Detachable High Heel Shoe Construction

by

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Abstract

The goal on this investigation was to develop a detachable high heel shoe construction that could enter the current high heel market. The impact of high heel shoes on women's fashion is enormous but there are associated issues of comfort and health with these shoes. This work aims to maintain the appealing aspects of a high heel shoe while adding a concealed mechanism to enable the heel to be easily removed to convert the shoe into a flat at the discretion of the user. The current solutions and products in the nearly 7 billion dollar a year women's shoe market are minimal. The prior arts of detachable heels fail to develop a simple comprehensive detachable high heel that can enter the market. A feasible and complete design that takes into account arch stiffness, heel removal, styling, and manufacturability is the goal of this work. This investigation deconstructed high heel shoes to learn and leverage the current high heel shoe infrastructure as a basis for adapting the shoe into a detachable high heel shoe construction. Three prototypes of the detachable high heel shoe were developed with a shoe assembly that consisted of a modified insole and a detachable heel that consisted of a dovetailed aluminum shank fastened to a high heel. The prototypes were able to display the ability for the detachable high heel to maintain high heel stability, styling that is consistent with the industry, ease of use, a flat shoe and other critical functional requirements identified in the work. The construction was consistent with the current industry high heel infrastructure. The development of the detachable high heel construction displays the feasibility of such a product in a market where none exist. The detachable high heel construction needs further refinement and optimization to complete a design that is ready to enter this exciting market.

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Introduction

High heel shoes are one of the most dominant fashion trends for women across much of the world. The scope and appeal of high heel shoes can be observed on fashion runways, in magazines, the workplace, and even on young flower girls. The concept of high heels shoes dates back to the medieval times when they were first introduced for practical purposes. Catherine de Medici of France is considered the first person to wear high heels with the intent of fashion in 1533. High heels quickly rose in stature among the wealthy. The French Revolution saw a decrease in high heel usage because high heels were commonly associated with the wealthy class. High heels reappeared in the mid-1800s but made their largest resurgence among women after World War II. The growth in consumer spending combined with improvements to manufacturing capabilities and the diversity of shoes fueled the growth and intrigue of the high heel shoe[1].

The appeal of high heel shoes is a result of social mechanisms that have existed within our society for hundreds of years. The ancient Greeks considered the ideal women's foot petite and curved. The Chinese had a tradition of foot binding from the 10th century to the early 20th century maintaining the ideal image of a woman's foot as small and for light duty. The same influences are apparent in children's tales such as Cinderella which idolizes a petite foot as beautiful and fit for a prince. High heel shoes elevate women from the ground with an elevated heel that varies from 1" up to 5". The change in angle at the ankle accentuates the calves, makes the feet look smaller, arches the foot and allows the wearer to appear taller. According to a survey conducted in conjunction with this thesis, women wear high heels because the shoes make their legs appear longer, give them additional height, make them appear thinner and keep their posture upright. Women enjoy the physical appearance changes that are delivered by high heels, and many women wear them because of psychological reasons where heels can invoke feelings of femininity, sexiness, sophistication, fashion, prettiness, class, and elegance. The physical, social, and emotional benefits of high heels often overshadow the serious damage that high heels inflict on women in both the short and long term.

Women who choose to wear high heels often recognize the short term consequences in the forms of pain and damage to the skin on their feet. The angle of high heel shoes shifts a women's weight to the front of her foot compressing the toes in the part of shoe commonly know as the toe box which leads to blisters, corns, hammer toes, bunions and other ailments[2]. The increased pressure on the toes and balls of the feet can lead to the deterioration of the natural padding under the feet, bone disfiguration, bone stress factures and nerve damage[3]. The more serious long term effects of high heel shoes on a woman's health continue to come to light. Based on the altered function of the ankle, the knee and hip are forced to compensate for the unnatural position[4]. There have been reported cases of elderly women suffering from a permanently shorter Achilles tendon which makes them unable to wear a flat shoe[3]. A study by Dr. Kerrigan of Harvard Medical has shown that walking in high heel shoes increases normal varus torque at the knee by an average of 23%. These increased forces lead to tension on the ligaments and increased wear on the cartilage and bones. This is one likely reason to why knee osteoarthritis defined as the degradation of the cartilage and bone in the joints is twice as common in women as men[4].

The disproportionate statistics between men and women display the effects of high heel shoes on women's health. In the U.S. more than 400,000 knees are replaced annually with close to two-thirds are replaced in women[5]. A 1993 study found that more than 80% of all foot surgeries are performed on women[6]. Despite the apparent pain and risks associated with wearing high heels, the demand for these products and styles remains very strong. These health concerns display the well-defined need for a solution to these issues.

Looking at the current landscape of the shoe industry there continues to be growth in the female shoe sector as offshore manufacturing continues to be the trend of the industry. In 2004, 98.4% of US shoes were imports. From 2005 to 2006, US footwear imports rose 5.3% to 2.4 Billion pairs worth $18.7 Billion. 38.3% of all shoe imports are women's shoe which exceeds all other classes of shoes[7]. Chinese manufacturing of US footwear is the most dominant source of US Footwear imports increasing 8.7% in January of 2007 from January 2006, with a staggering market share of 87.2% of total US footwear imports. The greatest demand for footwear is women's shoes with imports increasing 11.5% from 2003 to 2004 compared to men's imports which increased 3.4%. US Footwear production dropped 11.5 percent in 2004 to a negligible 35.2 million pairs[7].

Taking in account the social footprint that high heels have in our society and weighing the discomfort as well as health risks associated with these shoes, there must be a better solution. There are many solutions that have been devised to tackle the negatives aspects of wearing high heel shoes. The two major segmentations are shoe inserts that attempt to alleviate the stress concentrations due to the geometry of high heels, and shoe structure redesign which adds alternative functionality to the shoes. Shoe inserts can be found in a wide array of forms from a cheap version that one can purchase at a local pharmacy that provides extra cushioning to the more costly doctor prescribed orthotics that are customizable and made of special composite materials[8]. Insolia is a current shoe insert product which is sold on the market that aims to shift the weight of the bearer from the forefront of the foot to the heel[9]. The major downside to inserts is that they only fractionally reduce the excessive pressure on the foot from high heel use. Additionally, inserts can not provide instantaneous relief to women who want to immediately get out of heels. Shoe structure design that enables women remove the heel is an idea that been floating around in the minds of women and on drafting boards for many years but a simple feasible marketable product has not yet been designed. Most of the current designs and patents are overcomplicated, incomplete in addressing the technical challenges and do not maintain the current styling that appeals to women.

The solution investigated and designed in this work maintains the same stability and styling of a current high heel shoe with a concealed mechanism that allows easy adjustment from the high heel position to a flat position by simply removing the heel. The design minimizes additional cost to the shoe manufacturers by developing a design that is consistent with the way shoes are currently manufactured. The design can also be applied to any designer high heel shoe because it maintains most of the construction and manufacturing elements of current industry heels. The solution is comprehensive addressing all major issues that will enable this product to be marketable such as arch stiffness, heel stability, flat position and heel removal.

Background

The following listed prior art has come to the attention of this investigation. The prior art is relevant to, but patently distinguishable from, the high heel shoe construction proposed in this thesis. The following patents discussed below are relevant to the work of this thesis.

U.S. Pat. No. 4,610,100 Shoe with Replaceable Heel, Clifford A. Rhodes, Sep. 9, 1986.
U.S. Pat. No. 4670996 Women's Shoes With Flexible Spring Steel Shanks For Use With Replaceable Heels Of Different Heights, Mary J. Dill, Jun. 9, 1987
U.S. Pat. No. 4,805,320 Shoe with Exchangeable Heel, Tzvika Y. Goldenberg, Avraham Y. Levi, Feb. 21 1989.
U.S. Pat. No. 5058290 Shoe Construction With Self Seating Removable Heel, Timothy Koehl, Oct. 22, 1991
U.S. Pat. No. 5079857 Shoe Having A Detachable Heel, Barrieann C. Clifton, Jan. 14, 1992
U.S. Pat. No. 5,309,651 Transformable Shoe, David B. Handel, May 10, 1994.
U.S. Pat. No. 5,347,730 Low Heel Shoe Convertible to High Heel Shoe and Vice Versa With an Adjustable Shank, Jorge A. Rodriguez Colon, Sep. 20, 1994.
U.S. Pat. No. 5,953,836 Shoe Having a Removable Heel, William T. Watt, Lisa C. Watt, Sep. 21, 1999.
U.S. Pat. No. 6,631,570 Rotationally Detachable Low To High Heel Shoes, Lisa Walker, Oct. 14, 2003
U.S. Pat. No. 7168184 Shoes, Rosemary Jane Wallin, Julian Francis Ralph Swan, Philip Richard Shade, Jan. 30, 2007

Rhodes has created a shoe with a replaceable heel that has a tapered dovetail in the heel of the shoe. The art does display a dovetail on the high heel but the taper of the male dovetail on the heel will get wedged into the female dovetail because the critical angle is 16. The art also fails to address the arch stiffness complication of a detachable high heel shoe.

Dill creates a flexible spring steel shank that sits between the sole and the insole of the high heel with the intended purpose of varying the heel height. The patent introduces a complex set of locking and aligning pins that fasten the heel as well as operate the flexible spring steel shank. The patent also claims an undercut in the insole of the shoe where the spring steel shank is nested and anchored at one end. The patent also claims a rotationally detachable heel fastener. The patent does not address the issue of rigidity when using a flexible spring steel shank to obtain height adjustment. Additionally, the design claims a fastened spring steel shank which renders it unable to slide or be removed from the heel to convert into a flexible flat shoe. The design does not consider the role of the sole in the design as a fastened shank would exert a force on the adhesive of the sole potentially destroying the shoe.

Goldenberg has developed a new heel construction that enables the heel to have an exchangeable heel. The art addresses different heel geometry that could enable the shoe to connect to the heel. The art presents many variations of internal bores and locking clips applied directly to the heel. The work fails to address the rigidity issues of a detachable high heel shoe and does not maintain the current industry standard heel design.

Koehl has created a self-seating removable heel that maintains the aesthetic appeal of the current market high heel shoes. Koehl's self seating construction utilizes a dovetail that encompasses the entire heel. The bottom portion of the heel acts as the male dovetail and the top acts as the female guide. The heel slides onto the shoe from the front to rear where it contacts a wall. The heel locks in place during loading based on the angle of the high heel connection which continuously forces the heel into the socket. Koehl depicts a screwed fastening place which prevents the heel from detaching on the front side of the heel. This design has no mention of an active locking mechanism that is quick and easy to operate. Additionally, this design does not address the rigidity in the arch of the high heel shoe.

Clifton has designed a detachable low to high heel shoe focusing on a simple design that contrasts the complex designs before his work. He claims an easily detachable heel with the use of a threaded portion and a locking pin fastened in the heel. This patent fails to address the issue of arch rigidity in a current high heel shoe construction. This art does not remain consistent with the current infrastructure of an industry produced high heel shoe.

Handel has introduced a heel that can convert from a high heel to a flat or low heel via a stowable heel. This stowable heel is not removable and it adds a complexity to the heel that will burden the manufacturing process and changes the basic style of the shoe. The pivoting shank and interlocking sections address the arch stiffness problem but the construction to achieve dynamic arch stiffness can be further simplified. The art has many hardware components are well as locations with tight geometrical clearances which further complicate the design and its ability to enter the market.

Colon has developed a low heel shoe construction that can be raised into a high heel shoe using interlocking heels and an arch stiffness shank can be varied by angle. The art addresses both the interlocking heel methodology and the arch stiffness issue associated with changing the heel height. Colon fails to consider the flat shoe position and the affect of having a rotating element underneath the ball of the foot. Additionally, Colon fails to adhere to currently accepted styling of high heels with locking devices and a low heel that will turn the targeted consumer off from the product.

Watt has developed a simple detachable heel structure that accomplishes the assembly and disassembly utilizing a ball and spring socket. The art fails to address the arch rigidity issues. The work also has a very thin pin insert perpendicular to the heel that fastens the heel is place which would most like bend making the shoe useless with one sudden impact or an attempt by the user to remove the heel. The design fails to leverage current industry construction methodology by introducing an extraneous new element to the heel in the ball and socket joint.

Walker has designed the concept of detachable high heel shoes but fails to address all the issues associated with creating this product. Walker proposes a rotationally detachable high heel shoe that uses fixed mounts. This solution enables the heel to remain connected is such a form that is maintains the "conventional design" by having "no visible structures that comprise the shoe form." This is important to the design but the patent fails to address the stiff arch structure and how the shank within the shoe will affect the convertibility of the shoe from a low shoe to a high heel. Walker fails to consider the current infrastructure of an industry high heel.

Walin has developed a flexible member that is shaped by a rigid member for the purpose of adapting a shoe to a plurality of foot supporting configurations and heights. Walin does not aim to develop detachable high heel shoes but the patent does cover a similar element of the proposed design of this thesis. Walin does not aim to maintain the current high heel shoe infrastructure but aims to make a complete new type of shoe that is configurable. This art is a generalization of possible shoe configurations and does not have a specific design for a detachable high heel shoe that can be converted into a flat. The flexible portion of the assembly consists of the entire footprint of the shoe which is unnecessary to achieve the aims of this thesis. The art fails to consider the current high heel shoe construction and presents a passageway with a supporting arch element that adds a locking clip element which overcomplicates the solution that is pursued in this thesis. The art also makes use of flexible hinges and an arch supporting element that would get wedged into the shoe if the tapered angle is less than 16 degrees. The patent also claims a hollow heel structure which again does not maintain the current high heel infrastructure. Overall, this patent does not maintain conventional high heel design and the structures presented in this art will distort the styling of a detachable high heel.

High Heel Construction

Current high heel construction and manufacturing processes were investigated in order to determine current industry practices. Several pairs of high heel shoes across different price ranges and brand names were disassembled and the various parts were identified. The focus of the investigation was to determine components of the shoe, material choice, manufacturing process and assembly techniques. Although, many high heels appear to be unique, the general construction and components are very consistent across designers of high heels. The high heel shoe can be segmented into four major sections: the upper, the insole, the sole and the heel.

The upper section of the shoe is the part of shoe that holds a woman's foot when she is standing in a heel. This section is where the styling is applied to shoe in the form of material choice, color, and fabric cut. The upper section as shown in Figure 1 consists of the toe box, top line throat, the quarter, the counter and the insole cover. The upper portion of the shoe is determined by the designer of the shoe which is why there is great variation in the appearance of high heel shoes. The material of the upper portion of the shoe that renders the styling of the shoe is cut and tailored to meet the specifications of the designer. The styling can be reinforced with the use of paper elements along the walls of the upper. The styling material of the upper portion of the high heel is fastened between the insole and the sole of the shoe with adhesives and in some cases, tacks or nails. The insole cover is a piece of fashionable material cut to the size of the shoe that covers the insole. The insole cover is typically a material such as cloth or leather and usually has a brand label of the shoe designer on it.

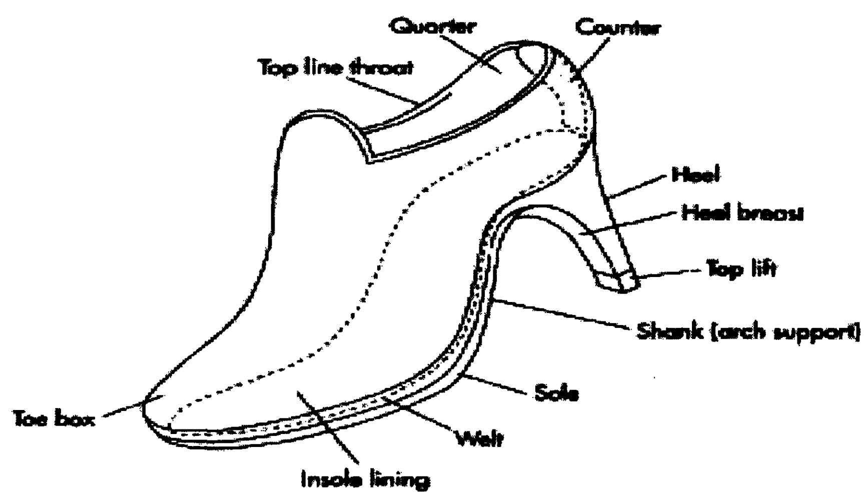

Figure 1: A simple illustration of a high heel shoe that displays the different parts that compose a high heel shoe[1].

The insole is the part of the shoe that the user steps on and is a layered composite paper structure with a steel support shank. The insole acts as the core support for the user standing in the high heel and is shown as the insole lining and welt in Figure 1. The top layer of the insole just below the insole cover has some form of foam padding to improve shoe comfort. The next layer, the top paper layer runs from the back of the heel to just before the balls of the feet. The top paper layer with a range of thickness of .05 to .1 inches is fairly flexible similar to chip board one can find at an arts & crafts shop. The middle paper layer which is a pink paper material in every disassembled shoe in this investigation is very soft and flexible with a thickness of approximately .05 inches. This center material runs the entire length of the shoe from the heel to the front tip of the toe box. This center material is either just above or right below the steel shank in high heels. The steel shank gives the user the distinct arch and rigidity of a high heel shoe. This shank is held in place with rivets through either the paper layer above or below the shank. The steel shank has an indentation that runs parallel to the material which increases the structural rigidity of the piece. The bottom paper layer that comprises the insole is similar to top layer in that is runs from the back of the heel to just before the balls of the feet. The bottom layer ranges in thickness from .1 to .15 inches and is fairly flexible again similar to chip board. The bottom layer tends to be the most rigid of the three paper layers due to its thickness. The paper layers are bound together using adhesives. Figure 2 is an image of a disassembled shoe insole with the top layer of paper, remnants of the middle pink layer and the steel shank visible.

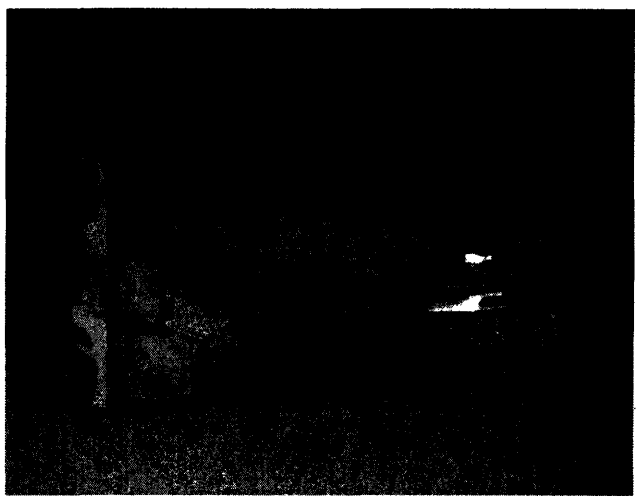

Figure 2: An image of a deconstructed high heel shoe used to investigate the manufacturing choices. The image is the top paper layer of the insole with an attached steel shank.

The sole of the shoe is the strip of material that runs along the bottom of the shoe which is used to walk on but also has styling implications for the shoe. The sole of the shoe as shown in Figure 1 is labeled as the sole and the heel breast. The sole is made out of leather or synthetic durable materials such as rubbers and plastics and ranges in thickness from about .08 to .15 inches. This range in thickness and material selection affects how compliant the shoe is once it is disassembled. This is important to consider for the proposed design in this work. The material that is the sole runs from the tip of the shoe under the toe box, down to rear of shoe and often times along the heel breast. The choice of material is determined by the goal of the designer but the contour of the sole is fairly consistent across brands. The sole is fastened to the insole and the upper material that fastens the stylized upper portion to the shoe with the use of adhesives.

The heel of the shoe is the section of the shoe that distinguishes a high heel shoe from a flat shoe. The design of the heel varies with parameters such as height, covering material and the shape of the heel. The major element of the heel is the injection molded core heel that supports a woman's weight. Attached to the bottom of the plastic heel is an abrasion resistant material shown as the top lift in Figure 1. The main exposed section of the heel is typically covered in the form of strips with a material that complements the style of upper section of the shoe. Above the heel, but underneath the insole lining are additional parts that compose the heel. These parts facilitate the fastening of the heel and sometimes the steel arch shank to the shoe. These pieces vary between shoes but are typically a metal enforced fastening device. The heel is fastened to the upper with nails, tacks, and screw combinations driven down through the insole into the heel.

Most of the heels disassembled were common in terms of construction, materials used and most likely manufacturing processes. This commonality displays the efficiency and refined state of the high heel shoe manufacturing business. This common platform is an exciting opportunity to leverage the current momentum and practice of the high heel industry in order to modify a few components that would fit within the packaging of the shoe design yet add the ability to remove the heel and comfortably walk in a flat shoe.

Detachable High Heel Shoe Construction

The detachable high heel shoe envisioned at the onset of this work was a simple high heel shoe that maintains most of the positives of the shoe while developing a construction that allows the negative aspects of the shoe to be quelled at the discretion of the user. The proposed construction was not intended to be a new form of a shoe that is unique in appearance but simply an alteration of the current commoditized sections of the high heel to enable it to be removed and the user to walk away satisfied with a level of comfort of a standard flat shoe. The only way to make this shoe market viable and feasible in terms of manufacturing was to leverage the current infrastructure of a high heel shoe. The work of this thesis designed and developed three prototypes based on this principle.

Prototype #1 maintained many of the components of an industry standard high heel. The prototype was developed from a store purchased high heel shoe which allowed the shoe to be modified as opposed to being built from scratch. The upper portion of the shoe remained identical in style with respect to cut and contour of a standard high heel shoe. All modifications to the shoe were performed from where the balls of the feet would rest to the back of the heel.

The heel was removed and the insole was modified to yield the desired functionality. The bottom paper layer was cut to facilitate two major components of Prototype #1. As shown in Figure 3, the bottom paper layer has an open slot that allows for the steel shank commonly found in a high heel to easily slide into its standard seating location underneath the arch of a high heel shoe. The slot is 3.2 inches long, .65 inches wide and recessed .2 inches from the sole. Also shown in Figure 3, the composite paper material just above the heel was removed in order to make packaging space for a female dovetail rail. The dovetail component has a length of 1.3 inches, width of 1 inch and a thickness of .2 inches. Figure 4 shows the female dovetail cross-section used in Prototype #1. The female dovetail rail is fastened to the remaining insole composite paper using rivets popped into four holes from above the shoe to ensure that the user will not feel the rivets. The upper material that wraps below the shoe was modified to allow the female dovetail component to sit slightly outside of the material to allow for mating. As shown in Figure 3, the sole was torn from the shoe to allow for easier modification and in order to learning about the inner workings of the shoe.

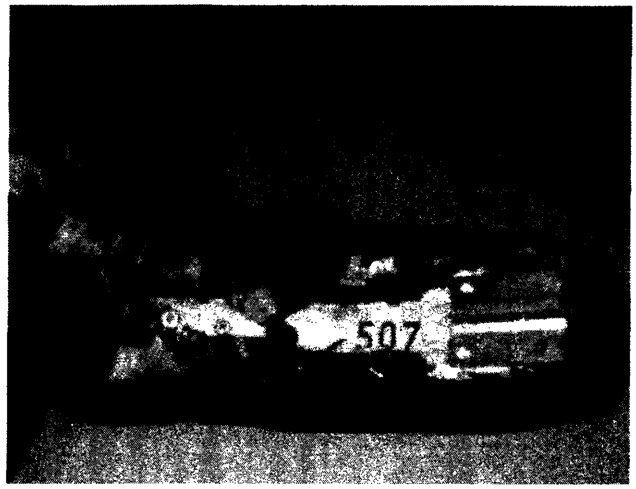

Figure 3: Prototype #1 displaying the bottom of a high heel shoe with a modified insole and a female dovetail component.

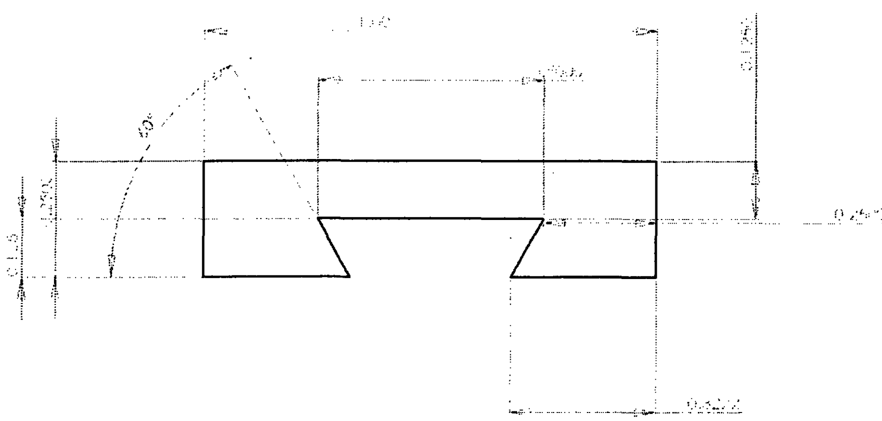

Figure 4: A drawing of the cross-section of the female dovetail used in this work.

The mating component used to complete the high heel shoe in Prototype #1 was composed of three distinct parts: The steel shank, the male mating dovetail and the heel. The components discussed in this section are shown in Figure 5. The steel shank which supports the user's arch is an industry manufactured component removed from the heel. The steel shank fits in the rectangular groove described previously in the insole of the shoe. The steel shank is fastened directly to the heel using a screw that is driven through the male dovetail mating piece and the steel shank. The male mating dovetail is a 1 inch by 1 inch piece that was fabricated using aluminum. The cross-section of the male dovetail is shown in Figure 6. The male mating part contains a recessed hole on top to allow the screw to sit flush with the male dovetail as to not interfere with the mating of the joint. The steel shank was thinned and the male mating part was slotted on its underside to allow these components to sit flush with the top of the heel. This assembly of the three parts enables the heel to be added to and removed from the shoe.

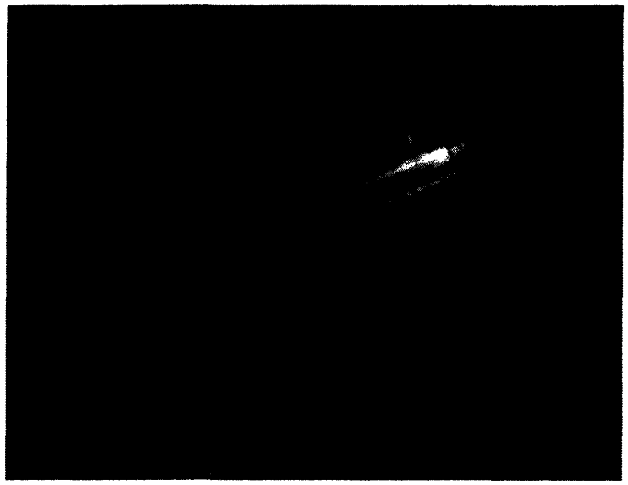

Figure 5: An image of the male mating assembly that depicts a steel arch support shank, aluminum male mating dovetail and a heel from a disassembled shoe.

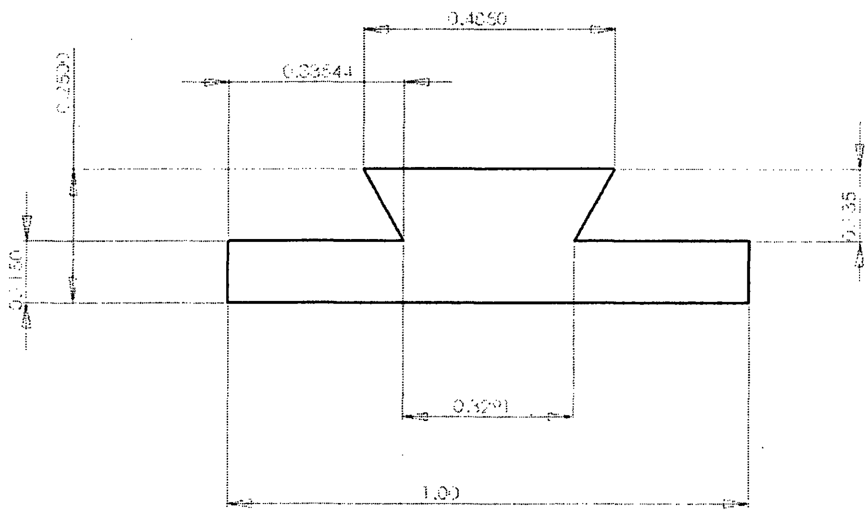

Figure 6: A drawing of the cross-section of the male dovetail used in this work.

Prototype #1, as shown in Figure 7, developed in this investigation was a learning model that did not meet the ideal functional requirements desired in this work. The open slot was just a display of the feasibility of removing the steel arch support shank and was unable to actually bear weight of a user because it had no support structure to remain in place. A simple metal fastener could have been added to keep the shank from ripping through the sole if a user would have tried on the shoe with the heel attached. In an actual high heel, the shank remains in place because of the rivets at both ends of the shank. A second issue with this prototype was that the alignment of the steel shank was not in its industry standard position due to the gap generated by the female mating dovetail. This offset would inherently change the angle of the arch in the high heel shoe. A third issue with Prototype #1 is mating the female and male dovetails while maintaining the look of the heel sitting flush against the shoe. The dovetails can only mate if the female dovetail is sticking beyond the bottom edge of the shoe and the heel can only sit flush if the female dovetail is deep enough in the shoe that it compensates for the height of the male component. There were many identifiable issues with creating a detachable high heel shoe but there were also many accomplishments and concepts learned with this prototype.

Figure 7: An image of prototype #1 in the high heel position.

Prototype #1 was able to display that detaching the high heel shoe was able to be accomplished in a simple fashion maintaining most of the current infrastructure of an industry produced high heel shoe. The stiff arch support that keeps the foot stable was able to be inserted and removed into the high heel. The heel of shoe was able to be removed and reconnected in its appropriate position on the high heel shoe. The heel was firmly fastened to the shoe using the hardware described previously. The styling of the shoe was able to be maintained and the components that assembled to create this prototype were all hidden in the high heel. Finally, the high heel was able to be a flat walking shoe once the heel was removed.

There were a few key items that were learned as a result of the development of this prototype that were not considered previously. The sole extends down the inner contour of the heel and is fastened using adhesives. This presents a styling issue if the heel is to be removed completely from the shoe. This extension of the sole down the inner contour of the heel can be remedied by eliminating this part of the sole which is currently done on some marketed shoes or a temporary fastener can attach this material to the heel when the heel is attached and to the exposed insole when the heel is detached. The mating of the heel performed well but the heel could easily slide out of the shoe if a user tried on the shoe because there was no inclusion of a stop, button, clip or other locking device. Although this appears to be a critical component of the idea, the means of achieving a locking feature was not considered in Prototype #1. The many accomplishments of Prototype #1 as well as its shortcomings were considered when developing the second detachable shoe prototype.

Prototype #2 aimed to develop a comprehensive solution that took into account the many issues already discussed. The focus of Prototype #2 was a detachable high heel shoe that could be worn and tested. Prototype #2 placed a dovetailed slot within the composite layered paper of the insole which acted act a site for a dovetailed shank to be mated thus completing the shoe.

A purchased high heel shoe was used as the basic infrastructure for constructing this working model. The top layer and bottom layer of the composite layered paper were removed leaving the pink middle paper layer. This layer was moved right beneath the insole covering. A piece of semi-flexible plastic, 4.8 inches long, 1.7 inches in width, .12 inches thick was slotted with a female dovetail dimensioned from Figure 4 and shown pictured in Figure 7. This semi-flexible female dovetail was riveted to the paper layer just below the insole cover. The female dovetail runs from about 2 inches from the back of shoe to just before the ball of the foot which is the location where the steel support arch shank typically rests in a currently manufactured high heel shoe. The female dovetail was then layered on two parallel rubber strips that run from the heel to just before the ball of the foot which are fastened using double-sided tape. These strips serve to leave space between the sole of the shoe and the female dovetailed part. These strips are spaced approximately 1 inch apart. The sole of the shoe is .125 inch thick rubber that runs the entire length of the shoe only having a 1.25 inch square opening leading into the insole of the shoe which is .8 inches from the back of the shoe. The shoe without the heel has a feeding hole which allows the male part to enter and leave the shoe by mating with the female layer of the insole. The male arch support entrance is shown in figure 8.

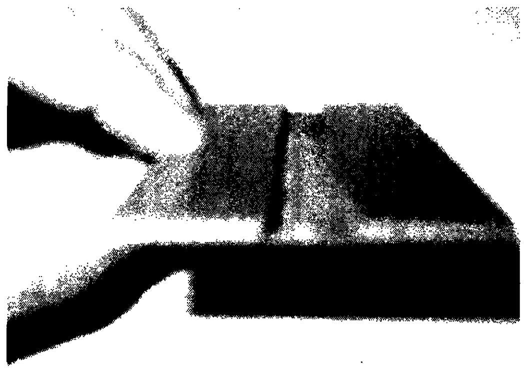

Figure 7: An open slotted dovetail machined into a piece of plastic to facilitate a male shank that would complete the attachment of a detached high heel shoe.

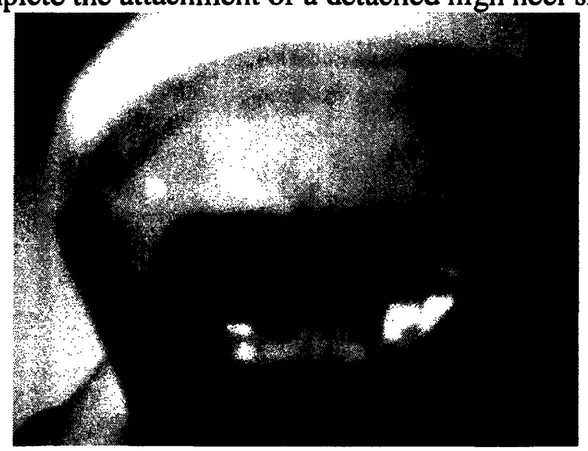

Figure 8: The entrance through the sole of the shoe where the male dovetailed shank with mate with the female dovetailed insole component shown in the photo.

The detachable high heel assembly for Prototype #2 as shown in Figure 9 is composed of a heel, a curved male dovetailed shank and spacers between the heel and shank. The heel in this case is completely covered with material that compliments the styling of the shoe and it also has a small elevation about .1 inches thick that was incorporated into the part when it was injection molded by the shoe manufacturer. Just above the heel are aluminum spacers that serve to ensure that the heel will ride flush against the sole once the heel is attached to the shoe. The spacers add .135 inches from the top of the injection molded heel. Resting on the spacers is the aluminum male dovetailed shoe shank about 4.4 inches long and 1 inch wide that gives additional support to the users' foot once the heel is attached. The aluminum arch has the same radius of curvature as the industry standard steel shank that is common in most heels. The aluminum male dovetailed shank was created by cutting a male dovetail slot into a piece of stock aluminum, 1 inch wide and .25 inches thick. This piece was then rolled in a bending machine to achieve the desired curvature. A screw runs through the male dovetailed shank, the spacers and into the heel. The screw is recessed in the aluminum shank so that it will not interfere with the mating of the heel and the shoe.

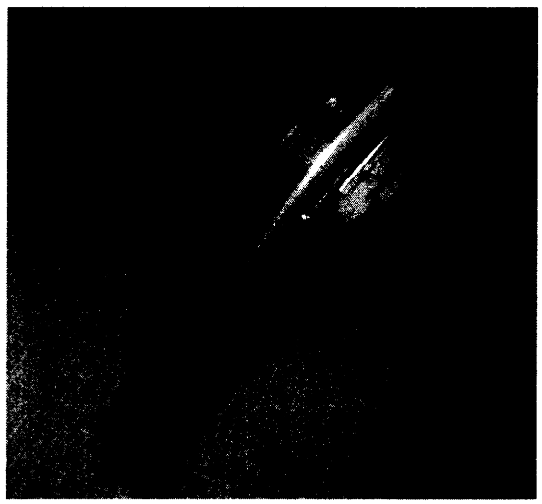

Figure 9: A picture of the detachable heel assembly used in Prototype #2 which consists of a curved male dovetailed shank, spacers and a heel.

Prototype #2 illustrated the ability of the detachable high heel construction to firmly fasten the shoe assembly and the detachable heel assembly. Based on a tight fit and the elevated portion of the heel assembly that fits inside the sole, the shoe in its high form did not have a need for a locking mechanism as friction is sufficient to keep the shoe intact. The shoe can bear a users weight and behaves very similar to a standard high heel shoe. The shoe can be converted into a flat by simply removing the heel.

Prototype #2 did have some room for improvement based on a few key findings. The aluminum shank did not go to the full length of a user's arch which caused the shoe to the have a little more flexibility than a standard high heel. The construction and fastening of the insole were poor in terms of material selection, orientation and choice of fasteners which led to more lateral wiggle than a standard heel. When the heel was removed, a very critical aspect of the flat shoe profile was discovered. Due to the fact that the cut of the material and the rubber sole of the heel were designed with only the intent of conforming to a high heel, the shoe causes the front toe box to point up at a level that is slightly less than appealing. The material on the shoe and the sole was cut and perforated at particular locations to determine if the shoe could be flattened with a slight change of the material cut and sole construction. It was determined that changes to the cut of the material and altering the characteristics of the sole can lower the toe box to a fashionable level. Figures 10 and 11 displays the altered upper and sole components of prototype #2. Prototype #2 also shed light on an additional factor to consider in future constructs. The material selected to act as the female mating portion within the insole is exposed to continuous wear and stress from constantly inserting and removing the heel assembly. The choice of material and ideal dovetail dimensions which could reduce the stress concentrations and wear of the material could not be fully explored within the scope of this thesis but the problem likely has a solution. After the success of the second prototype, a third prototype was developed to creating a matching pair of shoes for testing and to improve on the construction methodology of prototype #2.

Figure 10: The images displays the heel position of Prototype #2 of the detachable high heel shoe with cuts on certain parts of the upper to determine changes in the heelless shoe behavior.

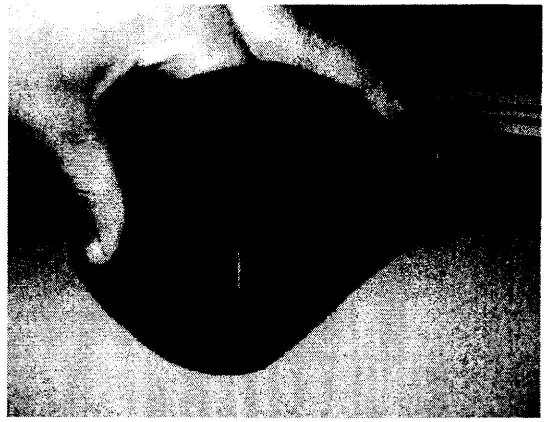

Figure 11: This image shows the perforated sole of Prototype #2.

Prototype #3 was modeled from the success of Prototype #2 keeping many of same features with an added attentiveness to the details. Prototype #3 utilized the basic shoe infrastructure from an industry manufactured shoe. The semi-flexible female dovetailed plastic insole component was again used as a prime component to the success of the prototype. The heel assembly was again fitted with a curved male dovetail aluminum shank.

The insole of prototype #3 was constructed with to allow a snug fit of the male mating dovetail that would inserted. The semi-flexible female dovetail plastic part was layered on top of a bottom layer of paper and below the insole cover. The bottom layer of paper was elevated .1 inch from the sole and spaced .83 inches apart which formed a firm fitting guide for the bottom of the male dovetail shank. This bottom layer was also set with the front portion of the bottom paper layer actually in industry shoes to mimic the feel of the current high heel shoe as shown in Figure 12. The semi-flexible layer was cut with a female dovetail slot as shown previously in figure 5 in order to mate with the male portion of the shank. The semi-flexible female dovetail insert is 4.5 inches in length with a width of 1.67 inches and .12 inches in thickness. The female dovetail runs from just behind the ball of the foot to about 2 inches from the back edge of the heel. The female dovetail part was fastened using staples. A piece of paper .1 inches thick was cut into a semi-circle and place in the back of the heel to fill in the gap between the bottom paper layer and the insole cover. This paper layer was on the same plane as the semi-flexible female dovetail and served as a ceiling to the male dovetail shank that would be inserted by the user. The rear edge of the sole where the male dovetail enters was cut at an angle to improve the ease of use of the prototype.

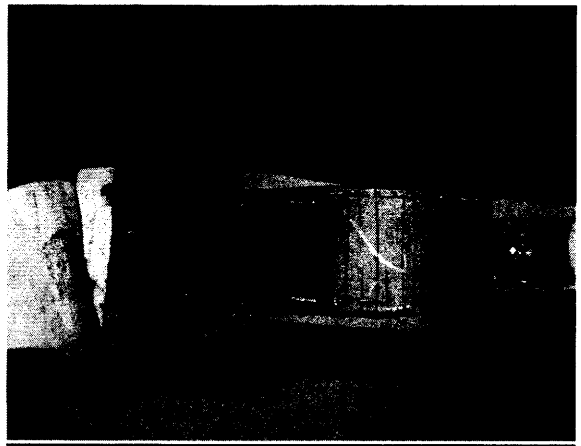

Figure 12: An image of the Prototype #3 displaying the bottom paper layer and the plastic dovetail.

The detachable high heel shown in Figure 13 consists of the manufactured industry heel, the male aluminum dovetail shank and the aluminum spacers. The male aluminum dovetail is approximately 4.4 inches in length, .75 inches in width and has the same curvature as the steel shank found in current high heels. The cross-section of the aluminum dovetail shank is shown in Figure 6. The shank is raised to a maximum height .4 inches from the top of the heel. This is important because this adds to the ability of the shank to remain in position once it has been inserted into the shoe. A screw was drilled through the top of the aluminum shank. The screw was placed in a recessed hole in order to ensure that there would not be any interference between the male and female dovetail mating. There are two aluminum spacers that have a total thickness of .125 which sit between the aluminum shank and the heel. Figure 13 shows the detachable heel assembly connecting with the shoe entering through the sole which has a slight inclined cut (not pictured) to help with the ease of attaching the heel.

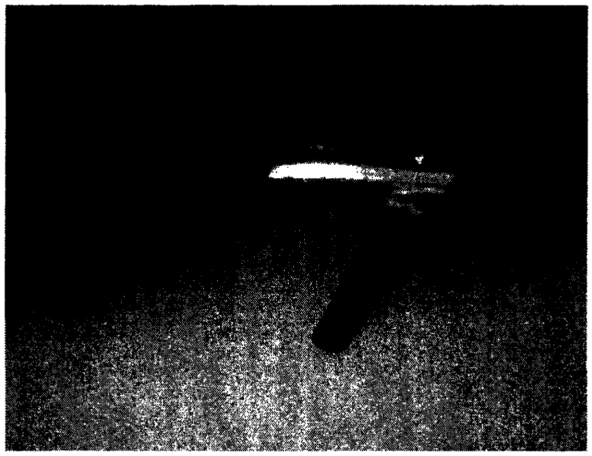

Figure 13: An image of the detachable heel assembly connecting to the shoe.

Prototype #3 displayed many of the desirable characteristics outlined throughout the course of this work as well as some room for improvement. The design implemented was simple and conformed to the current infrastructure of a high heel shoe. The heel was able to seat within the shoe firmly and flush against the sole giving it the look and feel of a current high heel as shown in Figure 14. The close fitting paper walls of the insole, along with the plastic female dovetail and the raised back edge of the male dovetail with spacers all contributed to the ability of the heel to remain in securely in the shoe. The components that enable the shoe to be detached and reattached were all concealed. The detachable heel was easy to attach and remove but there still exists some potential improvements in this realm. In the flat heel position as shown in Figure 14, the shoe was able to be lowered to the ground once the heel was removed but again it is apparent that the cut of the material on the shoe must be slightly adjusted or more compliant in order to have a suitable flat shoe in terms of style. The screw drilled into the heel which holds together the detachable heel assembly did not rotationally constrain the aluminum shank part which could be remedied with a different fastener or 2 screws. The plastic female dovetailed layered into the shoe began to show signs of wear as the detachable heel was inserted and removed quite a few times by different users. This issue is likely a factor of material choice and geometry. Overall, Prototype #3 was a great success for this work and gives a perspective of how this design has great market potential with some continued development work to optimize the idea which is addressed in the conclusion.

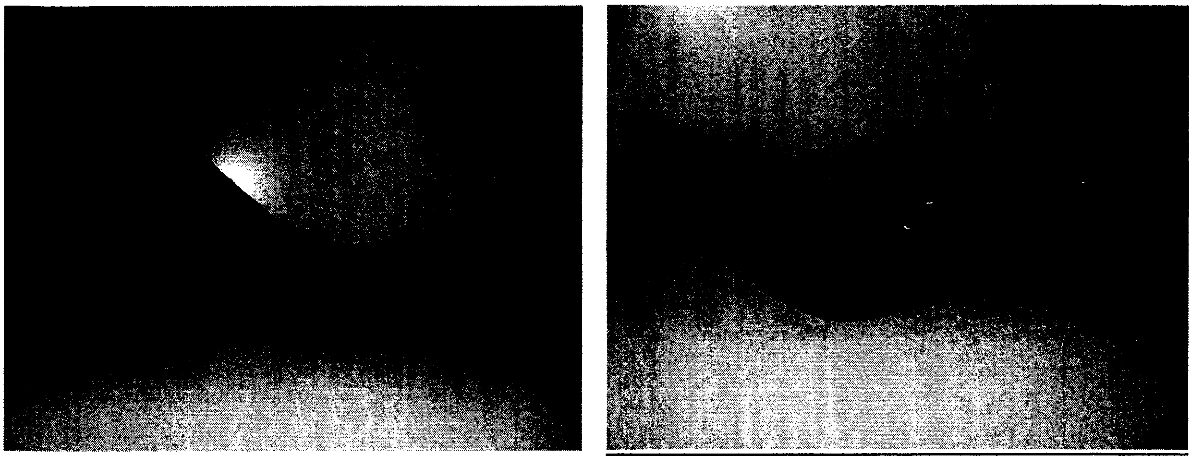

Figure 14: Prototype #3 with the detachable high heel shoe construction in the high heel position (left) and the flat position (right).

Conclusion

The detachable high heels developed in this work were given to women to try out the concept and give feedback on issues that still must be considered in the future. One clear point that was dictated was the pointing up of the toe when the shoe is in the flat position which can be seen in Figure 15. Prototype #2 is the left foot in the image which has incisions in the material and sole which has apparently reduced the stresses in the material as compared to the right foot shoe in the image which sticks up slightly higher because it does not have any incisions. This shows that a slight adjustment of the shoe cut at the design or styling level could remedy this concern. It was also explained by the women who tried the shoe that the current material cut causes discomfort on top of the foot based on the material being pulled taunt. One user also mentioned the altered balance because of how the shoe pushed against the toes, pulling the toes off the ground. Another comment was about the plastic female dovetail in the shoe which formed an edge behind the ball of the foot which the user said she could feel. She said the discomfort was a 2 on a scale from 1-10. This issue could easily be remedied with a continuous layer that tapers down as it approaches the front of the shoe. This tapered down approach is common in the paper composite layers currently in an industry high heel shoe. The shoe performed well in the flat position besides the concerns previously addressed.

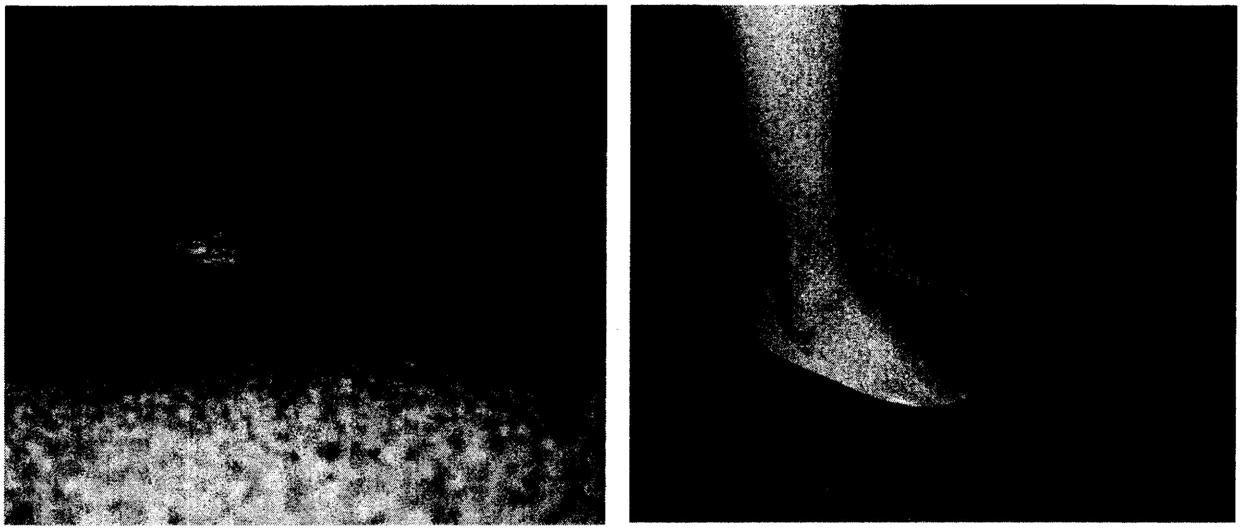

Figure 15: Prototype #2 is on the left shoe of the user and Prototype #3 is on the right foot which displays the front of the shoe pointing up when the heel is removed.

The feedback with respect to the shoe in the high heel position was a positive indicator of the potential success of this product. Prototype #2 which has a less refined internal construction than prototype #3 was described as a "wobbly heel" and it feels like it's "about to pop out" although it remained intact. Prototype #3 performed much better with user comments such as the shoe "doesn't feel likes its removable" and the user "could not feel the internal components." Prototype #3 had a better internal paper construction, longer dovetailed shank and had not been cut on its upper section as compared to Prototype #2 which are the potential reasons for the discrepancies between the two shoes. Prototypes #2 and #3 as shown by a tester in Figure 15 both enabled the user to walk around in the high heels and even run in the high heels without any disconnection between the two main assemblies. In terms of removing and inserting the detachable heel, the users were able to perform both of these tasks easily after it was demonstrated to them. The results of these trials display that with additional development work, detachable high heels are not far from the market.

Figure 15: A picture of a woman trying on prototype #2 (right in photo) and prototype #3 (left in photo) detachable high heel shoe in the heel orientation.

The design presented in this work of the detachable high heel shoe is a comprehensive solution that addressed all of the barriers to creating such a product. The design addresses a well defined need with a simple solution. The solution is market viable and consistent with the current layout and manufacturing process of the industry. This new construction fits within the business model and core competencies of most shoe designer firms. Maintaining the similar manufacturing process and composite layered approach to the insole will ensure that the idea with not invoke large additional costs for the manufacturer. Additionally, the proposed changes to the insole of the detachable high heel can be commoditized and applied across most high heel design platforms. This thesis has shown the feasibility of the detachable high heel which had the ability to be easily removed and inserted. The user was able to walk on the rubber sole once the heel was removed. In the high heel position, the shoe was stable and maintained the styling of the shoe with the heel remaining flush against the shoe. The detachable high heel shoe was able to support a user in the same orientation as a standard high heel. The frictional forces between the dovetail shank and the plastic dovetail layer in the shoe eliminated the need for a locking mechanism. A locking mechanism may be considered in the future and the options in terms of location and hardware components for this potential addition are numerous.

The detachable high heel shoe design needs to undergo a few more investigative variations and optimizations to bring the product to the market. The geometry and materials used for the dovetail shank and the plastic female dovetail in the insole need to be optimized to select to the best combination for a firm fit and the elimination of wear that will destroy the lifetime of the detachable high heel shoe. The manufacturing process that best fits the mass production of these shoes must be determined. Injection molding the female plastic dovetail layer is a possible method for the mass production of these heels. The packaging of this female plastic dovetail layer within the insole composite paper must be incorporated into the current industry methodologies. Extruding the aluminum dovetail part which could potentially be made in another material is a possible method for mass producing these new high heel shanks. The high heel shank with respect to stiffness, resistance to bending and its propensity to fatigue with aluminum and other material choices must also be further tested. A strengthening element such as dimple running parallel to the length of the shank could stiffen the shank as it is done in the industry. The fasteners to be used for manufacturing this heel will likely involve adhesives as used in industry and a few strategic placed screws or tacks to hold the hardware in place.

The detachable high heel shoe construction must be further developed and analyzed to ensure a product that will be able to penetrate and potentially transform the landscape of the current heel industry. The form of the shoe must compliment the functionality of the shoe to guarantee that the user has a pleasant experience operating the heel. An alteration of the composite paper layer just above the proposed female dovetail layer could help with the seating of the detachable heel by forming a guide that eliminates incorrect heel insertion. The sole could be cut at an incline to ease and guide the insertion of the detachable heel. The fabric cut of the upper portion of the shoe which is the specialty of the shoe designer must be altered to allow the shoe to be comfortable and fashionably contact the ground in the low heel position. Additional considerations for the possibility of dirt and exposure to the natural environmental elements must be analyzed and adjustments must be implemented. The durability of the shoe must be tested extensively once a final prototype is developed. The safety of using this shoe should also be investigated to ensure the safety of the consumer and the sustainability of the product.

The potential for the detachable high heel shoe construction in the marketplace is grand as the design addresses an unfulfilled need. The market is already developed and continues to grow at a fast rate. The proper investment would enable further development and a refined design that would be able to enter the marketplace and potentially make a huge impact. The research and development of the detachable high heel shoe construction has thus far been very promising and the potential opportunities of this product are exciting.

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