Design for the Adjustable High Heel

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Abstract

High-heel shoes with a dual function of working as both high heels and flats have long been sought for ladies. The dual-function high heels not only allow the wearer to go out with only one pair of shoes but also save time in commuting back and forth between home, office, and venues for social gatherings. Mime et Moi, a German high-heel brand, makes a dual-function high heel where the heel can be switched between different heights. The drawback of this approach is that the user needs to carry the extra heel in her purse, causing inconvenience. Other approaches are described in various patents. Among them, Camileon Heels uses a pivotal heel mechanism such that the shoes are high heeled during normal office time but can be converted to flats during leisure time by bending the heel around the pivot. The pivotal mechanism and locking/unlocking mechanism are intriguing and complex. Investigation of an adjustable high heel shows that the root problem is the technical contradiction of the shank. The contradiction is solved by changing the shape of the shank. We change the shape from the S shape to a curved surface located from the middle sole to the rear sole. This paper also uses the TRIZ inventive principle to analyze the patents WO2016/179675 and CN205106566 and applies inventive principle 1, segmentation, to get a simpler version of a high heel with a dual function. A prototype is prepared to demonstrate its usage.

Keywords: Locking mechanism, Pivotal heel mechanism, Segmentation, TRIZ inventive principle, Shank.

1. Introduction

Social gatherings are an important activity in human society. People are social creatures. Through social activities, people get support, security, happiness, and recognition. As woman rights expand throughout the world, social gatherings for women have started to become popular. Most of the women work. As for single or even married women, wearing high heels to attend formal gatherings is required by dress codes. After the gathering, it is nice to wear a flat in order to feel less stressed. Thus there is a need for dual-function high heels.

There have been many attempts in various countries to solve the problem of a high heel with a dual function. However, many of them are in the stage of concept drawing; for example, the famous Skywalker, as shown in Fig. 1. It was originally designed by a group of students in Greece in 2014 (Tsagari, 2014). They have been trying to find a manufacturer to make it a commercial product, but to no avail. However, there is a successful German company, Mime et Moi (Kausch, 2018), that has brought dual-function high heels onto the market, as shown in Fig. 2. It is claimed that the flats can be easily converted to high heels, and vice versa, in four steps, as shown in Fig. 3. In Step 1, the lever is pulled firmly backwards until the heel releases and then the heel is pulled backwards. In Step 2, the lever is pulled into the closed position and the new heel is inserted until it snaps into place. In Step 3, the weight is placed on the toe bed (A) and then the wearer presses firmly with the heel of the foot (B) until the high heel locks into place. In Step 4, then press on the toe bed (A) and again press on the heel (B). Now the high heel is fixed. Based on the conversion process, however, the user needs to carry an extra heel in her purse, which causes inconvenience. This prompts the question: would it not be wonderful if the high-heel shoes could be automatically converted into flats without carrying the extra part?

Fig. 1 Skywalker

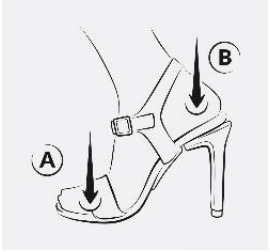
(a) High heel

(b) Flat

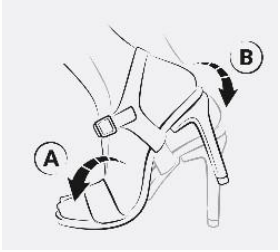
Fig. 2 High heel and flat

(a) Step 1

(b) Step 2



(c) Step 3



(d) Step 4

Fig. 3 Four steps of converting flat to high heel

The rest of the paper is organized as follows: Section 2 provides a literature review of the works on dual-function high heels and TRIZ inventive principles. Section 3 gives a detailed description of the innovative technology used in dual-function high heels. Section 4 concludes the paper.

2. Literature review

High heels are a type of shoe in which the heel, compared to the toe, is significantly higher off the ground. The origins of the heel trace back to Persian warriors of the 10th century who rode horses and needed to hold tight to the saddle (High-heeled shoe, Wikipedia, 2018). Heels were later regarded as the sign of a wealthy status, because high-heel shoes are so impractical that one cannot work while wearing them. The first recorded instance of a high-heeled shoe being worn by a woman was by Catherine de' Medici in the 16th century. Up until that time, women had been wearing platform shoes in Europe. During the 17th century, courtesans began wearing high heels. As time went by, heels became more associated with women, and men wore heels less often. During the Enlightenment, European men quit wearing high heels in favor of more sensible footwear. It was not until the 19th century that women began wearing heels again (The history of high heels, 2018). A more stable stiletto was created for women during the 1950s. However, it was difficult to walk in them. High heels force women to walk in a way that adds stress to the hips and back by causing their rear to move, their hips to have to compensate and wiggle, and their chest to expand out. They thus create biologically determined markers of mating attraction. It is well known that those in high heels were judged as significantly more attractive by both men and women than those who wore flats.

2.1 Design process of high heel

The design process of high heels is just like the process of any commercial product. It starts with research, then development, refinement, and, finally, determination. In the research stage, a market survey is conducted and fashion data are collected. In the development stage, a theme is decided and its market is segmented. A sketch of the high heel is then drawn. In the refinement stage, the upper, sole, and heel are developed, and the material and accessories are provided. Drawings are then modified and finalized. In the determination stage, each part of the high-heel shoe must be confirmed with its materials. A prototype is made (Lee, 2012). In the determination stage, a shoe

last is needed to make a prototype (Luximon, 2013). A shoe last is a mechanical form that has a shape similar to that of a human foot. It is used by shoemakers in the manufacture and repair of shoes.

2.2 Shoe human factors and market

Generally speaking, when designing comfortable footwear, several human factors are considered. They are: a moderate or low heel (<2 in.), a cushioned midsole, breathable, conformable uppers, an adjustable fastening (e.g., laces, straps) and a stable heel counter. General shoe fitting principles include an understanding of posture, overall length, heel-to-ball length and flex angle, ball joint-to-toe length, heel and seat fit, instep, waist and arch fit, joint width and vamp, top line, throat and entry, patterns and styles, and measurement and size systems. Various factors can affect foot posture, including age and disease processes. When customized footwear is needed, a 3D scanner can be used to reconstruct the profile of the foot. Then a pair of shoes can be made with all the human aspects being considered. According to Kouchi's (2012) research on high-heeled shoes, the effects these have on wearers are: 1. discomfort, corns, bunions, pain, deformation; 2. increased risk of sprains and falls; 3. fatigue and pain; 4. low back pain and arthritis. The last three effects are due to change in the forces operating on the body and change in gait; the first one is caused by the foot sliding down the footbed. A footbed simulator is used to manipulate various footbed parameters to achieve greater comfort (Goonetilleke and Weerasinghe, 2012).

The market for high-heeled shoes grew from 2013 to 2017 and will reach its peak in 2023. In 2017, the global revenue from high heels was nearly 34.1 billion USD. The three leading brands of high-heeled shoes are Pierre Hardy, Manolo Blahnik and Jimmy Choo. The major regions that play a vital role in the high-heeled shoes market are North America, Europe, China and Japan. The three most important types of high-heeled shoe products are the stiletto heel, court shoe and wedge boots (Maia Research, 2018).

In sum, high-heeled shoes are a rich market. If comfort, convenience and safety are achieved through an adjustable high-heeled design, this could be the next star of the high-heeled shoes market.

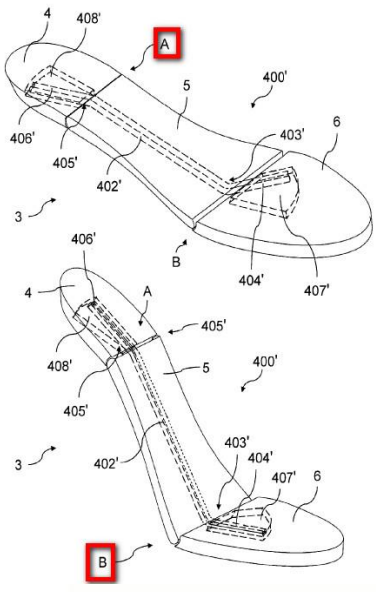
2.3 Drawbacks of wearing high heel

Wearing high-heel shoes causes more physiological problems than flat shoes. It has been reported (Baaklini et al., 2017) that an estimated 78% of women regularly walk in high heels. However, up to 58% complain about low back pain, which is commonly thought to be caused by increased lumbar lordosis. Besides, regarding the influence of high-heeled shoes on venous function, Filho et al. (2012) evaluated 30 asymptomatic women (mean age, 26.4 years) wearing appropriately sized shoes by air plethysmography (APG), a test that measures changes in air volume on a cuff placed on the calf, while they performed orthostatic flexion and foot extension movements and altered standing up and lying down. The test was repeated in four situations: barefoot (0 cm), medium heels (3.5 cm), stiletto high heels (7 cm), and platform high heels (7 cm). The experiment concluded that high heels reduce muscle pump function, as demonstrated by reduced ejection fraction (EF) and increased residual volume fraction (RVF) values. The continuous use of high heels tends to provoke venous hypertension in the lower limbs and may represent a causal factor of venous disease symptoms. Another clinical survey of about 200 women (Borchgrevink et al., 2016) showed that for women aged 40–66 years wearing high-heeled shoes had not caused foot deformation, but it did cause more foot pain and callosities. There are many more studies (Moore et al., 2015; Wiedemeijer & Otten, 2018) indicating that wearing high-heel shoes indeed causes more physiological problems (e.g. altered gait) and injuries than wearing flat shoes.

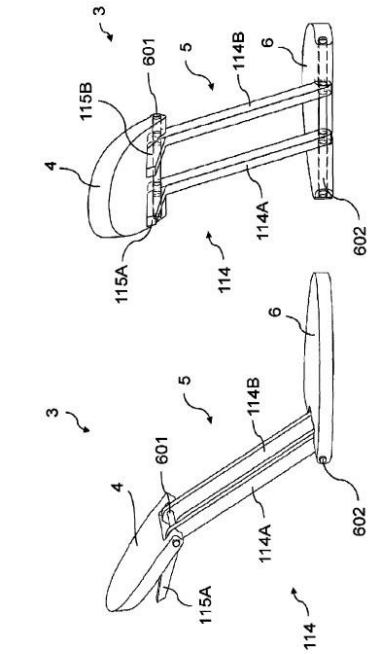
2.4 Flexheel technology

Despite its drawbacks, however, the loveliness of wearing high heels has urged many ladies to risk their health because it is suggested (Morris et al., 2013) that there is a strong contemporary association between high heels and female sexuality. How can one remain sexy and relaxed at the same time? This contradiction is solved by the principle of time separation. The solution has been implemented by some health-oriented shoe-making companies that are aware of the need for dual-function high heels. Among them are Mime et Moi in Germany and Camileon Heels in the USA (Volusion, 2018). The Mime et Moi adjustable high heel implements Flexheel technology to pull the heel in and out to adjust the height. It was invented by Huber Christian and has been patented (Huber, 2018). In the Flexheel technology, the sole component comprises a front, a middle, and a rear sole portion as well as a mechanism (shank) for adjusting the sole curvature in a transition region A between the rear and the middle sole portion and a second mechanism for adjusting the sole curvature in a transition region B between the front and middle sole portion (Fig. 4a).

The mechanism comprises a rotatable supporting element provided in such a way that it may have a first angular position causing a first sole curvature in the transition region A and a second angular position causing a second sole curvature in the transition region B, wherein the first sole curvature is different from the second. Note that other mechanisms (shank) such as leaf springs can also be used in the sole, which are firmly connected to both the middle and the rear sole portion and the middle and the front sole portion to provide defined curvatures to the first transition A and the second transition region B, respectively. Fig. 4b shows the second embodiment of the shank. The supporting element (shank) 114 is formed by rails 114A and 114B, wherein one or more than two rails may also be used. Rails 114A and 114B extend along the middle sole portion 5, wherein the sole is not shown in the middle sole portions for better illustration of rails 114A and 114B. For example, rails 114A and 114B may be made of flat-rolled steel. Rails 114A and 114B provide a first hinge 601 by which the rear sole portion 4 is movably attached to rails 114A and 114B, and a second joint 602 by which the front sole portion 6 is movably attached to rails 114A and 114B. For this purpose, rails 114A and 114B may each comprise a first hole for receiving an axis of the first hinge 601 and a second hole for receiving an axis of the second hinge 602.



(a) Shank with sole in one embodiment.



(b) Shank without sole in second embodiment

Fig. 4 Flexheel technology of US9980533

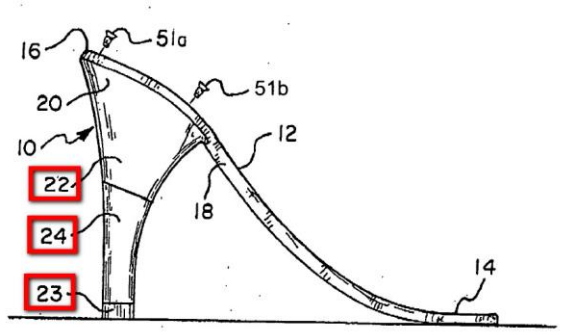
Fig. 5 Camileon Heels convertible high-heel shoe

The Camileon Heels patented (US8322053, Handel, et al., 2012) convertible high-heel shoe is shown in Fig. 5. The high heel (Stage 1 in Fig. 5) can be pulled outward and then bent forward to make the shoe flat (Stage 2 in Fig. 2). Some key figures of US8322053 are shown in Fig. 6. Converting the shoe from a high heel to a flat takes four steps. A sturdy support beam, 38 in Fig. 6 (b), is activated by a spring so that it can be pulled out and bent forward. Note that a high heel lift, 23 and 28, is secured so that the high heel extension piece, 24, and a low heel block, 22, can be protected. One thing worth noting is that the

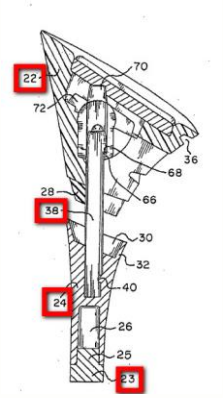
assignee of US8322053 is Sean Flannery. However, its patent family member, TWI544877, shows that its assignee is Camileon Holdings, LLC. Putting these two assignees together in a Google search, one finds that Camileon Holdings LLC has assigned the patent right of the adjustable height high heels to Camileon Heels. It seems that the patent did not address the shank issue between high heel and flat. According to the drawing the shank should be underneath the arch region 18. When the heel is bent, the arch region should not be changed because the shank is embedded in it. It then will create a strange shape in the sole in the flat mode.

2.5 The 40 inventive principles of TRIZ

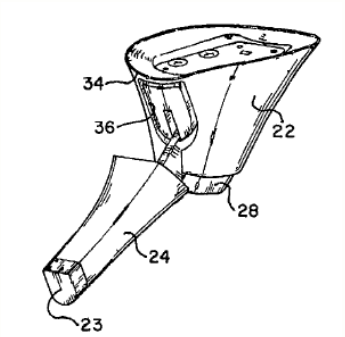
The 40 inventive principles of TRIZ were invented by Altshuller et al. (2005). It is reported that 40,000 patents were analyzed to extract the inventive principles. Each inventive principle has its rules of usage to help users apply it. For example, inventive principle 1 has three rules, as follows: 1. segment the object into independent parts; 2. divide the object so that it can be assembled easily; and 3. increase the degree of segmentation. The 40 inventive principles can be used alone or with a contradiction matrix (Altshuller, 1984). According to the literature, it is probably the most widely used tool in the TRIZ toolbox (Mann, 2002). The patent US8322053 is an example of inventive principles 1 (segmentation), 7 (nested doll) and 15 (dynamics). The heel is in one piece in the conventional high-heeled shoe. However, patent US8322053 segments the heel into two parts, a low heel block 22 and high heel extension piece 24 (the segmentation principle). Support beam 38 is imbedded into the low heel block 22 (the nested doll principle). A rotatable slotted pivot 54 makes the high heel extension piece 24 moveable along the slot (the dynamic principle).



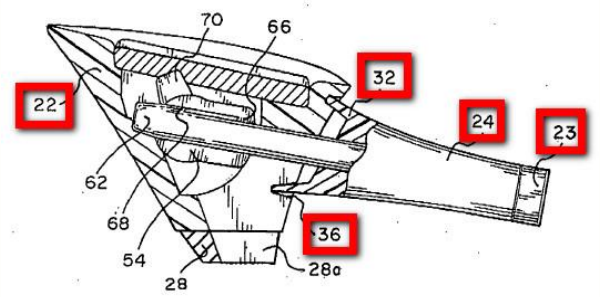
(a) High heel position



(b) Pull the heel downward



(c) Bend the heel forward to make a flat



(d) Flat position

Fig. 6 Four stages of US8322053

3. Proposed high heel

After studying various patents on dual-function high heels such as CN205106566 (Ye, 2016) and WO2016/179675 (Roberto, 2016), as shown in Figs. 7 and 8, we have invented the proposed dual-function high heels. Concerning CN205106566, Fig. 7 shows that the way in which the two segmented parts of heel 3 and lift 2 join together is by means of a slot and plug. For WO2016/179675, however, the segmentation is more complicated. Fig. 8 shows that the invention

relates to a women's heeled shoe (C) with a shank (1) having a recess for a quick release screw (2), which allows the heel to be quickly removed and replaced (3), and which, together with a flexible and preferably PVC molded insole and an elastic junction (5) in the quarters (6) or vamp (7), allows a closed shoe (C) with a heel (3) to be converted into a flat shoe (8) and vice versa.

In the aspect of shank, the patents CN205106566 and WO2016/179675 did not mention about the issue of shank in different height of shank. In the CN20510656, no drawing of shank even was mentioned. In the WO2016/179675, shank was depicted in component 1 in Fig. 8. Since the shape of shank cannot be changed, it is hard to believe how the shoes can be converted from high heel to flat.

These two patents suggest the use of a segmented heel to solve the flat and high heel problem. They both apply principle 1 of the 40 inventive principles: segmentation. Two segmented parts join together by means of a slot and plug. Interested readers can refer to those patents. Our method of joining the parts is by thread and screw. A prototype has been made to test its validity, as shown in Fig. 9. Our contribution to making the proposed high heel is to use 3D printing to make the high heel support, a middle heel, a high heel, and a lift (the black pieces in Fig. 9). After making the heel support, heel and lift, a thread and screw are installed in the heel and lift respectively. Note that this sample adjustable high heel is specially made for a model.

The support is made by 3D printing overlaid with leather. Within the support, a bored hole with a thread is made. The heel is also made by 3D printing overlaid with glassy decoration. A bolt with a thread is put into the heel and a washer is inserted in it. The lift is used to protect the wear from the ground and a washer is inserted in it. The adjustable high heel has three modes: high mode, middle mode, and flat mode. When the adjustable high heel is in the high mode, it works just like an ordinary high heel. The support is connected to the high heel, which is connected to a lift. Then it can be switched to middle mode by changing the high heel to the middle heel. Lastly, a flat shoe can be made by taking out the middle heel. The support is connected directly to the lift.

Fig. 10 shows a magnified image of the high heel, revealing the support, heel, and lift. Note that the support is designed to fit the insole of the high heel and its three-view engineering drawing is shown in Fig. 11, where a hole is bored through the support for receiving the bolt with thread.

Black washers are inserted in the middle and high heels and lift to secure their connection to the support, as shown in Fig. 12. Fig. 13 shows that the heels and lifts are kept in a fountain pen case when not in use. Lastly, a female college student was invited to help prove its utility, as shown in Fig. 14.

In order to make a complete design, the prototype picture of flat shoes is taken and inserted into Rhino for surface modeling to construct the 3D computer model. Its design and specification are depicted in Figs. 15–17. The shoe is a length of 230 mm, width of 77 mm, and height of 50 mm. The height of the top lift is 10 mm, and the height of the vamp is 14 mm. The distance between the supporting points in the out sole and top lift is 130 mm. The heel base is a disc 12 mm in diameter with a heel base size (HBS) of 1.13 cm^2. Luximon et al. (2015) showed that high-heeled shoes with a small HBS do not provide stable support, particularly on a small slope angle.

The computer model is drawn in Rhino for surface modeling with plugged-in utility of T-spline for Rhino. As shown in Fig. 17, the computer model is almost identical to the prototype. In order to show the match between the computer model and the prototype image, a wireframe model is displayed in top and left views.

Normally, an iron-like metal is embedded within the two supporting points in the out sole and top lift to support the weight of the user, as shown in the red lines in Figs. 18 and 19. As shown in Fig. 19, for different heel heights in conventional high-heel shoes, the structure of the shank is different. Thus, it is impossible to put the same shank into high-heel shoes with different heel heights. This poses a challenge for adjustable high heels, since there is only one shank for different heel heights. The shank normally is made of iron/steel plate and is rigid. When the high heel is changed to a different height, it changes the position of the shank, and the shank is no longer fitted to the foot comfortably. Thus, a technical contradiction occurs. When wearing high heels, the shank needs to be rigid; however, when changing from high heels to flats, the shank needs to be soft.

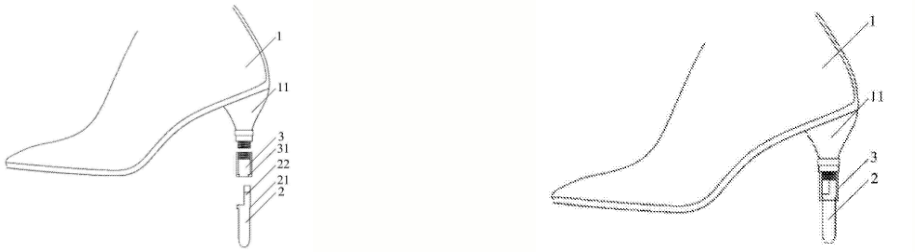
The problem is solved by using a different position embedded within the shank. If we shift the shank to the heel side and change the shape of the shank from an S shape to a curve with a large curvature like the one marked in yellow in Fig. 20, then the contradiction is solved. Note that in this design even the heel height is increased, and the shank will just be lifted on the right without changing the shape of the shank. Contrary to the conventional shape of the shank, the new shank design can fit into different heel heights.

To make a completion, a computer model is drawn for the middle heel and high heel following the procedure of flat shoes, as in Figs. 21 and 22. Note that the heights of middle heel and high heel are 10 mm and 20 mm, respectively. Looking carefully at Figs. 21 and 22, the heel for the middle-heel and high-heel shoes is tilted at 85 and 77.3 degrees, respectively, because the shank is fixed in shape and size. When the heel is increased by 10 mm with the insertion of the middle heel, the support will be lifted by 10 mm, with an effect that the support is somewhat rotated about the left supporting point. Note that in the middle-heel shoes the left supporting point is 128 mm away from the right supporting point underneath the top lift. This rotation effect causes the heel to tilt 85 degrees. As the height of the heel in high-heel shoes increases to 20 mm, the rotation effect becomes larger, which causes the heel to tilt 77.3 degrees.

It appears that the tilting of the heel is not good for users when walking because it causes instability. But through the experiment of the female model, the middle heel can be used without any problem in walking. However, the high-heel shoes can cause slowed-down walking. If we use the aspect of the shank to compare the four patents and the proposed adjustable high heel, with the wisdom of hindsight, it is easy to see the differences between them. Their differences are shown in Table 1. The design process is shown in Fig. 23.

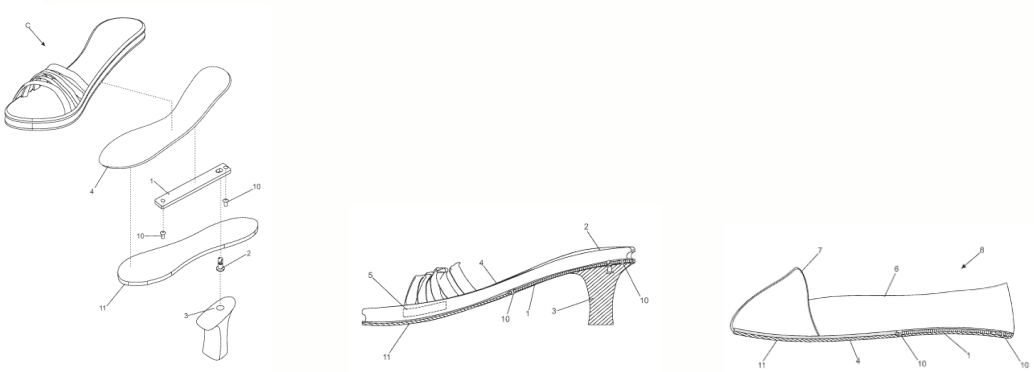
In sum, the identified problem is the technical contradiction of shank. The research objective is to develop the adjustable high heel in simpler version without carrying additional heels. The development procedure starting with patent search to find out four patents and compare their difference in table 1, then use inventive principle to solve the problem. The used theories or techniques for generation of design alternatives is shown in the design principle in Fig. 23. The generated design alternatives examination or evaluation is dealt by three designs in our proposal as shown Figs. 15, 21 and 22. The evaluation is shown in Fig. 14 and table 1.

The inventive principle we use to solve the shank problem is principle 15, dynamics. Item (a) refers to changing the object (or outside environment) for optimal performance at every stage of the operation. In our case, whereas the conventional shank is in an S-shape located from the outsole to the heel, the new shank design shrinks back away from the outsole such that the heel can be adjusted. Of course, principle 1, segmentation, can be easily seen in the detachable heels.



(a) Disassembled stages of heel com ponents (b) Assembled stage of heel components

Fig. 7 Structure of heel components of CN205106566



(a) Disassembled stages (b) Assembled stage (c) Flat shoe

Fig. 8 Structure of heel components of WO2016/179675

(a) Flat (b) Middle heel (c) High heel

Fig. 9 Proposed adjustable high heel

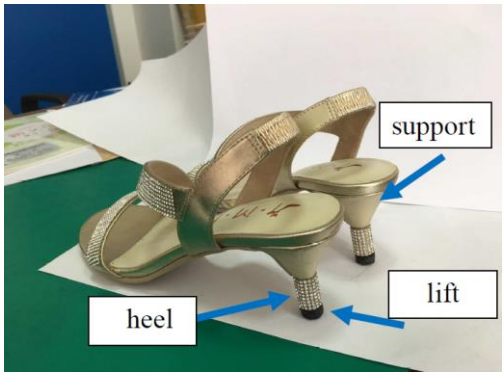


Fig. 10 Magnified version of Fig. 9(c)

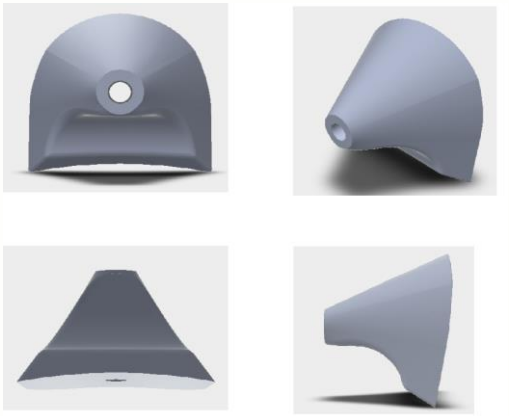


Fig. 11 Support

Fig. 12 Heels and lift

Fig. 13 Case for heels

(a) Snapshot 1 of walking model (b) Snapshot 2 of walking model

Fig. 14 Model wearing the shoes

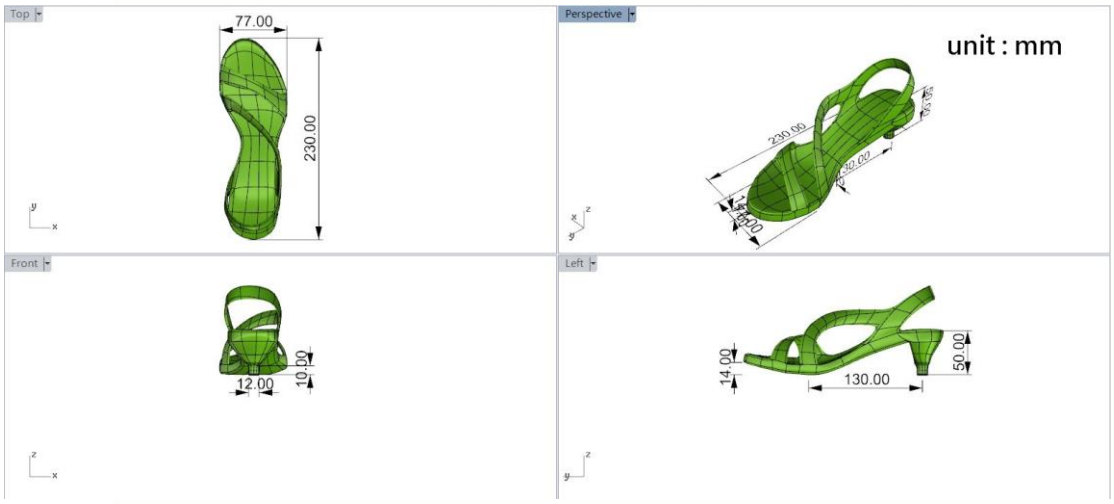


Fig. 15 Flat shoe design with specification

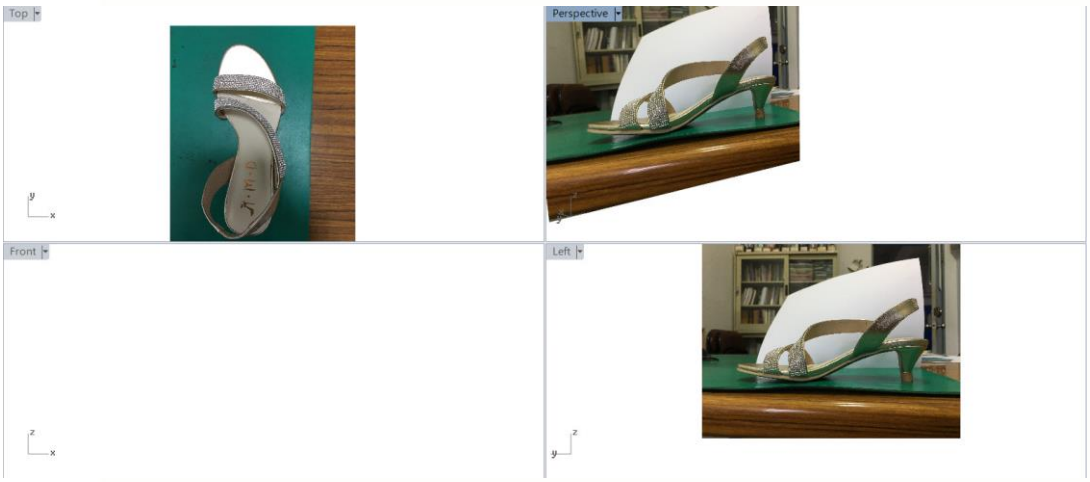


Fig. 16 Embedded with flat shoe images

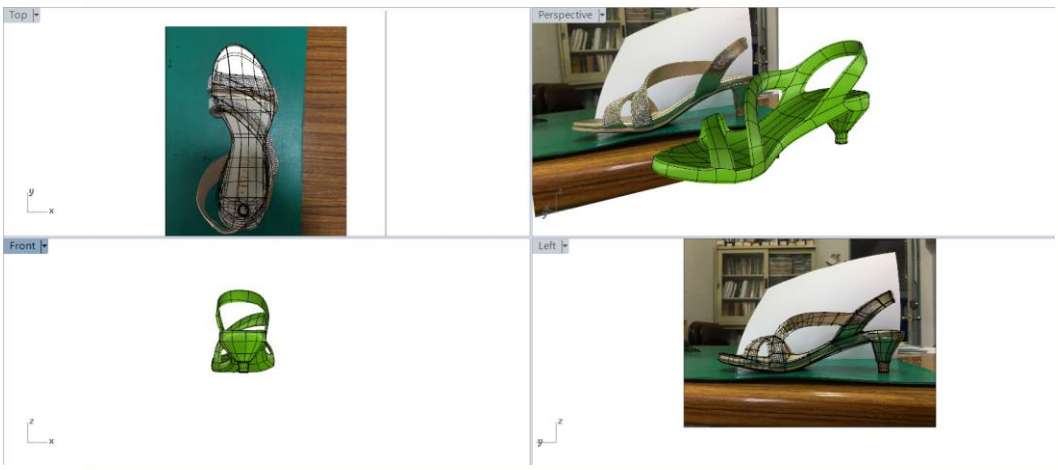


Fig. 17 Superimposed with flat shoe images and shoe model

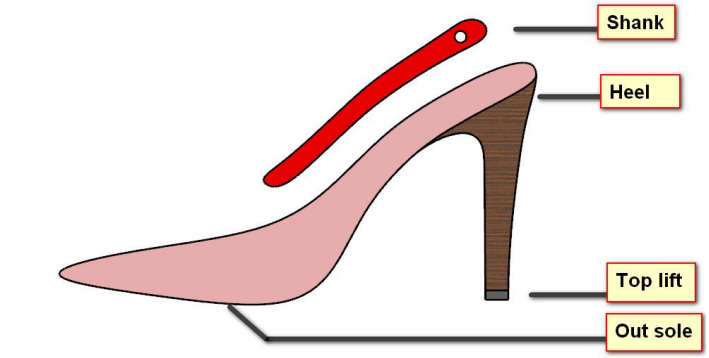


Fig. 18 Shank embedded in outsole-exploded view

Fig. 19 Shank embedded in outsole-for different heel height – taken from (Lee, 2012)

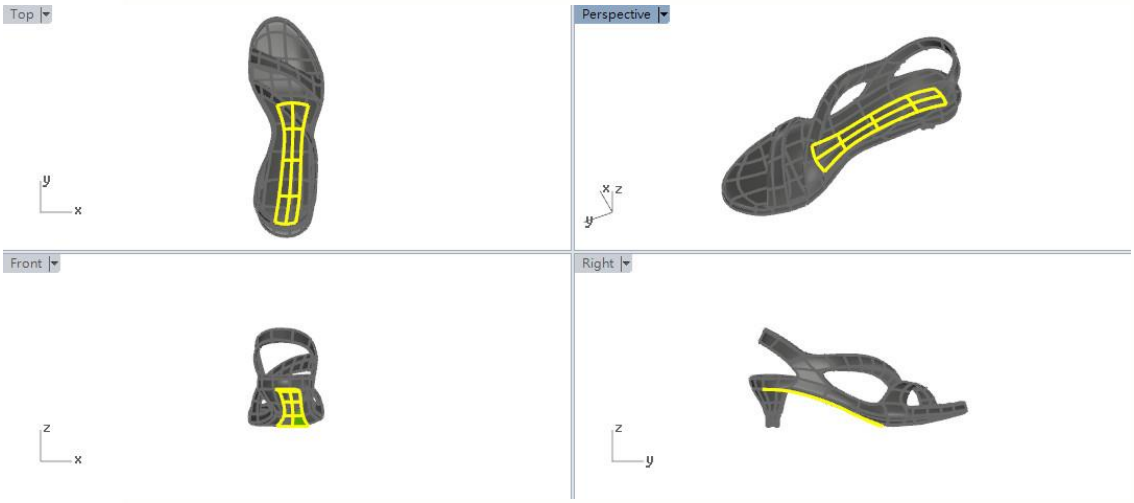


Fig. 20 New shank design

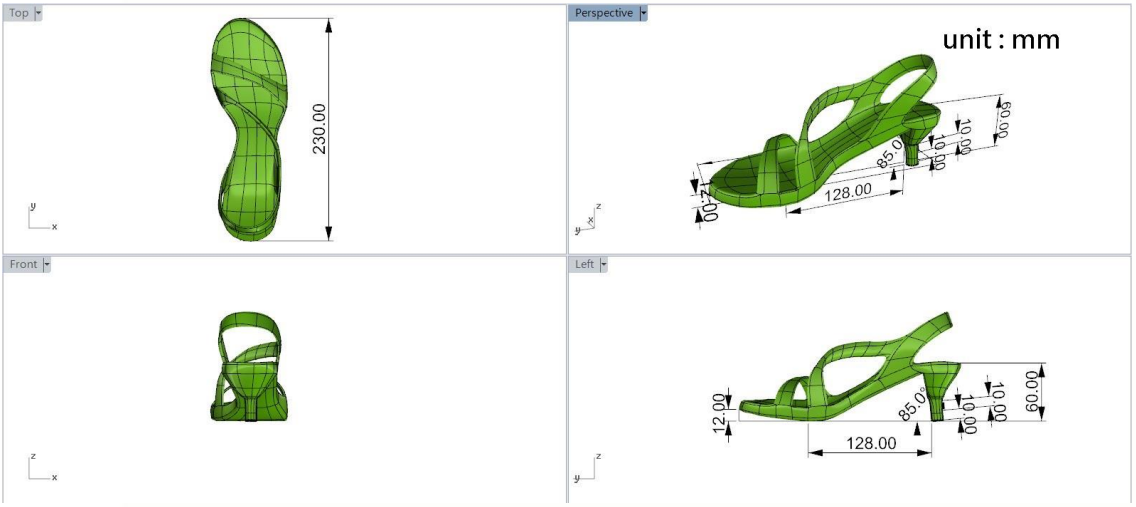


Fig. 21 Dimension of middle heel

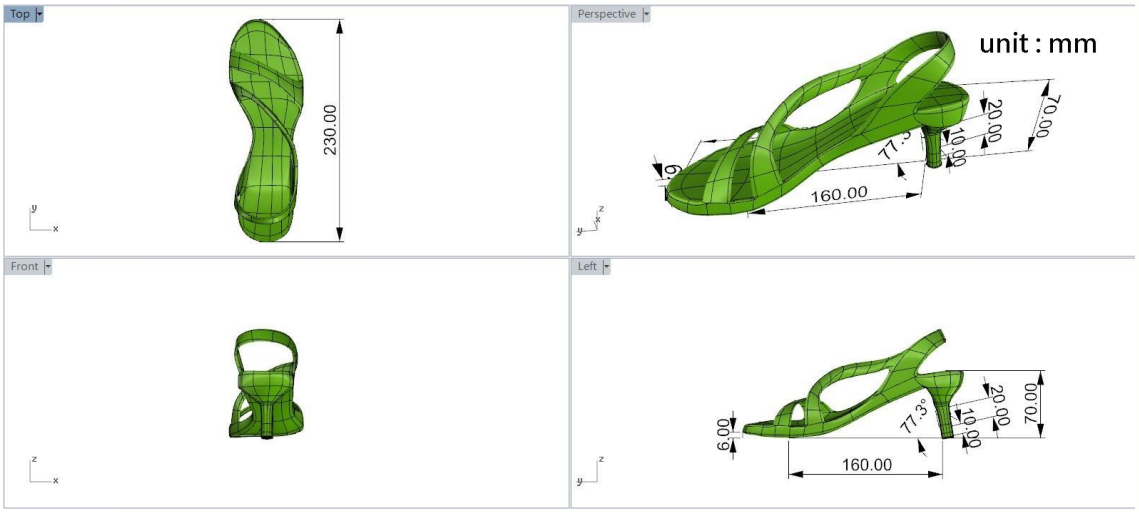


Fig. 22 Dimension of high heel

Table 1. Comparison between the four patents and the proposed adjustable high heel

Features / Patents	Operating principles	Aspect of shank	Strengths and weaknesses
US9980533	The invention relates to a sole component for a shoe suitable for use with different heels. The sole component comprises a front, a middle, and a rear sole portion as well as a mechanism for adjusting the sole curvature in a transition region between the front and the middle sole portion. The mechanism comprises a rotatable supporting element provided in	The supporting element (shank) is formed by two rails, 114A and 114B. Rails 114A and 114B extend along the middle sole portion 5, wherein the sole is not shown in the middle sole portions for better illustration of rails 114A and 114B. For example, rails 114A and 114B may be made of flat-rolled steel. Rails 114A	It fully solves the shank problem in different high-heel heights. However, the user needs to carry another pair of heels to replace the current ones.

	such a way that it may have a first angular position causing a first sole curvature in the transition region and a second angular position causing a second sole curvature in the transition region, wherein the first sole curvature is different from the second.	and 114B provide a first hinge 601 by which the rear sole portion 4 is movably attached to rails 114A and 114B, and a second joint 602 by which the front sole portion 6 is movably attached to rails 114A and 114B.	
US8322053	A shoe has a sole with a toe, heel, and arch. A two-part heel has a low-heel block attached to the sole heel and includes a slot therein. A high-heel extension is attached to the low-heel block through a support beam having a substantially rectangular cross-section capable of limited axial and pivotal movement. The fit between the beam and the slot prevents rotational movement of the high heel about its axis. The high-heel extension can be pivoted between a first position where it underlies the low-heel block and a second position where it lies beneath the sole arch. The bottom of the low-heel block has a heel lift extending downwardly engaging the ground when the high heel is stowed. This low-heel lift is enclosed by a beveled edge at the top of the high-heel piece when it is vertical.	The shank is not discussed in the patent.	The shank seems to be solved by the commercial product from Camileon Heels. The strength of the product is that the user does not need to carry additional heels. The conversion between high heels and flats is done by bending the high-heel extension.
CN205106566	The utility model discloses heel-detachable high-heeled shoes, including the shoes' body, heel, and locating part. The locating part includes a protrusion, whereas the heel includes a plug so that the plug and protrusion can be joined together. The locating part is joined with the support by a screw and thread. The user needs to carry different heel heights to exchange from a high heel and a flat.	The shank is not discussed in the patent.	The strength of the patent is that it is simple to change from high heels to flats. It divides the heel from the shoes, which is added to the locating part. The locating part is joined with the support by a screw and thread. However, the shoes can be unstable as flats because the upper will be tilted up, causing walking difficulty.

WO2016/179675	The invention relates to a woman's heeled shoe (C) with a shank (1) having a recess for a quickscrew fastener (2), which allows for quickly removing and replacing the heel (3), and which, together with a flexible insole (4), preferably a PVC molded insole, and an elastic junction (5) in the quarters (6) or vamp (7), allows a closed shoe (C) with a heel (3) to be converted into a flat shoe (8) or a sandal-like shoe (C) with a heel (3) to be converted into a flat sandal (9), for example, or vice versa.	The shank (1) is mentioned in the patent. However, its effect on different high-heel heights is not addressed.	The strength of this patent is that it contains an elastic junction (5) in the vamp to provide flexibility in the vamp when converting from high heels to flats. However, the shank problem is not solved.
Proposed high heel	The high heel has a shank with a curved shape covering the middle sole and part of the rear sole, but not the front sole. In this way, the shank can be fitted into different high-heel heights. In addition, a simple screw and thread are used to join the support and the heel without the locating part, as in CN205106566. It is also different from WO2016/179675 in that the quickscrew fastener (2) and part (11) are eliminated. The shank in our design is also different from that of WO2016/179675 in that our shank has a curved shape, whereas the shank (1) in WO2016/179675 looks like a straight bar.	The shank is fully addressed to accommodate different high-heel heights.	The strength of our design is that it is simple. The user does not need to carry additional heels. All the accessories are put in a pen case that is easy to carry. The drawback of the design is that in the high heel the heel is tilted to 77.3 degrees due to the influence of the shank on the heel.

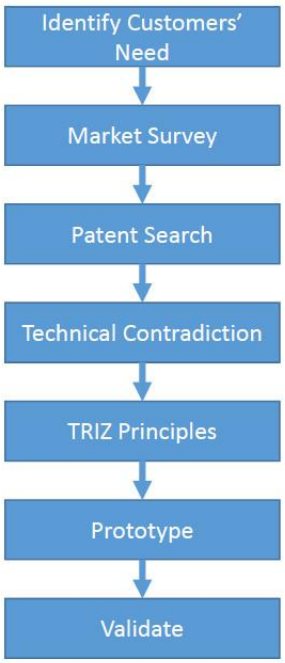


Fig. 23 Design principle of high heel

4. Conclusion

Dual-function high heels provide a useful function. Changing from flats to high heels and vice versa indeed creates a lot of convenience during the work and play of career women. In this paper, three types of high heels are mentioned: Skywalker, the Mime et Moi high heel with innovative height adjustment, and the Camileon Heels convertible high-heel shoe. Only the last two have been put on the market. The technologies of the last two are examined. Mime et Moi high heel uses FlexHeel technology to solve the shank problem in that the shank is broken down in three parts so that different curvatures can be made in the front and rear region of the sole. A key feature to accommodate the different height of high heel. As for the Camileon Heels, it bends the high heel extension so that high heel can be converted to flat in one clip. However, nothing is done on the matter of shank.

To invent a new high heel, a study of the patents was made and patents WO2016/179675 and CN205106566 are referred to in this work. These two patents suggest the use of a segmented heel to solve the flat and high heel problem. Principle 1, segmentation, of the 40 inventive principles is applied. Concerning CN205106566, two segmented parts are joined together by means of a slot and plug. In addition, a locating part is used to join the support and heel. Our method of joining the parts is by thread and screw and the locating part is eliminated. Our design is different from WO2016/179675 in that quickscrew fastener (2) and part (11) are eliminated. The shank in our design is also different from that of WO2016/179675 in that our shank is a curved shape whereas the shank (1) in WO2016/179675 looks like a straight bar.

A prototype has been made to test its validity. Our contribution in making the proposed high heel is to use 3D printing to make the high heel support, a middle heel, a high heel, and a lift. After making the support and heel, a thread and screw are installed in the support and heel respectively. On the top of the middle and high heels and lift, a black washer is inserted to secure their connection to the support. The heels and lifts are kept in a fountain pen case when not in use. Lastly, a female college student was invited to help prove its utility.

Another contribution of this paper is that it addresses the issue of the shank. The shank normally is made of iron/steel plate and is rigid. When the high heel is changed to a different height, it changes the position of the shank, and the shank is no longer fitted to the foot comfortably. Thus, a technical contradiction occurs. When wearing high heels, the shank needs to be rigid; however, when changing from high heels to flats, the shank needs to be soft. The contradiction is solved by changing the shape of the shank. We change the shape from the S shape to a curved surface located from the middle sole to the rear sole. Our design does not completely solve the shank problem, because it raises another issue of the heel tilting in high heels at 77.3 degrees. Further research needs to be conducted on this matter.

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