongated section of the pawl.

3.2 Simple Mechanism Design (SMD)

The SMD is basically a design that is concentrated on simplifying the mechanism of the ID, in hopes of optimizing cost and weight, while improving performance and maintaining practicality of use. The major difference between the SMD and the WRD is the combining of the latch and the pawl into one part. This would allow better stress distribution as well as decrease the number of components. Lowering the number of components was important for the cost aspect, as we can assume that the less number of components there are, the cheaper the part is to manufacture. We also cut off sections in the part that we felt were unnecessary, meaning sections where there is no stress distribution and have no functions in the part. The last modification we applied to the part was the rearranging of the rivet latch hole. We moved the hole slightly to the right to allow for better stress distribution around the concentrated area near surrounding the striker. This also was helpful in allowing more rotation within the given dimensional constraints. The finished part of the SMD can be seen in Figure 8.

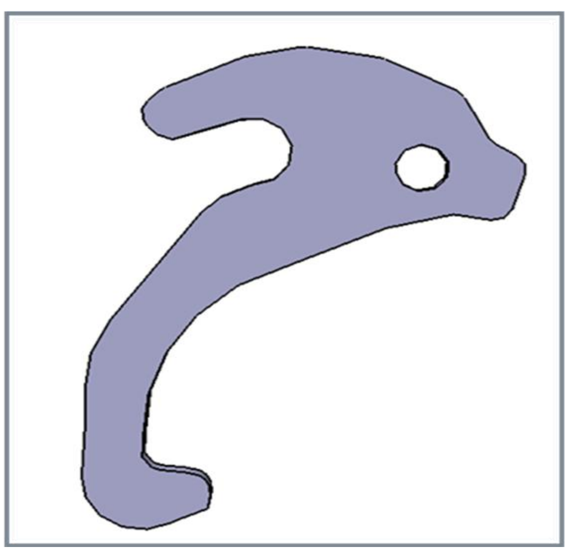

Figure 8 the SMD part

The mechanism itself is very similar to the previous ID and WRD mechanisms. However, the SMD relies more on the springs than the previous designs as the pawl needs to be able to rotate with the latch. Therefore, the only force keeping the latch from locking the striker is the springs. Otherwise, the mechanism is still the same.

3.3 Structural Reinforced Design (SRD)

This design is probably the most complicate one from the new designs. The SRD focuses on an entirely different construction of the hood latch system. This is remodeled from the base plate on and has an entirely different structure that we hope will make the system much stronger. Hence the design got his name. Figure 9 is a display of this design.

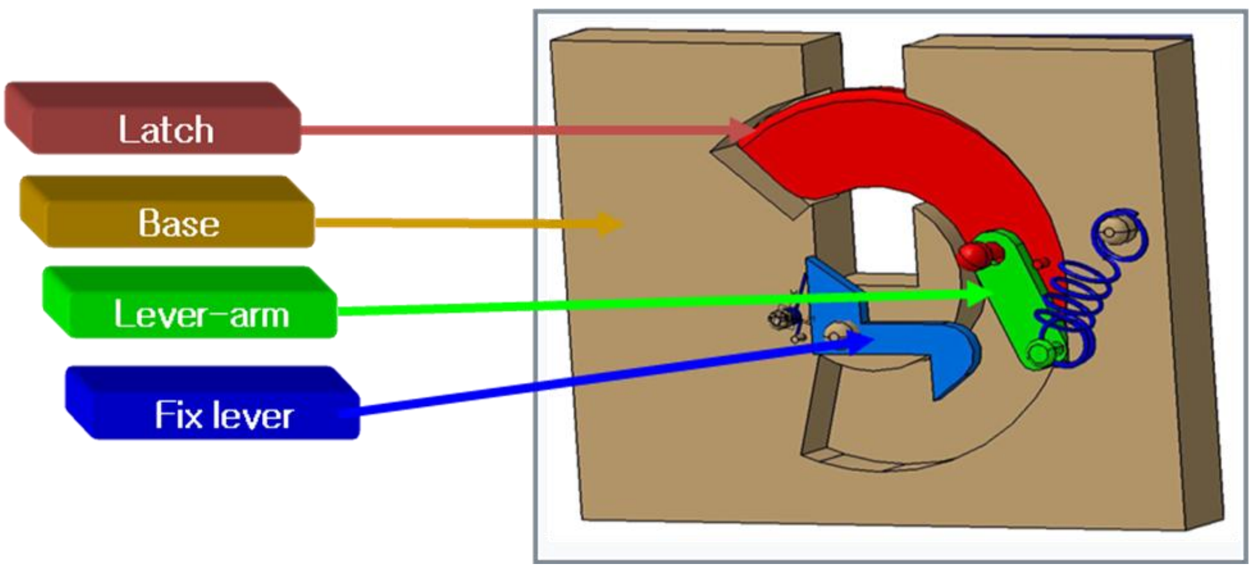

Figure 9 the SRD with labels

As you can see, the concept in this design is a different way of holding the striker in place. The most important feature of this design is that the striker will be completely enclosed by the latch and the base.

In the result we also found, that we can make this design much smaller than the ID, i.e. the base of the ID has a width of about 120mm and the one of the SRD is only 90mm wide. As you will see even in these dimensions the SRD has a much higher maximum strength. The mechanism to open and close the system is very simple. Follow the pictures and the description below to understand the operations of closing the system.

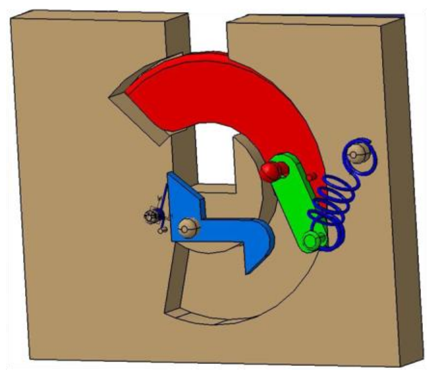

Figure 10 SRD closed no striker

The SRD is in Figure 10 is shown in its closing position with the striker outside. This is the system's neutral state, where no force is acting on the system besides the spring forces which hold the latch closed. The operator of the vehicle has to initiate the mechanism by pulling on a lever located in the car that attaches to the lever arm (component in green). This is mostly done by wires. The forces that the operator exerts will move the lever arm in a downwards and to the left direction. This force will counteract the spring force that is attached to the latch component.

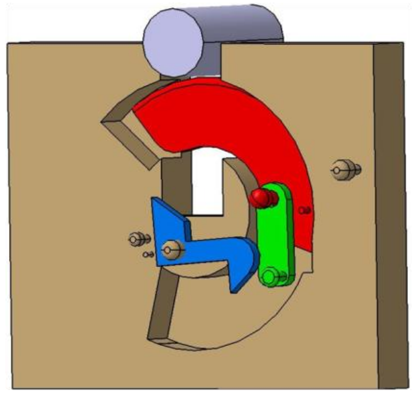

Figure 11 SRD operation step 1

As viewed above this motion will allow the latch to move, or rotated, in its bearing. The lever arm needs to be pulled back far enough so that the entire latch clears the slot for the striker. When the nipple where the lever arm is attached to latch makes contact with the fixed lever it forces the fixed lever to rotate as far as it needs to pass by.

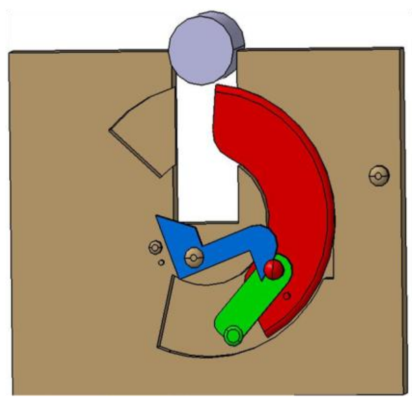

Figure 12 SRD operation step 2

When the latch is rotated far enough, the spring force on the fixed lever forces it to snap back to its original neutral position, shown in operation step 3 below. As you can see the latch moved far enough to clear the slot for the striker. The important component in this position is the fixed lever, which acts as a support to hold the latch from snapping back into its closed position. The position shown in Figure 13 is the position in which the system stays in until the operator of the vehicle closes the hood. The hood is represented by the striker that can now move downwards into the slot.

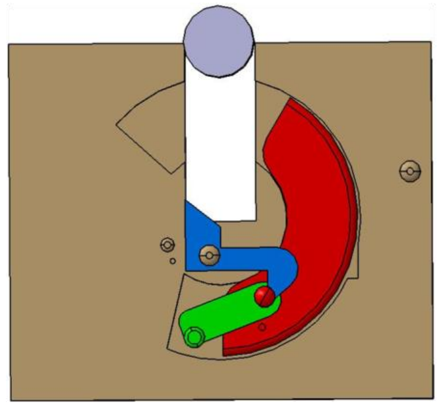

Figure 13 SRD operation step 3

As the striker moves downwards it passes the latch and reaches the bottom of the slot. Here the fixed lever hast a small inclined portion which sticks out over the edge of the slot. When the striker hits this inclined section it makes the fixed lever rotate counter clockwise which in return will release the latch from its locked position.

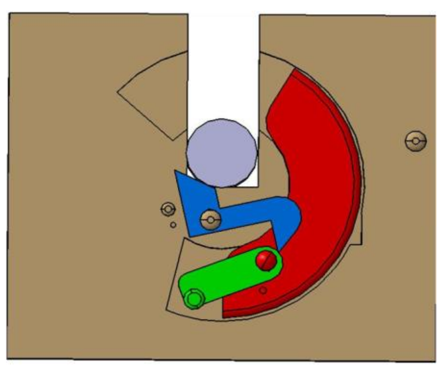

Figure 14 SRD operation step 4

The latch rotates back to its closed position, forced by the attached spring and encloses the striker to keep the hood shut.

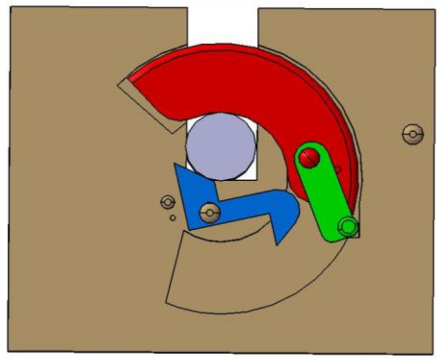

Figure 15 SRD operation step 5

Now to open the hood again the operator needs to just use pull back the lever arm so that the striker is free to move upwards.

3.4 New Safety Hook Design

The safety hook is our third component that we focused on. The first thought to change the design of this component was to see where we could save up some material from the initial design safety hook. In Figure 4 one can see that the handle part is thick and fairly far away from the load application. This means that one can assume that there will not be high stresses reaching the end of the handle portion of the safety hook. A logical result for this is to try ad relocate the handle portion or to create a different handling system completely. Once we thought about this we came up with simply moving the handle to the other side of the components. This means that we would need to attach it to the hook that comes off the base of the part. After relocating the handle we received a new design which is depicted in Figure 16 below.

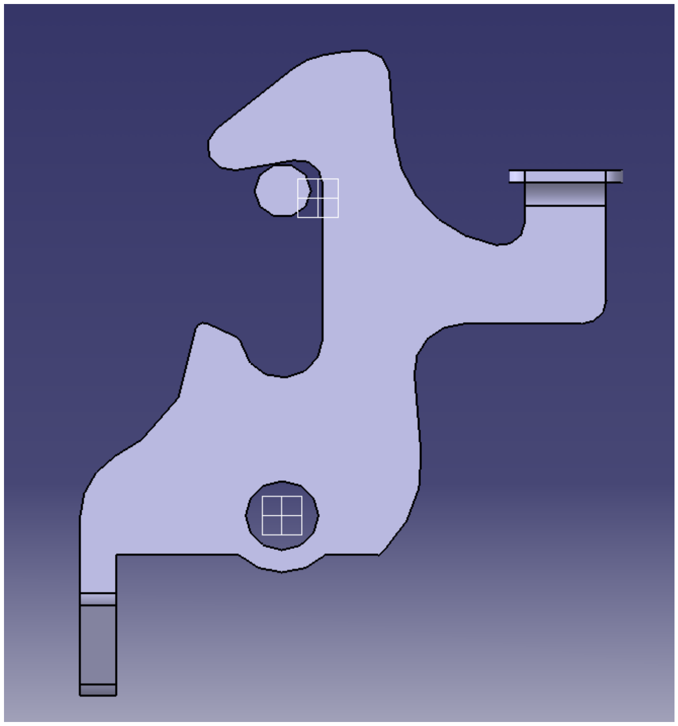

Figure 16 new Safety Hook Design

The handle is now on the opposite side of the hook but still allows the operator to get access to the handle in order to rotate the safety hook to open the hood. This design keeps the same fastener and motion then the original one. What has been improved is the mass of the part which is reduced in the new design. And, as you will see in the next Chapter, the stress distribution has also improved. The new safety hook allows a higher maximum stress from the movement of the striker. These outcomes were as we thought when we relocated the handle to the side of the hook.

4. Design Analysis and Weight Calculations

This section is dedicated to the FEA analysis that we received for our final designs, discussed in the chapter 3. The reason why we used a program like ABAQUS is to find the stress distribution in the component that is being analyzed. In our case the simulations are run for the latch/pawl system and the safety hook. When using a FEA program one has to be very clear with the input data. The input data includes geometric features, mesh size, element type, boundary conditions and various other criteria.

The geometries for the analysis are the parts that we modeled in CATIA. To use the parts in ABAQUS we converted the file types to an .igs format and imported them into ABAQUS. The mesh sizes are created for ever part individually and the element types are picked according to the function of each component. The boundary condition are set for every simulation to the specification of where a part is fixed, or how far it can move, or rotate. For our simulations it is important to understand, that we are not applying a load directly to the system, i.e. the latch or the safety hook. We used the striker as a moving element that exerts a contact force on the latch or the safety hook. In every simulation the striker is a rigid body that can only move in a vertical direction up. We set the striker to move with a constant velocity of 30mm/sec and a distance of 30mm from its original position. From this motion ABAQUS simulates a stress distribution within the latch or safety hook. From this stress distribution we can find the maximum load that was created by the striker on the part and check if it is over the specified load conditions. To recap, the minimum load that the latch should be able to withstand is 5,500N and for the safety hook it is 2,700N.

In the following sections we present our finite element analysis for our designs. To see if we reached our goals we also include our first analysis of the initial design and compare it to the new designs. The comparison emphasizes on the number of components each design has, the total mass, and its strength.

4.1 Initial Design

We used the analysis of the ID as our starting point for remodeling the system and as a mark to see if our new designs would be better. For the ID we received the CATIA files from our sponsors and we started off with studying their concept design. We used those CAD files as input data for the first ABAQUS simulation. In the simulations we use four components, the striker, the latch, the pawl and rivets. A summary of the simulation data is listed in Table 1

Components	Body	Element type	Element size	Boundary Condition
Latch	deformable	C3D4, solid elements	0.8 mm, Thickness : 4 mm	U1=UR2=UR3=0
Pawl	rigid	R3D3, solid elements	0.8 mm	U1=U2=U3=UR1=UR2=UR3=0
Rivet	rigid	R3D4, 4 node shell element	0.8 mm	U1=U2=U3=UR1=UR2=UR3=0
Striker	rigid	R3D4, shell element	0.8 mm	U1=U2=UR3=UR1=UR2=0, U3=25

Table 1 FEA Model for ID

You can find that the Latch is the only deformable body in the model where the rest are stationary rigid bodies. This means that the latch will be capable of deformation when applied a load against, while the rigid bodies will be incapable of any sort of deformation. It is important to note that we have set 4 nodes per element and each element is 0.8mm apart. You can find the boundary conditions for this model as shown above (note the directions: x=U1, y=U2, z=U3 and corresponding rotational directions): the latch is restricted to move in the x direction as well as in the y and z-rotational direction, but free to rotate about the x axis and move in the y and z direction when a force is applied. Below in Figure 17 is the simulation model with the specified directions.

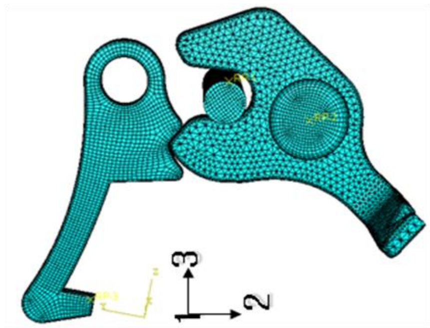

Figure 17 FEA Model of ID

. The results for the contact force and stress distribution can be found in the result section of this report.

4.2 Weight Reduction Design

Since this design is very similar to the initial design we used the same FEA model. In fact for all following designs the FEA model is very similar to the ID.

Components	Body	Element type	Element size	Boundary Condition
Latch	deformable	C3D4, solid elements	0.8 mm, Thickness : 4 mm	U1=UR2=UR3=0
Pawl	rigid	R3D3, solid elements	0.8 mm	U1=U2=U3=UR1=UR2=UR3=0
Rivet	rigid	R3D4, 4 node shell element	0.8 mm	U1=U2=U3=UR1=UR2=UR3=0
Striker	rigid	R3D4, shell element	0.8 mm	U1=U2=UR3=UR1=UR2=0, U3=30

Table 2 FEA Model for WRD

Table 2 show the data used for the WRD design in the FEA simulation. As you can see it is exactly as the ID. The picture below shows this model in the FEA.

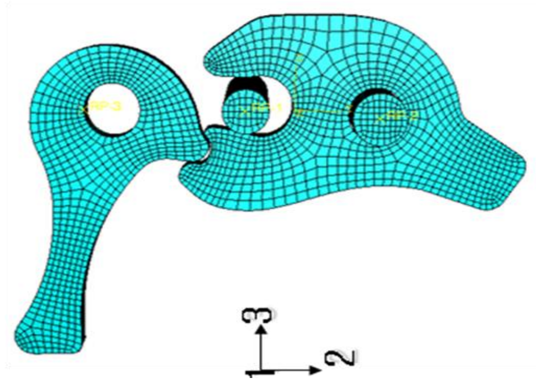

Figure 18 FEA Model of WRD

4.3 Simple Mechanism Design

As said before we use similar simulations for all the designs. Table 3 shows the FEA data that was used for the analysis. As you can see this is the combined component so we do not need data for a pawl.

Components	Body	Element type	Element size	Boundary Condition
Latch	deformable	C3D4, solid elements	1.0 mm, Thickness : 4 mm	U1=UR2=UR3=0
Pawl	N/A	N/A	N/A	N/A
Rivet	rigid	R3D4, 4 node shell element	0.8 mm	U1=U2=U3=UR1=UR2=UR3=0
Striker	rigid	R3D4, shell element	0.8 mm	U1=U2=UR3=UR1=UR2=0, U3=25

Table 3 FEA Model for SMD

A picture of the SMD model in ABAQUS is shown below.

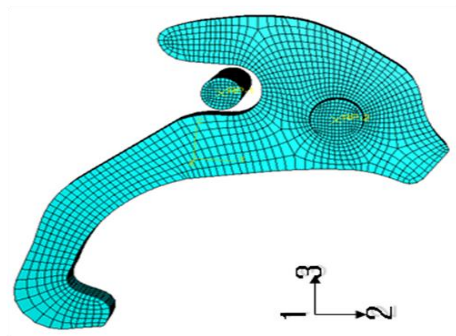

Figure 19 FEA Model of SMD

4.4 Structural Reinforced Design

Applying the simulation to the SRD we used the parameters shown in Table 1. It should be mentioned, that the SRD has no pawl like the SMD and that the Rivet component is represented by the base of the system.

Components	Body	Element type	Element size	Boundary Condition
Latch	deformable	C3D4, solid elements	1.0 mm, Thickness : 4 mm	U1=UR2=UR3=0
Pawl	N/A	N/A	N/A	N/A
Rivet	rigid	R3D4, 4 node shell element	0.8 mm	U1=U2=U3=UR1=UR2=UR3=0
Striker	rigid	R3D4, shell element	0.8 mm	U1=U2=UR3=UR1=UR2=0, U3=25

Table 4 FEA Model for SRD

A picture of the FEA model is presented in Figure 20.

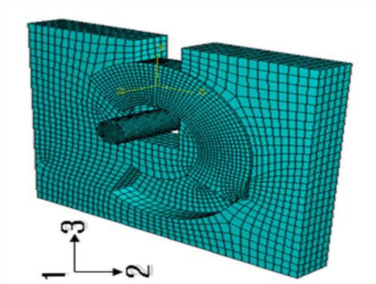

Figure 20 FEA Model of SRD

4.5 Initial Safety Hook

For the safety hook we also use a similar FEA model with the following data.

Components	Body	Element type	Element size	Boundary Condition
Hook	deformable	C3D4, solid elements	1.0 mm, Thickness : 1.6 mm	U1=UR2=UR3=0
Rivet	rigid	R3D4, 4 node shell element	0.5 mm	U1=U2=U3=UR1=UR2=UR3=0
Striker	rigid	R3D4, shell element	0.5 mm	U1=U2=UR3=UR1=UR2=0, U3=20

Table 5 FEA Model for Initial Safety Hook

You can see that the Hook is the deformable body here with the same boundary condition than the latch in the previous sections. The striker and rivet still stay as rigid bodies. The picture below shows the safety hook model.

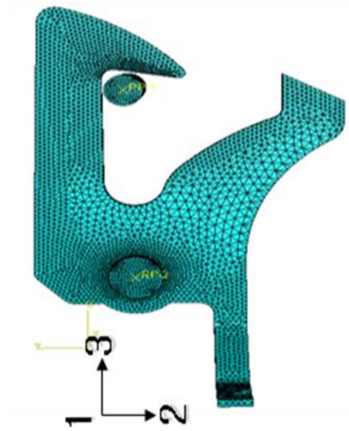

Figure 21 FEA Model of Initial Safety Hook

4.6 New Safety Hook

The last simulation is for our new safety hook design where we used similar data for the analysis than for the initial safety hook design.

Components	Body	Element type	Element size	Boundary Condition
Hook	deformable	C3D4, solid elements	0.8 mm, Thickness : 4.0 mm	U1=UR2=UR3=0
Rivet	rigid	R3D4, 4 node shell element	0.8 mm	U1=U2=U3=UR1=UR2=UR3=0
Striker	rigid	R3D4, shell element	0.8 mm	U1=U2=UR3=UR1=UR2=0, U3=30

Table 6 FEA Model for New Safety Hook

The picture below shows this design in the FEA model.

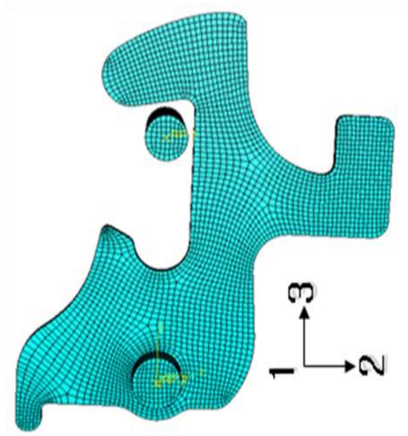

Figure 22 FEA Model of New Safety Hook

4.7 Weight Calculations

The weight calculations are an important step in this project, since our objective is to reduce the weight of the designs and because the cost is dependent on the weight of the design. To find the weight of the design we use a volume measuring tool of the CATIA applications. This tool allows us to select each component of each design and measure its volume. Once we found the volumes of each component we add them up to receive an accumulated value for the design’s volume. Below you can find Table 7 which shows all of our calculations.

Weight Calculations for ID, WRD, SMD and SRD						
	Comments	**Variable**	**Value**	**Unites**		
Density	density of steel*	ρ	0.0785	kg/cm^3		
Volume		V	**Formular**	cm^3		
Mass	mass calculation from volume and density	M	M=ρ*V	kg		
Design		**Volume****	**Δ=difference to ID**			
ID	Volume of ID	31.307	0			
WRD	Volume of WRD	30.014	1.293			
SMD	Volume of SMD	28.85	2.457			
SRD	Volume of SRD	12.989	18.318			
		Mass	**Mass (in g)**	**Δ'=difference to ID (in g)**		
ID	Mass of ID	2.4575995	2457.5995	0		
WRD	Mass of WRD	2.356099	2356.099	101.5005		
SMD	Mass of SMD	2.264725	2264.725	192.8745		
SRD	Mass of SRD	1.0196365	1019.6365	1437.963		
Safetyhooks		**Volume**	**Δ''=difference to ID**			
ID	Safetyhook for ID	4.438	0			
WRD	Safetyhook for WRD	3.674	0.764			
SMD	Safetyhook for SMD	3.674	0.764			
		Mass	**Mass (in g)**	**Δ'''=difference to ID (in g)**		
ID	Mass of safetyhook for ID	0.348383	348.383	0		
WRD	Mass of safetyhook for WRD	0.288409	288.409	59.974		
SMD	Mass of safetyhook for SMD	0.288409	288.409	59.974		
	*) http://www.efunda.com/materials/common_matl/common_matl.cfm					
	**) Volume is calculate with base plate, latch, pawl, fasteners and safetyhook; springs are not included.					

Table 7 Weight Calculations

We used the relationship between density and volume to find the mass (weight). This relationship is,

$$M=\rho*V$$

where M is the mass, ρ the density and V the Volume.

Since we are using SAPH 440 steel we used the density of steel as shown in the table. From the Volume we found that the SRD’s volume is significantly smaller than the other designs, including the ID. Resulting from this is that the design has a much lower mass value. So from the weight objective we can say that the SRD is by far the better design than the WRD and the SMD.

5. FEA Results and Design Table

Upon completion of the FEA modeling for each design, it was time to view the results. This section will show the FEA results for each design, which consists of the stress analysis, force vs stroke graphs, and the percentage of max load over the spec load for each design. An important note here is that as long as the max load is over the spec load, the part meets the company's load constraints. However, the percentage of how much the max load is more than the spec load is an added incentive for the design.

After viewing the results of the FEA models, we will continue to choose the best design. This will be done by a design table.

5.1 Initial Design

The figure below is the stress analysis results we received for the initial design.

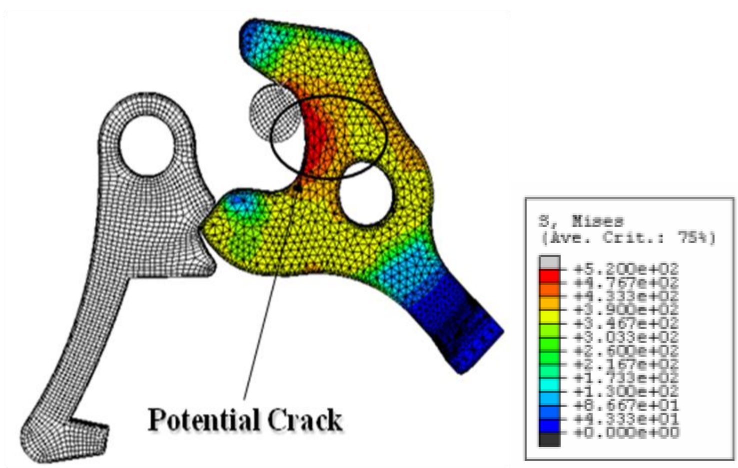

Figure 23 FEA Results for ID

The color contour plot shows the areas with the most stress concentrations through a range of colors with red being the highest stress concentrations on the part and blue being the lowest. The highest stress concentration is the area of a potential crack. This means that there will not necessarily be a crack, but if one were to appear, it would at that area. Notice that since the striker and the pawl were set as rigid bodies in the FEA modeling, they were incapable of deformation and therefore received no stress analysis.

The figure below is the force vs. stroke graph for the initial design.

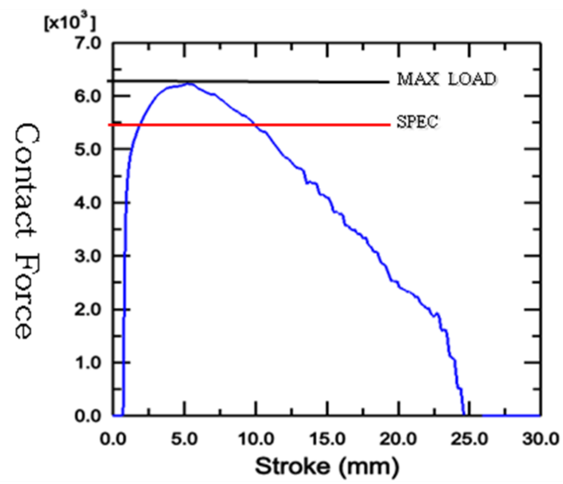

Figure 24 Force - Stroke Curve of ID

The blue curve shows the amount of contact force the striker applies on the latch as it moves upwards. The spec line for all of the latch designs is at 5,500N, which is the load constraint given to us by the company. The max load is the peak of the curve, and is the maximum amount of contact force the latch can handle before deformation or potentially cracking. As you can see, the max load is approximately 6,400N. We can create a percentage value to that will help us to better evaluate the design.

We use the equation

PercentageDifference = (Maximum Load/Specification Load)*100%

The percentage for this design is 116%. This percentage is going to be a factor in the design table to come.

5.2 Weight Reduction Design

The following figures are the stress analysis and force vs. stroke results for the WRD.

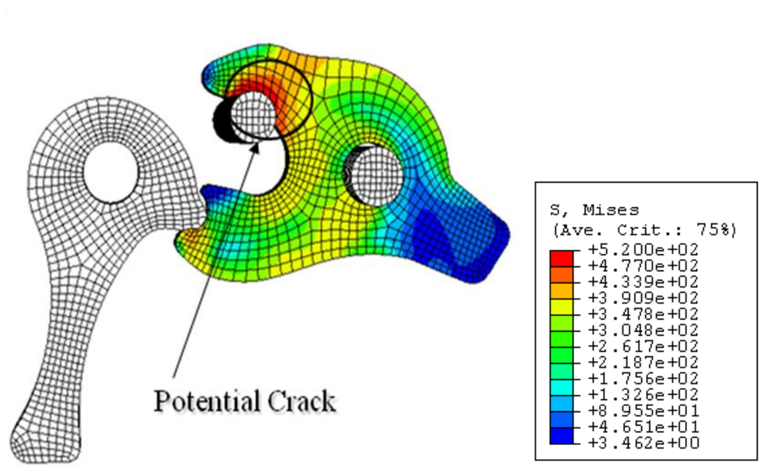

Figure 25 FEA Results for WRD

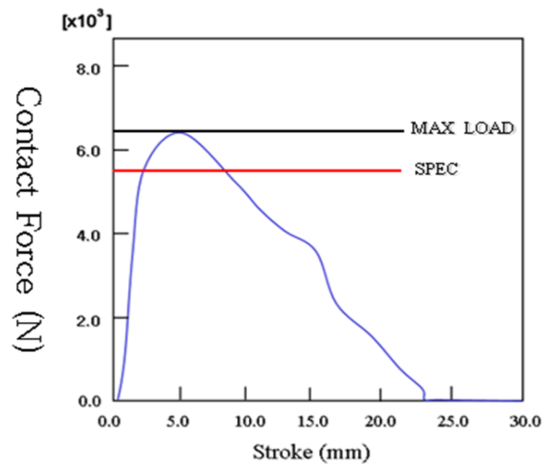

Figure 26 Force - Stroke Curve of WRD

The max load for the WRD is 6,200N, which is 200N less than the initial design's. The max load is still over the spec load and is therefore acceptable. The percentage of the max load over the spec is 112.7%.

5.3 Simple Mechanism Design

The following figures are the stress analysis and force vs. stroke results for the SMD.

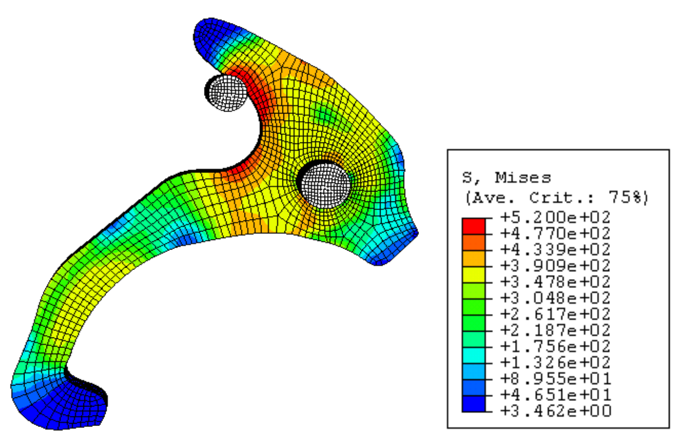

Figure 27 FEA Results for SMD

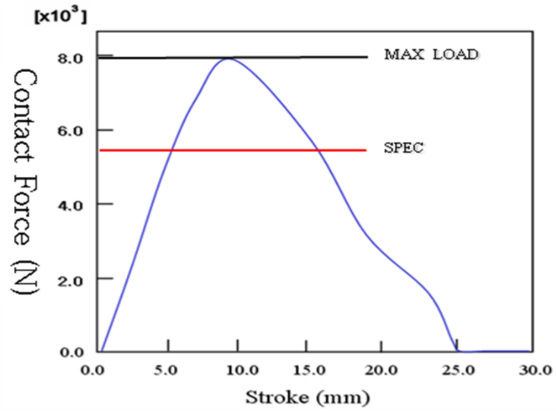

Figure 28 Force - Stroke Curve of SMD

The max load for the SMD is at 8000N which happens to be the highest of our designs. The percentage of the max load over the spec is 145%.

5.4 Structural Reinforced Design

The following figures are the stress analysis and force vs. stroke results for the SRD.

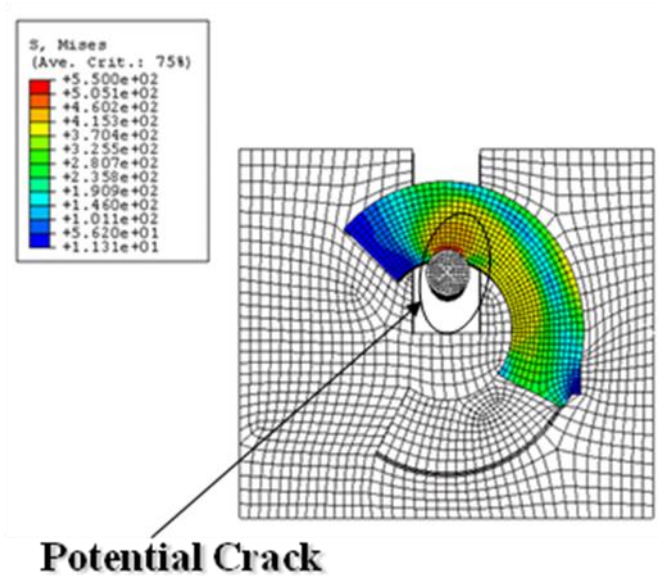

Figure 29 FEA Results for SRD

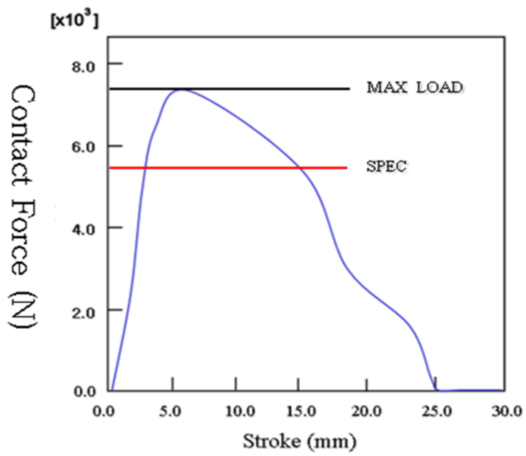

Figure 30 Force - Stroke Curve of SRD

The max load of the SRD is at 7,400N which is 1000N more than the initial design. The percentage of the max load over the spec is 135%.

5.5 Initial Safety Hook

The following figures are the stress analysis and force vs. spec results for the initial safety hook.

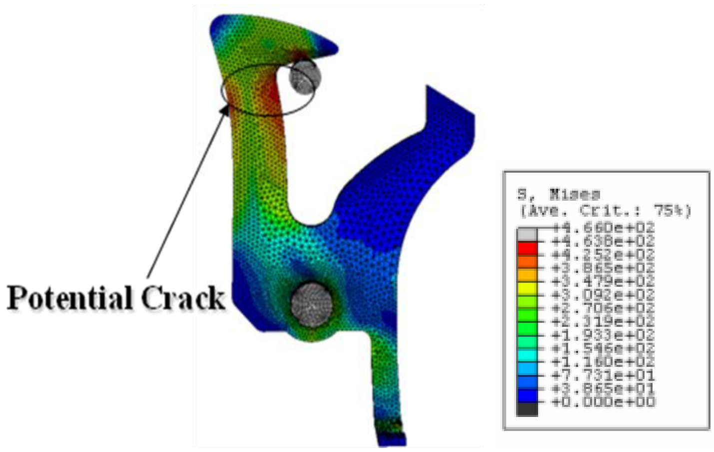

Figure 31 FEA Results for Initial Safety Hook

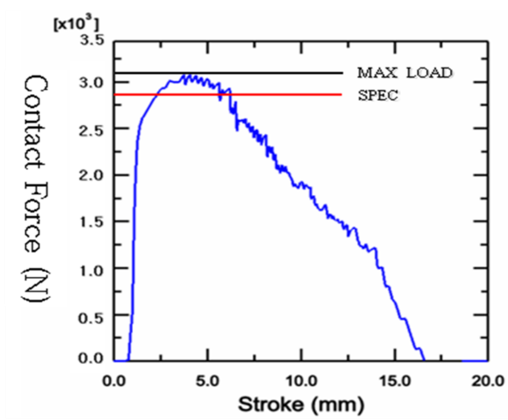

Figure 32 Force - Stroke Curve of Initial Safety Hook

The max load for the initial safety hook was at 3,100N. The spec load constraint for the safety hook is at 2,700N. The percentage of the max load over the spec is 114%.

5.6 New Safety Hook

The following figures are the stress analysis and force vs. stroke results for the new safety hook.

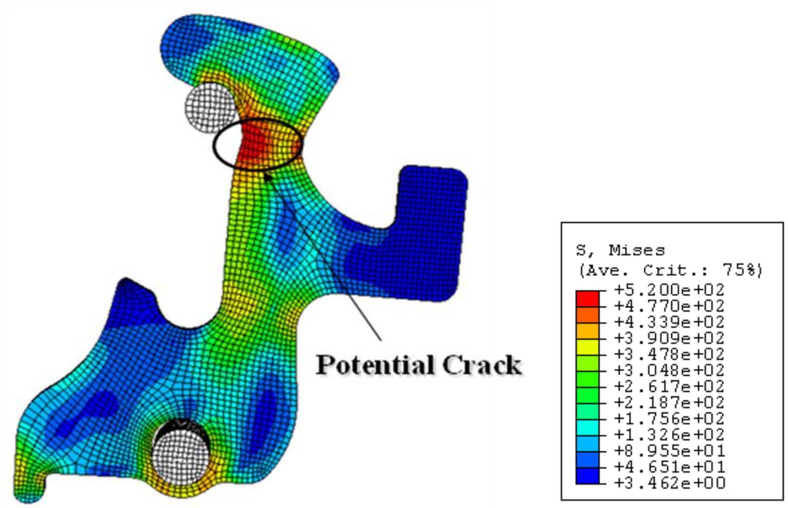

Figure 33 FEA Results for New Safety Hook

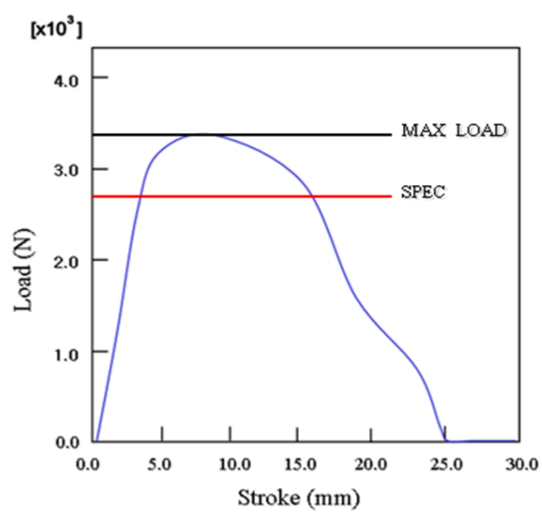

Figure 34 Force - Stroke Curve of New Safety Hook

The max load for the new safety hook is 3,300N which is 200N improved from the initial safety hook. The percentage of the max load over the spec is 122.2%.

5.7 Design Table

The following is the design table we used to choose the final design. We used 4 parameters for each design: Number of components, mass, latch strength, and hook strength. We then found the values of each design for each component and subtracted them by the initial design to find the difference. We then multiplied the difference by a multiple of 10 in order to give each difference value a similar starting value. Finally, we gave each component a value based on their importance to the company. We multiply the modified difference by the importance value to get the final value for each component. Add the value from each component and you get each design's value number. This is how we judged which design was the best and would be recommended to the company.

Design Table					
	Comments				
Parameters		ID	WRD	SMD	SRD
Components	number of components	7	7	6	6
Mass (kg)	mass of design	2.4576	2.356099	2.264735	1.019637
Latch Strength (%)	strength of latch	116.00%	112.50%	145.00%	132.70%
Hook Strength (%)	strength of safety hook	114%	122.20%	122.20%	0
Difference			ID-WRD	ID-SMD	ID-SRD
Components			0	1	1
Mass (kg*10)			1.01501	1.92865	14.37964
Latch Strength (%/10)			-0.35	2.9	1.67
Hook Strength (%/10)			0.84	0.84	0
Design Values					
Components	Multiply Difference by 2		0	2	2
Mass (kg*10)	Multiply Difference by 1		1.01501	1.92865	14.37964
Latch Strength (%/10)	Multiply Difference by 0.5		-0.175	1.45	0.835
Hook Strength (%/10)	Multiply Difference by 0.5		0.42	0.42	0
		Totals	1.26001	5.79865	17.21464
		Notes:			
		x=0; Same as ID			
		x<0; worse than ID			
		x>0; better than ID			

Table 8 Design Table

6. Conclusions and Discussions

In this section of the report we present our final design choice of our project. From the design table it is easy to see, that the SRD exceeded the other designs by far.

We expected this design to be much better and more effective than the others. This design is a very innovative idea that still can use more detailed analysis. As for this project we are very satisfied with our solution of the problem statement.

To recap the Structural Reinforcement Design, Figure 35 shows the components of the design.

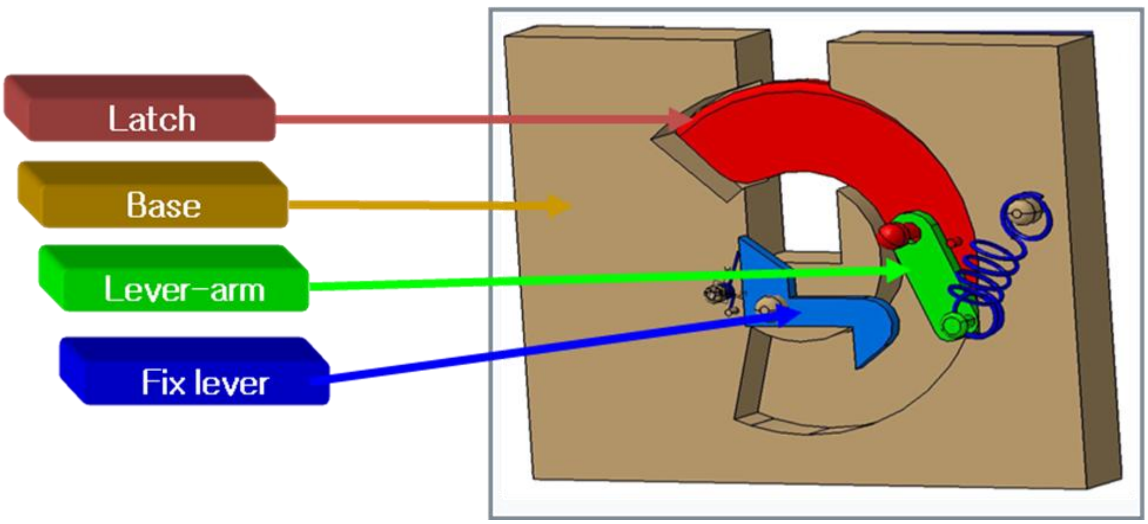

Figure 35 The SRD

From our analysis we found this design to be the best one we came up with: it is much lighter then the ID, it has a higher maximum strength, and it has less number of components. Besides these result the SRD offers a few numbers of other advantages over the ID.

First is, that the SRD can be said to be a closed design. This means that it completely encloses the latch in the system, whereas the ID shows a gap in between the latch and the pawl. This gap in the ID occurs naturally, because it has two components in the closing mechanism instead of one. Figure 36 below shows this idea.

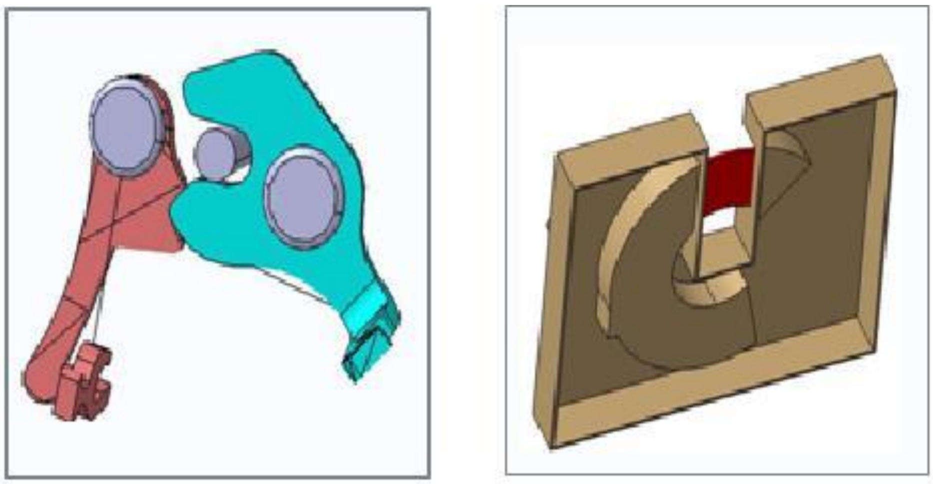

Figure 36 Open and Closed Systems

As you can see the difference above you can imagine, that the same force on both latches results in different effects. The latch on the left has more freedom to deform in its system. The latch of the SRD on the right is more confined in its track of the base. The latch on the right has not as much room to deform. This can result in a better ability to receive higher strength.

A second advantage that relates to the first one mentioned is, that the latch of the SRD is in contact with the base all around it. Now when a force is applied to the latch and it tries to deform the base will prevent it. In return this contact of the two components can result in a stress distribution all throughout the base. The base can be modified easily to withstand high stresses. Although this is just an assumption, because time limited our research and analysis we can say that the strength of the system will increase with a more detailed analysis where the base is set as a deformable body. This analysis will be tricky because the base is attached to the chase of the car at certain points. These points would be represented by boundary conditions that need to be set in an FEA model.

To summaries the project, it was a very interesting experience to work in a different country on this project. The group effort to compile and exchange ideas to reach our goal was most valuable during the duration of the project. Then creating the ideas using CAD software was a challenging process, but with everyone's participation we were able to create the three designs that were presented in this paper. The most challenging part of this project was the use of a FEA software. But the FEA program was a vital program that was needed to reach a profitable conclusion for a new design.

One of our goals was to make the new design cheaper. For this we needed a cost analysis; however it was difficult to find the cost for the process of manufacturing the initial concept design, which we were going to use as a set bar for our new designs. For this reason we can only say that it is cheaper due to the reduction of weight, components and processing steps. This is then only an assumption, that the new design is cheaper than the initial design.

References

http://www.acskorea.com

ABAQUS 6.5-Standard (FEA software)

Appendix

Acronymes

ID – Initial Design
WRD – Weight Reduction Design
SMD – Simple Mechanism Design
SRD – Structural Reinforcement Design
FEM – Finite Element Method
FEA – Finite Element Analysis
CAD – Computer Aided Design

Material Properties

- Material: SGH440
- Young's modulus (E): 210GPa
- Yield strength: 284MPa
- Tensile strength: 466MPa
- Poisson's ratio (ν): 0.3
- Density: 7.8E-009 tone/mm3