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Araştırma Makalesi/Research Article

The Improvement of Tamper Evident Closure Mechanism

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Abstract: The enhancement of the original content within the package with another similar range of low quality without evidence is the most common problem of the world. The danger in such counterfeit attempts is seriously understood by not just developing countries but also by developed countries as well. Counterfeit contents may lead to the death of people by damaging them and especially engine oil, fuel, cooking oil, fruits, tomato paste, milk etc. Tamper evidence (TE) in industrial containers becomes more critical with the improvement of forgery techniques by unauthorized persons. However, although security measures have been taken against unauthorized persons, an unauthorized person who makes extra-special efforts to remove the original closure mechanism can access the contents of the package before the first user without visible evidence. The user spending a lot of money to buy high-quality product wants to know whether he/she uses the original content or not. Therefore, a closure mechanism that prevents unauthorized persons from removing the actual closure mechanism without any damage to the closure mechanism, or, for such industrial containers, the container piercing mechanism can be used. In this study, a closure mechanism has been developed that prevents unauthorized persons from removing the original closure mechanism without damaging the closure mechanism. Analyzes regarding the first opening guarantee of the relevant closure mechanism have been created. Thus, it is proved that closure mechanism could not be reused in case of any opening due to the permanent deformation it is achieved in the designed closure mechanism.

Key words: Closure, tamper evident, sealing

Kurcalamaya Dayanıklı Bir Kapak Mekanizmasının Geliştirilmesi

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Özet: Bir paket içerisindeki orijinal içeriğin başka bir ürün ile değiştirilmesi dünyanın en yaygın sorunudur. Bu tür sahtecilik girişimlerindeki tehlike sadece gelişmekte olan ülkeler tarafından değil, gelişmiş ülkeler tarafından da ciddi bir sorun teşkil etmektedir. Özellikle motor yağı, benzin, yemeklik yağ, salça, süt, meyve gibi sahte içerikler, insanlara zarar vererek onların ölümüne sebep olabilmektedir. Endüstriyel kaplardaki kurcalama kanıtı (TE), yetkisiz kişiler tarafından sahtecilik tekniklerinin geliştirilmesiyle daha kritik hale gelmiştir. Ancak, yetkisiz kişilere karşı güvenlik önlemleri alınmış olmasına rağmen, orijinal kapatma mekanizmasının kaldırılması için ekstra özel çaba sarf eden yetkisiz bir kişi, görünür bir delil olmaksızın paketin içeriğine ilk kullanıcıdan önce erişebilmektedir. Yüksek kaliteli ürün satın almak için çok para harcayan kullanıcı, orijinal içeriği kullanıp kullanmadığını bilmek istemektedir. Bu nedenle, yetkisiz kişilerin kapatma mekanizmasına herhangi bir zarar vermeden gerçek kapatma mekanizmasını çıkarmasını önleyen bir kapatma mekanizması veya bu tür endüstriyel kaplar için, konteyner delme mekanizması kullanılabilmektedir. Bu çalışmada, yetkisiz kişilerin kapak mekanizmasına zarar vermeden orijinal kapak mekanizmasını çıkarmasını engelleyen bir kapak geliştirilmiştir. İlgili teminatın ilk açılış garantisine ilişkin analizler gerçekleştirilmiş ve tasarlanan kapakta elde edilen kalıcı deformasyon nedeniyle herhangi bir açılma durumunda kapağın tekrar kullanılamayacağı kanıtlanmıştır.

Anahtar Kelimeler: Kapak, kurcalama, sızdırmazlık

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1. Introduction

The packaging is a functional outer protection material used to protect the product, to reach it to use clean and reliable, to facilitate transport and storage and to introduce the product with signs and labels. Since the packaging is specially designed for each product, there is always the threat of

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counterfeit in high-quality products. Food packages typically require tamper-evident features to deter criminal activity and increase consumer confidence in product safety. So, unauthorized and malicious people tend to counterfeit the content and packaging. The practice of maliciously tampering ingestible products such as water and food by administering poison is not new (Logan, 1993). As an example of product tampering, it can show agricultural produce such as Chilean grapes which were laced with cyanide in 1989 (Shenon, 1989). For this reason, trademark holders have begun a quest for anti-counterfeit packaging. The closure mechanism, which is the subject of this study, is designed to prevent the threat of counterfeit and has the first opening guarantee.

Designs of the closures are varying according to systems of the bottles, properties of products within these bottles and, both requires and desires of the users. There are many studies on covers properties. Crawford et al. (2002) studied the effect of the shape, diameter, and height of the cap on the ankle torque strength. It was found that participants could apply more torque with square test pieces compared to equivalent-sized circular test pieces. Data for tests on circular parts showed that the application of torque for 20–50 mm diameter test pieces increases as the diameter and height increased. The surface area of the test pieces was found to be positively correlated with the torque application level, and a linear model was developed to describe this relationship. They hypothesized that this model could be used to estimate maximum torque shutoff levels for use in the packaging industry. Mirman et al.(2008) studied on computer-aided engineering, and experimental techniques were used in the design iterations to develop a closure system which increases overall support stiffness by 25% and stiffness in the opening mechanism by over 50% while decreasing the volume of material by nearly 15%. Also, numerical analysis was applied to the moulding process to allow the designers to predict mould fills and gating properties. Langley et al. (2005) developed a "design inclusive" approach to improving the open ability of package. By examining the specific actions used in handling and opening the package, measuring the torque and gripping forces that consumers can apply with these actions, and then using these values as design limits for the packaging's sealing forces, and they estimated it is possible. New or changed designs should be physically tested for all this approach to understanding how packaging systems such as roll-on pilfer-proof (ROPP) caps work and combine this with the human ability so that better open ability could be achieved. A wide variety of designs are available, such as tamper-proof caps, breakable caps, sealed metal or plastic tubes, inner seals, blister packs, crown caps, screw caps, labels between container and cap, vacuum knobs and shrink sleeves (DTI, 2020).

While a crown cap, which is a shallowly threaded cap, is typically found in glass beverage bottles, it is increasingly being used in aluminum bottles as well. A crown cap usually needs a bottle opener to remove the cap, but some crown caps can be screwed out of the bottle without an opener. A screw cap is an "end" unit on a container and a screwing mechanical device. It is designed to be cost-effective to provide an effective seal and fit the product. Some caps need to be tamper-proof and have childproof packaging features. Tampering tape is a standard tamper warning for screw caps of bottles, for example. The flip-top plastic cap has a wide usage area as plastic packaging. The hinged cover definition is also used for flip-top cover. Flip Top Cap is used to complete many packages such as shampoo, liquid soap, and food products. The reason why these sectors use flip-top covers is that they are safer and easier to use than other cover models. The user who buys a high-quality product is attentive to know whether he/she uses the original content or not. Therefore, many different types of caps have been designed to provide first opening safety in the packaging sector. Generally, the closure of the metal packaging closure designs is usually achieved by pull tab to the cap. Designs have been made, such as the use of a tearable seal or frangible element to prevent re-use. However, unauthorized people can change the contents of the packaging by repairing the proof of tampering or removing the cap directly from the packaging without leaving any evidence. A new cap design has been started considering these difficulties in the sector. In addition to preventing the filling the same packaging with a counterfeit product after the usage of the original product, the cap mentioned in this study designed to ensure the sealing and safety both visually and functionally.

Although the essential function of a closure is to allow easy access to the content within a packaged product and to reclose the package until the content is used again, the expectation from the functions of closure has increased much in recent years. Besides, closures have been diversified according to both the content properties required to be saved and expectations of customers.

Since the contact between the content within the package and the air causes the content to have deteriorated and lose its properties in a short time, sealing is one of the most crucial functions of a closure. The edible content within a package that is not sealed enough starts to spoil before its date of expiry. So, it becomes a poison that waits for careless customers such as children, elders. Closures used for carbonated packaging content such as cola, carbonated water etc. have to show a pressure resistance against the pressure occurred within the bottle. Chemical contents used as cleaning materials are dangerous for young children and older people. There are many cases of poisoning that happened as a result of drinking such chemical content by a child or an older person. In recent years, customers pay attention to buy chemical products having child-resistant closure. Although there are so many kinds of child-resistant closure, their technologies are mainly based on the requirement to combinate the hand pressure and wrist motion to open such closures. The three most common types of child resistance caps are based on principles of push down and unscrew, squeeze, and turn, line up arrows and push off (DTI, 2020). So, since they require an elder child’s ability (above the age of seven), they are difficult for young children to open. Liquid contents within packages require different dispensing spout according to both the physical properties of atomic structure, the usage area and customer desire. For examples, odours need a spray cap according to the physical properties of smell.

Sauces such as ketchup, mayonnaise etc. require a screw cap with hinged over the lid for domestic usage. A pump dispenser for restaurants; cosmetics such as shampoo and moisturizer are offered with flip-top closure or press-on according to the desires of customers. However, the main criteria in the determination of which kind of cap will be used are to provide proper flow control of content within a package.

The packages comprising high-quality liquid content such as edible oil, wine, fuel are always under the risk of forgery. Unauthorized people can change the original content within the package with another similar range of low quality by removing and reclosing the closure without giving any damage to the closure mechanism or the container piercing. So, it is impossible the costumers to understand whether the closure is opened before or not. This causes both the health of the customers to be under danger, and the brands of these products are unjustly announced with a bad reputation. In recent years, so many anti-refilling closure mechanisms have been designed. The most common method is to use a ball allowing the flow of fluid just from interior space of bottle to outside by showing one-way valve property.

All tamper evidence aims to provide the first opening guarantee to the users. Tamper-proof closures are available in a wide variety of designs (DTI, 2020):

- breakable caps, e.g. roll-on pilfer proof aluminum closures and plastic rings which either has to be broken off or drop-down;
- sealed metal or plastic tubes;
- inner seals, membranes, or diaphragms;
- blister packs;
- labels between the container and closure;
- vacuum buttons on metal caps;
- shrink sleeves and bands.

Most common tamper evidence means are tearable seal, tamper evidence band that is connected to the closure with several frangible bridges, tear-out membrane integrated with a pull-ring etc. As well as this common tamper evidence means, there are also high-level tamper evidence technologies applied on closures such as color change, RFID detection. Despite all current tamper-evidence means used by manufacturers, unauthorized people continue to reach the original content within the package before the first users without detection.

In this study, a closure mechanism has been developed to prevent the removal and reinstallation of the cover mechanism without leaving a trace.

2. Material and Method

2.1. Design of the Closure Mechanism

The new closure mechanism which is suitable to use for a closing container comprising high-quality liquid products such as oil, fuel etc. consists of a cap member, a flexible nested pouring spout and two metal securing rings. The first ring of the new closure mechanism has the same structure as the ring of the current closure mechanism. Moreover, the first ring is used inside the metal container. The second ring structure stays on the metal package.

As known, pouring spouts comprises a neck portion, flexible wall portion and outer peripheral flange. Since the current closure mechanism is mounted on the metal package by clamping the metal closure on the mouth of the metal package, it is sufficient to loosen the interlocked parts to access the contents of the metal package without damaging the closure mechanism and the metal package mouth. Unlike conventional pouring spout, the present pouring spout comprises a downwardly extending anchor portion with outer flap tab located horizontally at its bottom side, as an extension of mentioned outer peripheral flange.

In this study, S235JR steel as the material was used while developing the closure mechanism. S235JR is a prevalent carbon steel used in many applications, including industrial pipes, food, rail and pipelines that supply gas and oil (Tsonev et al., 2018). Material properties of the steel which is used are shown in this study as in Table 1.

Table 1. Material properties of the steel which is used in the study

Name	DIN EN	Yield-Stress [MPa]	Strength [MPa]
TS275	10202	275	375

In case of removing the closure mechanism, the metal securing ring, which is the element of the closure mechanism is irreversible remains within the package. Re-use of the same packaging with a counterfeit product is prevented. 3-dimensional design of the closure mechanism is given in Figure 1. As seen in Figure 1, the first ring of the current closure mechanism is used inside the metal container. The second ring of the new closure mechanism protects by staying on top of the metal container.

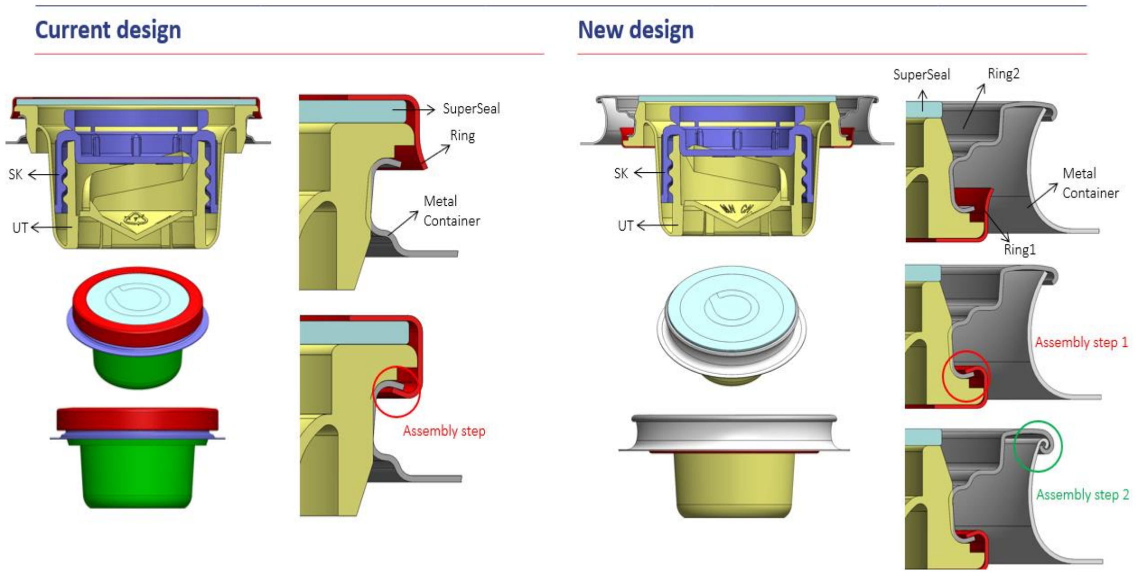

Figure 1. The Three-dimensional design of the current and new closure mechanism

2.2. Analysis of the Closure Mechanism

Two steps are simulated to perform tamper resistance tests in this study. In the first step, the bending behavior of the underside of the closure mechanism is determined. The underside of the closure mechanism is the current closure mechanism and remains inside the container. The new closure mechanism is the upper part of the closure mechanism and, protects by remaining on the container. In the second step, the bending behavior of the upper part of the surface is determined. A screwdriver with displacement limit conditions is substituted for bending. The model bends in a quarter of the ring. Out of these boundary conditions, the needed Force is read. The new design of the new closure mechanism assembly steps is as in Figure 2.

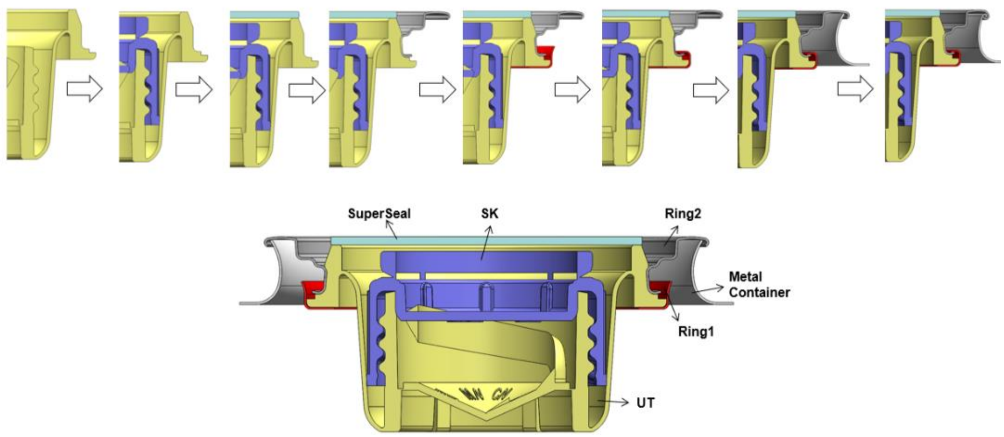

Figure 2. The new design assembly steps are shown

In this analysis, the first step starts with bending the lower side and in the second step, the upper side. For reducing calculation time, both measures are simulated separately. Due to the missing stress-strain curves for the material type, the best way to model material behavior is a bilinear elastic-plastic model (Chang, 2016). The following modelling was used in the experiment;

- Young's module for the elastic part of behavior
- Yield voltage value
- Strength values (stress and strain)

The assumptions of value for elastic modulus and the strain at break are as follows:

- Young’s modulus: 190000 MPa
- Strain at Yield: 0.0015 (0.15%)
- Strain at break (strength): 0.25 (25%)

3. Result and Discussion

3.1. Simulation 1

The first step starts with bending the bottom side and the second step the top. To reduce the calculation time, both measures are simulated by bending separately with a 10 mm screwdriver. The ring bent in the first step is also the ring used in the existing closure mechanism. For this reason, a re-analysis is not performed for the ring in the existing closure mechanism.

The design of the lower part of the closure mechanism is in an interlocking structure as in Figure 3.

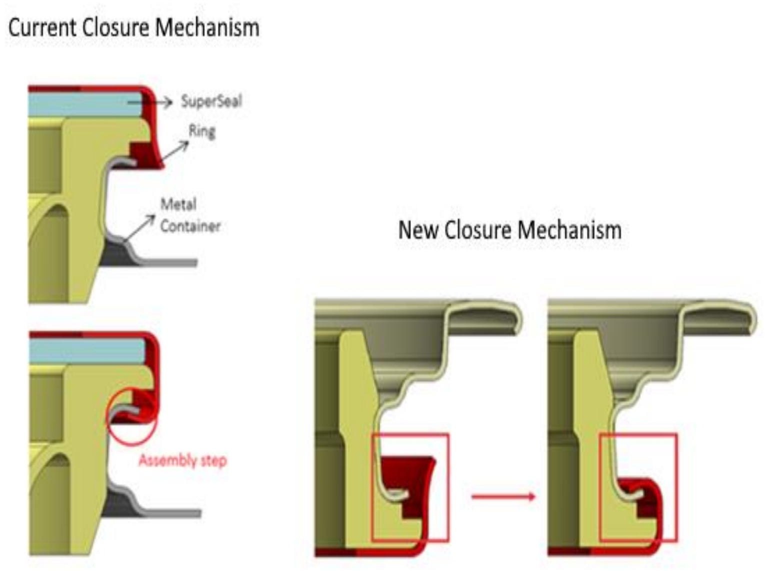

Figure 3. Step 1 is shown

Due to pressing metal upwards, happened the pressure of a 10 mm wide screwdriver and the stress and deformation graphs is shown in Figure 4.

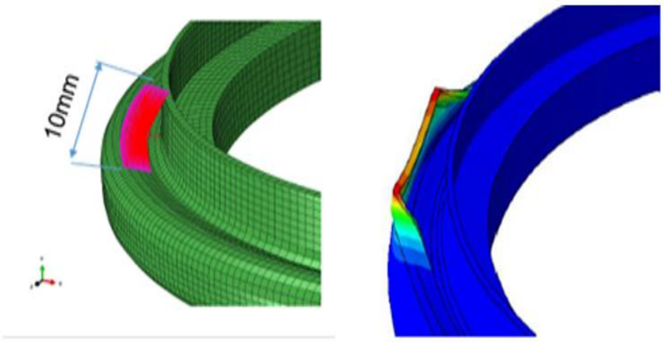

Figure 4. The stress and deformation graphs are shown

The values formed after applying pressure to the closure mechanism with a 10 mm screwdriver are found. There is three simulation result for the first part of the simulation for the lower part of the closure mechanism. They are; Von Mises Stress, plastic strain, and reaction force.

The von Mises stress and the plastic strain values as shown in Figure 5.

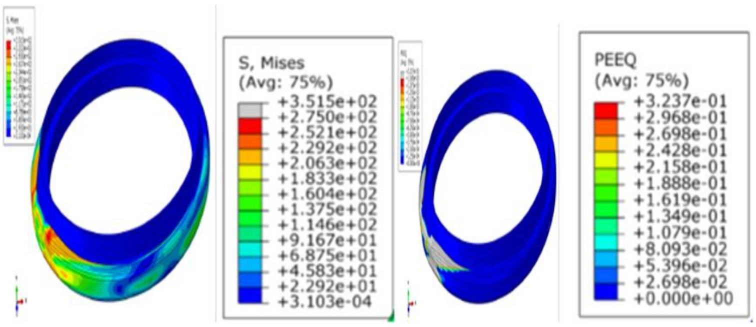

Figure 5. The Von Mises stress force values and plastic strain values

The von Mises stress, and the plastic strain according to the 275 MPa yield stress and the plastic strain at the efficiency (0.15%) as a result of the applied process was as in Figure 5.

The reaction force analysis resulted as in Figure 6.

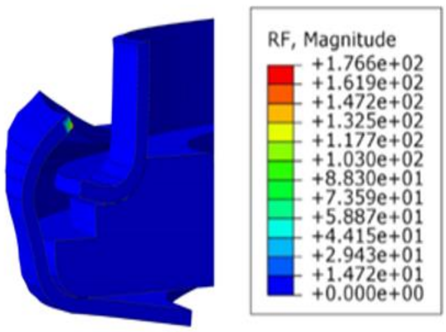

Figure 6. The reaction force values

According to analysis, it has been observed as a result of the study that the usability of the lower part of the closure mechanism may continue.

3.2. Simulation 2

In the second stage, it is simulated above the closure mechanism. The upper closure mechanism is opened in 3 steps. The displacement limit condition replaces a 10 mm screwdriver that bends the metal in three steps. In step 2, like in step 1, a constraint of beams, referred to a reference point, bends the metal like a screwdriver. When the first area is bent up, the place to the right is bent up. The second step and the oil sump closure mechanism are shown is Figure7.

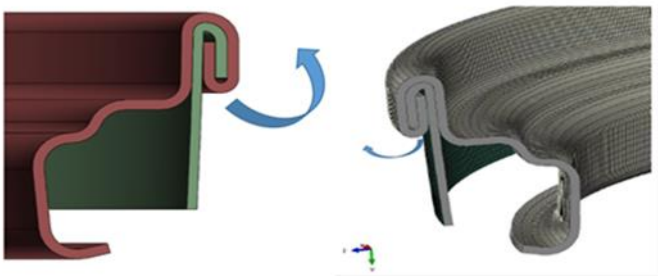

Figure 7. Step 2 and closure mechanism

There is four simulation result for the second part of the simulation for the upper part of the closure mechanism. They are reaction force, deformation, plastic strain, and Von Mises Stress.

As one of the results, we obtain a reaction force. The Force you need to bend the metal with a screwdriver depends on the lever arm (length of the screwdriver). It is desired to open the edge of the oil sump by bending it upwards in three stages with a screwdriver, as shown in Figure 7.

The metal is bent up in three steps. The reaction force analysis required for this opening process is observed. Three forces are applied to the upper closure mechanism. The reaction force simulations for these forces are shown in Figure 8. The first force applied to open the closure mechanism is determined as 286N, the second force applied to open the closure mechanism is determined as 249 N and the third force applied to open the closure mechanism is determined as 310 N.

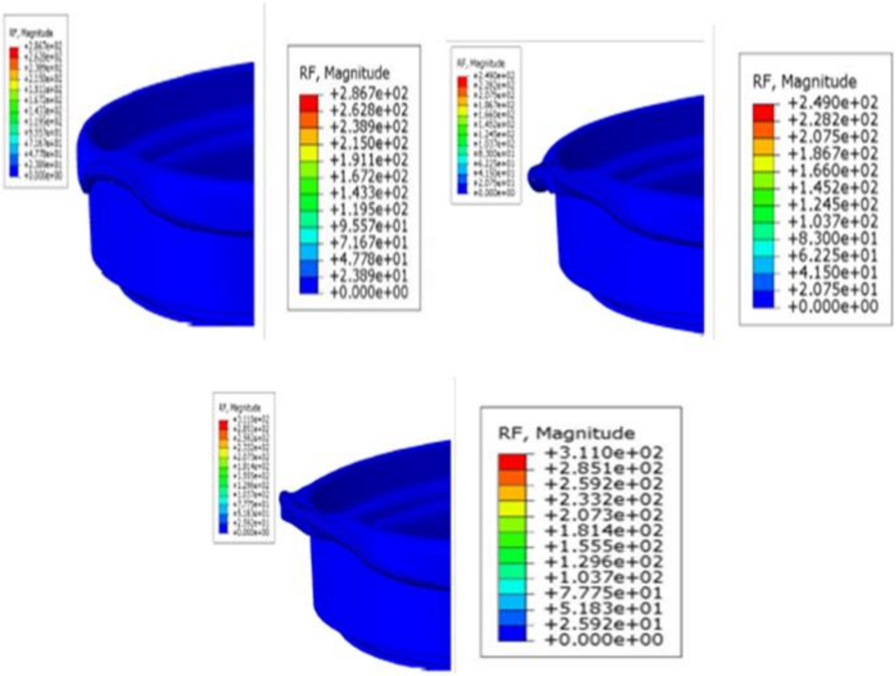

Figure 8. First, second and third step of bending up analysis result

The plastic strain scaled to 0.0015 (0.15%) is shown in Figure 9. The area shown in grey is permanently deformed. It is observed that the deformed area cannot be assembled back

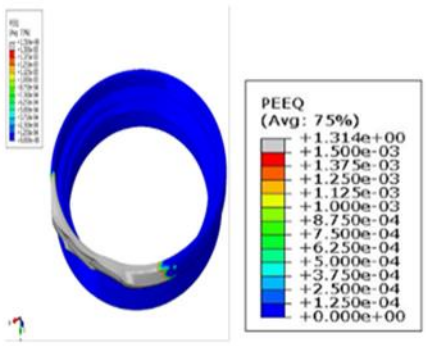

Figure 9. Plastic strain value

Analysis result according to V. Mises stress scale 275 MPa (Yield stress) are deformation are as in Figure 10.

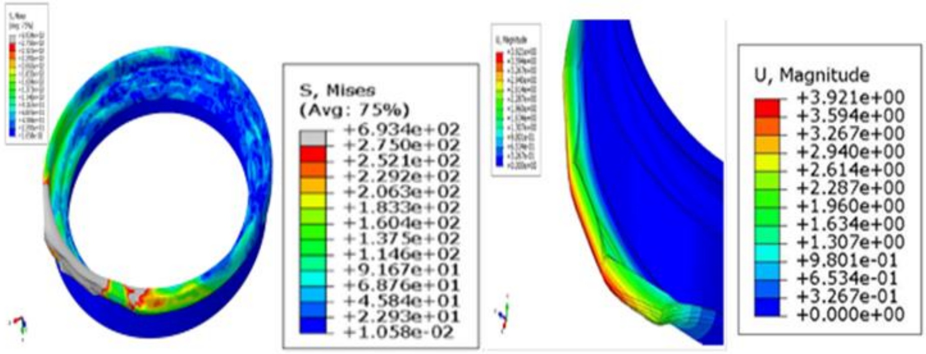

Figure 10. Von Mises stress value and deformation value of the upper part of the closure mechanism

Kaya (2018) studied on S235JR, and S355JR construction steel plates with 3 mm thickness both were joined using cored wire electrode type filler metal by MAG welding method. Joined materials between themselves (S235JR-S235JR, S355JR-S355JR) and different (S235JR-S355JR) were carried out in three different combinations, including. Krella et al. (2020) studied on the erosion resistance of S235JR steel to flow cavitation was investigated. To understand the influence of steel properties and cavitation intensities on the degradation mechanisms, low-carbon S235JR steel was tested in the as-received state and after thermal treatment (annealing) under four different flow velocities. In this study, for preventing unauthorized people from reclosing the container piercing with same or similar closure mechanism to original one after the content exchange by providing damages on both the new closure mechanism and box piercing; unlike mounting operation of conventional closure mechanisms, mentioned metal securing ring is inserted from the opposite side of the nested flexible pouring spout as holding both the bottom and outer sides of said downwardly-extending anchor portion and then, higher tab of the metal securing ring is clinched onto the metal lid's lower tab positioned on external flap tab of the flexible pouring spout. The cap structures in the existing systems are easily opened with a screwdriver. In the new system, the current cap structure cannot be intervened from the outside due to the remaining inside the bottle. When the outer cap structure is pressed, permanent deformation occurs.

4. Conclusion

In this study, a closure mechanism has been developed that prevents unauthorized persons from removing the original closure mechanism without damaging the closure mechanism. The lower part is the existing closure mechanism structure and remains inside the container. The new closure mechanism is the upper part and, protects by remaining on the container. Analyzes regarding the first opening guarantee of the relevant closure mechanism have been created. The von Mises stress, and the plastic strain according to the 275 MPa yield stress and the plastic strain at the efficiency (0.15%) were applied to the lower part and the three forces are applied to the upper closure mechanism. The first force applied to open the closure mechanism is determined as 286N, the second force applied to open the closure mechanism is determined as 249 N and the third force applied to open the closure mechanisms determined as 310 N. As a result of these analyzes, it was concluded that there was no permanent damage as a result of the force applied to the lower part of the closure mechanism. However, permanent deformation occurred on the upper closure mechanism. Regarding to the analysis, it is proved that the new closure mechanism could not be reused in case of any opening due to the permanent deformation we achieved in the designed closure mechanism.

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