

Silence can be Golden **沉默是金**

(Eliminating Noise, Vibration, & Harshness)

消除噪声，震动和刺耳的声音

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Right now, all the major brake manufacturers seem to be fixated on the word QUIET.

目前，所有主要的刹车系统制造商看起来将目光都转移到“安静”这个词上

The "J.D. Powers factor" is another driving force in the ongoing development of new brake pads and application-specific friction materials. Every vehicle manufacturer wants their cars and trucks to be ranked at the top of the latest J.D. Powers' survey. A high ranking means more sales. To achieve higher customer satisfaction ratings, the OEMs are leaning on their suppliers to do everything they can to minimize noise, vibration and harshness (NVH) — which includes tweaking and fine-tuning the brakes.

“J.D.Powers指数是新型刹车片及摩擦专用材料持续发展的又一驱动力，每个交通工具制造商都希望他们的轿车及卡车能在最新的”J.D.Powers”调查中能名列前茅。一个靠前的排名意味着更多的销量。为了取得更高的客户满意率，原始设备制造商正在依赖于他们的供应商尽一切的可能去降低噪声，震动及刹车时的刺耳声音，其中包括调节及微调制动器



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Physics of Braking Factoids

刹车的物理因素分析

Customer Requirements

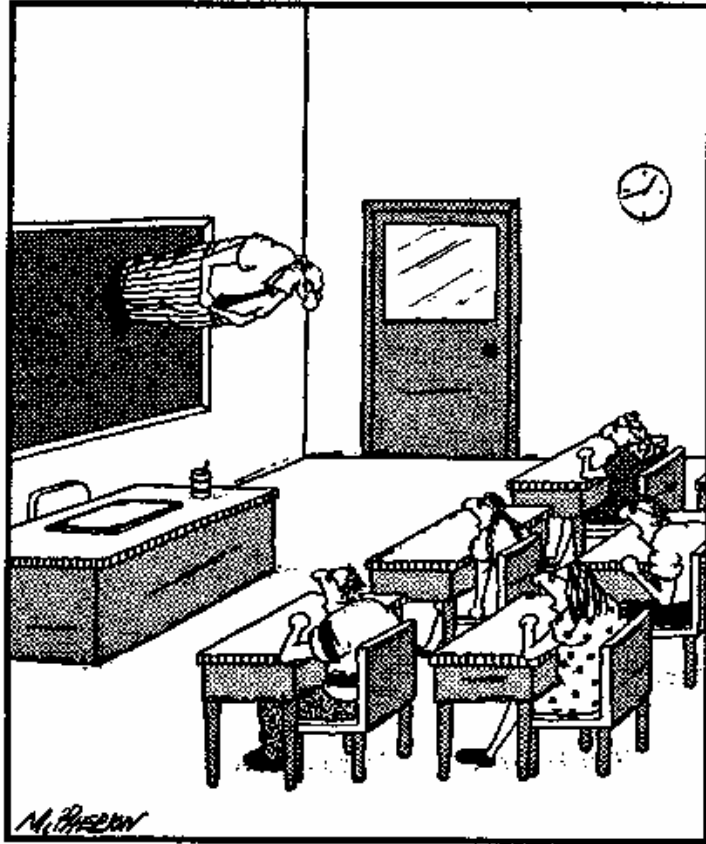
客户的需求

Tools for Eliminating NVH

消除NVH的方法



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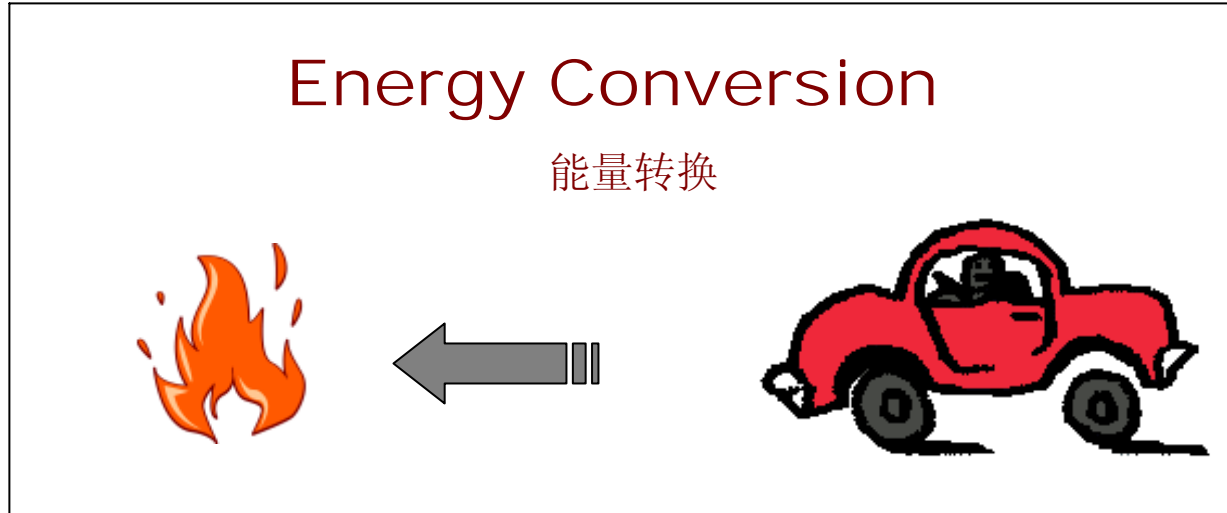
Physics of Braking

刹车的物理 原理

“Good Morning and welcome to
the wonders of Physics”

早上好，欢迎来到奇幻的物理世界

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**The brake system converts the kinetic energy
of the moving vehicle into heat.**

刹车系统将运动着的交通工具所具有的动能转换为
热能

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Vehicle Kinetic Energy

交通工具的动能

$$KE = \frac{1}{2} MV^2$$

动能=质量×
(速度)²

Model	Weight	Top Speed	Kinetic Energy
	(Kg)	(Km/hr)	(KJoules)
Model TT型车	550	65	90
Typical mid-sized典型的中型车	1,600	140	1,210
Mercedes 600 S-class奔驰600S	1,850	250	4,461
Ferrari 550法拉利550	1,850	320	7,309
747 Aircraft (loaded)满载的 波音747客机	495,000	300	1,718,750

Stopping a 1600 kg car traveling at 100 km/hr at .8 G's it takes 3.5 seconds The average power is 174 kilowatts (233 HP)欲停止一个重1600公斤拥有8个油缸以100公里时速运行的汽车，需3.5秒。

平均功率是174千瓦（233马力）

An interesting observation is that a typical, 1600 kg car has an engine with about 90-105 KW (120-140 HP). This means that the brakes have to deal with about twice the power of what the engine puts out.一个有趣的调查表明：一个典型的，1600公斤的车，它的引擎一般在90-105千瓦（120-140马力）左右。这就意味着刹车系统要随是引擎所发生的近2倍的拉力。

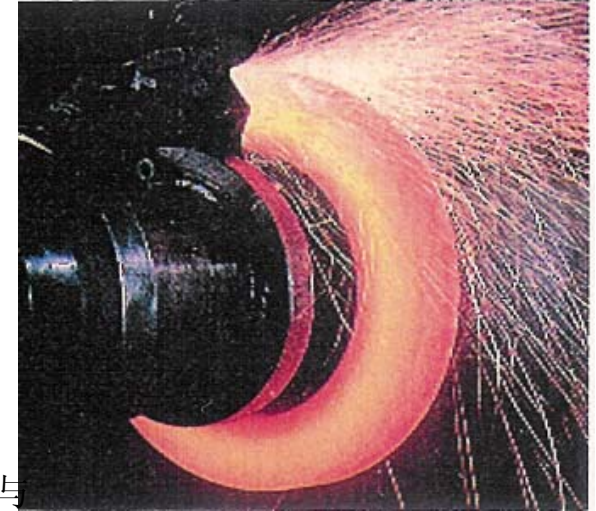


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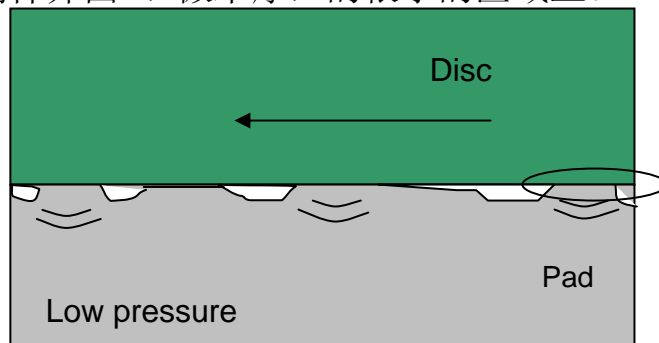
What happens to the Kinetic Energy and at the rotor-pad interface????动能和对偶件与刹车片的接触面有什么变化?

Stopping a mid-sized vehicle traveling at 100 km/h can lead to average power dissipation at each front pad of more than 82 kilowatts

如果一个中型车辆在以100km/h的速度行驶时刹车，每个前轮的刹车片会获得超过82千瓦的能量



This energy is initially concentrated in a small zone at the pad/rotor interface (1 micron thickness).这个82kw的能量最初集中作用在刹车片与对偶件介面（1微米厚）的很小的区域上。



This leads to an energy density of ~ 1 Gigawatt/m³

Equivalent to that of a small Nuclear Reactor

这种情况引发的能量的密度为1千兆瓦特/m³，相当于一个小型的核反应堆。

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Most of the mechanical energy converts to heat...Only a small portion is converted to sound大部分机械能转换成了热能只有一小部分（机械能）转化成了声能

The logarithmic decibel scale is used to measure sound对数的比例尺用来衡量声音。

A young person with normal hearing can hear sounds levels from 0 to 130 decibels

一个听力正常的年青人能听到的声音范围为0~130分贝

The sound level for conversational speech is about 45 decibels.

交谈式说话声音大约为45分贝

The sound level in close vicinity of a starting jet airplane is around 145 decibels

在发动的飞机附近的声能大约为145分贝

An audible brake squeal has radiated power on the order of

90 decibels ~12 milliwatts (for a 175 kilowatt stop).....一个可听见的刹

车的刺耳的尖叫声散发的功率相当于90分贝（对于制动一台具有175千瓦动能的汽车来说）

Less than (1/1,000,000) of the stopping power results in noise generation产生噪声的能量还不到制动汽车所需能量的百万分之一。



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The brake engineer has Three challenges:

刹车系统工程师面临的3大挑战

- 1. Create enough deceleration to stop the car as quickly as the driver wishes, without exceeding the drivers comfort level with regard to pedal effort or pedal travel.**
1、在不牺牲驾驶员在对于刹车踏板的感觉和对于刹车踏板行程的舒适度的前提下，制造出驾驶员所希望的能够尽快制动的减速装置。
- 2. Manage the resulting heat energy so as not to damage the brake system or the rest of the vehicle.**
2、控制由此产生的热能，以不至于损害刹车系统及交通工具的其它部位。
- 3. Eliminate NVH.... Silence is Golden**
3、消除NVH，沉默是金。



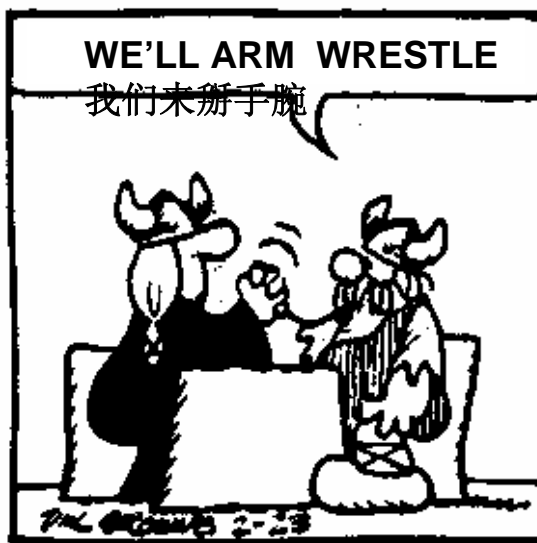
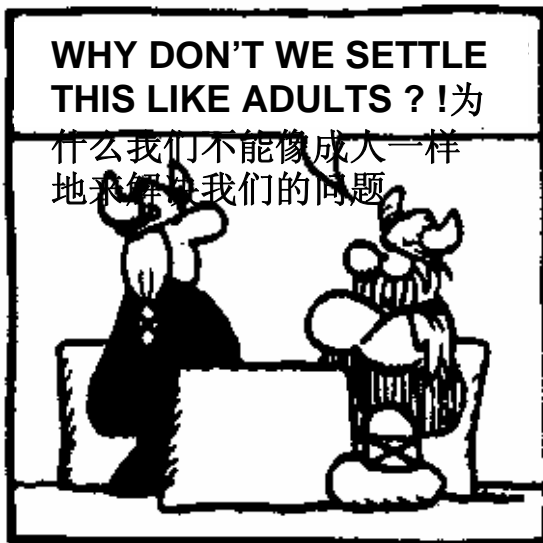
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What do the customers want?

顾客希望什么？

A MEETING WITH MARKETING 与市场先生的会面

DON THE HORRIBLE



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Customers:Users, Brake systems suppliers, & OEM's have needs that determine market acceptance
客户（使用者），刹车系统供应商，原始设备制造商有着各自的需求。
这些需求决定看摩擦材料在市场的受欢迎度。



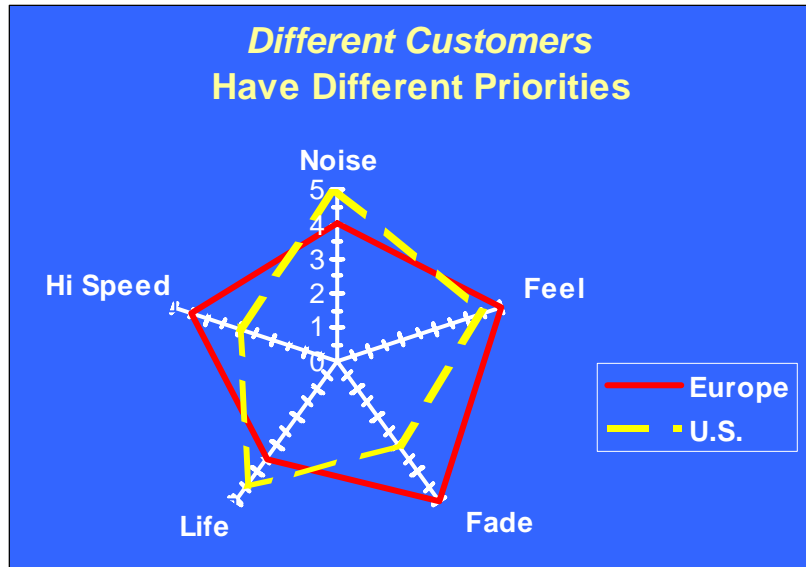
In the first half of the 1990s, an advancement in one area was usually achieved at the expense of performance in another area. Today's customers require performance in all areas. 二十世纪的最初五年，在某一方面的改良通常是以另一方面的性能受损为代价来实现的。今天的客户需要全方位的良好性能。



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Performance Requirements Differ by Region

不同的区域的客户对性能的要求也各不相同



A recent J.D. Powers survey in Germany revealed that many European car owners are not that happy with their brakes and would prefer quieter, cleaner, longer lasting brake linings.最近“J、D Powers”在德国的调查中揭示：许多欧洲车的主人对于他们的刹车不是很满意，并且喜欢更安静，更清洁，更耐用的刹车器内衬。

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Brake Linings Contribute Significantly in all Areas

刹车内衬在很多方面具有重要性

This provides both Opportunity and “Headaches”

这为我们提供了机遇与挑战

Brake linings are probably the least understood part of the braking system
刹车的内衬可能是我们对刹车系统了解的最少的部分

Fade, high speed performance, and wear requires control of the friction coefficient. These are controlled exclusively by the friction material supplier
快速的反应，性能的衰退及磨损方面的问题需要对磨擦系数进行控制，这些由磨擦材料供应商专门负责。

Pedal feel and particularly NVH performance requires control of the friction material mechanical properties. These involve other components of the braking system
踏板的感觉，特别是NVH的性能需要对磨擦材料的机械性能的控制。这些也涉及到刹车系统的其它组件



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Friction Material Industry is Mature

磨擦材料工业已成熟

Many of the critical problems associated with the high energy part of the Braking problem have been solved. Stopping the car, Reducing fade, Reducing wear许多与刹车能力相关的重要问题都已被解决。刹车系统降低性能衰退，降低磨损。

Attention is focused on elimination of NVH

人们的关注现在集中在消除NVH上。

Customers demand friction materials from both OEM and aftermarket must have improved noise performance

消费者要求，从OEM到售后市场提供的磨擦材料都具有在噪声方面更好的表现。



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Why to Automotive Companies Care about NVH?

汽车公司为什么关注NVH表现

NVH has been a costly warranty problem in the automotive industry for decades.

近十年，在汽车行业中确保NVH性能已经是一个非常昂贵的问题。

More than \$100 million is spent annually on brake NVH warranty work in North America alone. A similar amount is spent in Europe

光在北美市场，为了保障制动时的NVH性能每年的费用超过1亿美金。

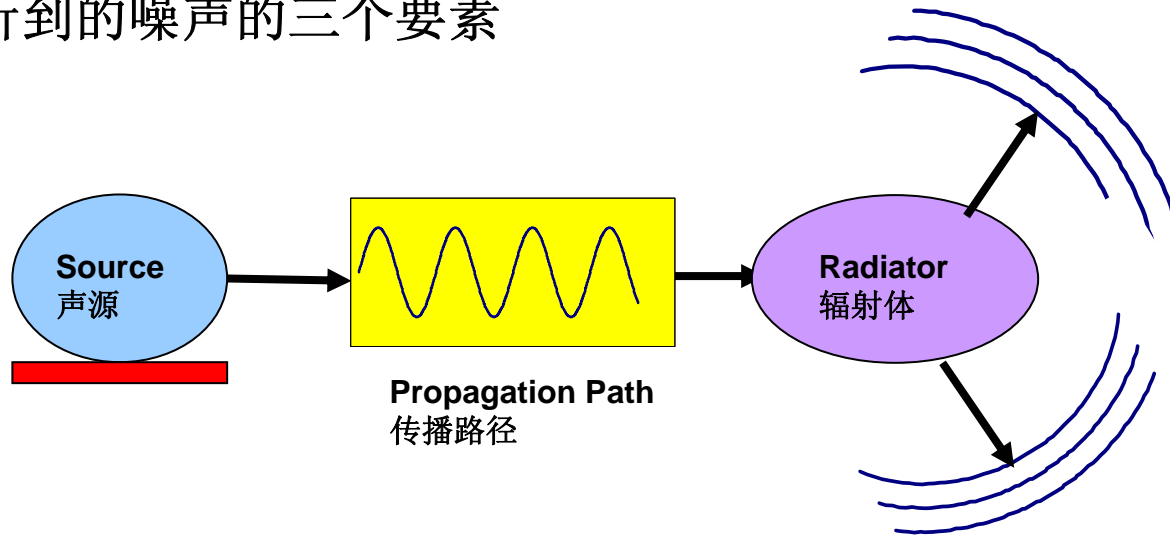
在欧洲每年的花费将近一亿美金



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Three basic attributes required to produce audible noise.

产生可听到的噪声的三个要素

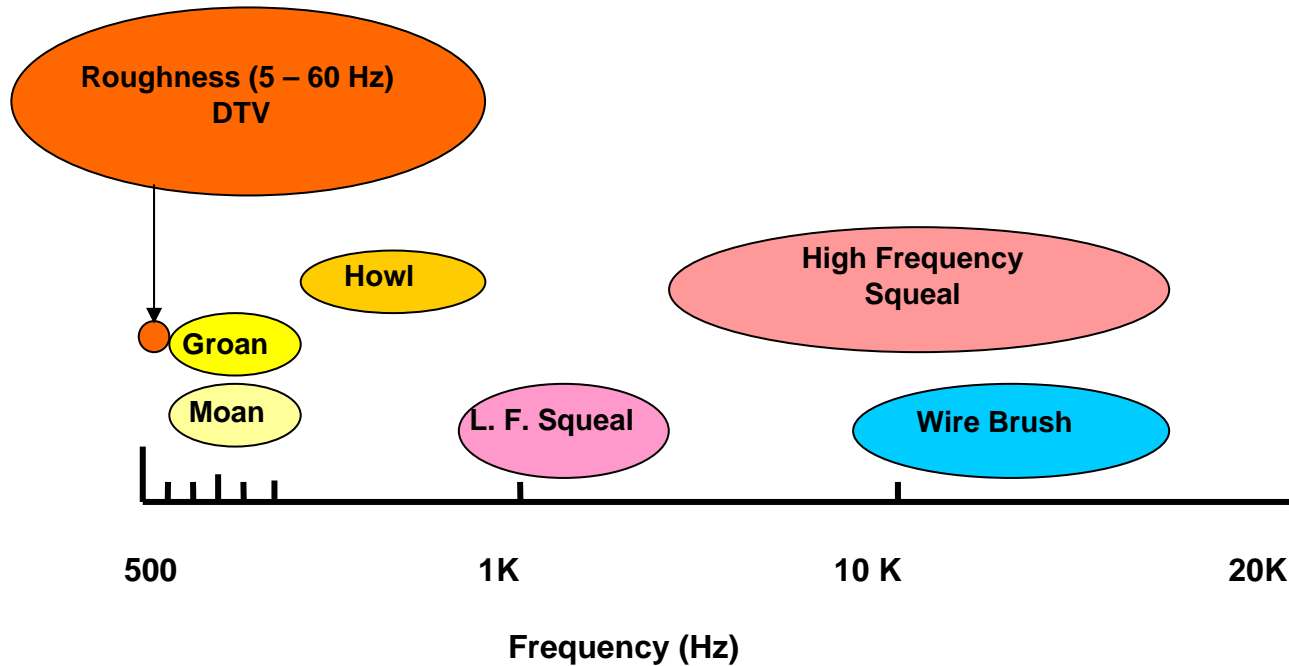


Friction induced vibration is always the source. Other brake components must contribute to the propagation and radiation in order to produce an NVH performance problem.

摩擦所产生的震动是（可听到的噪音的）根源，其它的刹车部件也成为传播发射（噪音）的路径，结果产生了NVH性能问题。

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Frequency Range for NVH NVH的频率范围



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Modern Simulation Methods can eliminate NVH problems

现代的，可以消除NVH问题的模拟方法。

Current Simulation Methods

现有的模拟方法

Precise rendering of geometry

精确的形状描述

Realistic boundary conditions

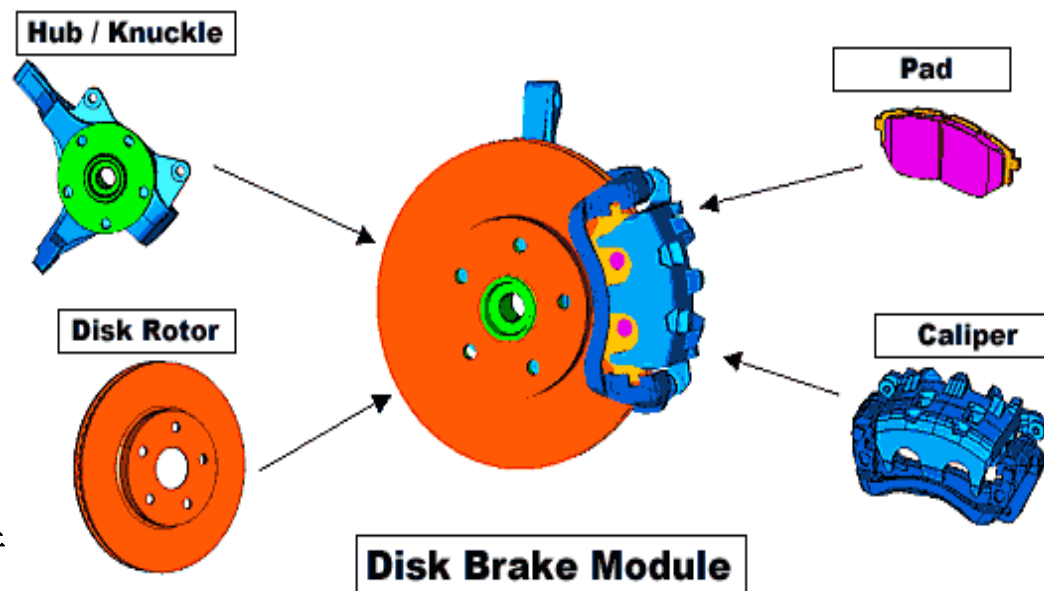
真实的边界条件

Temperature dependence, 与温度相关,

Sliding friction, 粘滞效应,

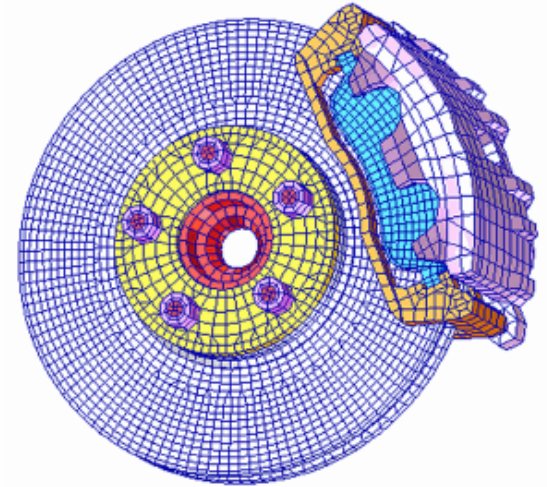
Non-linear behavior 非线性表现

Multiple component Analysis 多部件的分析



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$$\{\lambda^2[\mathbf{M}] + \lambda[\mathbf{C}] + [\mathbf{K}]\}(\Phi) = 0$$



Compressibility (modulus) is indicated as influencing low frequency vibration groan as well as being indicated in numerous high frequency squeal trials. 可压缩性（模数）已表明低频率和高频率的噪声都有关键影响

Quantitative use of linear, isotropic friction material properties is inadequate for current modeling calculations

在线性同性的摩擦材料中使用的特性数值对目前的模型计算是不够的

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Quantitative simulation requires material property for all of the manufactured components and the lining material. 定量的模拟需要所有的元部件及内衬材料材料性质数据。

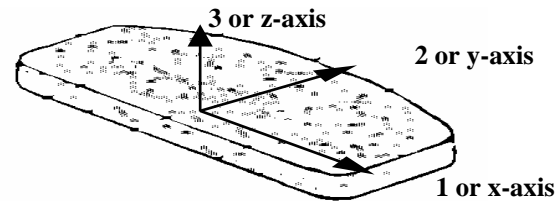
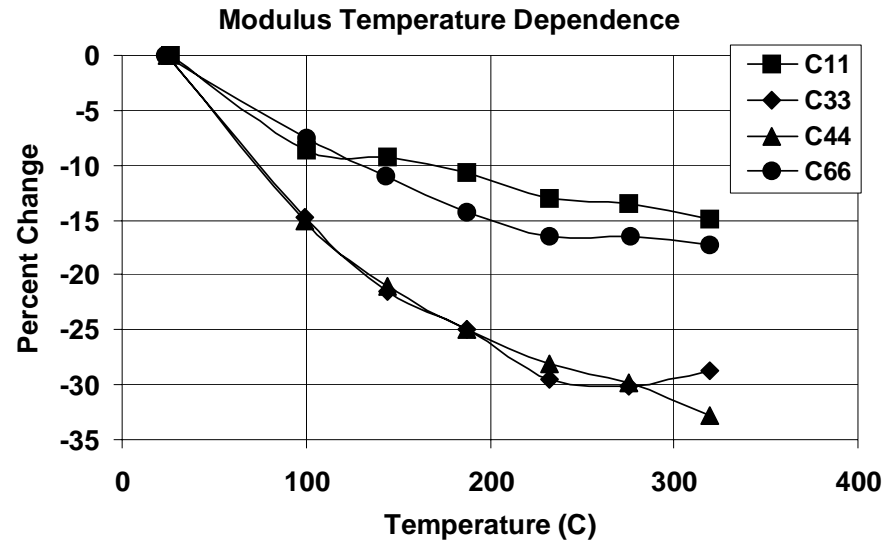
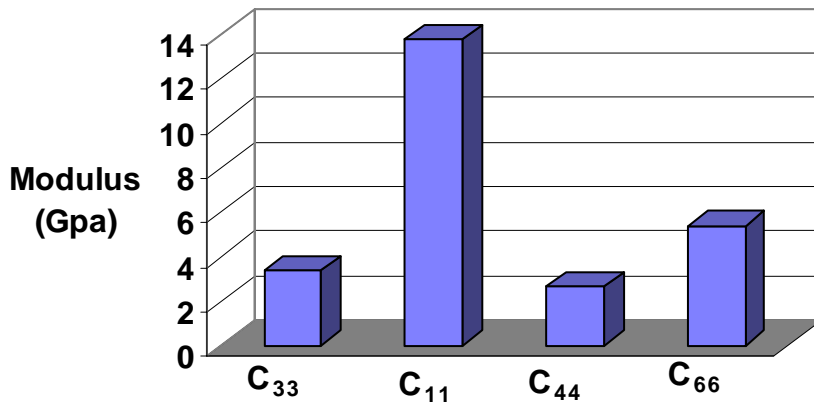
For friction material data must include the 摩擦材料数据必须包括:

Anisotropic properties 各向异性特性

Temperature dependence 与温度相关特性

Non-linearity 非线性特性

Anisotropic Friction Material



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What does Quiet Mean for the Marketplace??在竞争性的市场交易中安静意味着什么？

The Era of “Designer Brakes” “设计者的刹车”的时代

Noise free, application specific friction materials that have been carefully chosen to match the braking requirements of a particular vehicle platform无噪音，特殊的摩擦材料的运用已经紧密地与具体的车型平台所需的刹车要求相适应。

These Premium friction materials provide the best combination of stopping power, fade resistance, NVH performance, and wear. They also command a higher price, which more consumers are willing to pay on late-model, luxury-laden cars and light trucks.这些宝贵的磨擦材料提供了良好的制动力，抗衰退性，好的NVH性能及耐损破性。同样它们的价钱也很高，而这价钱是消费者愿意为新型，豪华多功能车，轻型卡车付出的



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The Future for Aftermarket Linings 刹车 系统内衬部件的售后市场前景

“Right now the marketing guys who package and sell aftermarket brake linings are mostly emphasizing QUIET over other features of their products.”现在包装及销售售后市场刹车内衬的商家，与该产品的其它性能比，更把其“安静”性能做为卖点。

The main reason why the aftermarket got into , quiet, ceramic friction materials is because the OEMs were using them. According to industry sources, quiet, ceramic linings are now used on 75% of 2004 cars and light trucks.售后市场采用安静的具有陶瓷填充物磨擦材料的主要原因在于汽车原厂生产商在使用它们。根据业界信息：**2004年75%的轿车与轻型卡车使用安静，具有陶瓷填充舞的内衬材料。**



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Summary 总结

- **NVH does not in any way influence the primary function of stopping the car. Audible squeal power is less than 1/1,000,000 of that of a stop** NVH在任一程度上都不影响其“刹车”这个最基本的性能。可听到的尖叫声能不足“刹车”动能的百万分之一。
- **Elimination of NVH will become Increasingly important market driver in both the OEM and Aftermarket**在原厂生产和售后市场上，消除NVH的努力，越来越成为重要的市场趋势。
- **Friction induced vibrations are the source of NVH but other braking systems components are involved**摩擦所产生的振动是产生NVH的根源，刹车系统其它组件也参与其中产生NVH。
- **Simulation combined with appropriate material property data can be used to identify low NVH materials**使用有精确的材料性能数据的模拟仿真可用来鉴定识别出具有好的NVH表现的材料。



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“The Greatest Revelation is Silence”

“大道希声”

Lao-tse (4th century before Christ)

老子（公元前四世纪）

Chinese Philosopher, Founder of Taoism

中国道家创始人，中国的先哲

