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Studies on squeak of vehicles' sealing strip

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ABSTRACT

Squeak and rattle (S&R) has become serious issues, because of their influence on the initial quality experience of consumers. The complaints of S&R have gone beyond the usual NVH issue.

In this paper analysis the principle of sealing strip force and the compression amount of the door and the door sash exceeds the maximum static friction force, that is the prerequisite for the squeak of sealing strip. Controlling the relative displacement between door and door sash can effectively reduce the squeak risk of the seal strip.

The investigation of new and used cars with squeak, and the stick-slip test of sealing strip are carried out. The influence of dust on sealing strip will not only affect the loudness of squeak noise, but also change to the frequency spectrum of squeak sound.

Keywords: Squeak, Sealing strip, Dust
I-INCE Classification of Subject Number: 70

1. INTRODUCTION

Sealing strip is an important part of the car body, usually applied for the gap between the door and the door sash, play a role in windproof, rainproof and dust-proof, but also play a role in the door opening and closing process of the buffer, can effectively reduce the interior noise. With the gradual popularization of electric vehicles, the interior background noise reduced. The frictional noise of the sealing strip previously was masked by the noise of powertrain is increasingly prominent. With the increasing of vehicle mileage, relevant after-sales service problems are getting more prominent. The

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door seal strip frictional noise refers to the relative displacement between the door and the door sash when the vehicle is driving on a bumpy road or twisted road surface such as in an underground parking lot, which causes the ‘squeaking’ sound generated by the friction between the door and the door sash seal strip and the corresponding sheet metal paint. Currently, there are few systematic solutions to solve the squeak problem. The main solution is spraying PTFE coating on the interface of sealing strip. The after sale service issues are all solved by applying grease.

At present, the work on the friction noise of sealing strip mainly focuses on the coating of sealing strip. Trapp et al. studied the influence of various coatings on the friction squeak of sealing strip [1]. White et al. introduced the influence of coating material, coating thickness and coating spraying quality on the friction noise of sealing strip [2].

Sealing strip squeak is caused by two components or surface in form of stick-slip rubbing against each other, which is widely recognized in engineering field at present. The stick-slip phenomenon is closely related to the friction coefficient of static and kinetic. However, Kuo et al. believed that this was also related to the local stiffness of the vehicle door sash [3], but it did not give the specific cause. Therefore, the paper studied the specific correlation between the relative displacement of the door sash, the stick-slip characteristics of the sealing strip and sealing strip squeak through experiments. In addition, the paper analysed the squeak change of the sealing strip through experiments on the full vehicle(both new car with 0km and high-mileage customers) and the single sealing strip, which laying a foundation for reducing the squeak of the sealing strip in its whole life cycle.

2. PRINCIPLE ANALYSIS OF SQUEAK PRODUCED BY SEALING STRIP FRICTION

Under the conditions of ride on body twist road, cobblestones road or some working condition such as braking and starting, relative displacement Δ is generated between the door and the door sash. This relative displacement causes the top of the seal strip to deform δ relative to the base, generating a deformation force $F(\delta)$. When the relative displacement δ reaches a certain value, the deformation force $F(\delta)$ is greater than the maximum static frictional force F_R, the top of the sealing strip and the sealing surface will slide relative to each other, resulting in the risk of friction squeak. Its mechanical model can be expressed by the following formulas:

X-direction deformation force $F(\delta_x)$:

$$\mathrm{F}(\delta_{\mathrm{x}}) = \delta_{\mathrm{x}} \times k_x$$

Maximum static friction force F_R

$$F_R = F \times \mu_{max} = \delta_y \times k_y \times \mu_{max}$$

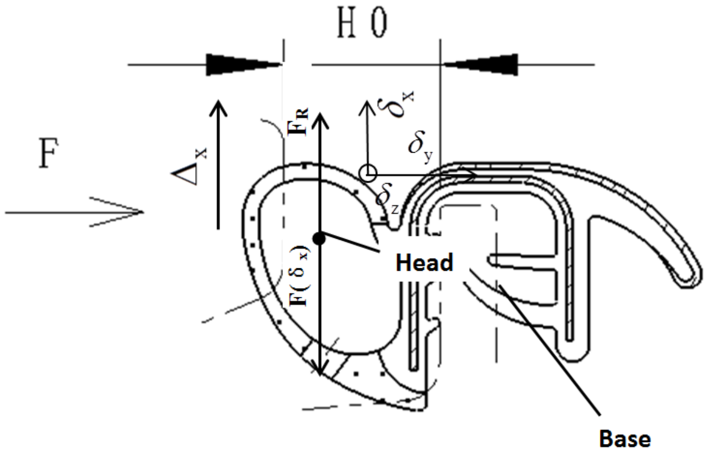


Figure 1 Force direction

δ_x is deformation of sealing strip at X-direction, k_x is stiffness of sealing strip at X-direction.

F is the compression load of the sealing strip, δ_y is the compression amount of the sealing strip, k_y is the Y-direction stiffness of seal strip, μ_{max} is the maximum coefficient of static friction. The necessary conditions for squeak generating is $F(\delta_x) > F_R$.

$$\delta_x \times k_x > \delta_y \times k_y \times \mu_{max}$$

$$\delta_x > \frac{\delta_y \times k_y \times \mu_{max}}{k_x}$$

Same thing in the Z-direction,

$$\delta_z > \frac{\delta_y \times k_y \times \mu_{max}}{k_z}$$

For a sealing stip, μ_{max} is fixed value, k_x ,k_y ,k_z, δ_y are related to the vehicle seal clearance. Therefore, under the fixed seal clearance, both $\frac{\delta_y \times k_y \times \mu_{max}}{k_x}$ and $\frac{\delta_y \times k_y \times \mu_{max}}{k_z}$ are constant values, and we call them the minimum abnormal sound displacement of seal strip Δ_{min}(*X*-direction,Z-direction).

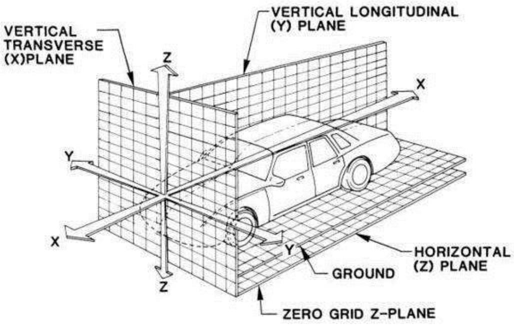


Figure 2 Full-vehicle coordinate system

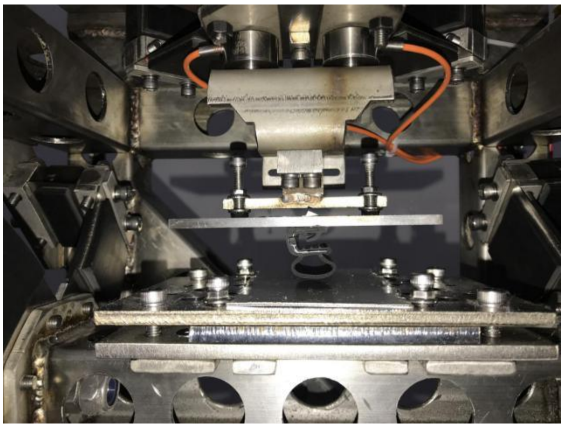


Figure 3 COF test bench

On the COF(Coefficient of Friction) test bench, we can test out the minimum squeak displacement Δ_{min} of the sealing strip. The Figure 4 below shows the curve of Friction coefficient vs Displacement.

The distance of abscissa between two points(point 1 and point2) on the curve is twice of the minimum squeak displacement Δ_{min}. The displacement corresponding to the inclined line segment is the displacement of the first deformation recovery plus the displacement of the second deformation.

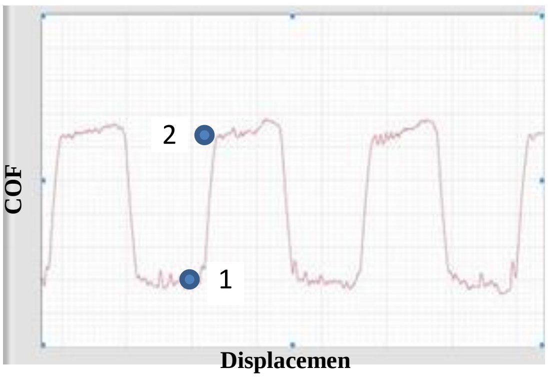


Figure 4 Friction coefficient vs Displacement

The test results of the minimum squeak displacement of the door sash sealing strip of a SUV under different compression loads are shown in the Figure 5.

The minimum squeak displacement in X-direction increases with the increase of compression load, K_x of fomula $\frac{\delta_y \times k_y \times \mu_{\max}}{k_x}$ is significantly increased by δ_y. The minimum squeak displacement in Z-direction reduce with the increase of compression load, K_x of fomula $\frac{\delta_y \times k_y \times \mu_{\max}}{k_z}$ does not change significantly as δ_y increases.

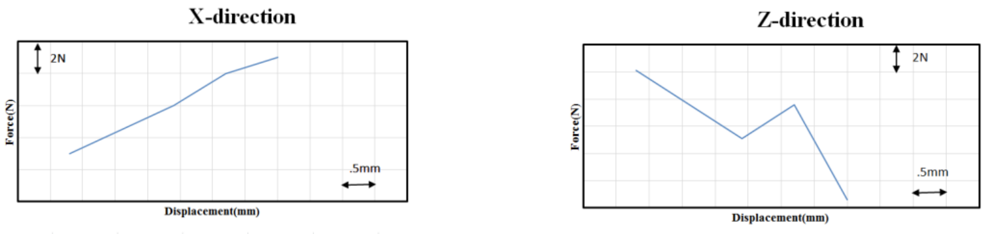


Figure 5 Displacement vs Force

As shown in the figure below, the relative displacement between the door and the door sash of the SUV (corresponding to the X-direction and Z-direction of the sealing strip) was tested by using the road spectrum excitation (cobblestones road and twist) excitation on a 4-poster(MTS 320 serious). The test result of relative displacement at point A/B/C/D shown in Tabel 1.

Figure 6 Setup of displacement meter on 4-poster

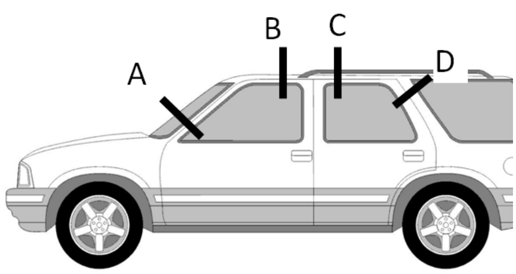


Figure 7 Test point of vehicle

Tabel 1 Displacement result of full vehicle

Road spectrum	Direction	Displacement(mm)			
		Point A	Point B	Point C	Point D

Body twist road	X	0.05	0.05	0.04	0.23
	Z	0.41	0.41	0.53	0.48
Cobblestones road	X	0.16	0.21	0.12	0.16
	Z	0.17	0.23	0.28	0.27

In the case of cobblestones road, the relative displacements in the X and Z directions didn't exceed the minimum squeak displacement (standard seal clearance) of the sealing strip. The top of the sealing strip and the sealing surface will not slide with each other, that is, the sealing strip will not generate squeak. It is consistent with the evaluation result of real vehicle.

In the case of twist road, when the relative displacement of door and door sash in the Z-direction which marked in picture above exceed the minimum squeak displacement of the sealing strip (standard sealing clearance), the top of the sealing strip and the sealing surface will slide with each other, that is, the squeak of the sealing strip will occur. It is consistent with the evaluation result of real vehicle.

3. SQUEAK OF SEALING STRIP

The relative displacement between sealing strip and sealing surface would cause loud noise or not is related to the characteristics of the sealing strip itself.The studies on the new sealing strip have been relatively mature at present. However, in engineering practice, it shows that in the later period of vehicle use, the complaints of the sealing strip squeak have a growing strongly.

By chosen the same vehicle (SUV) new (0 km) and high range vehicle (50000 ~ 100000 km) which borrowed from real comsumer, the subjective evaluation of full vehicle’s squeak has been taken on 4-poster under the normal temperature. The results showed that most of the sealing strip squeak of vehicle increased by its mileage, however there was an exceptional case, the sealing strip squeak of less mileage one among vehicles with high mileage is higher than others. After disassembling and comparing, it found that there was more dust on this sealing strip than others. Therefore, taking sealing strips from all three vehicles, cutting off sealing strips at length of 100mm as specimens, to test out coefficient of friction and frictional noise on COF test bench.

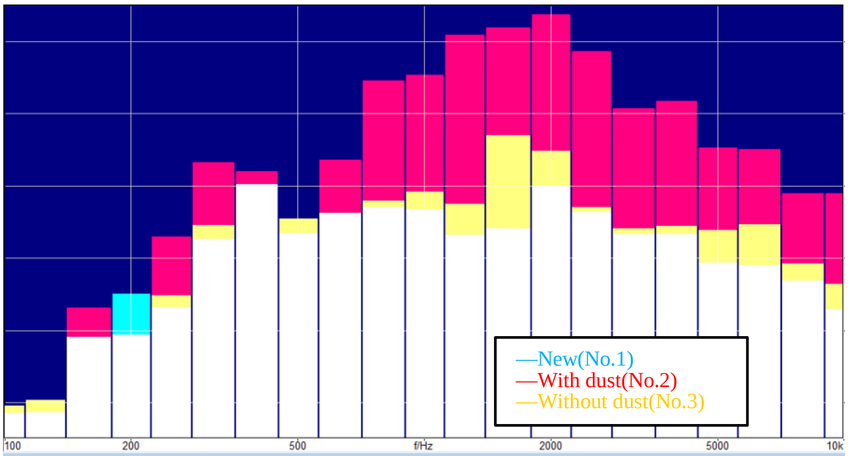
Tabel 2 Subjective evaluation of full vehicle

		Car No.		
		1	2	3
Milage(km)		0	101900	53000
Subjective evaluation	Irritating			X
	Medium			
	Light	X	X	
	Not noticeable			

The test results show that , on the one hand , the trend of noise of single seal strip tested is consistent with that of vehicle evaluation , on the other hand，the dust-free sealing strip with high mileage has a smaller increase in squeak than the new sealing strip . From 2.16sone to 2.25 sone , the noise is mainly concentrated on the 1/3 octave range of 1250~2000Hz . The loudness of the dusty sealing strip(6.85 sone) is much higher than that of the non-dusty one and the new piece(2.25 sone). In the 1/3 octave range of 630~10000Hz , the noise increases greatly , which is about 15dBA higher on average . The kinetic and static friction coefficient of dusty sealing strips are changing by dust . Besides, the Δ_C (the difference between kinetic and static friction coefficient) increased greatly, resulting in the aggravation of stick-slip.

Tabel 3 Loudness of sealing strip

	Sealing strip from Car No.		
	1	2	3
Milage(km)	0	101900	53000
90% Loudness(sone)	2.16	2.25	6.85



4. CONCLUSIONS

This paper analysis the principle of sealing strip force at vehicles' movement. The compression amount of the door and the door sash exceeds the maximum static friction force, that is the prerequisite for the squeak of sealing strip. In the development of vehicles, the maximum stick-slip displacement of the seal strip can be measured in advance using the material friction test bench (known as the squeak limit). Controlling the relative displacement between door and door sash within this squeak limit by design can effectively reduce the squeak risk of the seal strip in the later period.

Through the test of full vehicles, both the new vehicle(0 km) and vehicles with high mileage, and sealing strip monomer, most of sealing strip squeak of vehicle increased by its mileage.

The wear of seal strip caused by the use of vehicle will increase in the frequency range of 1250~2000hz. However, the dust attached to the seal strip will significantly change the kinetic and static friction coefficient of the seal strip, resulting in an overall increase in the 630~10000Hz broadband band.

Due to the lack of equipment such as microscope, the research on the wear surface characteristics of seal strip and the specific principle of dust on high-mileage vehicles has not been carried out.

5.ACKNOWLEDGEMENTS

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