Polypropylene is also used in medium-sized and upper-class automobiles for manufacturing e.g. high-quality instrument panels, door trim, and center consoles

Making Sure that Looks Are not Deceiving

Surface Quality. Contrary to classical surface properties such as scratch resistance or glossiness, it is far more difficult to quantify haptic characteristics. Nonetheless, surface properties with names like Soft Touch, Cool Touch or Silky Touch have gained increasing importance in the plastics industry during recent years. For this reason, a new testing method has been developed that is intended to make research and developments in surface quality more efficient.

GEORG GRESTENBERGER ET AL.

Due to their versatility and easy shaping properties, polymers have successively replaced classic materials such as wood and leather for automobile interiors since the middle of the last century. Hereby, the use of plastics not only resulted in lower component weights, but also offered advantages in terms of design freedom, functional integration, and of course, manufacturing costs.

Thanks to their particularly good cost/properties balance, polypropylene (PP) based materials in particular have become firmly established over the years. Initially found mainly in compact cars, PP is meanwhile also used successfully in medium-sized and upper-class cars, e.g. for manufacturing high-quality instrument panels, door trim, and center consoles **(Title picture)**. However, in order to satisfy the highly diversified and permanently increasing demands placed on materials, also polypropylene was subjected to continuous further development. For example, polypropylene block copolymers with ethylene and other alpha-olefins are mainly used nowadays, due to the somewhat limited impact strength of PP homopolymers. Fine-tuning of the materials, i.e. the adaptation of mechanical properties, coloring, and stabilization, is usually carried out in a final compounding step.

But the general use of PP and polymers also has a few disadvantages. For example, due to their low stiffness and surface hardness, plastic parts are susceptible to mechanical surface damage.

Surface Quality in Automobile Interiors

High scratch resistance, low reflection, and a uniform, homogeneous appearance are primary demands for the surfaces of visible plastic components in automobile

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interiors. But these properties can only be regarded as intrinsic material characteristics to a limited extent. Rather, the surface characteristics of a component are the interactive result of material, manufacturing process, and design.

For instance, glossiness and scratch resistance of injection molded interior trim parts are influenced decisively by the structure and/or roughness of the component's surface, which in turn depends on the design of the mold [1, 2]. If the technical manufacturing aspects are not taken into account, glossiness and scratch resistance of PP compounds are determined primarily by material design, type and content of filler, and the specific use of additives. Regarding the latter, low-molecular migrating fatty acid amides such as oleamide, erucamide, and behenamide should be mentioned in particular. Due to the migration of these substances, an anti-friction layer with reduced friction coefficient (external lubricant) is formed on the component surface [3 to 5]. Because of the reduced friction, lower shear forces are induced in the material in case of a sliding contact, thereby increasing the scratch resistance and reducing surface roughening **(Fig. 1)**.

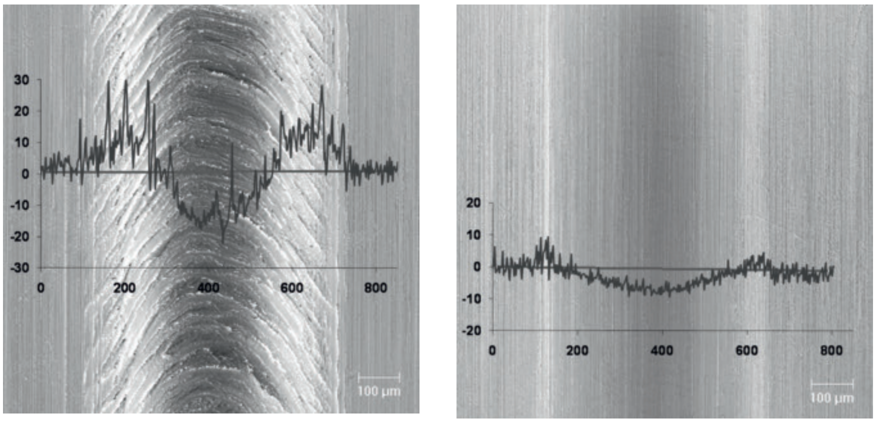

Fig. 1. Confocal laser microscopic image of the surface of PP/talcum compounds: without (left) and with scratch-resistant finish (right, external lubricant)

Unfortunately some of these additives are suspected of increasing surface tack [6]. This aspect has become all the more critical, since greater attention has been given to the haptics of automobile interior surfaces in recent years. Consequently, the development of a polymer with a highly scratch resistant, matte, and non-adhesive surface is a central issue with automakers.

Therefore, a reliable determination of the parameters is essential for targeted and efficient material development by the material producers. In terms of scratch resistance and glossiness, these demands have been adequately fulfilled [6]. But due to the lack of correlations between physical values and human sensory perception, the haptics of a surface can usually be assessed only by means of elaborate or hardly reproducible panel tests.

Most methods for determining surface tackiness make use of haptic reference scales or describe the corresponding sensory perception. One example is the "Sensotact tactile reference frame" (manufacturer: Cemas, Besançon, France). This reference scale consists of a set of ten descriptors, each made up of five reference parts in ascending order of sense of touch intensity. Each descriptor represents a different haptic sense. In this way, Sensotact distinguishes ten surface characteristics, which are determined according to specific finger movements – orthogonal or tangential – across the surface. To determine the tackiness of a surface, the index, middle, and ring fingers are lightly pressed onto the surface at an angle of about 15°. The resistance felt during the subsequent lifting of the fingers is regarded as a measure for tack [7].

Nonetheless, this – and all other comparison-based methods – is always centered around one or more test persons who attempt to determine the haptic quality of a surface, whereby the sensory perception of various references is the standard applied. Consequently, the findings made by two test persons (or groups) depend greatly on the sensibility and experience of the persons involved, and are only comparable to a limited degree. In order to increase the reliability of the findings, a relatively large number of persons would have to be included in the tests. And if gender and age-specific differences in sensory perception are to be taken into account as well, the limits of economical testing in the field of materials development are reached very quickly. Therefore, the introduction of a simple and reliable testing method for the haptic quality of a surface would be highly desirable.

In their first attempt to quantify the tackiness of plastic surfaces, Huber and Solera [8] adapted a film block tester. Normally, this device is used to determine the block strength or lubricity of plastic films. In order to determine the tackiness of artificially aged plates, LDPE films were pressed onto the still-warm plates (30 minutes with 5 kg). After a defined conditioning period, the films were peeled off with the block tester, and the adhesive force recorded. Using this setup, Huber and Solera were able to show that under corresponding UV radiation of the components, the decomposition products of erucamide resulted in higher film adhesion. But the measured forces were not placed in any kind of relation to human perception. Moreover, the film block tester only permitted a differentiation of adhesive forces up to max. 21 N. All samples with higher values were classified as being bad.

Making Haptics Measurable

Due to the inadequacies of the above test procedure, a new method for quantifying tack was developed within the scope of a master's thesis at the Montanuniversität in Leoben, Austria [9]. The primary aim of the thesis was to develop a procedure for tack determination that is based on objective measurement values, provides reproducible results, is flexible in terms of component pre-treatment, and can be implemented with the minimum possible outlay. But above all, the measured values were to reflect human sensory perception as closely as possible. For this reason, the first step – i. e. even before development of the actual method was started – involved the installation of a haptics panel in the Borealis Innovation Headquarter in Linz, Austria. Consisting of about 30 persons of different ages and genders, the panel was then trained in the assessment of tackiness with the help of the Sensotact reference frame.

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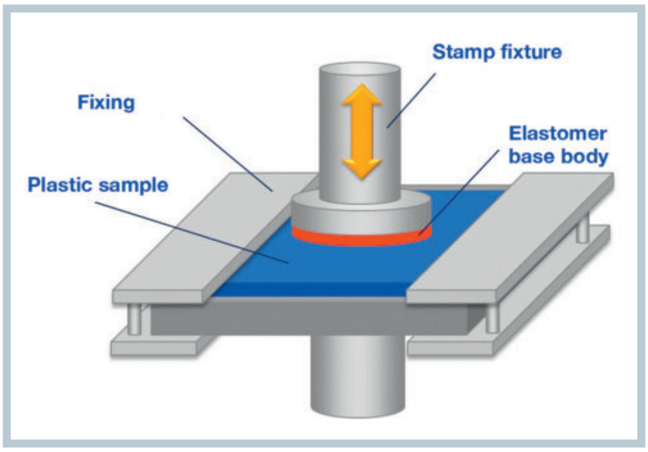

Fig. 2. Schematic diagram of the test setup to determine the tack of polymer surfaces

Using the same principle as for tackiness assessment, a pressure/tension test was also implemented for the subsequent measurement of tack. In the fully instrumented simulation of the tactile procedure, an elastomer stamp is used for the measurement instead of a human finger. By means of a simple measurement setup in a tensile testing machine (type: ElectroPuls E3000, manufacturer: Instron, High Wycombe, UK), a defined force is used to press this elastomer stamp onto the surface to be characterized **(Fig. 2)**. Following a specified holding time, the stamp is pulled away from the surface at a controlled speed, whereby the required maximum force is recorded.

Depending on the scatter of the measured values, this procedure is repeated several times, and a mean value generated from the measured forces. To prevent the stamp transferring the contamination from one sample (e.g. migrated additives and their decomposition products) to another, thus falsifying the measurement values, a new stamp is used for every measurement. In addition the stamp's adhesive force is determined on an anodized aluminum reference plate before the measurement. Subsequently, a quotient is created for the adhesive forces measured on the reference plate and the sample. This prevents variations in quality or dimensions of the stamp materials having a decisive influence on the later result. The non-dimensional value obtained in this way is described as the adhesive factor. It is directly proportional to surface tackiness, and typically lies in the range of 0.2 to 1.5.

During the implementation phase, the haptics of the sample surface were assessed by the haptics panel (statistical evaluation acc. to DIN 10963 [10]), and also with the new measurement method. Hereby, a very good correlation between measured values and human tactile sense could be established. At the same time, this method was used to determine which delta in the tack factor of two samples could be detected reliably by the panel as a difference in surface qualities, i.e. which differences in the measured values correspond to a "tangible" difference in the haptics.

Composition Is Decisive

In the next step of this assessment method, systematic investigations were conducted to determine the influence of the composition of polypropylene compounds on the surface tackiness of components made thereof. Apart from the anti-scratch additives already mentioned above, also the influence of anti-oxidants, UV stabilizers and other additives and fillers, as well as the polymer used was examined. In order to simulate the conditions of an automobile interior, the samples were stored in an oven before the measurement or were aged artificially in a Xenotester (type: WeatherOmeter Ci4000, manufacturer: Atlas Material Testing Technology GmbH, Linsengericht, Germany). In the following, excerpts of the findings obtained for some of the anti-scratch additives will be summarized.

In this study, the most common migrating additives (lubricants) were examined together with several non-migrating additives (silicones). As shown in **Figure 3**, the choice of anti-scratch additive has a decisive influence on the material's tackiness/scratch resistance balance. While Lubricant 1 exhibited very good scratch resistance and low tackiness in the unstored state, these properties are lost to a great extent with increasing storage duration. Lubricant 4 behaves in exactly the opposite manner – the surface properties of the materials treated with Silicone A and Silicone B only changed insignificantly during the observed period.

Similar trends are exhibited under UV radiation. The successive reduction of surface tackiness in the case of Lubricant 2 was associated with a disproportionate reduction of surface glossiness. After 400 hours, the surface was finally considered

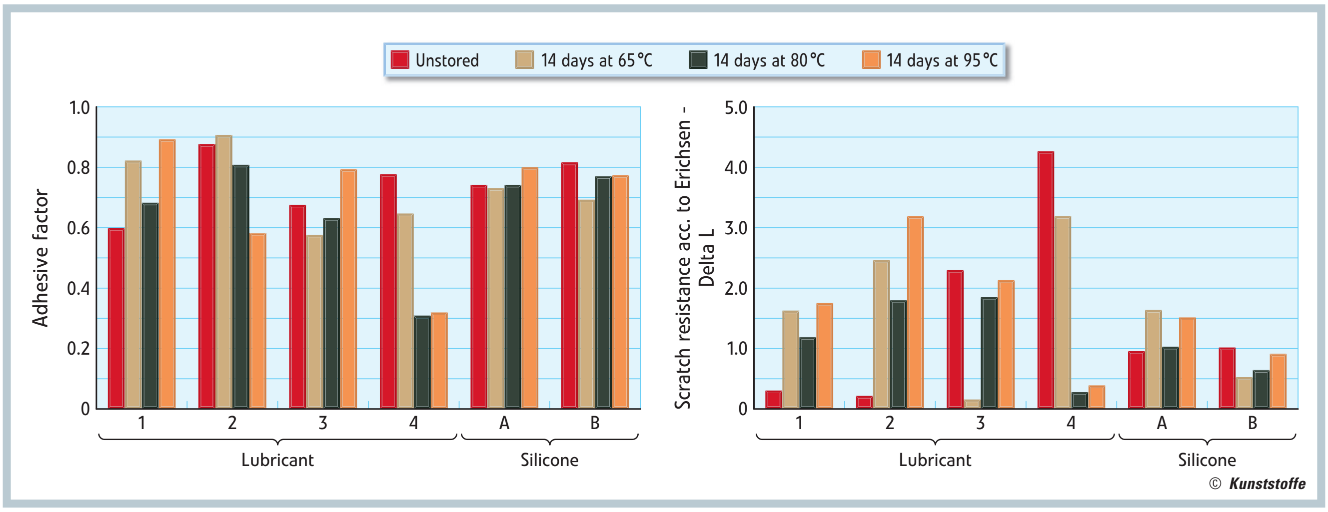

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Fig. 3. Dependence of tackiness (left) and scratch resistance (right) on the oven storage duration for different anti-scratch additives

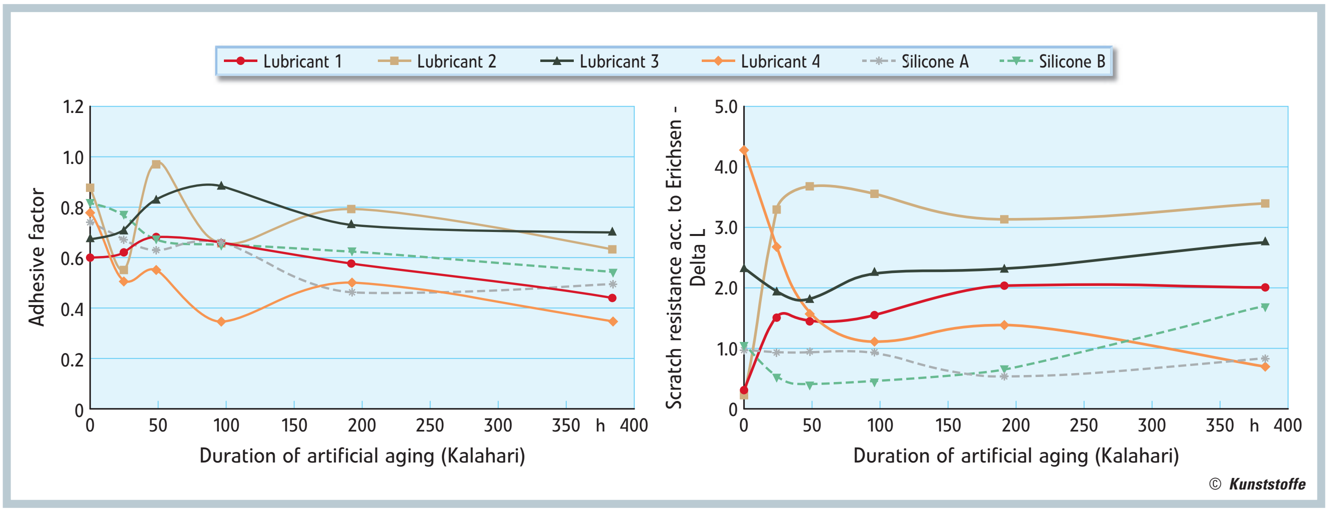

Fig. 4. Dependence of tackiness (left) and scratch resistance (right) on the aging duration for different anti-scratch additives

to be resinified. With all the other samples, only marginal changes of glossiness were determined (**Fig. 4**).

New Material Concepts for Optimum Surface Quality

Based on the findings made during these and further investigations, various material concepts for applications in automobile interiors as well as the associated additive packages were developed. With unchanged good scratch resistance, low glossiness, low emissions, and minimum smell, these materials exhibited a clear reduction of surface tackiness when compared with present benchmark products (**Fig. 5**).

By means of corresponding development work in the area of measurement methods, it is also possible to make very subjective sensory perceptions such as the haptics of a surface measurable. The key to success lies in breaking down complex sensory perceptions to the most important influencing factors. If this simplification is successful, it is possible to make deductions about the complex human sense of touch also if a very simple test setup is used. With the help of supplementary and targeted panel tests, material developments can also be advanced efficiently. ■

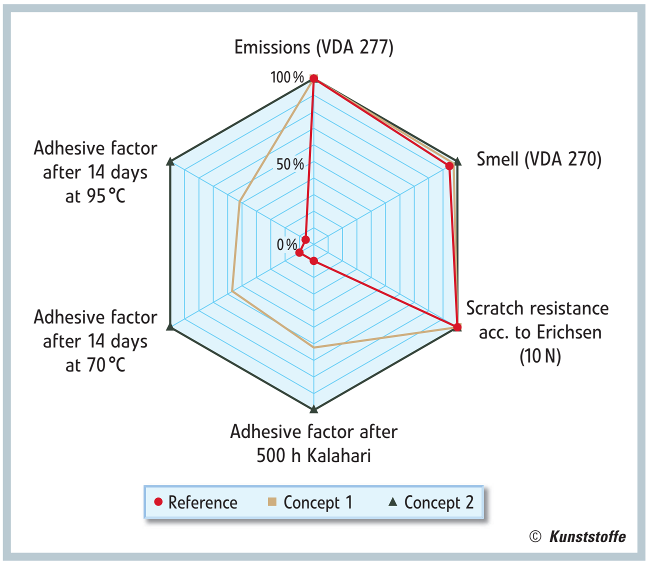

Fig. 5. Comparison between the property profile of a previous benchmark product and the property profiles of two new material concepts

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