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Recent Topic in the Development of Automotive Aftertreatment Tecnologies

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Guest Forum
技術講演会

Recent Topics in the Development of Automotive Aftertreatment Technologies

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Dr. David Gregory has been working at Ford's Dunton Engineering Centre for 3 years, previously as an Emissions Chemist, but recently promoted to Technical Specialist in Combustion Chemistry within the Emission Compliance Department. Currently working on the development and optimisation of aftertreatment systems for future generation powertrain technologies.'

1999年5月17日ホリバ京都本社において，フォードモータ社のグレゴリー博士をお招きし，ガソリン排ガス処理システムやディーゼルパティキュレートに関する技術講演会を開催しました。ご講演は，排ガス規制に対する議論に始まり，博士の研究所におけるNO_x還元触媒等の研究にホリバのフーリエ変換赤外分光計(MEXA-4000FT)がいかに活躍しているかに及びました。フォードモータ社の発明であるEGIシステムでは，非常に具体的な内容を話され，更に三元触媒に対する硫黄の悪影響の研究にはホリバの質量分析計(MEXA-4000MS)が極めて重要な解析ツールになっていることに言及されました。最後に，これからのディーゼルパティキュレートについては，粒子を正確に輸送できるサンプリング手法の大切さを指摘して講演を締めくくられました。

At Horiba's headquarters in Kyoto on May 17, 1999, Dr. David Gregory from the Dunton Engineering Centre at the Ford Motor Company (UK) presented results from studies of exhaust gas after-treatment and diesel engine particulate emissions. Beginning with a discussion of regulatory requirements, Dunton reports how his team used the Horiba MEXA-4000FT system to take high-speed and high-precision measurements of the performance of a NO_x-reducing three-way catalyst system and a lean-burn NO_x trap. The lecture included results from an analysis of a catalyst-based de-NO_x system for diesel passenger cars. Dunton notes the effects of temperature on the performance of the catalyst and describes a Ford innovation: the Exhaust Gas Ignition (EGI) fast catalyst light-off system. Dunton's group used a Horiba MEXA-4000MS system to study the effect of sulfur-containing fuel on catalyst performance. The lecture concludes with a discussion of nanoparticle (< 50 nm) emissions from diesel engines and presents an example of data artifacts resulting from characteristics of the particle sampling method.

1. Introduction

"My name is David Gregory and I work at Dunton Engineering Centre for Ford Motor Company. It is my great pleasure to have the opportunity to give a presentation here at Horiba. My responsibilities at Dunton include the development of exhaust aftertreatment systems for diesel and direct injection spark ignition (DISI) engines, and also C/D car catalyst specifications (C/D cars are medium sized vehicles, such as the Ford Mondeo). I am also responsible for the understanding of automotive particle emissions.

As you are aware, there is increasing pressure on automotive manufacturers to reduce vehicle emissions to the levels required by future emissions legislation. Organizations such as the Ford Motor Company are continuing to work to meet these requirements."

"Clearly, to meet these limits, an improved understanding of emissions formation and control processes is required. In addition, there are other unregulated emissions that may influence the formation of regulated emissions or be a potential customer concern. In this presentation I would like to discuss our present understanding of emissions formation of regulated and unregulated constituents and how they may be controlled using different aftertreatment technologies.

The development of different vehicle systems have different requirements with regard to the type and configuration of aftertreatment system and the exhaust gas components which need to be measured dynamically. For example, Port-Fuel Injection (PFI) engines operating at stoichiometric, require three-way catalysts for emissions control. In contrast, however, the recent development of Direct Injection Spark Ignition (DISI) engines which operate fuel-lean under certain driving modes require a different type of aftertreatment system; more specifically, lean-NOx traps have been developed which are able to store NOx under lean conditions with short, periodic regeneration under rich conditions.

"For the development of these aftertreatment systems, analytical instrumentation must be used which can measure a range of exhaust components, organic and inorganic, with high speed and high precision. Recently, we have been using two such techniques, FT-IR and mass spectrometry.

2. Features of FTIR and MS

The following is a brief outline of the features of the two instruments; the MEXA-4000FT and MEXA-4000MS:

2.1 MEXA-4000FT

* 22 components can be characterized every 1.0 second.
* Developed specifically for automotive emissions analysis.
* Can measure NO, NO_2, N_2O, NH_3, and C_1-C_4 HCs (ppm levels).
* Useful for lean-burn gasoline aftertreatment development.
* Suitable for application to diesel de-NO_X catalyst systems.

2.2 MEXA-4000MS

* Can measure a wide range of organic and inorganic species.
* User can specify components to be monitored and sampling.
* Can measure SO_2, H_2S, COS, NO_2, NH_3, C_4-C_6 alkanes and BTEX (ppb levels).
* Very efficient for measuring sulfur species from three-way catalysts and lean-NO_X traps.
* Suitable for use with hydrocarbon traps and fast catalyst light-off systems.

自動車排ガス処理技術開発における最近の話題

1. はじめに

みなさん, こんにちは。私はフォードモータ社のダントンエンジニアリングセンターでエンジン最適化の研究を行っています。

エンジン最適化の後処理技術は , エンジンの大きさ，種類により異なります。従来のポート燃料噴射(PFI)は , 三元触媒を用い理論空燃比で操作し後処理されるのに対し , 直噴エンジン(DISI)では , リーン条件下で，周期的リッチパージを備えたリーン NOx トラップ(LNT)による後処理技術が開発されました。

異なるシステムを扱う上では優れた分析装置を用いることが非常に重要です．最近ではFTIRおよびマススペクトロメトリーという二つの技術が用いられていますが，いずれも，排気物質の有機，無機成分を広いレンジで高速・高精度で測ることができます。

2. FTIR と MS の特徴

2.1 MEXA-4000FT

3. Application Example of FTIR Measurement

"It is very clear that for European Stage III regulations and beyond, the use of lean-burn engine technology will require the use of a close-coupled three-way catalyst (CC-TWC) in conjunction with an underfloor lean-NO_x trap (UF-LNT) for emissions control."

3.1 Lean NO_x Trap

"Here I would like to talk about the function of the lean-NO_x trap. NO in the exhaust is oxidized to NO_2 on the surface of the LNT. NO_2 is then taken up by adsorbents, such as barium, to form the corresponding nitrate. These reactions are shown below:"

(1) $2NO + O_2 \Leftrightarrow 2NO_2$

(2) $2BaCO_3 + 4NO_2 + O_2 \Leftrightarrow 2Ba(NO_3)_2 + 2CO_2$

"Because the lean-NOX trap has a finite capacity for trapping NOx, periodic rich purges are required to regenerate the trap. "

"This example is the actual vehicle trace using a chassis dynamometer. See how the NO_x in the emissions is reduced from the feedgas through to the tailpipe. For the analytical instrumentation, we used the MEXA-4000FT. The vehicle was tested at 70 kph steady-state lean-burn conditions, with periodic rich purges (once approximately every minute) to regenerate the LNT."

"**Figure 1** shows the FTIR data for each of the nitrogen-containing species at each of the sampling points (engine-out, post-TWC and post-LNT).

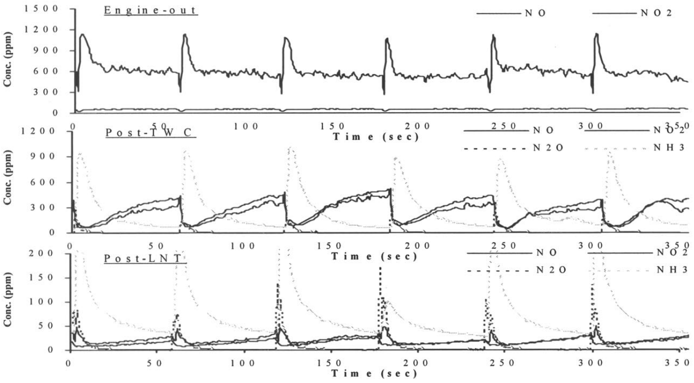

Fig. 1 Concentrations of oxides of nitrogen and ammonia from a lean-burn gasoline vehicle1)

In the engine-out emissions, the periodic increases in engine-out NO correspond to the rich purges where the EGR is switched off. Notice that the engine-out NO_2 is approximately 10% of the total NOx emission at this point. Post-TWC emissions show that the TWC is having a significant impact. The platinum component in the TWC is oxidizing a considerable portion of the NO to NO_2. The NO_2 formed by this reaction is stored in the form of nitrates (e.g. $Ba(NO_3)_2$). The storage mechanism appears to decrease in efficiency with time after the purge as the adsorption components become occupied by nitrates. The efficiency for oxidation of NO to NO_2 on the platinum surface also decreases gradually after the rich purge."

"This is a result of the thermodynamics of the NO to NO_2 oxidation process. The storage of NO_2 will shift the equilibrium of the reaction towards the formation of NO_2. However, as the NO_2 adsorption sites become occupied, the NO_2 is not being removed efficiently and the chemical equilibrium will shift so there is less conversion of NO to NO_2. Another striking feature of the post-TWC data is that the levels of N_2O and NH_3 are quite high. These nitrogen-containing components are formed during the fuel-rich purge

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・22 個の物質を毎秒特定
・自動車排気の解析のために特に開発された
・NO, NO_2, N_2O, NH_3, C_1-C_4 HCs を ppm レベルで測定可能
・リーンバーンガソリン後処理装置の開発に最適
・ディーゼルの NO_x 還元触媒システムの解析にも有用

2.2 MEXA-4000MS

・有機・無機成分を広いレンジで測定可能
・測定・サンプリングしたい成分をユーザー側で指定可能
・SO_2, H_2S, COS, NO_2, NH_3, C_4-C_6 alkanes, BTEX を ppb レベルで測定可能
・三元触媒とリーン NOx トラップを用いて硫黄 測定に非常に効果的
・炭化水素トラップ，速い触媒ライトオフシステム解析に有効

3. FTIR 測定の応用例

3.1 リーン NO_x ラップ

ヨーロッパ排ガス規制のステージ III 以降では，リーンバーン車も対象となってきます。そのために , リーン

from reactions involving the desorbed NO.”

“The third chart shows the NO_X storage and reduction process in the LNT. Notice that the y-axis scale in the third chart is much lower than the first two charts. This clearly shows significant reduction of NO and NO_2. However, we still see the presence of tailpipe N_2O and NH_3 that cannot be observed with conventional analyzers.

3.2 Diesel de-NO_X Trap

“These data (see **figure 2**) are taken from an intercooled turbocharged 2.5 liter diesel engine with exhaust gas recirculation and an active (fuel injection pre-catalyst) diesel de-NOx catalyst system.

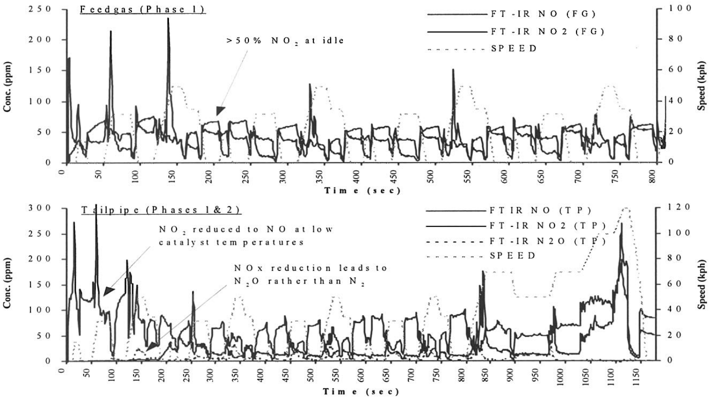

Fig. 2 Concentrations of oxides of nitrogen from a diesel engine over phase 1 (and 2) of the NEDC[1)]

The data is taken over the European Stage III driving cycle. Observe the sharp increases in NO at the point of acceleration. This is the result of an increase of the combustion temperature. Also, note that the NO_2 concentration during the idling period is approximately 50% of the total NOx concentration; this is much higher than the conventional number of 10% - 30% that most people used to believe. The higher the engine-out NO_2 to NO ratio, the better an automotive manufacturer can reduce NOx by application of diesel de-NO_X catalyst technology.”

“Profiles for the tailpipe nitrogen components are in sharp contrast to the engine-out NOx (see **figure 2**). In particular, NO_2 is not observed in the tailpipe until approximately 200 seconds have elapsed. Some of the feedgas NO_2 may be stored on the cold catalyst surface or dissolved in condensed water. Comparing the engine-out to the tailpipe data, however, suggests that a proportion of the NO_2 is being reduced to NO during these cooler regimes. This is confirmed by the higher tailpipe NO during these periods and also agrees with literature data. The profiles also suggest that the overall NO_X reduction (of the order of 10%) does not lead to the desired formation of N_2, but instead forms N_2O. This may be an important criterion when different manufacturers’ diesel de-NO_X systems are being assessed”

“It is clear that by using the MEXA-4000FT we can obtain improved scientific understanding from the analysis of lean-burn gasoline engine aftertreatment systems as well as diesel engine de-NO_X systems. This data used to be impossible to collect by using conventional analytical tools such as CLA. I believe that the 4000FT is a capable tool for use with aftertreatment systems.”

4. Applications of MS

4.1 Impact of Sulfur of TWC

Impact of Sulfur on Three-Way Catalyst (TWC) Performance

“You are all probably aware of the negative impact sulfur has on TWC performance, but you don’t have this problem in Japan because the sulfur levels in your fuel are very low.

NOx トラップ(UF-LNT)を伴ったクローズドカップル三元触媒 (CC-TWC)が必要になります。

リーンNOxトラップの機能について説明します. 排ガス中のNOは酸化してLNT表面でNO_2 になります。NO_2 はバリウムのような吸着剤に吸着され，硝酸塩が作られます。(**式(1)**,**(2)**)

リーンNOxトラップはNOxをつかまえるのに限られた能力しかもっていないため，トラップを再生させるためには周期的なリッチパージが必要となります。

次の例のような．排気中の NO_Xが軽減されている様子(**図１**)に注目ください。

それぞれのサンプルポイント(供給ガス , TWC後 , LNT 後)における含窒素種のFT-IR のデータです。エンジン直後のNO_2 は 全NO_X の約 10% となっています．TWC 中の白金成分は NO のかなりの部分を NO_2 に酸化しています。この反応で形成された NO_2 は硝酸塩(たとえば $Ba(NO_3)_2$)の形で蓄積されます。TWC 直後データのもうひとつの大きな特徴は N_2O と NH_3 のレベルが極めて高いことです。３番目のチャートにより , テールパイプでは , 従来の測定装置では観察が不可能であった N_2O と NH_3 が現れているのがわかります。

3.2 ディーゼル NOx 還元触媒

図２により, 加速時のNOが大きく増加していることがわかります。これは燃焼温度の上昇によるものです. また , アイドリング時のNO_2 が 約 50% であり，従来信じられてきた 10% ～ 30% という値よりも高いことにも注目ください。

Sulfur in the fuel is still a major concern in Europe and in the United States. Let us begin with a brief overview. Sulfur dioxide, SO_2, formed from the fuel during engine combustion is able to interact with various components of the three-way catalyst such the precious metals (especially palladium) and also components of the washcoat (e.g. ceria and alumina).”

“The data in **figure 3** come from a 1.8 liter gasoline test vehicle, equipped with a close-coupled starter catalyst upstream of an underfloor three-way catalyst. This kind of aftertreatment system will be very common to meet European Stage IV legislation.

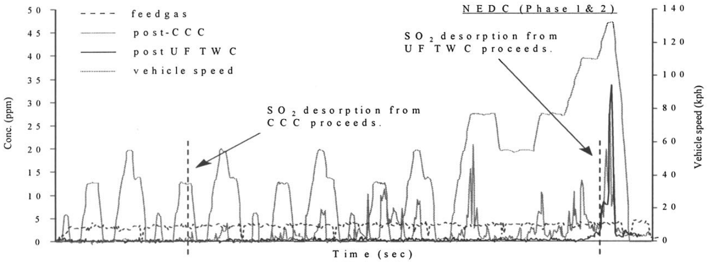

Fig. 3 Changes in SO_2 over a cascade system (NEDC)1)

“These data was taken using the MEXA-4000 MS. The increasing amount of SO_2 after the close-coupled three-way catalyst is shown in red, and tailpipe SO_2 emissions are shown in yellow.”

“If we look at the post-close-coupled TWC SO_2 emissions, we see that desorption of SO_2 starts at 300 seconds when the catalyst reaches approximately 600 ℃. Sulfur desorption from the catalyst usually occurs at these temperatures. It is obvious that the temperature plays a major role in the desorption from the close-coupled three-way catalyst. However, the underfloor three-way catalyst does not start to desorb SO_2 until very close to the end of the cycle. Sulfur will therefore build up on the underfloor catalyst which will eventually lead to a deterioration in catalyst performance. So it is very important to optimise the aftertreatment configuration to minimise the effects of sulfur.”

4.2 Fast Catalyst Light-off

“To meet future legislation, it is quite clear that we need to minimize the emissions that occur during the engine start prior to catalyst light-off. Nearly 70% - 90% of the emissions occur before the catalyst reaches the light-off. A solution for this is a Ford innovation called Exhaust Gas Ignition, or EGI. This reduces the light-off time of the catalyst 10 seconds or less.”

“**Figure 4** shows the general schematic of the EGI system. Feedgas is engine-out emissions. The exhaust flows left to right, to the tailpipe at the end. The front brick is a hydrocarbon trap which adsorbs hydrocarbons at low temperature and releases them at high temperatures. On the rear brick, there is a three-way catalyst, and a glow plug is located between the two bricks. There is modulated secondary air injection prior to this catalyst system. From cold start, the engine operates fuel-rich to produce high levels of engine-out hydrocarbons, carbon monoxide and hydrogen. Secondary air is injected prior to the catalyst assembly, to produce a flammable exhaust mixture with a lambda value just greater than 1. The glow plug ignites the fuel between the bricks

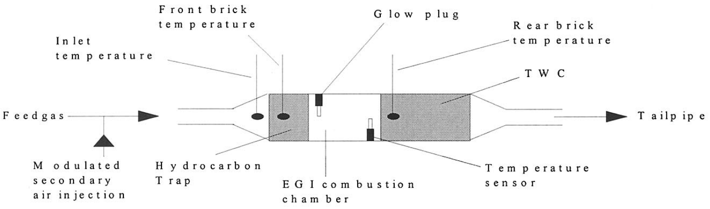

Fig. 4 Components of the HC trap-EGI system1)

エンジン直後とテールパイプのデータを比べると，触媒の温度が低い間は，NO_2に比例した量がNOに還元されます。このことはこの間テールパイプでNOがより高濃度であることからも実証され，また文献データとも一致しています。NO_x全体にわたる還元 (10%程度) は，望ましいN_2よりもN_2Oを生成していることがプロファイルから言えます。これは異なるディーゼル車NO_x還元システムを評価する際の重要な基準となります。MEXA-4000 FT を用いてリーンバーンガソリンエンジン後処理システムやディーゼルエンジNO_x還元システムの分析に新しい科学的知見が多く得られました。従来の分析ツール，たとえば化学発光法(CLA)等では不可能だったことを考えると，4000FT は後処理システムについて極めて優れたツールだといえましょう。

4. MS の応用例

4.1 三元触媒に対する硫黄の悪影響

硫黄がTWCに多大な悪影響を及ぼすことは有名です。日本では燃料中の硫黄のレベルが極めて低いためあまり問題にはなっていないかもしれませんが，ヨーロッパやアメリカでは燃料中の硫黄は大きな問題です。

２段触媒システムにおけるSO_2の作用を**図３**に示します。このデータはMEXA-4000 MSで採ったものです。触媒の温度が約 600℃に到達した時点で，CC- 三元触媒からSO_2の脱離が始まっています。三元触媒からの脱離に温度が大きな役割を果たしていることがわかります。SO_2の脱離プロファイルを観察し，触媒から硫黄を取

and the resulting heat lights-off the front face of the rear three-way catalyst brick very quickly. The resulting exotherm is maintained throughout the catalyst by careful calibration.”

“The EGI system reduces tailpipe CO and HC emissions considerably compared to conventional catalyst systems. Despite the rapid catalyst light-off characteristics of EGI, there is still a significant THC spike during the first 20 seconds. This can be reduced by including an upstream HC trap.

“The data (see **figure 5**) shown here are taken using the MEXA-4000MS. By sampling the feedgas directly behind the HC trap and post-TWC, it is possible to assess the trapping efficiencies and light-off characteristics for a range of hydrocarbons. There is considerable adsorption of each hydrocarbon on the trapping material from cold start; since during the first 20 seconds, the hydrocarbon concentration exiting the HC trap is significantly lower than that entering it. There does appear to be some selectivity towards adsorption, however, in that heavier hydrocarbons, such as toluene, are more efficiently stored on the trapping surface. Hydrocarbon desorption proceeds as the trap surface temperature increases. Desorption is characterized by a higher HC concentration observed at the ‘post-HC trap’ location than that observed at the engine-out location. There is selectivity in the temperatures at which desorption from the trap proceeds. Figure 5 shows toluene desorbing 30 seconds later than either propene or pentane. The characteristics of the fast catalyst light-off of EGI are clearly observed from the very low tailpipe profiles for each of the hydrocarbons.1"

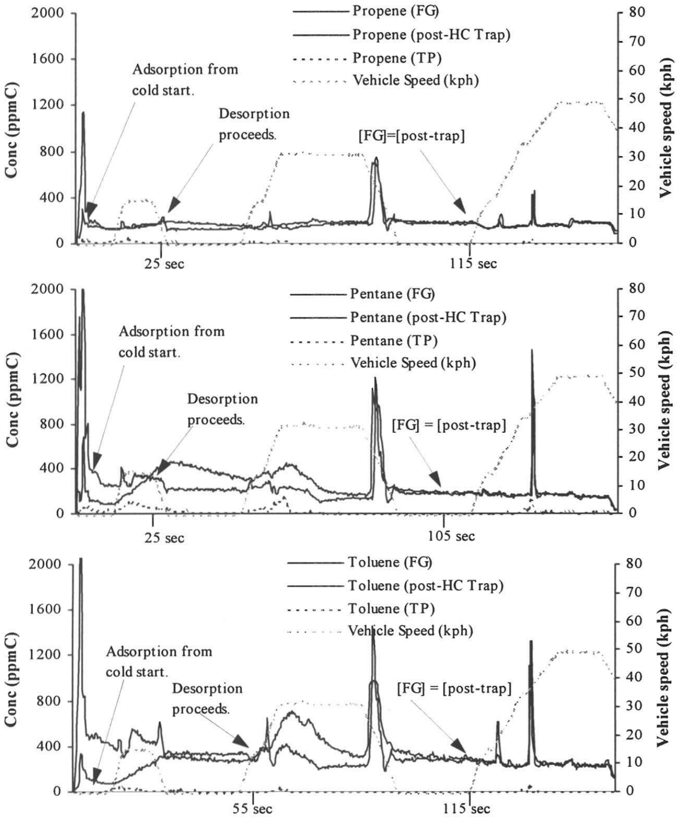

Fig. 5 Exhaust propene, pentane and toluene profiles in the HC trap-EGI configuration$^{1)}$

5. Particle Size Distributions

“Recently, both the size and number of particles from automotive exhaust have become very topical issues. Particle emissions by size and number are not easy to measure. It is very important that people are aware of this. There is certain literature available, which suggest that gasoline vehicles can produce as many particles as diesel. Under certain abnormal conditions, such as when a vehicle has a malfunction, or is operating very rich, then a gasoline vehicle can produce significant particles. But, unlike what is suggested in the literature, normal gasoline vehicles, operated in controlled conditions under closed-loop operation, do not produce as many particles

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り除くことが非常に重要です。

4.2 超低排出触媒システム

エンジンをスタートさせてから触媒の起動までに起こる排ガスを最小に抑える必要がありますが, およそ70% - 90% の 排ガスは, 触媒が起動しはじめる前に排出されています。フォードが開発したExhaust Gas Ignition システム (EGI)は, 触媒の起動を少なくとも 10 秒は短縮することができます。

図4 はEGI の概要を示しています。フィードガスが左側から入ります。前方のレンガはHC トラップで, 後方は三元触媒です。その間にグロープラグが置かれており, このプラグにより, 混合ガスが着火され, 余熱により発熱化学反応が維持されます。EGI システムは従来の触媒システムに比べ, テールパイプのCO とHC 排ガスをかなり低減しています。

図5 のデータは MEXA-4000 MSを用いて採ったものです。フィードガスを直接, HC トラップ直後, テールパイプの３ヶ所でサンプリングすることにより, あるレンジのHC吸着特性 と 触媒のライトオフ特性 を評価することが可能です。トラップからどの解離が先に進んで行くかについては, 温度による選択性があります。

図5 に見るように, トルエンの解離がプロペンやノルマルーペンタンよりも約30秒遅れて起きています。テールパイプではHCが極めて少ないことにより, EGI による触媒の速いライトオフ特性をはっきりと見ることができます。

as diesel engines. It is possible, therefore, that under certain conditions, there is some influence on particle size and number emissions which are not a direct result of the vehicle itself (see section on ‘Influence of Sampling’).”

“Potential harmful effects of particles are reflected in the legislation (currently mass emissions of particulate needs to be controlled). The current concern, when it comes to human health effects, is that size and number of particles are potentially more important than mass. It has been suggested that the smaller the particles become, the more harmful they are for the human health. Very important are the so-called ‘nano-particles’ - particles that are smaller than 50 nanometers in diameter. Nano-particles penetrate deeply into the human body possibly leading to respiratory diseases. It is quite clear that the engine designers are very efficient in developing engines with low particulate mass emissions. It has been questioned, however, that reducing particulate mass may be accompanied by an increase in particle numbers. Recent work with particle traps has shown that reductions in particle mass are in fact accompanied by a reduction in particle number.

6. Influence of Sampling

“One important concern I would like to emphasize for nanometer-size particulate measurement is the consideration of the influence of the sampling conditions. This is clear from the data shown in **figure 6**. From this we will see that the particulate measurement is difficult and is affected not only by the instruments but also by the sampling conditions and the sampling system itself.”

“These data (**figure 6**) show a comparison of particle size distribution from a 4-cylinder European gasoline car sampled using an ejector pump system and also using a dilution tunnel: a) was taken using an uninsulated transfer line, b) used an uninsulated transfer line, c) used an uninsulated transfer line and a 1-meter silicone rubber coupler, and d) used an uninsulated transfer line and a 15-centimeter silicone rubber coupler.”

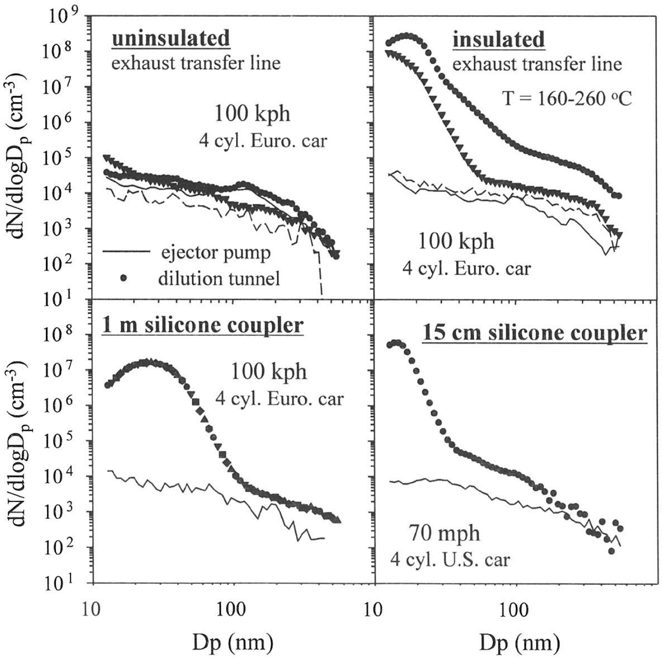

Fig. 6 Particle size distribution with different transfer lines2)

“When an insulated hose or one containing a rubber coupler is used, a very intense spike of ultrafine nanoparticles (smaller than 30 nm) develops in the dilution tunnel particle size distribution. In this case, the ultrafine particles are attributed to desorption and pyrolysis of the silicone rubber material by the hot exhaust gases.”

“Data in **figure 7** shows the sequence of size distributions for a 1998 diesel car. Data was taken at 3 minute intervals while the vehicle speed was increased from 50 to 60 mph. The top panel illustrates the growth of the 20 nm artifact due to heating of the transfer hose. The bottom panel shows

5. パーティクル粒径分布

今日, パーティクルの大きさや数はとても大きな問題となっています。パーティクルエミッションの大きさや数を計測することは大変難しく, まずこの事実を知ることが大切です。現在では多くの文献があり, ガソリン車はディーゼルと同じだけパーティクルを排出しているとありますが, これは真実ではありません。パーティクルエミッションが正しく計測されていないことになります。

パーティクルの潜在的な悪影響は規制からも明らかです。人体に対する悪影響から, 現在ではパーティクルの大きさと数が, 質量よりも問題だと考えられています。パーティクルは, 小さい程人体に害が大きいと言われています。ナノパーティクル(直径50ナノメータ以下のパーティクル)は人体深くに浸透し, 呼吸器官疾患を起こします。このより小さなパーティクルの影響を実証するデータはまだありません。

6. サンプリング系の影響

ここで強調しておきたいのは, ナノサイズのパーティクル計測がサンプリング系の影響を受けると言うことです。これは**図6**に示したデータからも明らかです。このことからパーティクル計測は難しく, 測定装置だけでなくサンプリングシステムにも影響を受けることがわかります。

図6は排気ポンプ と ダイリューショントンネル でサンプリングされた, 4-シリンダー ガソリン車のパーティ

a transient artifact from hydrocarbon build-up that ‘burns off’ the j-tube sample probe in the tailpipe.”

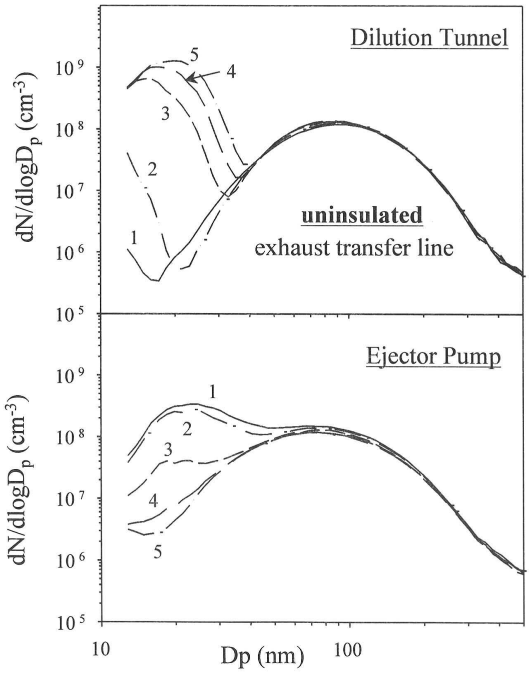

Fig. 7 Artifact formation - diesel vehicle2)

“The distributions exhibit an accumulation mode up to 10 to the power 8 particles/cm^3 that is centered near 100 nm. As the speed increases, the discrepancy becomes apparent: the tunnel-derived distributions are bimodal, whereas those from the tailpipe show only the accumulated mode.”

“The number of ultrafine particles (up to 18 nm) sampled in the 60 mph dilution tunnel test exceeds the accumulation mode by a factor of 10. We conclude from this study that the hydrocarbon storage in the transfer hose and its subsequent release by the hot exhaust gasses can have a profound influence on the number and character of particles2.

“To summarize, it is very difficult to compare data using different sampling conditions. We face questions about the effects of the dilution ratio and the temperature. It is important that robust sampling and measuring procedures are developed. It is very important that clearly- defined testing protocols are used, which avoid possible artifact formation.”

“Of course, besides system optimization, we need a close collaboration between ourselves: Ford, the catalyst supplier, and the people developing the control systems. We all must work together. It is important that we recognize that emission analyzer development is an integral part of the process. It is true that we are not fully sure about particulate measurement yet. To clarify it, not just a static but a dynamic measurement property is required. In this field I am looking forward to developments in Horiba’s technology and I hope we can continue the collaborative work between Horiba and Ford Motor Company. Thank you for your attention.”

References

1. Gregory, D., Adachi, M., et. al, JSAE, No. 183 1999
2. Maricq, M.M., SAE, No. 1999-01-1461

クル粒径分布の比較を表しています。a) は非加熱移送ラインを用い，b) は加熱移送ラインを用い，c) は非加熱移送ラインと１mのシリコンラバーカプラーを用い，d) は非加熱移送ラインと15cmのシリコンラバーカプラーを用いて 採取されました。

図７のデータは1998年製のディーゼル車で採った分布図です。上方の図は，移送ホースの加熱に起因する疑似 粒子を示しており，下方の図は，テールパイプの採取管から燃え出したHC集団に起因する 疑似 粒子を示しています。

まとめると，どのような規制においても，排ガス中のパーティクルを低減することが必要であることは明らかです。その大きさ，数，そして質量において．異なる希釈率のデータを比較するのは非常に困難です。希釈率と温度の影響についての問題が顕著になっています。確固としたサンプリング手法と計測手段の発展が重要となります。正確に粒子をサンプルできる，しっかりと定義されたテストプロトコルを用いることが重要です。もちろん，システムの最適化だけではなく，我々同士，フォードと触媒メーカー，制御システムの開発者たちとの密接な相互関係が必要です。我々はいっしょに進んでいかなければなりません。排ガス分析装置の開発はプロセスの中核だと認識することが大切です。パーティクル測定についてまだ十分に分かっていないことは事実ですが，それを解明するためには，静的なものだけではなく動的な測定手法が求められています。この分野でのホリバの技術開発に期待したいし，フォードとホリバが協力して開発に当たっていきたいと希望しています。

(抄訳　編集部)