7. Haptic Optima for Endlessly Touchable Surfaces and the Paradox Double Egg Shell Effect

Thin film solutions are often applied where they are quite visible to the final customer or user, namely on the surfaces of products. Things like design, optical appearance and haptic will then automatically play an important role in the market. In order to incorporate these rather soft aspects into a technical coating optimization procedure as shown in figure 43, the mechanism proposed here, namely the Higgs field mechanism, might be of good use, too. The reason may not only be seen in the fact that we can keep the classical, technical optimization and quality control, but also that the mechanism chosen to consider these new boundary conditions will be of the same soft character right as the boundaries themselves.

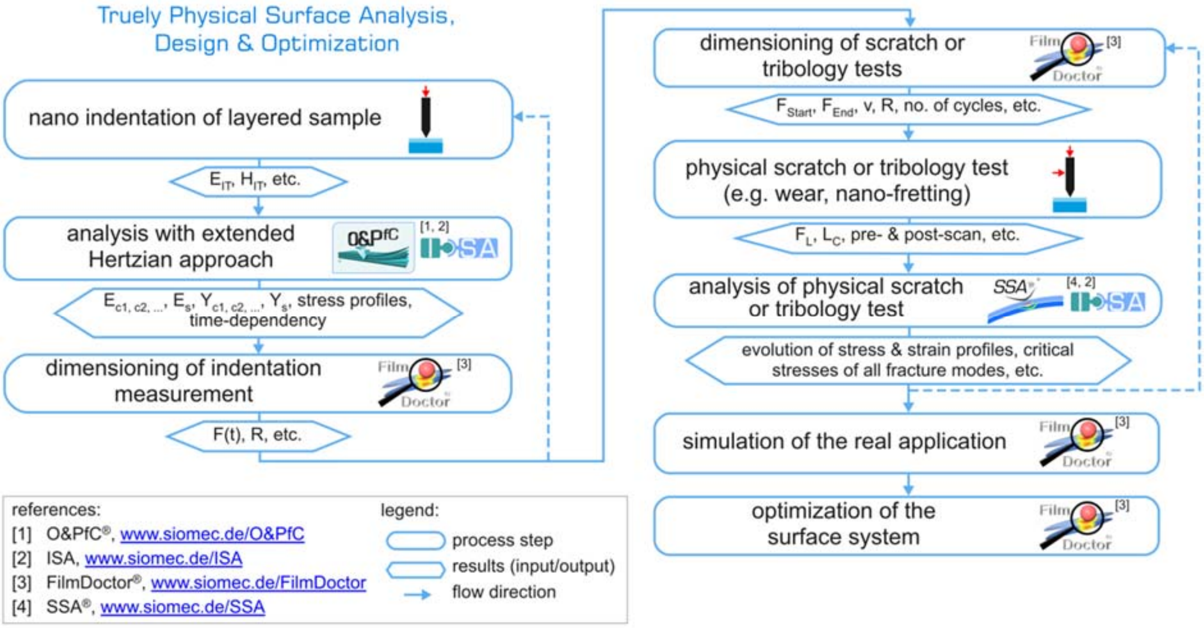

Fig. 43: A flow chart of the procedure of mechanical characterization and optimization of arbitrary structured surfaces with respect to mechanical stability and reliability.

Here, we will concentrate on the problem of finding optimum haptic solutions.
No matter how important it might be for certain products to provide stable and reliable surfaces with respect to mechanical loading, there are various applications where the surfaces have to provide not only this kind of stability but also a certain haptic. This means, how these surfaces feel like if being touched respectively how they do interface with the user to the sense of touch. Especially for applications like mobile phones, tablets, smart phones, game consoles, steering devices or the interior of a car one can imagine how important solutions for this boundary condition are.

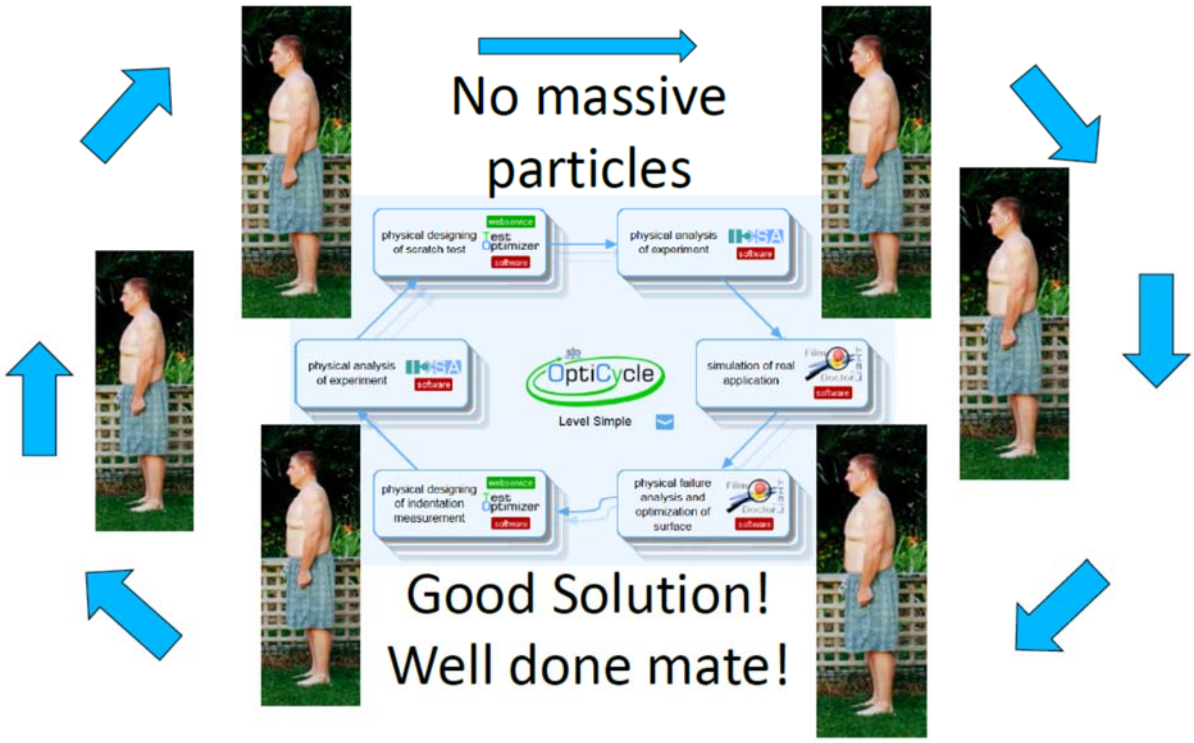

Fig. 44: Illustrative presentation of Higgs-enforced surface optimization with a good outcome..

Here "important" not only means, of course, with respect to optimum usability but also regarding market aspects. As simple as it is, the demanding customer does not only purchase a product because of its looks and functionality. More and more designers realize that touching something and the feeling connected with this process is extremely important for the customer and her or his final purchase decision.

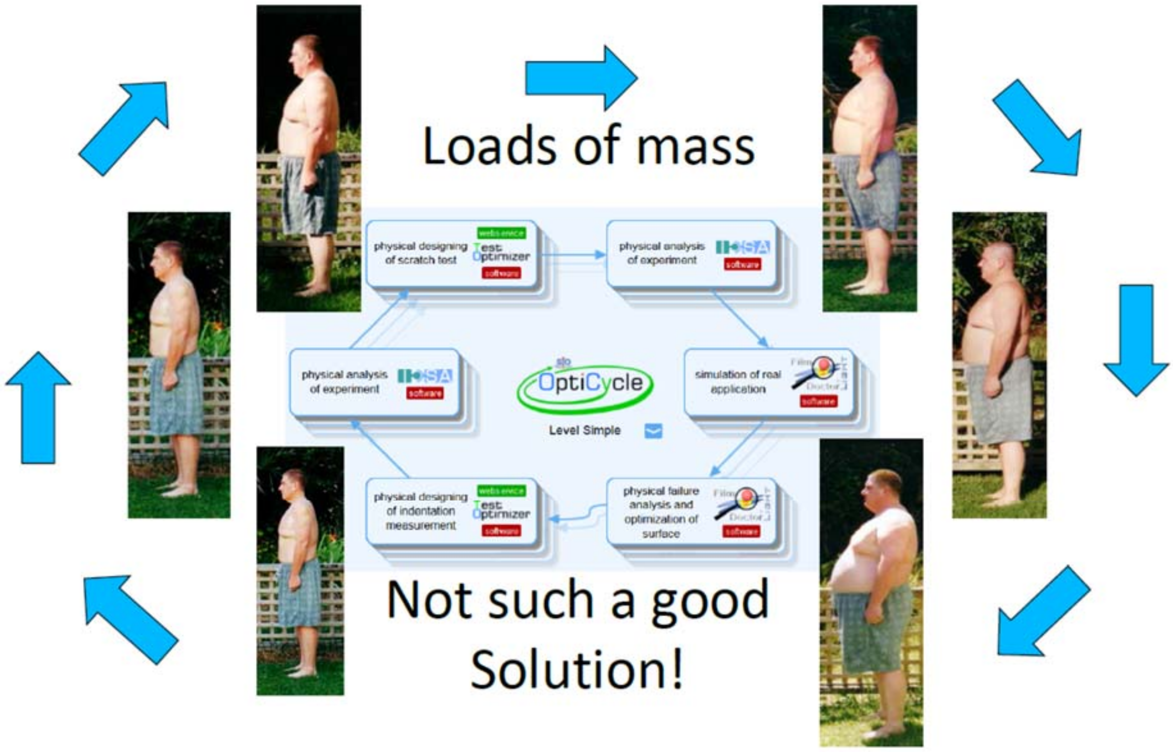

Fig. 44: Illustrative presentation of Higgs-enforced surface optimization with a suboptimal result. Figuratively one might even interpret such bad solutions as such that the "solver" has gained too much mass to leave his chair in order to present his solution.

A Higgs field mechanism coupling to the classical optimization about stability and reliability could provide the necessary control procedure with respect to these haptic aspects. We will not go into detail here, but it suffices to characterize typical, pre-defined human touch situations with technical surfaces, weigh them within a well-balanced field and determine the resulting parameter summing up all negative aspects (as an effective mass). The more mass the worse (see figures 44 and 45 for illustration).
In order to combine high flexibility, variability with maintained stability and reliability it seems intuitive to seek a coating solution for such haptically optimized systems in a combination of a polymer coating with a hard top layer. Probably every experienced coating specialist would now immediately argue that this could lead to a contact situation well known as egg-shell effect potentially producing dangerous so-called star cracks (figure 45).

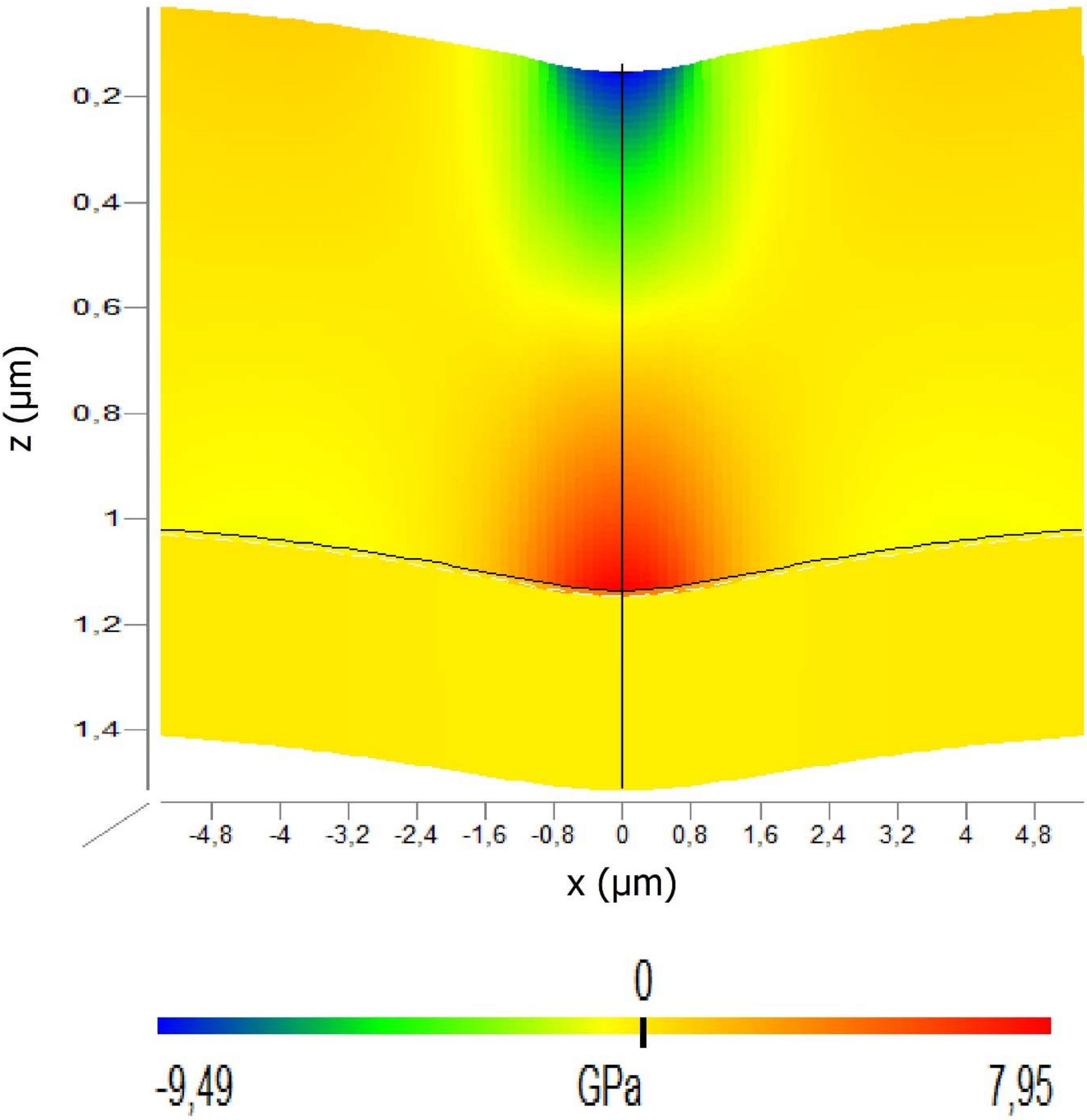

Fig. 45: Radial stress for a typical contact situation known as egg-shell effect. It appears when a stiff top layer has been coated on a softer substrate material.

The similar well-known solution against this effect now is to provide a good gradient at the interface. We construct such a system within our holistic optimization model and immediately encounter another failure mechanism. This time we discover high tensile stresses on the surface. They have nothing to do with the classical Hertzian cone cracks [47] but arise from a completely different source of tensile stress production. Considering the typical structure given in figure 46 closely, we see that the polymer is been enclosed between the relatively stiff foundation (here aluminum) and the now cleverly graded hard top layer. Usually polymer has a high Poisson's ratio which simply means that it behaves incompressible. It is known from geology that in cases of such structure, where the incompressible layer usually is a water-bearing formation while the foundation is made out of rock, the amazed observer will detect an upwards bending of the surface even though only normal loads in downward direction are applied. The reason for this apparently paradox behavior is to be found in the incompressibility of the polymer (or the water-bearing formation in our geological example). Being hindered in downward movement by the stiff foundation and not being able to densify due to its large Poisson's ratio, the polymer deforms elastically sideways and upwards (partially even above the original surface, c.f. figure 46) simultaneously and this way, bends the surface in a concave manner. This finally leads to strongly enforced tensile surface stresses for the hard top layer endangering it to fracture there. The final holistic solution to this complex stability problem is to also drag intrinsic stresses in, consider them as a new degree of freedom and combine it with the current structural solution. The latter, namely ***F**unctionally **S**tressed **C**oatings* is the principle idea of the EU-research project iStress (c.f. *www.stm.uniroma3.it/**iSTRESS***) for which now even a completely automatic software package has been developed solving the task of designing the intrinsic stresses for a given external or internal load problem respectively worsts case contact scenario [49].

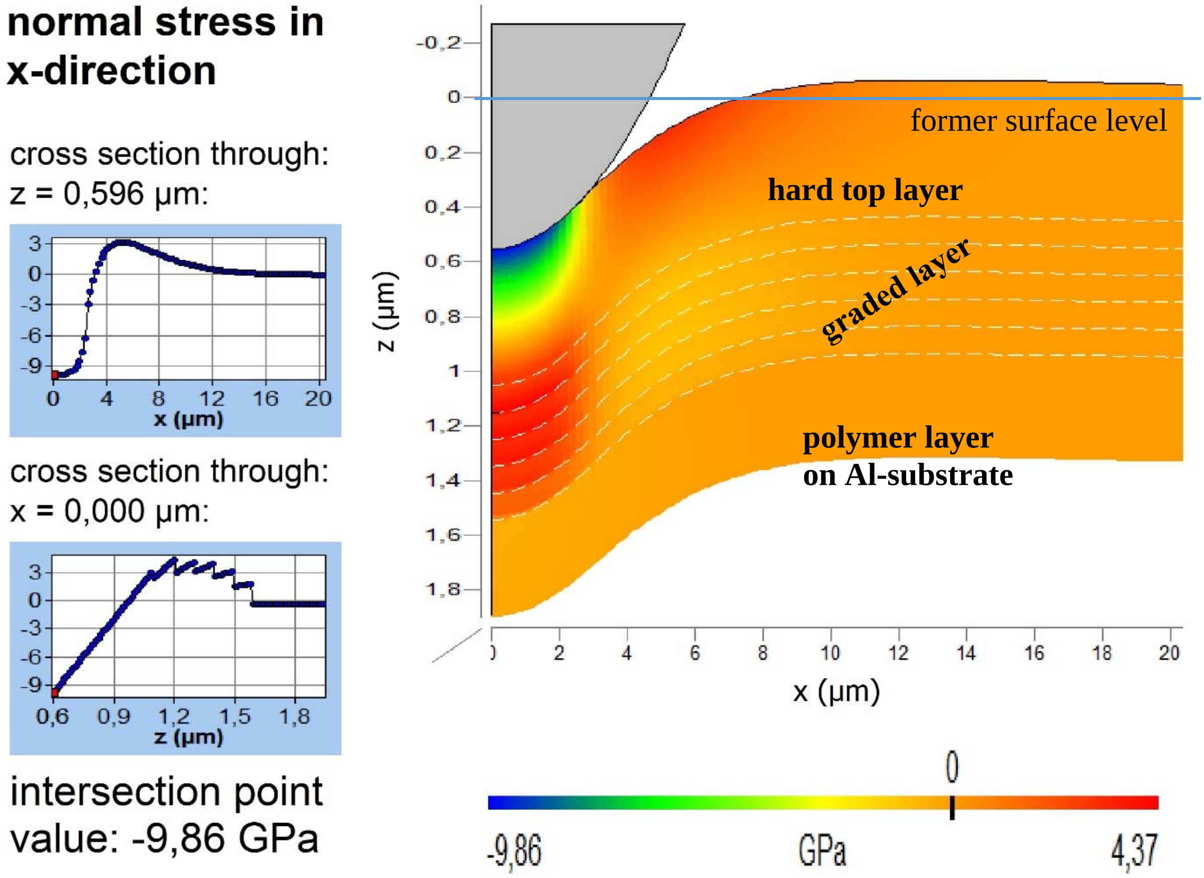

Fig. 46: Radial stress for a contact situation leading to the double egg-shell effect (s. text). Even though the material has been graded at the interface, it is now sensitive to surface fracture due to a surface upwards bending caused by the incompressible intermediate polymer layer supported by a stiffer substrate (see concave bulb exceeding former surface level [blue line]).