Flocking of rubber profiles for the automotive industry

R. Wefringhaus
Henkel KGaA, Düsseldorf

SUMMARY
Over the past few decades, electrostatic flocking of rubber profiles has developed into an important technique which is now extensively used in the automobile industry. Flocked profiles are used on car doors, sunroofs and windows. They have two functions in cars: seals with the bodywork and the facilitation of opening and closing functions with a low degree of force.

This article provides a brief explanation of the theoretical and practical aspects (with examples).

1. INTRODUCTION
Over the past few decades, electrostatic flocking of rubber profiles has developed into an important technique which is now extensively used in the automobile industry.

From the original applicational concept, which was purely to create a decorative surface, this technique has now developed into a method which may be used to produce high-quality articles with excellent industrial properties.

The following provides a brief explanation of the theoretical and practical aspects of the flock coating of rubber profiles for the automobile industry.

2. PROCEDURE

2.1 Flocking methods
Flocking means the coating of surfaces with short textile fibres of 0.5 to 0.9 mm in length using a suitable adhesive.

Electrostatic flocking is primarily employed by profile manufacturers.

A flock pile usually only forms in cases where the flock impinges on wet (“open”) and still unreacted adhesive.

Flocked and unflocked areas may be produced by restricting the application of adhesive.

For rubber profiles, this is achieved either by selective spraying (for example, using templates) or by application with brushes.

In cars, flocked profiles are used for doors, sun roofs and windows. Here, they perform a dual function: sealing with the bodywork and the facilitation of opening and closing functions with a low degree of force. The technical advantages of flocking may be explained using the example of a car side window. The movement of a glass pane over a rubber profile requires the application of a relatively high degree of force. In accordance with the friction law, the friction force measured here is described as the coefficient of friction. In the case of glass/rubber, this is more than 1. Flocking the rubber may reduce the coefficient of friction to 0.25-0.3.

Two procedures are relevant for the production of flocked profiles.

With discontinuous production, the cold vulcanised profile is roughened, preheated if necessary, coated with adhesive and flocked. The adhesive is cured at approximately 160-180 °C for about 1-5 minutes.

There are, in principle, two possible variants of the continuous process.

The difference is whether application of the adhesive and flocking is performed before or after the vulcanisation of the profile. The flocking of the vulcanised profile in a continuous process is the most rational method. After
extrusion, the profile is vulcanised in a UHF channel and hot air channel. The adhesive is then applied to the surface when it has cooled down to approximately 100 °C and roughened. This is followed by flocking and then curing of the adhesive at approximately 180 °C for 1-2 minutes.

The production of high-quality flocking requires numerous factors to be taken into account.

2.2 Elastomer mixture

In the automobile industry, the main material used for profiles is EPDM. SBR or CR and SBR/CR blends are used in a few exceptional cases.

The excellent weather and ozone resistance of EPDM and the cost advantages are the decisive factors in favour of this particular elastomer. The fracture strength and elongation at break after hot air ageing are much higher with EPDM than with the other two elastomers when measured on flocked profiles. It is not only the elastomer which is of crucial importance, but also the formulation. Naturally, the specifications of the automobile industry regarding the mix characteristics should be observed.

The following requirements are also levied on flocking.

The following points are evaluated as the criteria of good flocking:

a) adhesion to profile surface (sealing varnish test, Figure 1)
b) flock adhesion (chisel test, Figure 2)
c) hot air ageing, for example at 90 °C/96 h
d) immersion in water, for example at 70-90 °C/120-96 h

These facts should be taken into account during the development of the mix. This means that the choice of the “correct” plasticiser and internal lubricant and extrusion aid is a crucial factor. If excessive or incorrect additives are used, migration significantly impedes the adhesion of the adhesive to the elastomer.

The same applies to internal lubricants or extrusion aids whose mode of action causes them to migrate to the surface of the rubber where they impair adhesion to both the surface of the rubber and possibly the flock.

A typical example from practice may be demonstrated using the following test results (Table 1).

1) Flocksil 1501 diluted with ethyl acetate in a ratio of 2:1
2) Flocksil 1501 undiluted
3) as 2, but stored 1 day at room temperature
4) as 2, but stored 6 days at room temperature
5) as 3, but conditioned for 5 minutes at 180 °C
6) as 4, but conditioned for 5 minutes at 180 °C

Evidently, the mix used contains components which migrate to the surface under the action of heat in storage where they severely impair the adhesion of the flocking adhesive to the surface of the profile.

We can also see that it is necessary to apply sufficient adhesive to achieve optimum results.

The following rule of thumb applies: in cured condition, the amount of adhesive applied should amount to approximately 7-10% of the flock length.

2.3 Flock material

Different types of flock material are used according to the specified application.

The most familiar and most used types are polyamide and polyester cut flock – the colour is generally black.
However, recently coloured flock has also been used on occasions.

Another important feature in addition to the length of the flock is the dtex number (g/1000 m). In addition, the flock must be straight, i.e., not curved.

For electrostatic flocking, the preparation of the flock is of decisive importance. This determines the conductivity and free-flowing properties.

Known flock preparations are all hygroscopic and hence the conductivity and free-flowing properties are heavily dependent upon the relative atmospheric humidity in the environment. A relative atmospheric humidity in the 60-70% range and a temperature of 15-25°C should be maintained.

Moisture absorption is very different in the two types of flock named above.

Polyester absorbs about < 1% compared to 6% in the case of polyamide. The influence of water absorption on the coefficient of friction with glass has not yet been explained.

The preparation of the flock also plays a role in this.

2.4 Flocking adhesive

The choice of adhesive is essentially determined by the method of application and the requirements for the flocked profile.

The adhesive to use must have the following properties:

- problem-free application
- defined viscosity limits
- low surface tension
- good wettability
- sufficient “open assembly time”
- electrical conductivity
- agreed pseudoelasticity
- adequate curing rate

- pot life suitable for processing

Usually, the adhesive is applied by spraying or with a brush.

To avoid problems with application, the viscosity of the flocking adhesive should be within a relatively narrow range. At the same time, the adhesive must not run off curved or inclined surfaces, which are commonly found in profiles.

The most important criterion for optimum flocking is the penetration of the flock into the adhesive. The higher the surface tension, the more difficult it is for the flock to penetrate the adhesive. The flocking adhesive must have a good wetting power in relation to both the substrate (rubber) and the flock.

In practice, a contact angle of < 60° is sufficient for wetting both the rubber and the flock. Relatively small contact angles are preferable.

On the one hand, this provides optimum contact with the substrate and on the other, the flock is encapsulated as in a sleeve. A contact angle of > 90° provides insufficient adhesion of (at least) the flock, as the flock “takes the adhesive with it” in the direction of penetration and hence a smaller adherend surface forms (Figure 3).

The so-called “open assembly time”, which is essentially determined by the evaporation rate of the solvent used and the ambient and surface temperature of the profile, is extremely important for the penetration of the flock in the adhesive.

To meet practical requirements, the time should be between 10 and 30 seconds.

The adhesive’s wetting power depends upon the polymers and solvents used. In addition, suitable solvents cause the surface of the rubber to swell which can significantly improve adhesion.

The factors “preparation of the flock” and “conductivity of the adhesive” and the tension generated in the electric field are essentially responsible for the flock density attained.

Only when the flock comes into contact with a sufficiently

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Sealing varnish test (N/mm)</th>
<th>Chisel test (cycles)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.7</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&gt; 5</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2.3</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2.0</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.3</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.0</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Specification</td>
<td>2</td>
<td>250</td>
<td></td>
</tr>
</tbody>
</table>
thick layer of adhesive can an optimum result be obtained. The flock is then able to penetrate sufficiently, but it must not drop or sink. At the same time, it must be fixed so that it is not lifted up again by the tension of the electrical field.

The structural viscosity of the polymers used must be matched to this.

Frequently, the factor deciding whether a flocking adhesive is suitable for the flocking plant in question is also determined by the curing time. This should in turn be seen as the sum total of the factors “temperature”, “time in the drying tunnel” and “adhesive curing rate”.

The type of heating is also very important.

The profile may be heated using hot air or IR radiators; these require different throughput rates (or tunnel lengths).

3. FLOCKING PLANT

The state-of-the-art technology is IR-heated tunnels which achieve a substrate temperature of approximately 180°C with a length of 16-20 m and take-off speeds of > 10 m/min. The combination of IR and hot air is also common. In this case, a hot-air tunnel with a length of 8-12 m is connected downstream to an 12-8 m IR tunnel.

To improve the adhesion of the flocking adhesive, the EPDM profile has to be roughened, with it also being possible to use a primer. In addition to eliminating the mix components which have migrated to the surface, this also effects mechanical anchorage. The application of the adhesive is followed by electrostatic flocking.

In principle, a differentiation should be made between the high voltage source, the flock storage bin and the workroom. The controllable high voltage source generates the voltage of between 30 kV and 100 kV required for the electrical field.

However, the current is only within the microampere range. The charged flock moves in the direction of the flocking adhesive at a rate of 100-200 cm/s where it is anchored and discharged.

Passage through the drying tunnel is followed by another cleaning in air and then any adherent non-bonded flock is brushed off before cutting-up.

Numerical results (such as sealing varnish values or abrasion resistance) are not the only way to determine flocking quality.

However, properties such as flocking density, flocking direction and “flock flexibility” are subject to a more individual evaluation.

If the flock lies in a fairly uniform vertical direction, the flock density is optimum and there is a balanced ratio of flock length to adhesive layer, the flocking will be subjectively assessed as “good” (Figure 4).

In the opposite case, a non-uniform alignment and insufficient flock density will result in a negative individual evaluation (Figure 5).

The following table lists a few of the possible causes of faulty flocking to assist users with their quality assurance (Table 2).

Due to the sum total of good properties (in particular the low coefficient of friction should be recalled here), the flocking meets the main requirements levied by the automobile industry on the rubber profiles used.

- long life of flocked profiles
- excellent ageing resistances (temperature/ozone)
- very low susceptibility to abrasion
- good sealing properties
- balancing of different tolerances (body/profile)
- low coefficient of friction (0.25-0.3)
<table>
<thead>
<tr>
<th>Effect</th>
<th>Flock adhesive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor flock density</td>
<td>Poor flock quality</td>
</tr>
<tr>
<td></td>
<td>Adhesive layer too thin</td>
</tr>
<tr>
<td></td>
<td>Poor flock conductivity</td>
</tr>
<tr>
<td></td>
<td>Excessive humidity in the flocking plant</td>
</tr>
<tr>
<td></td>
<td>Tension too high</td>
</tr>
<tr>
<td></td>
<td>Poor adhesive</td>
</tr>
<tr>
<td>Non-uniform flock density</td>
<td>Non-uniform adhesive application</td>
</tr>
<tr>
<td></td>
<td>Inadequate adhesive distribution</td>
</tr>
<tr>
<td></td>
<td>Excessive tension</td>
</tr>
<tr>
<td>Hard handle</td>
<td>Too much adhesive</td>
</tr>
<tr>
<td>Low flock adhesion</td>
<td>Adhesive layer too thin</td>
</tr>
<tr>
<td></td>
<td>Internal viscosity too low</td>
</tr>
<tr>
<td></td>
<td>Poor flock wetting</td>
</tr>
<tr>
<td></td>
<td>Tension too low</td>
</tr>
<tr>
<td>Low abrasion resistance (sealing varnish test)</td>
<td>Adhesive layer too thin</td>
</tr>
<tr>
<td></td>
<td>Poor flock wetting</td>
</tr>
<tr>
<td></td>
<td>Low flock density</td>
</tr>
<tr>
<td></td>
<td>Insufficient “open assembly time”</td>
</tr>
<tr>
<td>Low peel strength (chisel test)</td>
<td>Poor preliminary treatment of rubber surface</td>
</tr>
<tr>
<td></td>
<td>Adhesive layer too thin or non-uniform</td>
</tr>
<tr>
<td></td>
<td>Poor wetting of the rubber surface</td>
</tr>
</tbody>
</table>
• good slip properties of rubber lips against glass and varnished surface
• high elasticity
• possibility of “profile refinement” by means of coloured flocking

Nevertheless, it does not make sense to use flocked profiles in certain fields.

Examples include profiles for car boots or doors.

Flocking can also cause problems with frameless side windows. As in this case, the glass pane is on the outside of the profile, at fast driving speeds, the side wind may lift the pane slightly hence allowing water to penetrate the vehicle. This situation is aggravated by the increased “wind noises” cause by the formation of “air channels”.

Another negative point is the possibility that accumulations of water in the flocking could cause the side windows to freeze up at minus temperatures.

The solution to these sensitive points is to use varnished profiles.

REFERENCES

U. Maag: Electrostatic flock. Flock 12 (40/1985) 6
U. Zoll: Influence of pigment content and polarity on the adhesion of flocking adhesives to substrates and flocking Flock 14 (46/1987) 7

E. Schenk: Electrostatic flocking. Company Information
H.-G. Seltmann: Flocking rubber for the automobile industry. Flock 14 (49/1988)
H. Straakolder: Achievement in the weather-strip market Germany. International Workshop, Menaggio, 1995

(No date given)