



## Review Article

# Study on the Materials, Accessories Used in Protective Gears for Bikers and Selection of Material there of Using Finite Element Analysis - A Review

K Phebe Aaron<sup>1\*</sup>, K Krishnaraj<sup>1</sup>, D Suresh Kumar<sup>2</sup> and P Madhushankar<sup>2</sup>

### Abstract

Various fabrics and accessories have been employed in the past for designing the biker's jacket without taking into consideration the factors that affect the bikers. As much as one loves riding, the risks involved in riding also cannot be ignored and hence safety should be given a fair consideration. With the development of high impact resistant materials, riders bestow confidence on biker's jackets as they provide both style and safety. Different materials depending upon the features are available in the market. This review attempts to bring together vibrant research that has been done in the field of biker's jacket right from material to accessories. An attempt has been made in this paper to do FEM analysis on the materials that can be used as armors in jackets followed by development of biker's protective jackets. Based on the FEM analysis, it has been concluded that apart from PU, materials like Polyether sulfone, Styrene butadiene, Thermoplastic polyurethane can be recommended for armors in motorcycle jackets.

**Keywords:** Leather, Reflectors, Armors, Impact, Stress

## Introduction

Bikers jacket is a class of protective apparel which aims at protecting the individuals from environment & physical barriers they encounter during riding and preventing the bikers from injuries during long rides and races [1-3].

Bikers are subjected to severe injuries in the event of crash [4-7]. Bikers jackets are generally classified into two types. They are Racer jackets and Street jackets. The use of bikers jacket was initiated long back and has a long history [8,9]. Initially the jacket used by bikers was only for style statement but later they were used for safety. As per the article submitted by American college of surgeons the four E's are important in reducing the effect of the injuries, the four E's include Education, Engineering, Enforcement and Economics [10]. With the development of technology, new materials are coming into existence. Doyle reported that head and limbs are frequently injured in an accident [11]. The catalogue of materials used in designing bikers jacket includes traditional textiles and polymeric materials.

With the advent of above materials classic and high quality bikers jacket are being manufactured. The basic science behind the use of bikers jacket is to prevent direct contact of body with the atmosphere and terrain and make jacket act as the barrier [12]. Haworth and Hurt have discussed that use of jacket prevents injuries [13-15].

Leather was basically ideal material for bikers jacket but with increasing demand for added features it was clear that only use of leather would not completely fulfill the desired features like scratch resistance and moisture resistance [16]. In recent times, modern textile fibers like Kevlar and Cordura have taken the place of leather due to host of properties. More and more manufacturers are offering jackets made of a combination of leather and textile materials. Leather usually covers the most vulnerable parts of the body, including the upper back, shoulders, bottom and top of the arm. The textiles offer better comfort by creating extra ventilation. Research has indicated that protective gears can significantly reduce soft tissue injuries [17-19].

Accessories like armors and pads are able to absorb shock and exhibit scratch resistance. Armors added on to the jackets are a great advantage when under high thrust prevents the rider from injuries and bone dislocation. With the current trend moving towards memory foam, companies are using materials like D3O for armors which have high shock absorbing capacity [9,20].

The above said properties can be optimized through Finite Element Method (FEM) for better performance of the jackets. FEM is used by scientists and engineers to develop products and analyze it for its various real life conditions. The main advantage of using FEM is the ease of evaluation of design using different materials and conditions. The result will lead to selection of suitable design and material without wasting the materials and its manufacturing time. As this analysis avoid physical testing it gives an edge over the said method.

FEM analysis can be used for Static Structural, where Static structure is used to analyze deformation, stress and strain due to application of load, behavior of product in contact with other material. This is also used in to solve problems related to the field of computational fluid dynamics (CFD), which helps to predict air and fluid flow, heat and mass transfer, chemical reaction and related phenomena.

An attempt has been made in this study to discuss the various requirements for designing of jackets, types of armors and accessories to be used by rider for protection from injuries. Also, this review attempts to bring together vibrant research that has been done in the field of biker's jacket right from material to accessories followed by selection of materials through FEM analysis and development of biker's protective jackets.

## Motorcycle Jacket Requirement

The main objective of the bikers jacket is to produce light weight, low cost yet comfortable jacket with superior performance. Research has proved that head is the most injured part and leads to death of the riders. Apart from head, lower limb is the next most injured part [11,21,22]. In 1993, the European Experimental Vehicles

\*Corresponding author: K Phebe Aaron, Sr. Principal Scientist, Honorary Faculty Anna University, Shoe & Product Design Centre (SPDC), CSIR – CLRI, Adyar, Chennai 600020, Tamilnadu, India, Tel: +91 24437113; E-mail: kphebejohn@yahoo.co.in

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Committee opined that the legs are often prone to injuries in a crash [23]. Bachulis studied various pattern of injuries when the rider falls down both while wearing helmet and in the absence of helmet [4]. Begg investigated that many form of injuries lead to fractures which can be reduced by using armors [24]. Chest and abdomen are also frequently injured in a crash leading to 7% to 25% biker deaths [25]. The motorcycle jackets should be designed from both bikers and technologist perspective [12]. For bikers, the comfort, degree of mobility and maximum protection against injury, night visibility, cost and aesthetics are vital while for technologists, the level of protection from injury, and energy absorption characteristics of materials are imperative [26]. Since these garments are worn for long distance travel, comfort along with protection is given more importance.

In general motorcycle ride, the rider tries to deplete weight of the protective garment. Because during long rides, heavy weight jackets may lead to fatigue to the rider and will disrupt him from continuous travel [27]. The weight reduction, area of coverage, placement of armors in appropriate places provide additional advantage of mobility [28]. Protective clothing has been found to protect bikers from cuts and burns and peeling away of skin and muscle. They may also lessen the risk of infection from wounds [29-32].

## Materials Selection

The bikers clothing has to prevent thrust by absorbing and preventing from penetrating into human body. Several synthetic materials which have inbuilt properties are available in market which are being used in making jackets [30-33]. Nowadays various web based computer guides are provided by the companies to take correct decision about jackets [34,35]. Therefore, the primary factor which influences the performance of biker jacket is materials which go into the making of jackets.

### Outer material

**Aramid:** Aramid fibers are heat-resistant and possess stretch property. As they are highly abrasion-resistant, they are used for added strength.

**Cambrelle:** Cambrelle is abrasion resistant and has air pockets that create comfort around the body. It is also used in footwears [36].

**Carbon/Kevlar:** Carbon fibers are light weight, strong and stiff. These fabrics are used in knuckle protectors in gloves.

**Chamude:** Chamude is soft, durable, breathable and possesses insulation property.

**Clarion:** It is durable, breathable, lightweight, soft, and flexible for comfort on long rides.

**Cocona:** Cocona fibres are derived from coconut shells. They are found to perform well as they absorb the energy from the body to enhance breathability, thereby keeping rider dry on the inside.

**AirGuard:** This is a polyamide fabrics which has tiny air pockets, and hence improves wearer comfort. It is water repellent, which is easy to clean and dries quickly.

**Coolmax:** It is a Polyester fabric which removes moisture away from the body and keeps the rider cool. It is often used in garment linings and is breathable and soft.

**Cordura:** Cordura is abrasion resistant and generally used for heavy-duty procedures. It also has a soothing feel and natural woven look.

**Amara:** This is made of 60% polyamide and 40% polyurethane, which offers excellent grip and is used in motorcycle gloves.

**HiPora:** This is a waterproof film which has polyurethane coating. Numerous pores in the coating prevent water from outside, but enables moisture from the body to exit. They are waterproof, windproof and breathable.

**Kangaroo hide:** Kangaroos sweat through their tail as pores are not present in the hide. Kangaroo hides are resistant to moisture and very rarely do they lose their shape or degrade over time.

**Lorica:** Lorica excels over leather in that it is lightweight, waterproof and flexible.

**Primaloft:** Primaloft is light-weight, water-resistant, and durable. The hydrophobic fibres present help in insulation to a greater extent.

**Reissa:** Reissa is a functional fabric which has polyurethane resin coating with high sensitivity towards weather conditions. It is light weight, durable and breathable.

**Schoeller-keprotec:** The aramid fibre weave is five times stronger than steel and therefore provides excellent abrasion resistance. This material is normally used as reinforcement in high-risk parts in garments. It is also used for stretch panels, so that comfort and movement are not compromised.

**Stingray skin:** This is highly abrasion resistant material and hence used in gloves backed with shock absorbing gel pads to permit riders who fall down to slide more easily leading to less chances of fracture.

### Liners

Most of the jackets come with a removable liner with options for rain and wind-proofing that can be removed by simply unzipping it from the interior of the jacket. A liner helps to stay warm and makes sure that the body temperature remains normal in adverse conditions. Some of the liner materials are given below.

**Knitted lining:** The inner lining of the bikers jacket is made of a knitted fabric so they give good stretch and freedom of movement. The knit is very open so that air can circulate freely, cools and carries away moisture thereby allowing the body to maintain a more consistent comfort level.

**Cotton lining:** Cotton lining is soft, breathable, good for skin and can be easily washed but it shrinks easily and not so slippery which makes the rider uncomfortable while riding.

**Bubble liner:** This liner creates a chamber inside the jacket which insulates from climate both in summer and winter and mostly used by present bike racers [37].

### Accessories

**Reflectors:** A riding jacket essentially needs to have reflectors. In many foreign countries reflectors are essential for long ride bikers jacket as they avoid crashing [26]. Reflectors glow in light from other vehicles and make the rider highly visible. Hence, other motorists will be able to spot from a distance.

**Waterproof zips:** Waterproof zips play an important role in bikers jacket helping the bikers to travel in any terrain without fear of water entering into the apparel

**Hump:** Back Hump used in the bikers jacket play an important role in air flow dynamics. When a biker is in motion the air moving

in opposite direction offers resistance to the rider. As a result, more effort is to be exerted by the biker to move ahead and hence causes stress to the rider. To avoid this, back hump is generally provided in jackets so that at high speed the air gets dissipated and the resistance which is provided in the opposite direction is reduced [38].

**Co-Injected shoulder with metal insert:** The co-injected shoulder is armoured CE protector attached to the garment. It occupies less space and offers maximum protection [39].

**Titanium & aluminum shoulders:** These armors are light weight, have outstanding abrasion resistance and controlled sliding. The design benefits increased coverage to provide outstanding protection. It provides protection similar to level 2 armors [39].

**Replaceable slider system 2.0:** The design features a re-engineered slider profile and elbow construction, plus seamlessly integrated titanium armor for a substantial reduction in weight, improved fit and usability. Another advantage is that the slider replacement is quick, simple and reliable [39].

**Air bag:** Air bag offers instantaneous, high-pressure inflatable protection in a crash by covering the full back, shoulders, kidney areas and chest. The airbag is incorporated into a specially designed vest, which is then attached within and used with a compatible jacket.

## Requisites for Bikers Jacket

### Fit

A comfortable fit for a riding jacket is as important as its protection. The jacket should neither be too tight nor too loose so that it can be worn comfortably both, in summer and winter. Further, its length at the arms should be just perfect since longer sleeves do interfere with riders while riding.

### Zipped waterproof pockets

Pockets are important part of the jacket. The zippers provided for the pockets should not allow water to pass through. For added protection flaps are provided. As bikers carry mobiles and expensive gadgets along with them, it is imperative to have waterproof pockets [37].

### Air vent

In motorcycle jackets to prevent the riders from injuries, the outer layer is made up of tough material and sandwiched with different layers. So air flow is restricted. This limitation is a great challenge faced by designers [40]. One method of providing air flow is by providing perforated fabric over the area which is exposed to the flow [41,42]. Another method is providing vents with water proof zippers at shoulders and chest. In places like India where there are climatic variations the bikers can keep the vent open during hot climatic condition and during cold or monsoon days the rider can keep the zippers closed so that water or moisture does not enter into the jacket (Table 1).

## Combating Stress

### Cold stress

While travelling in cold climate it is necessary to make sure that bikers do not get affected as they may feel uncomfortable and stressful. This may lead to poor decision making regarding speed etc. So to avoid this bikers jackets are designed such the neck region is provided with foam like material which help in easy neck movement but does not allow the chillness to enter the jacket [43].

### Wet stress

Wet stress is the discomfort caused to the riders due to water accumulation in clothing which includes sweat accumulation and rain water. This leads to propagation of cold. Materials like Gore-Tex are water resistant which do not allow water to enter into the jackets but allow moisture to circulate and remove sweat out of the body [43,44].

### Heat stress

In India during summer, bikers ride without wearing jackets and hence are risky. To avoid the risk, vents are provided in jackets to permit air flow within the jacket. The vents are designed in such a way that air can enter and exit from jacket easily. The outer layer should be such that it reflects the infrared rays [43,44].

### Noise or vibration stress

Noise and vibration is one of the stress which affect the riders irrespective of the climate and terrain change. If the riders are exposed to vibration and noise for a long time it may lead to fatigue thus resulting in wrong decision making. Special vibration resistant shoes and gloves are developed with a layer of gel and foam within [43,44].

### Discomfort stress

Jackets should be designed such that they are flexible so that riders can move and bend easily [45,46]. The panels provided for inserting the armour are designed such that armour remains rigid and does not get displaced easily. The jacket should have zippers on the sleeve and vent [43,47].

## Armors

Armor is an important accessory in bikers jacket. The armors should absorb the shock and dissipate it without affecting the riders. Reports suggest that head, facial and bone joints, lower limbs are mostly affected during bike accidents [1-3,11,48]. Armors are generally made of polyurethane material, which have high shock absorbing capacity. British Motorcycle Federation in 2003 published an article which stated that out of the many companies that produce protective apparel very few companies provide certified products. So to prevent customers from getting tricked away by any artificial armour, CE (European) standards are being implemented. Those

**Table 1:** The results of the analysis of various materials are tabulated below.

	Polyurethane Foam		Polyether Sulfone		Styrene Butadiene		Thermoplastic Polyurethane	
Property	Min	Max	Min	Max	Min	Max	Min	Max
Deformation (mm)	0	1.25	0	0.031	0	329.21	0	4.13
Strain	0.003	0.273	0.0001	0.007	0.68	65.4	0.007	0.77
Stress (Mpa)	0.110	14.04	0.07	13.20	0.13	12.42	0.12	11.80

which satisfy the standards are given CE labeling.

There are two levels of CE protection, CE level 1 and CE level 2 protectors. Typically CE level 1 is needed for most tracks, however some more advanced and higher speed track schools or races require CE level 2. For Level 1 protectors, the maximum transmitted force must be below 18 kN, and no single value shall exceed 24 kN and for Level 2 protectors the maximum transmitted force must be below 9 kN, and no single value shall exceed 12 kN.

The certification is important as usage of any material does not confirm the safety of jackets. Ouellette investigated that apart from falling many bikers face serious injuries due to dashing against rail guards and hence care should be taken that sharp objects do not tear or pierce the jacket [49]. The CE standard testing zones are presented in Fig.

As per CE standards elbow, knee and shoulders are prone to high risks of injury due to the joints present there, so these armors are also called as joint protectors. Apart from these places back portion (spine) or tibia is secondly prone to injuries. for which armors are mainly available in market [31,38]. For bikers who are going for long ride but not in rough terrain level-1armour is recommended. But for bikers who are going to travel in rough and rocky terrain are advised to go with Level-2 armor. Apart from these regions there are also armors which are being used in other parts. They are tailbone protectors, chest protector, knuckle protectors. The protectors along with their placement are shown in Figures 1-5.

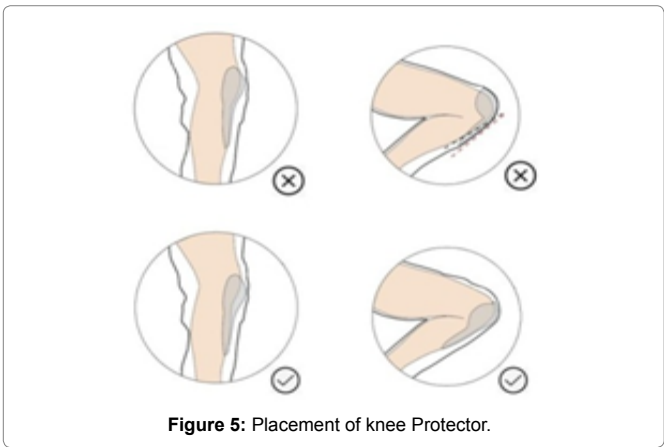
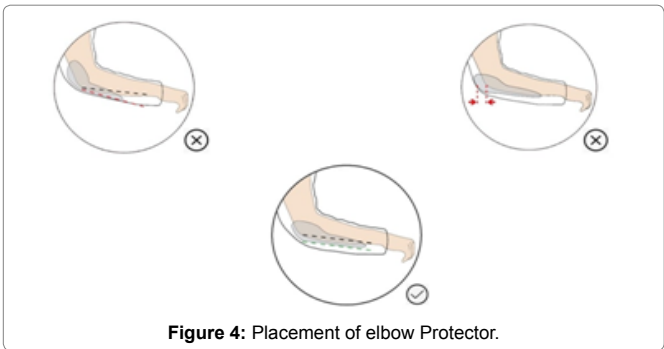
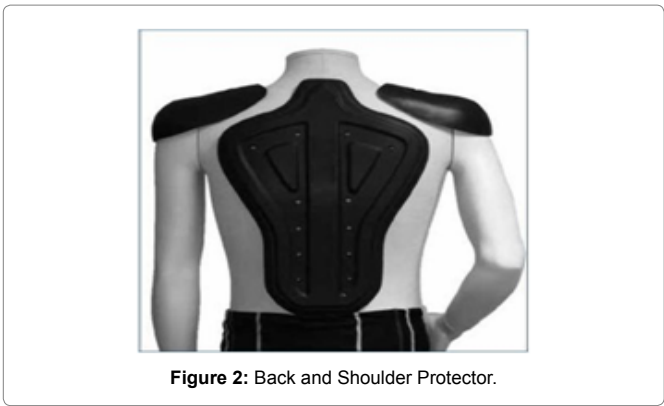
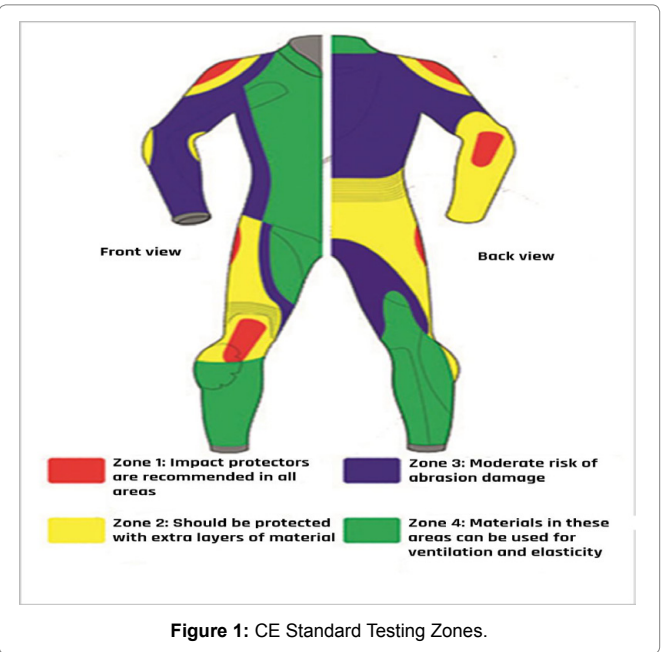
Testing Standards

EN 13595

The EN 13595 testing standards are used for designing apparel for motorcycle rides which includes Jackets, Trousers, one and two piece suits. The tests conducted under EN 13595 are divided into four parts

EN 13595-1:2002

The first part of EN 13595 includes the requirement and examination procedure for clothing [50].



EN 13595-2:2002

This test is Impact Abrasion Test. This test was introduced in 2002 and was published in European standard for protective clothing [51]. The method of testing involves a sample of weight 49N which



is dropped covering a distance of 50mm on a 60 grit abrasive belt that is moving at a speed of 8 m/s. The test ends when the sample is holed and a trip wire that is kept beneath the test specimen is also broken. The impact test helps us to identify whether the specimen will sustain abrasion during fall in rough terrain and prevent wear and tear during slip

**EN 13595-3:2002**

This test is done to detect Seam burst strength. In this test a circular sample cut from the clothing is placed over a diaphragm and is clamped around its edge. The specimen is gradually extended into a dome shape thereby applying forces to the seam in all directions. The pressure required to burst the sample is recorded [52].

**EN 13595-4:2002**

This test is done to detect Impact cut in the material. The sample is mounted over a block containing a rectangular hole. A striker of fixed mass with a sharp blade fitted to its lower surface is dropped with a defined energy level so that the blade impacts the sample directly above the rectangular hole. The maximum penetration of the blade through the material is measured [53].

**EN 1621-1:2012**

This test helps us to detect the Impact Protection quality. In all applications whether it is motorcycle riding or any sports activity the more the body is closely in contact with impact area the more are the chances of injury. So the protectors are used so that impact area of the body does not come directly in contact with the impact location. The protector during impact will get deformed to resist the transmission of impact to the body [54,55].

**EN 1621-2: 2014**

This gives requirements and test methods for motorcyclist back

protector. The sample is being placed over a rigid metal hemisphere anvil which is connected to a rigid and a massive base via a high speed force sensor. A 5kg impact or with a flat strike face 80mm x 40mm is then dropped onto the sample from a height necessary to generate an impact speed of 4.47 m/s. This equates to the impact energy of 50 joules. Then during the impact the force transmitted through the sample to the anvil is measured by the high speed force transducer. To pass the standard the transmitted force must be below 35KN and not exceed 50KN.

**Selection of Armor Material using FEM and Development of bikers Jacket**

**Methodology**

The material used for manufacturing armors for bikers jacket is Polyurethane foam. The major reason for the use of PU foam is it has high shock absorbing capacity. Armors should absorb the force applied and dissipate it and prevent penetration of stress. So back armor was designed using 3D modeling software (CATIA V5) and exported to FEM (Ansys workbench V19.0) software. As per SATRA standard a good armor should not transmit more than 50KN of load to the body. Therefore in Ansys the back armor was given the PU property and 50 KN of the load was applied and its deformation, stress and strain were calculated.

Subsequently other materials having good shock absorbing and stress distribution properties such as Polyether sulfone, Styrene butadiene and Thermoplastic polyurethane were also subjected for analysis.

**Results**

As it can be seen that the stress distribution in the armors made of Polyether sulfone, Styrene butadiene, Thermoplastic polyurethane is less than the stress distributed in PU foam (Figures 6-9). But, in

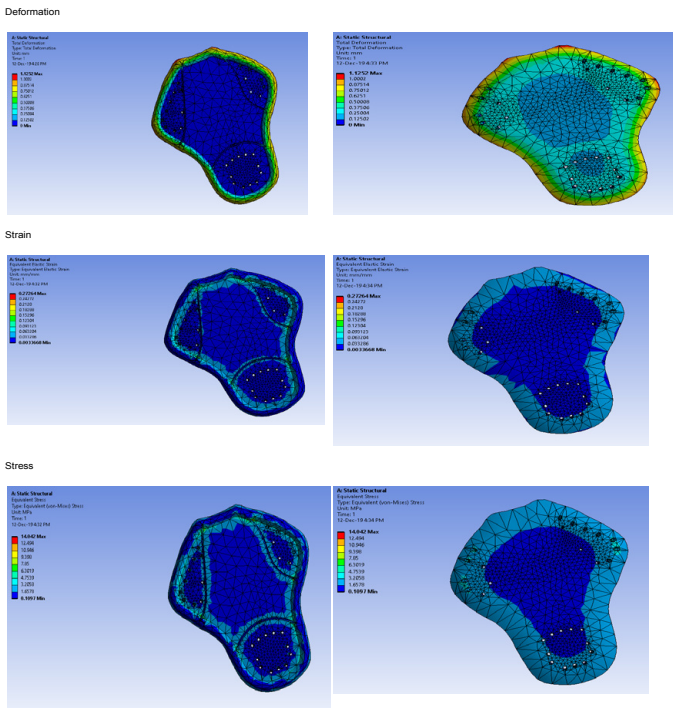


Figure 6: FEM analysis of Polyurethane.

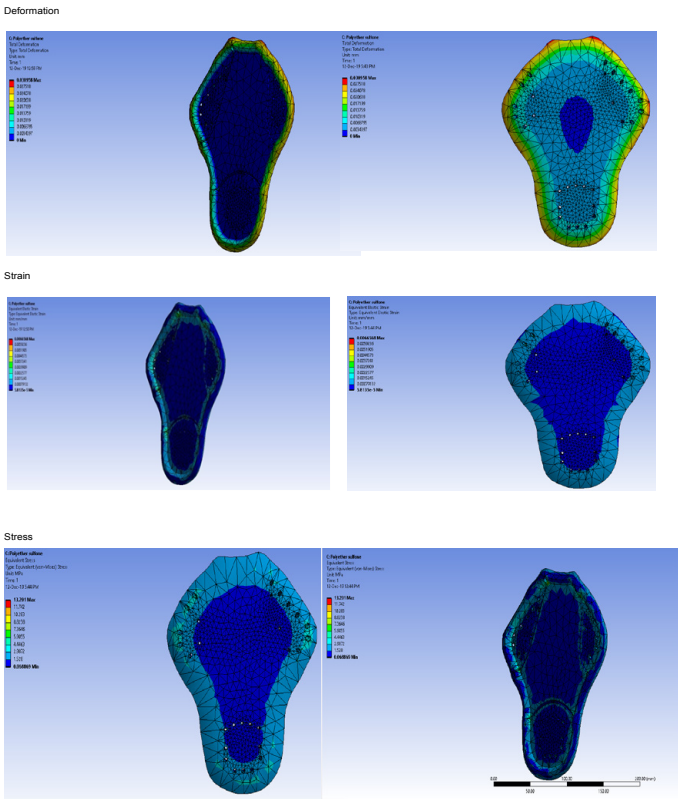


Figure 7: FEM analysis of Polyether sulfone.

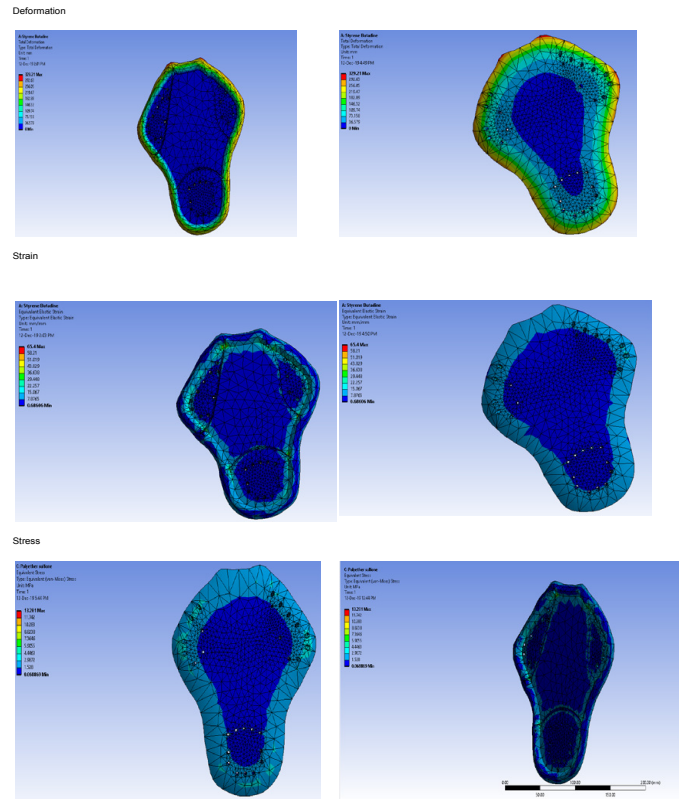


Figure 8: FEM analysis of Styrene butadiene.

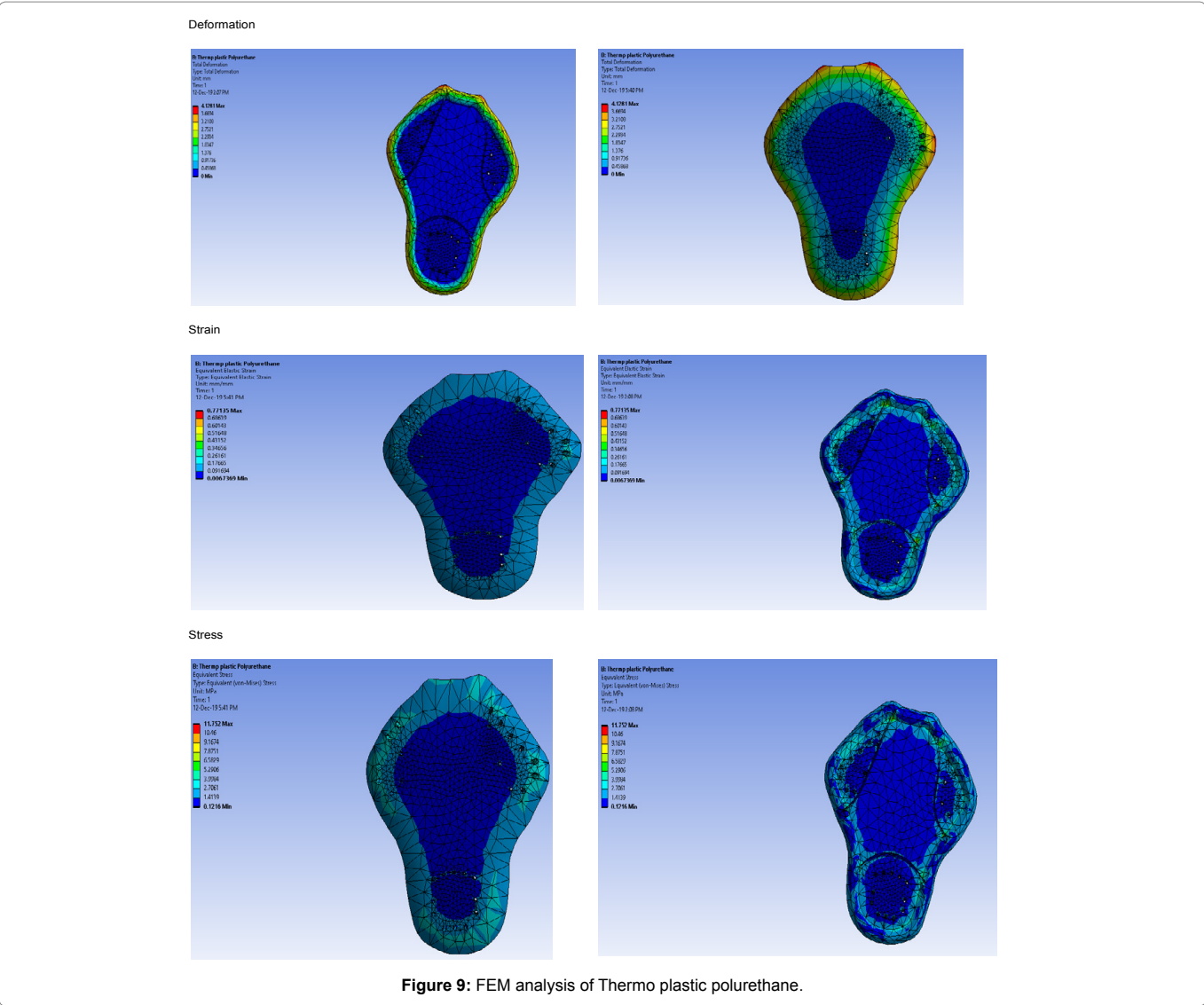


Figure 9: FEM analysis of Thermo plastic polurethane.

Styrene butadiene, Thermoplastic polyurethane we can see that the deformation value is higher. It shows that the strain energy storage capacity is high in both these materials and hence the material deforms and gains more energy and return to original position quickly whereas Polyether sulfone has good shock absorbing capacity, but less strain energy storage capacity. From the results it may be concluded that Polyether sulfone, Styrene butadiene, Thermoplastic polyurethane have good shock absorbing properties as well.

Based on the above review and analysis, Prototypes as shown in Figures 10 & 11 were developed based on the specifications and requirements making it a special one using highly abrasion resistant material, the leather. One of the important properties of biker jacket is that it should be flexible so that bikers can stretch and move their body easily. Keeping this in mind, the Prototypes have been developed by combining leather with Special elastic material for flexibility. Vents have been provided in the jackets for riders keeping in mind the airflow while travelling. The Padding materials in the jacket prevent the bikers from getting injured by efficiently distributing the energy in a crash when bikers fall down thereby reducing chances of injury.



Figure 10: Male Jacket.

The collar is made using chemical resistant and flexible fabric which contributes to neck comfort. Reflectors were used to make the rider more visible. Waterproof Zippers have also been provided which prevents water from entering the jackets.

The jackets were then field tested using Racing bikes. The jackets



**Figure 11:** Female Jacket.

were comfortable for the ride with good heat and wind deflection. The jackets fitted well along the arms with no restrictions to riding movements. It was observed that the materials, zippers, styling, stitching, stretch parts, lining, armor positioning, neck cushion, cuffs were good.

## Conclusion

The motorbike segment is rapidly growing and safety has become an important concern for people using any form of transportation. In India more than 10 million bikes are being sold every year and this would significantly grow in the years to come. Hence there is a huge market potential for protective gears.

In this paper, different materials which can be used for fabricating bikers jacket have been discussed. Also various features available in the jackets for the comfort of the riders and the safety standards for designing armors have also been discussed. Motorcycle jackets have been designed with proper heat and wind deflection and which can withstand various impacts and save the commuters from injuries. Also, based on the FEM analysis, it may be concluded that apart from PU, other materials like Polyether sulfone, Styrene butadiene, Thermoplastic polyurethane are also recommended for armor in motorcycle jackets.

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