UDC 621

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COMPUTER AIDED DESIGN FOR SILICONE SEALS USED IN ELECTRICAL CONNECTORS IN AUTOMOTIVE INDUSTRY

У цій статті представлена дуже важлива тему статичного кремнієвого друку, що використовуються для електричних з'єднувачів. Показані основні проблеми запечатаних зв'язків і як вибрати друк інтересу для кожного застосування.

В этой статье представленна очень существеннуя тему статических кремниевых печатей, используемых для электрических соединителей. Показаны основные проблемы запечатанных связей и как выбрать печать интереса для каждого приложения.

In this study I am trying to introduce very significant subject of static silicone seals, designed for electrical connectors. I am trying to show basic problems of sealed connections and how to choose seal of interest for each application.

1. Introduction

This days more and more designed connectors are sealed and they have to meet high leakproofness standards, requested by car producers. That kind of connection design requires great knowledge about all major types of seals, seal materials, fluid mechanics, strength of materials and also lot of experience in component design by artificial materials. The knowledge of advanced programs is of particular importance, since it allows to create models and perform the simulation before prototyping. Desire to avoid leakage totally, is a great challenge not only because of physical problems but also because of economical demands.

Seal failure will be associated with repair costs of the damaged parts, therefore good seal design is so important.

On the engineering software market there is many available programs that are very useful in design and simulations of the seal. These programs can be applied in every stage of product development starting from design up till production.

2. Purpose and range

In my work I am trying to specify relationship between the shape of the seal profile and its application

On top of that I am describing many materials used to produce seals and different kind of tests required to specify parameters for basic FEM analysis model creation. I also specify basic equations for sealing.

In this work you can find seals comparison based on forces between the sealing surfaces.

3. Basics of sealing

Depending on the application we can find different seals which can be made of varieties of materials or can have different profile section. For example on Fig. 1 we can see a few profiles used in various applications.

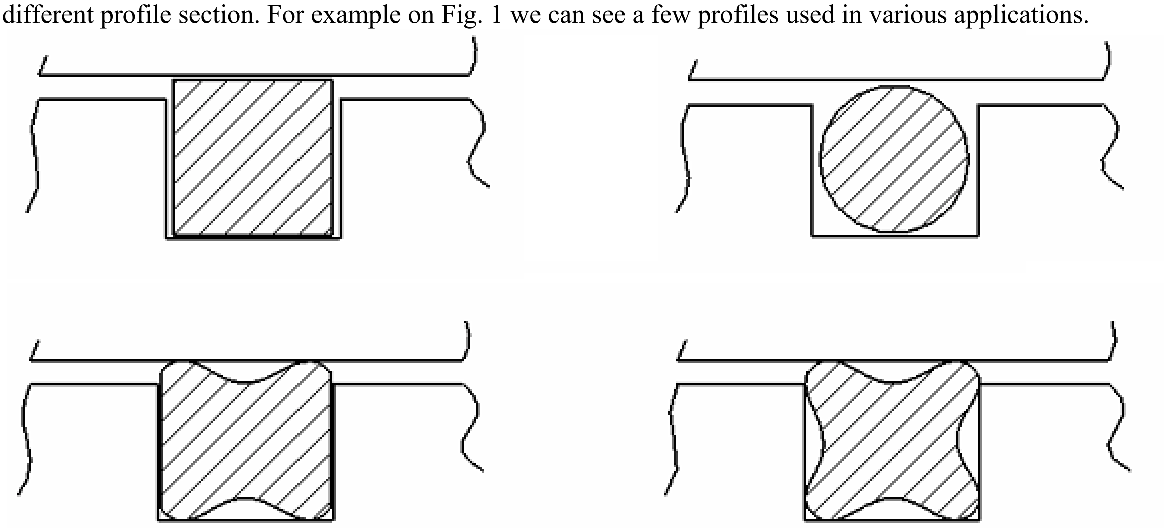

Fig. 1 Types of seal profiles used in different applications

Seal profile selection is very important. For example seal with O-ring profile will need fitted housing to gain best insulation. The best advantage of this type of profile is the lowest friction on sealing surface during installation. Another type of seal with quadrangle profile can withstand bigger pressure in comparison to O-ring one but there is much bigger friction on the surface that excludes that kind of seal from dynamical application. Much better solution is to join these two profiles with H or X shape by which we can benefit from both previous described seal advantages.

3.1 Materials used to perform seal

Application wise there is many materials that can be used to produce seals, most popular being Liquid Silicone Rubber thanks to its good manufacturing parameters. Connectors seals need to pass very strict tests required by car manufacturers. They should withhold very high and low temperatures, have a good resistance for chemicals and for ageing. There is many silicones materials available on the market that can have various applications depending on their parameters, one of the most important one being high temperature resistance. On Fig 2 we can see temperature range for different types of silicones.

But to select proper material for our seal we need to have much more information about its properties. Other very important is thermal resistance which we can check by measuring mechanical parameters during temperature changes. Seals applied for connectors should also have good dielectric parameters and be resistant to chemical compounds. Eventually seal need to be immune to compression set what is very important in applications where we can expect very high or low temperatures. Fig. 3 shows how temperature can affect compression set for different types of rubber.

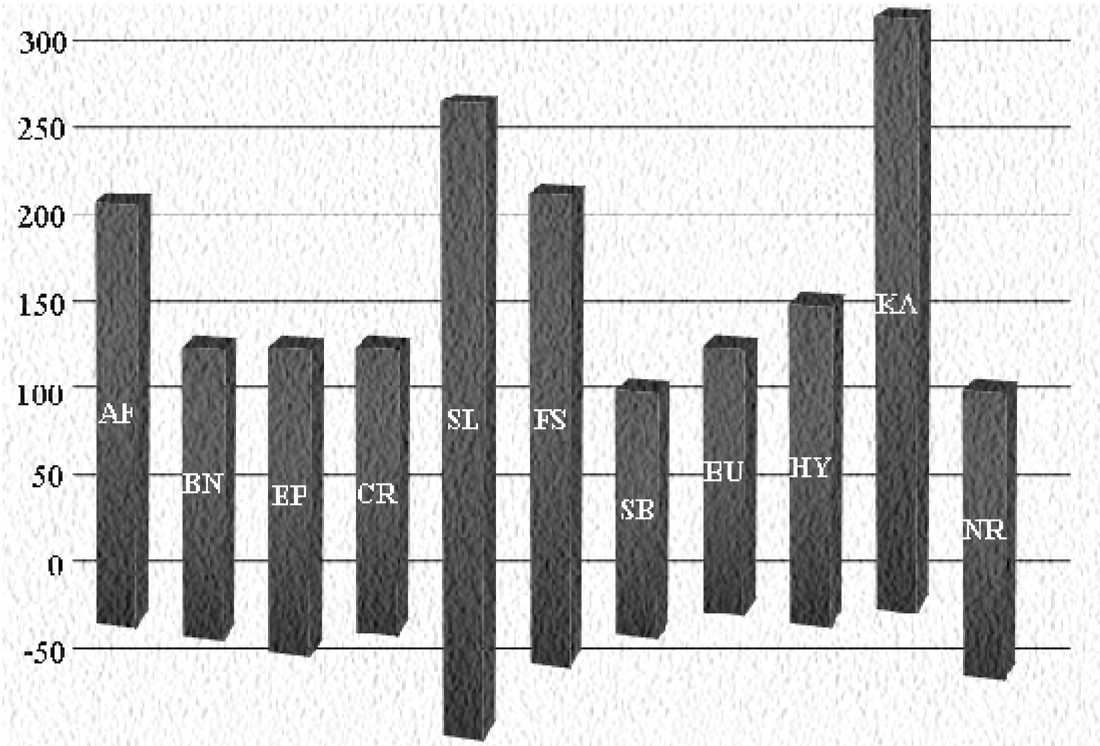

Fig. 2 Temperature resistance based comparison of seals manufacturing materials (AF-aflas, BN- buna-n, EP – ethylene-propylene, CR – neoprene, SE – silicone, FS – fluorosilicone, SB – SBR, BU – butyl, HY – hypalon, KA – kalrez, NR – natural rubber)

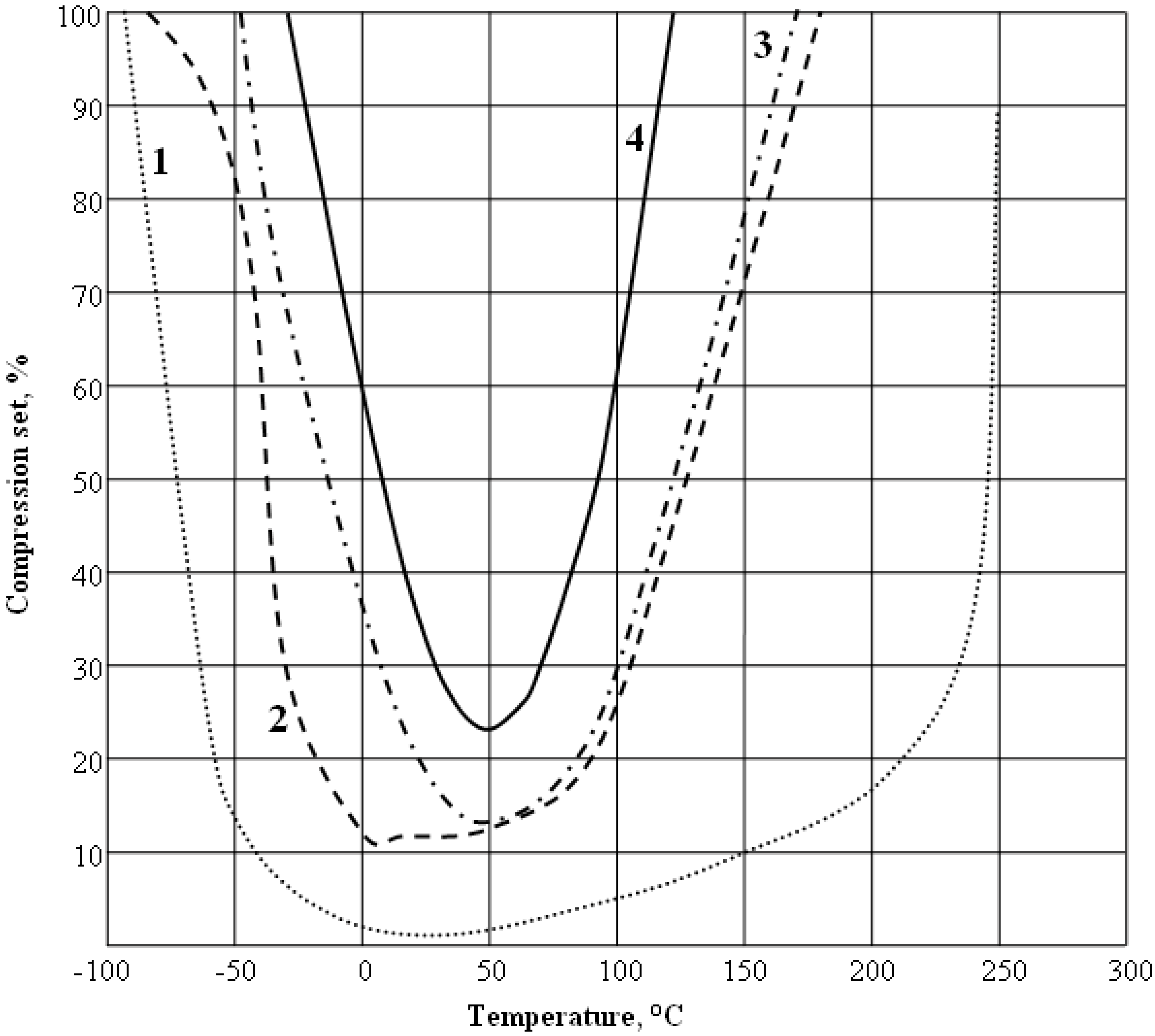

Fig. 3 Temperature impact on compression set for various types of rubber
(1-silicone, 2-ethylene-propylene, 3-polimer composed with ethylene-propylene, 4-polychloroprene

3.2 Mathematical basis of sealing

In the industry we can find many seals but the best way to describe how seal works is to show it on seal with quadrangle profile. First of all we should know that the elastomers as silicones characterize themselves with great elasticity and incompressibility therefore they can be used for seals. On Fig. 4 we can see forces which impact on seal when it is squeezed and when pressure is supplied onto its surface.

When pressure p is supplied and impact on the seal surface then it invokes stress σ_x. Because of great incompressibility we can say that initial stress σ_0 will be increased of value of σ_x, in the end we obtain total stress σ_p This mechanism of sealing is named automatically because total stress will be greater than fluid pressure until gain sealing as you see on equation (1).

$$\sigma_p \approx \sigma_0 + p \tag{1}$$

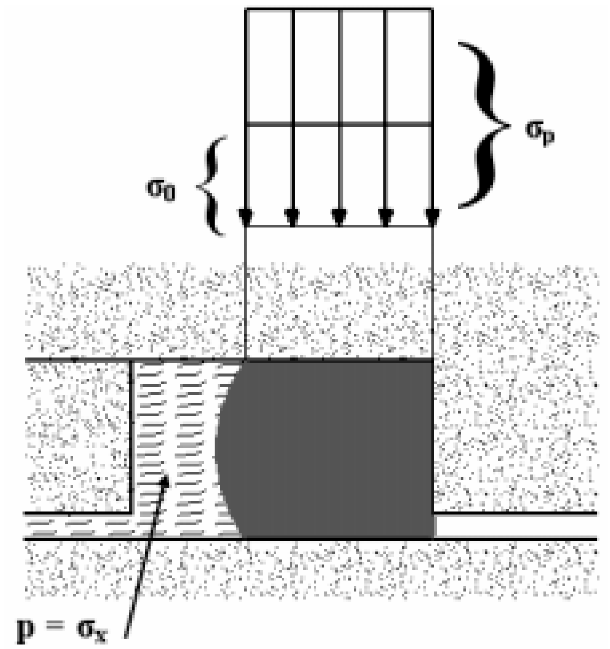

Fig. 4 Stress σ_p between sealing surfaces which result from initial stress σ_0 and stress revoked by pressure $p=\sigma_x$

3.3 Simulations

To carry out simulations I used program called ANSYS. To create mathematical model for material I performed simple stress test which allowed me to obtain basic parameters of my specimen. Of course to gain more precision our sample should undergo several various strength tests and model of this sample should also be examined by FEM analysis. For my simulations and research I used specimen of silicone and the effects of stretch test can be seen on Fig. 5.

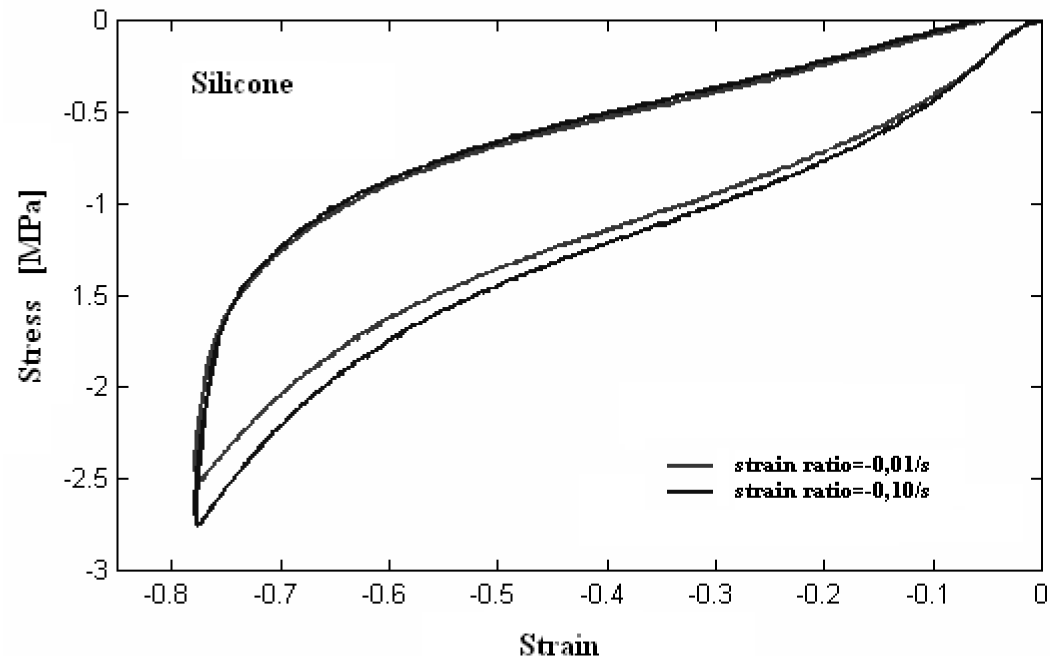

Fig. 5 Characteristic of stress for silicone performed in room temperature for various strain ratio

In this case it is nonlinear deformation that made me create a mathematical model for my sample of silicon.

I used a great tool in ANSYS named “curve fitting”. On top of that to obtain appropriate curve I used hyperelastic model “Mooney-Rivlin” with 9 parameters, what allowed me to create the curve which overlap with characteristic almost at all as you see on Fig. 6.

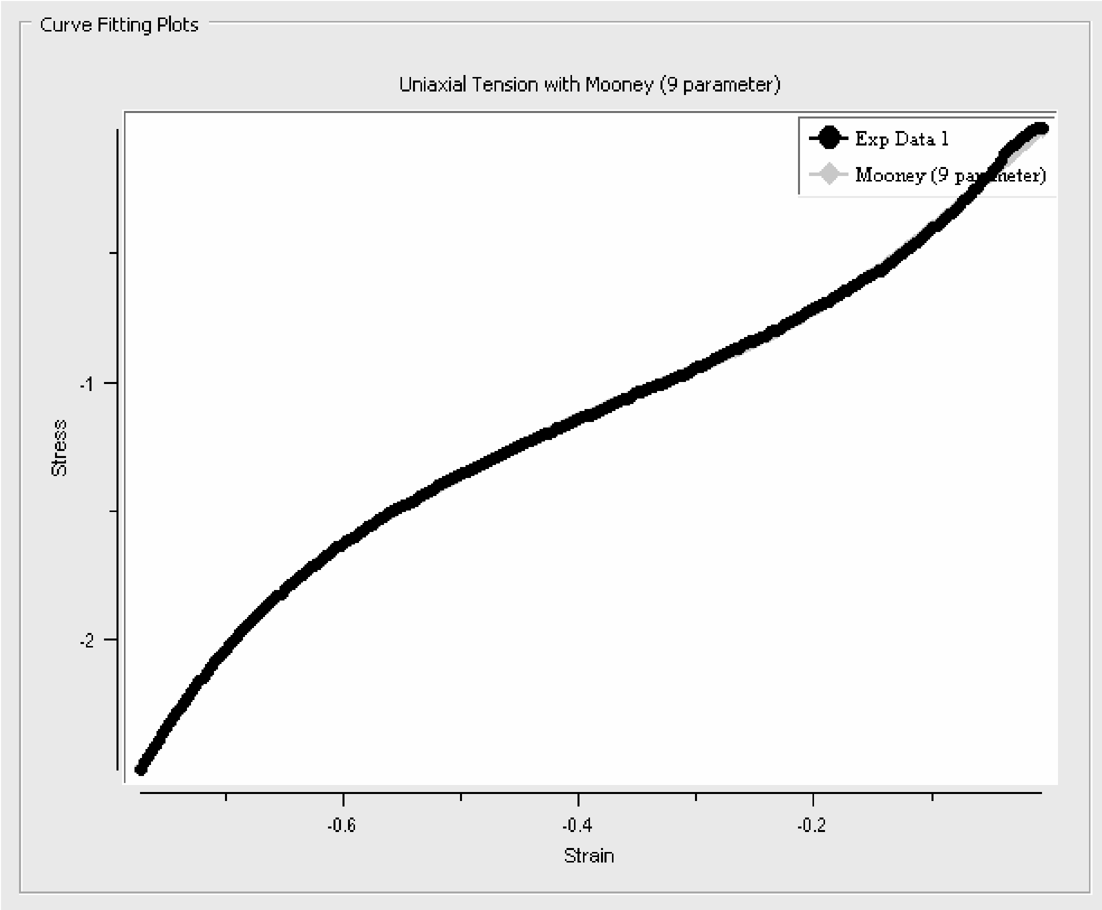

Fig. 6 Comparison of experience characteristic to Mooney-Rivlin

Then I created flat models for different types of seal profile and I put on every model finite element mesh with the same parameters for all. For example we can see on Fig.7 model of meshed O-ring seal.

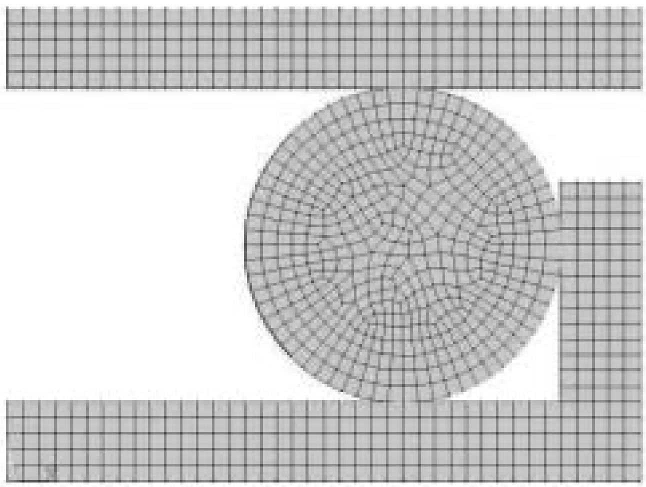
Fig. 7 O-ring seal model with mesh generated in ANSYS

On that prepared models I introduced forces which moved top element downwards what invoked forces onto contact surfaces. These forces allowed me to specify justifiability of using seals in dependence of application. On pictures below you can find my results.

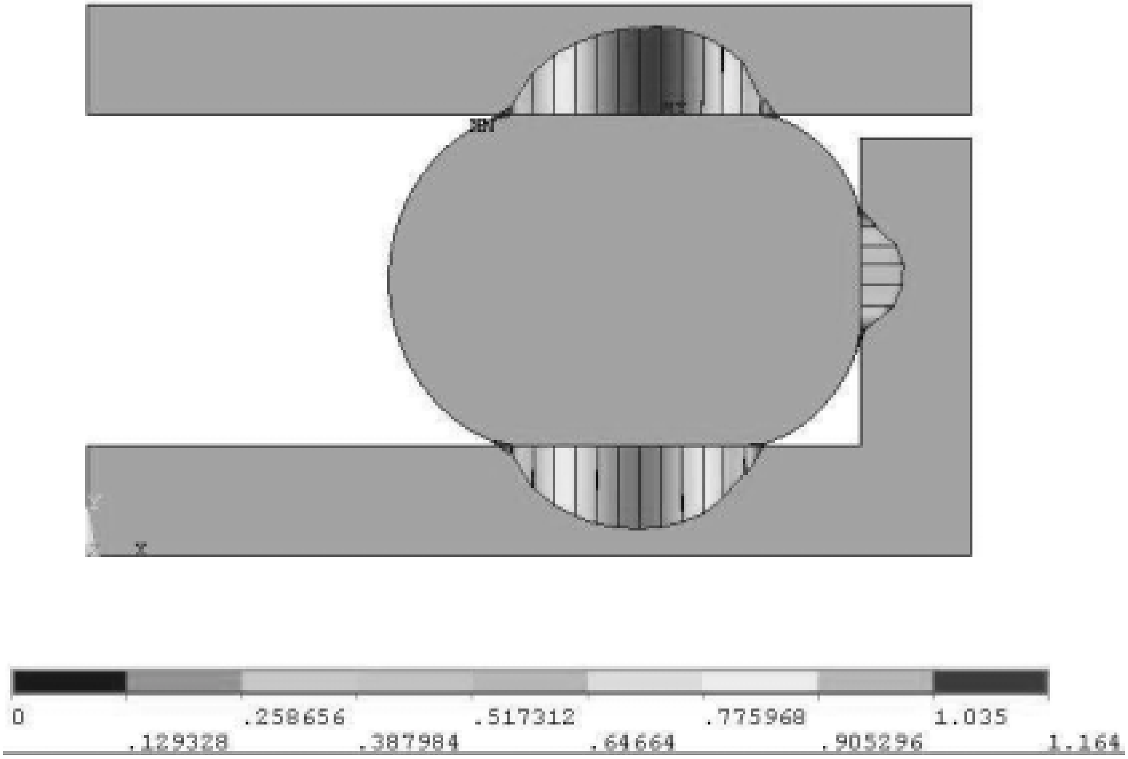

Fig. 8 Contact stress analysis on O-ring seal model

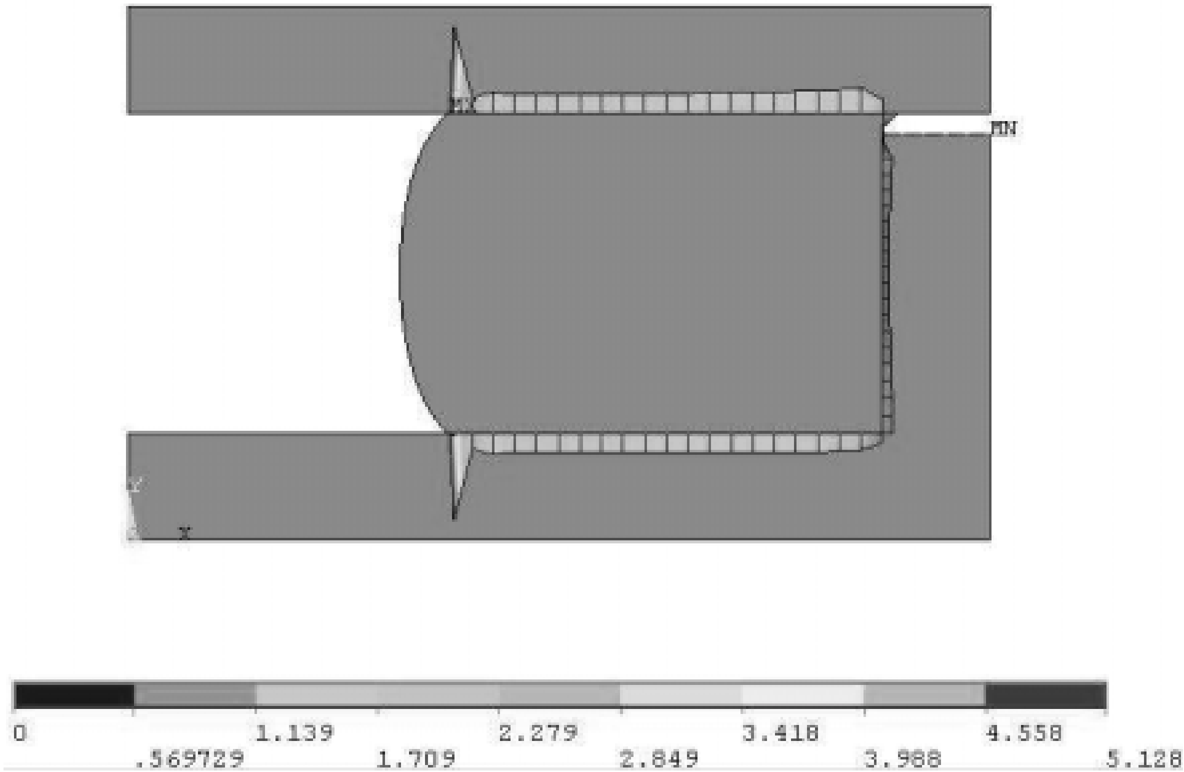

Fig. 9 Contact stress analysis on quadrangle seal model

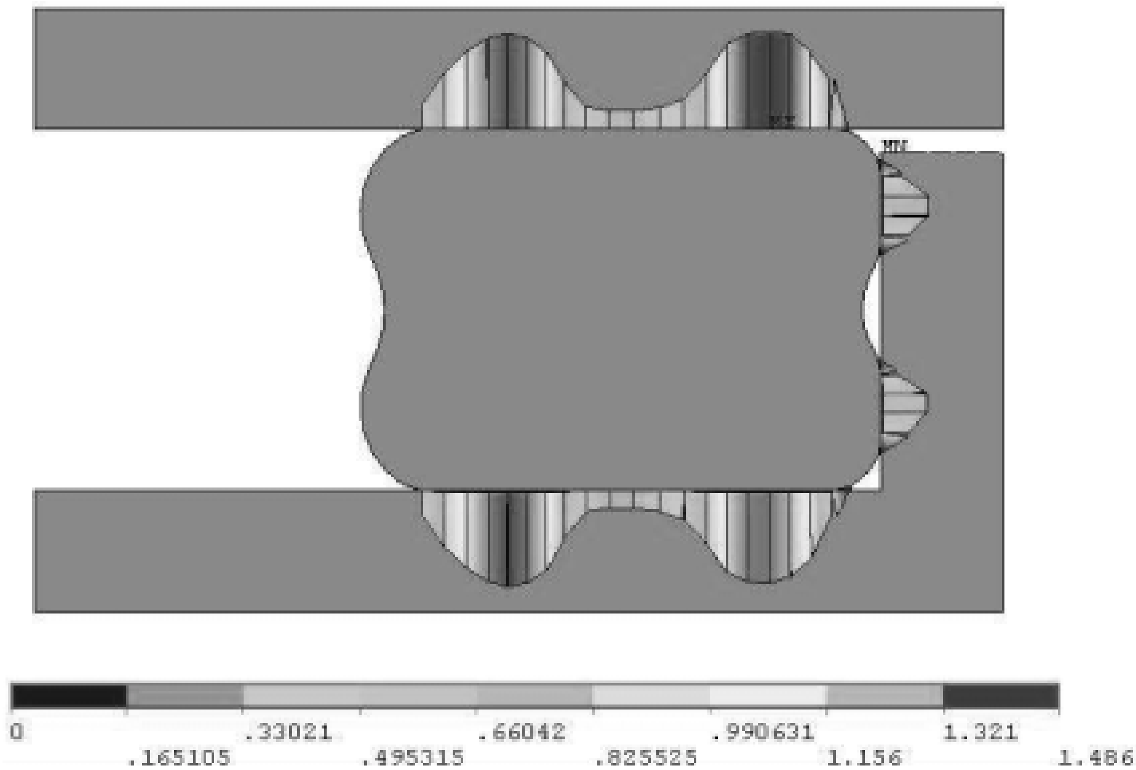

Fig.10 Contact stress analysis on X-ring seal model

4. Conclusions

From carried out simulations results advantages and disadvantages of examined seal profiles which prove possibilities of applications. The most stable solution as it turned out is seal with quadrangle profile, because stresses spreads evenly on whole sealing surface. Unfortunately it causes higher friction what decreases abilities to apply this type of seal for motion joints. O-ring seal characterizes itself by lower motion resistance when in contact with sealing surface, but maximum tension invoked in contact area is smallest of all examined seals. Moreover there is possibility for seal to rotate what will certainly cause leakage. X-profile seal can be specified as a combination of both previous types. Profile like that allows to decrease friction forces and as it is easy to notice, forces onto contact surfaces have almost the same value like in quadrangle profile seal. Concluding, the best solution is to use seal with X shaped profile and following on from this, using ribbed seals. Fig. 11 in cases where we can expect higher pressure, which would like to impact onto not covered seal surface.

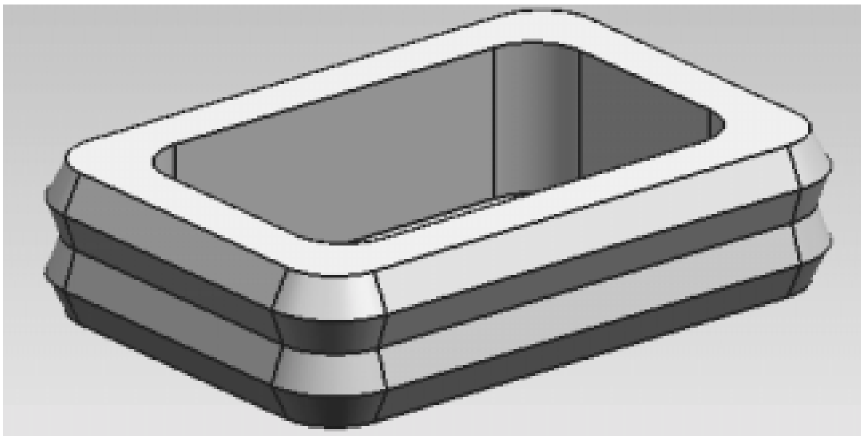

Fig.11 Example of ribbed seal used in electrical connectors

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