Development of Low-Noise and Large Air Volume Type Blower Equipped with an Environment-Friendly Engine

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A backpack blower powered by a small utility engine requires high operating performance, while at the same time, the demand by society for cleaner exhaust gas and lower noise is ever more intensifying. Thus, it was incumbent upon us to innovate the changes that would simultaneously satisfy all three requirements. To establish compatibility of higher operating performance with lower noise, a key technology is required that enables reduced fan noise without lowering its air volume. We have successfully solved this problem, and as a result, we have developed an engine blower of lower noise and large air volume that conforms to the Phase 2 emission regulations in the United States. This is a report on the results of that technological development.

Key Words: *CFD, Emission Reducing Technology, Low-Noise Machine, Noise Reducing Technology*

1. Preface

The backpack blower, powered by a small, two-stroke cycle utility engine (**Fig. 1**) has progressed, pursuing ever-higher performance in step with the steadily expanding landscaping business in the United States. Over the past several years, however, client requirements for this type of blower have intensely focused on alleviating the local environmental noise burden and improving global environmental conservation through purifying exhaust gas without sacrificing higher performance.

As we are at the doorstep of the 21st Century, small-sized agro-forestry machinery including backpack blowers are no longer allowed to remain exclusively performance and production efficiency oriented, but are required to reflect increased consideration to preserving the global environment. It has become a matter of course now that blowers are friendly to residents in the neighborhoods where they are used.

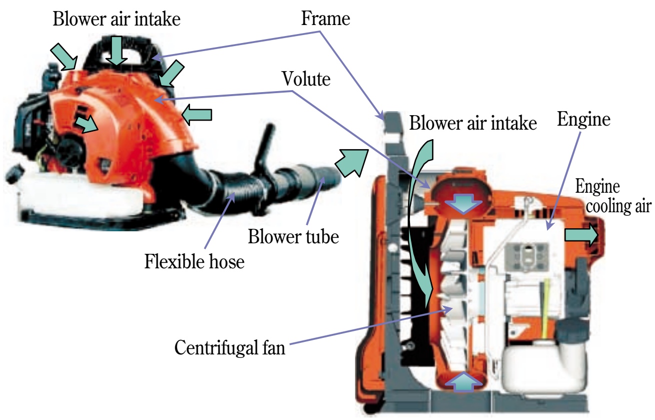


Fig. 1 Structure of backpack engine blower

We at Komatsu Zenoah have long been working on the development of products that are friendly to both people and the global environment alike. Our efforts bore fruit in the form of a low noise, large air volume blower teamed with an environment- friendly engine that has realized the foregoing client requirements. In subsequent chapters, we will report the results of that technological development process, focusing mainly on instances of applied CFD (Computational Fluid Dynamics).

2. Exhaust gas and Noise regulation trends

2.1 Emission regulations trend

A small 2-stroke cycle utility engine has advantages of lightweight, compact size and high power-to-weight ratio. Thanks to these merits, it is now widely employed as a power unit for small-sized agro-forestry machinery. In addition, simplicity and low cost may be counted as major additional advantages. On the other hand, a phenomenon termed "short-circuiting of mixture" inevitably occurs due to the engines design. That is to say, a certain portion of the mixture fed into the cylinders flows unburned into the exhaust port where a component of the unburned gasoline called THC (total hydrocarbon) is blown out into the atmosphere. The resultant air pollution has been found to present a threat to the preservation of both human health and the global environment.

Under such circumstances, in the year 2000 the California Air Resource Board (CARB) introduced Tier II Exhaust Gas Regulations, which are aimed at small-sized off-road engines under 18.6 kW. The federal Environmental Protection Agency (EPA) followed CARB in 2002, when it put into force Phase 2 Exhaust Gas Regulations which targeted small-sized off-road engines of under 19 kW. Phase 2 has drastically reduced allowable THC emissions to a third of the level allowed in Phase 1, a level which conventional 2-stroke utility engines find difficult to meet. (**Fig. 2**)

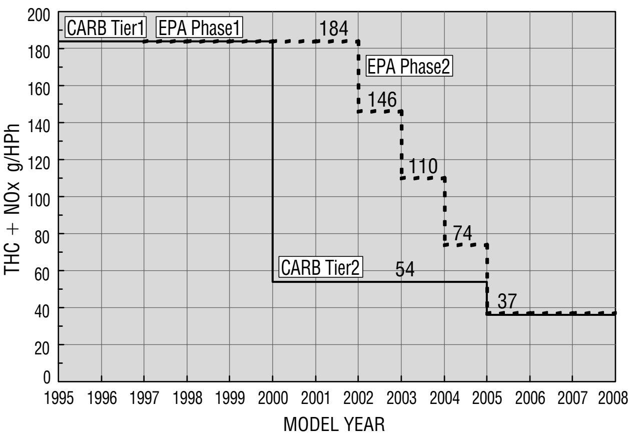


Fig. 2 History of small utility engine emission regulations in the US (20 – 50 cc)

In Europe, meanwhile, the EU Commission is planning to introduce, at latest by 2008, exhaust gas regulations controlling small-sized off-road engines. This European version is based on the US EPA's Phase 2 Exhaust Gas Regulations. Low emissions by small utility engines has become a set trend in our age.

2.2 Noise regulation trend

Backpack blowers are frequently used for maintaining greens in housing areas by landscapers who commonly start with their work early in the morning. In the US, a major market for the product, there have been incessant complaints and lawsuits filed by residents in and around the worksites who are bothered by the noise. City and county authorities have responded to the disapproving voices of their residents by imposing prohibitions on the use of engine blowers, such as limiting the hours of their use or restricting their allowable noise levels. This trend is more and more pronounced, and it is easily anticipated that general restriction of blower- generated noises will be brought to the federal level in the near future.

3. Aim of development

Against such a market backdrop, we have set the goals for our new backpack blower as discussed hereunder.

3.1 Response to emission regulations

In order to reduce THC emission levels, we decided that the air-head stratified scavenging method be adopted in place of the current Schnuerle scavenging method.

Fig. 3 is a conceptual drawing that shows the functioning of an engine using the stratified scavenging method. A major difference between the current 2-stroke cycle engine and the 2-stroke cycle engine employing the stratified scavenging method is that in the latter case, an air-head inlet is connected with the scavenging port via a groove on the side of the piston.

With the current 2-stroke cycle engine, negative pressure is created inside the crankcase as the piston moves up toward top dead center, and this negative pressure tends to draw the air/fuel mixture past the cylinder rings into the crankcase (suction stroke). The piston then compresses the mixture inside the crankcase as it goes down toward bottom dead center. When the scavenging port opens, the mixture is drawn from the crankcase into the cylinder while the burned gas is being exhausted. In this scavenging stroke, the scavenging port and exhaust port operations overlap, resulting in not only the products of combustion but also raw fuel being exhausted.

With the stratified scavenging type engine, on the other hand, the crankcase contains an air/fuel mixture and the scavenging port is filled with air coming from the air-head inlet during the suction stroke as the piston goes up toward top dead center. Then, as the piston goes down toward bottom dead center and the scavenging port opens, air inside the scavenging port is first sent into the cylinder and push out the burned gas. As the cylinder is again filled with air/fuel mixture, "short-circuiting" is reduced. That is why a dramatically improved THC emission rate can be expected of this type of engine as compared with the current 2-stroke cycle engine with the Schnuerle scavenging method.

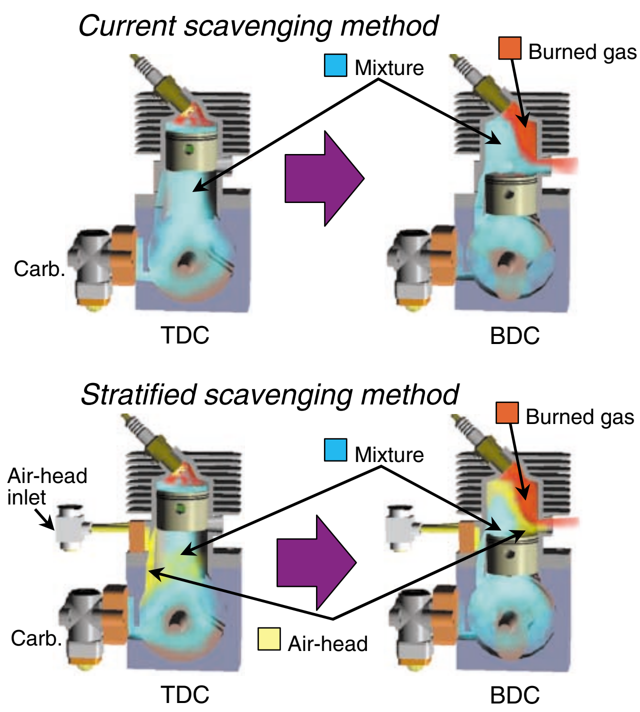


Fig. 3 Conceptual drawing showing operation of air-head stratified scavenging

3.2 Achieving lower noise and larger air volume together

In the case of small engine-mounted blowers, the amount that each noise source contributes to the total noise is reflected in the descending order of magnitude: ① Fan noise, ② Engine exhaust noise, ③ Engine solid noise, ④ Engine intake noise and ⑤ Blower solid noise, as shown in **Fig. 4**. Thus, a key technical assignment is to reduce fan noises.

In addition, a large amount of noise is generated by and emanates from the blower air intake inlet (suction port at the volute portion) and blower air outlet (blower tube outlet and engine cooling air opening). These sources present another technical hurdle to overcome in achieving noise abatement.

Now a small engine-mounted blower is a kind of capital goods, and as such there is always a demand for higher performance. An effective way of catering to this demand in the past was simply to introduce new models that produced larger air volumes at higher rates of flow. This practice will no longer serve future environmental requirements without significant engineering developments since, with the old technology, greater volumes and higher flow rates are accompanied by increases in fan noise.

Our development activities were initiated with the aim of successfully realizing lower ambient noises through reconciling this ambivalence of "larger air volume" and "lowering noises".

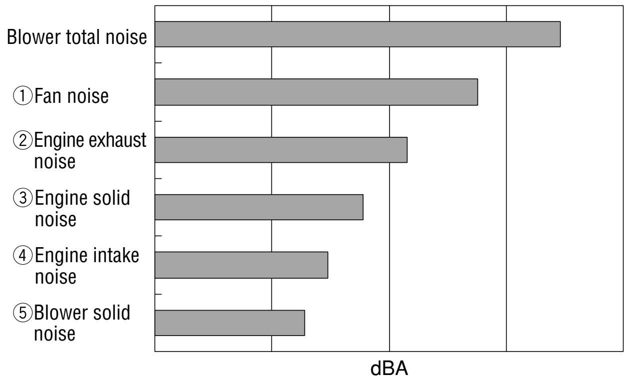


Fig. 4 Noise contribution by engine blower source

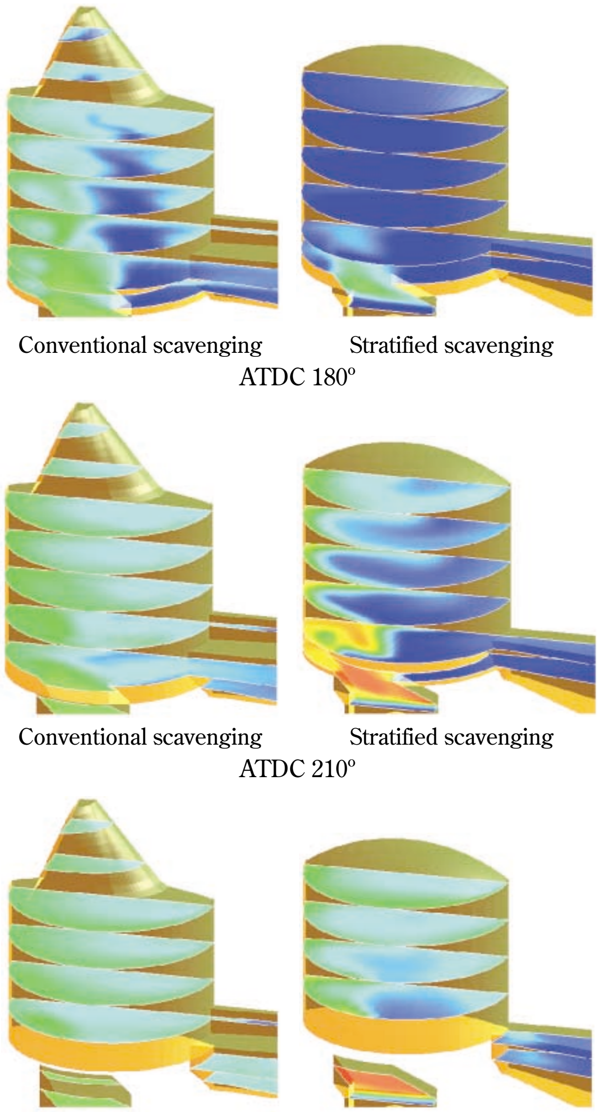


Fig. 5 Example of analysis: Comparison of mixture distribution

4. Contents of technical development activities

4.1 Reduction of mixture short-circuiting by the stratified scavenging method

In developing the new stratified scavenging mechanism, moving boundary analysis using CFD was employed in order to optimize the suction, scavenging and exhaust parameters of the engine.

Fig. 5 shows the analysis results of mixture short-circuiting in the stratified scavenging method as contrasted with scavenging in the conventional Schnuerle scavenging method.

The analysis reflects the ATDC (After Top Dead Center) position at 180°. It is understood from the photos that while a fairly large amount of mixture is filled in the conventional scavenging method, by comparison the mixture begins to be sent with a considerable time lag in the stratified scavenging method. This lag is due to air from the air-head being introduced prior to introduction of the air/fuel mixture. It can be read in the analysis that this time lag retards the onset of air/fuel mixture short-circuiting, resulting in lower mixture short-circuiting amounts.

Fig. 6 shows the results of measurements taken of the exhaust gas from an air-head stratified scavenging type engine. THC emission rate now stands at 1/3 the emission level of the conventional scavenging type engines. This achievement has enabled our new engine to meet the requirements of US EPA's Phase 2 Exhaust Gas Regulations.

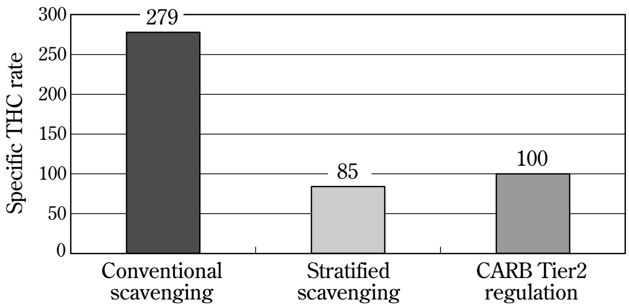


Fig. 6 Comparison of exhaust gas levels

4.2 Reduction of fan noise

4.2.1 Optimizing volute cut off geometry

Since the primary discrete noise from the fan is outstandingly high with the current shape of the volute cut off, we carried out a CFD analysis. Considering the time that was required for data calculation and model making, we made an analysis of the two dimensional cross-section. **Fig. 7** shows an example for the results of this analysis.

Prior to this CFD analysis, we had attributed the source of fan noise to periodic air compression that occurred between the fan and the cut off. However, this analysis revealed the fact that periodic air separation that occurs outside the cut off each time a fan blade passes near the cut off is largely responsible for fan noise.

As a counter-measure, the rounded portion of the cut off was enlarged to make it difficult to cause separation.

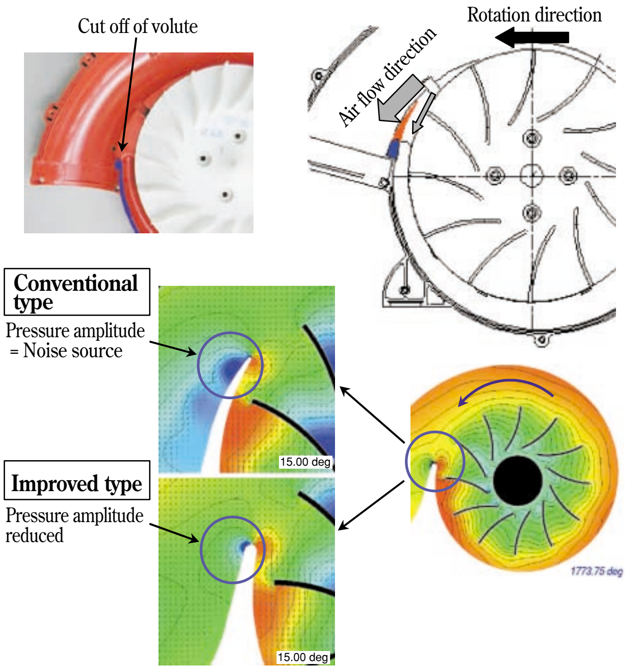


Fig. 7 Optimizing cut off geometry

4.2.2 Optimizing fan blade number and shape

With the aim of increasing air volume, we implemented a review of the blade shape through CFD. **Fig. 8** shows a sample analysis result for the two-dimensional cross-section. It became known as a result of this analysis that the conventional blade has a wide area of air separation, which is the primary cause for the reduction of fan efficiency. With engine blowers, the engine's rpm is determined by matching blade load with engine torque at full throttle. Because the rise in engine rpm is directly connected with the rise in noise, it is important to review load on the blade as well. In this analysis, we reviewed load on the blade by calculating the engine torque from pressure on the blade. The results of the analysis indicated that a reduction in the separation area leads to a reduction in blade load, while increasing engine rpm. Thus we regulated the blade load through increasing the number of blades, preventing a rise in rpm. In addition, reducing the separation area helped realize drastic reduction of the primary discrete noise from the fan. (See **Fig. 9**, **10** and **11**)

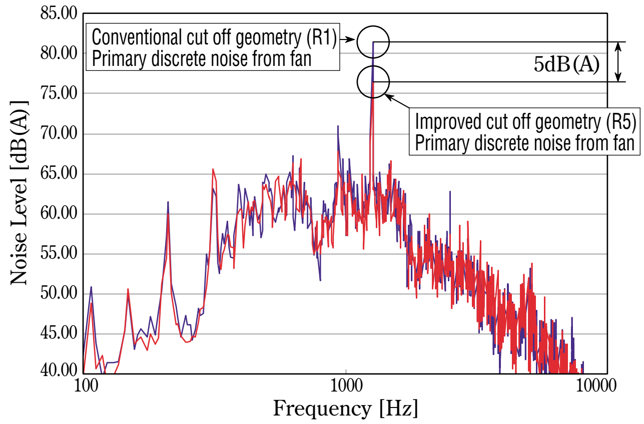


Fig. 8 Power spectrum according to difference in cut off geometry

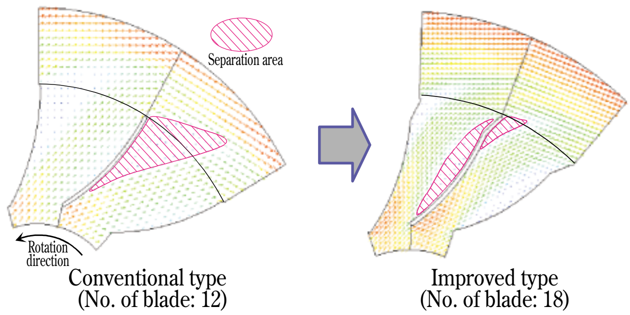
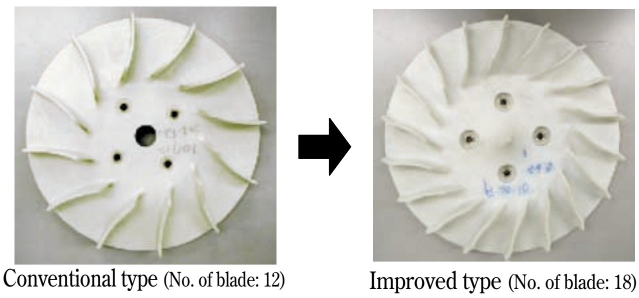


Fig. 9 Optimizing No. of fan blades and blade shape



Consistency of analysis results

	Air volume (against conventional type) (m³/min)	
Analysis value	+ 0.6	3.7 % UP
Measured value	+ 0.3	2.4 % UP

Fig. 10 Comparison of air volume by number of fan blades and blade shape

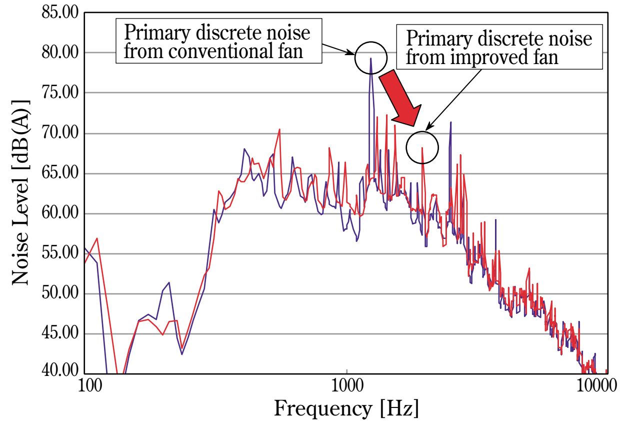


Fig. 11 Power spectrum by number of fan blades and blade shape

4.2.3 Optimizing flexible hose shape

Additional increases in air volume were brought about through the use of CFD to improve the blower tube cross-section. A sample analysis result is shown in **Fig. 12**. Analysis results for the conventional type hose reveal significant pressure loss at the outlet of the flexible hose. Hence we modified its shape as shown in Fig. 12.

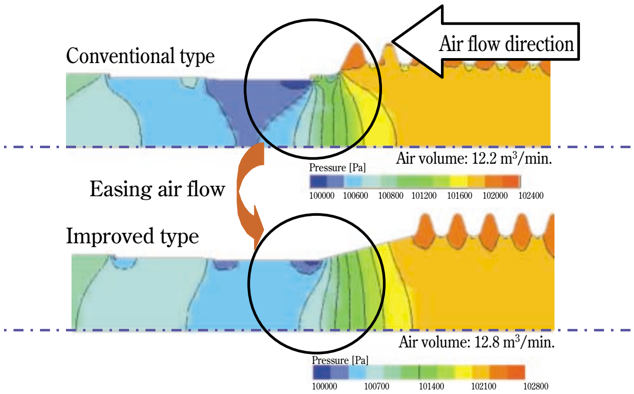


Fig. 12 Optimizing flexible hose shape

4.2.4 Optimizing blower air intake configuration

The blower's air intake configuration was also reviewed using CFD. This analysis was carried out under static conditions which did not take the fan revolution into consideration. **Fig. 13** shows the results of the analysis. It can be seen that airflow separation occurs at the inlet portion of the volute cover and at the center of the blades. For this reason, we tried to reduce air separation in the new model by providing a funnel to the inlet portion and conical protrusions on the blade center as shown in Fig. 13.

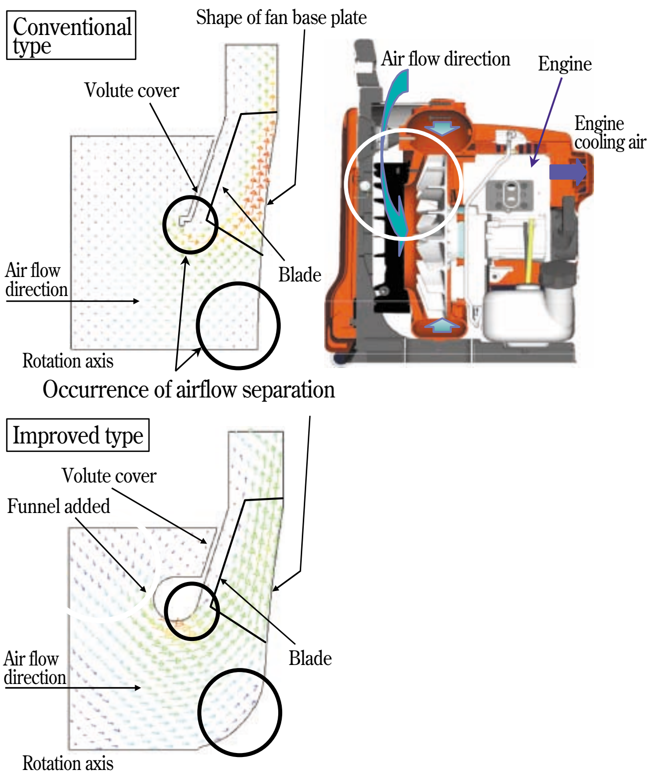


Fig. 13 Optimizing blower air intake shape

4.3 Measures against other noise sources

Measures have been carried out to reduce noise from the following sources.

① Fan noise
② Engine exhaust noise
③ Engine solid noise
④ Engine air intake noise
⑤ Blower solid noise

In this chapter, we introduce our analytical and counter-measures activities to reduce the second leading source of blower noise.

To determine the necessary counter-measures, we made a calculation for noise abatement which uses a 4-terminal matrix, and then tuned the component parts inside the exhaust muffler in accordance with frequency constituents of the exhaust noise from the test engine.

Fig. 14 contrasts calculated noise levels of the conventional exhaust muffler with those of the improved one. It is understood from the two figures that a decrease in sound level of approx. 20 dB is attained near the 1 kHz frequency where the engine exhaust noise considerably heightens.

The calculated noise values and the actual noise values measured using a loud speaker are contrasted in **Fig. 15**. Both patterns show considerable concurrence, which sustains the appropriateness of the calculation model.

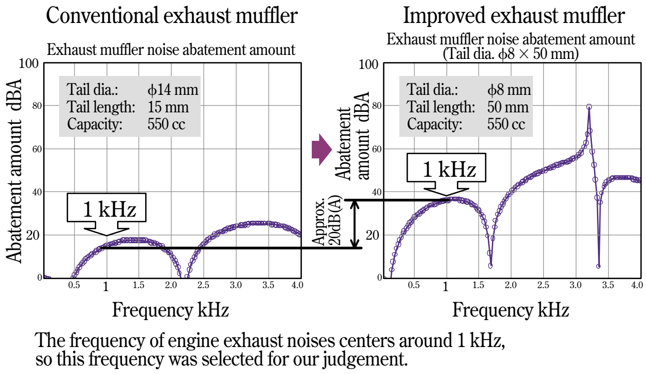


Fig. 14 Noise abatement calculation example

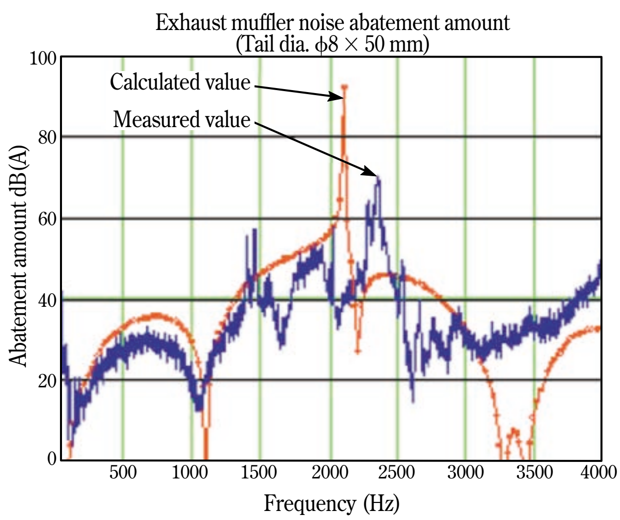


Fig. 15 Comparison of difference between calculated and measured noise abatement amounts

5. Conclusion

In this thesis, we reported instances for the use of CFD in cleaning the exhaust gas from the engine blower and in attaining compatibility between lower noise and higher performance (larger air volume).

We have proceeded with our technical development activities, implementing experiments and analyses alternately, and the results have been reflected in the development of new products. Now we have achieved the following results with our new products.

(1) Exhaust gas (THC) has been reduced by 70% as compared with conventional blowers.
(2) Noise from the blower has been reduced by 70% (–5.3 dBA) in terms of energy amount as compared with conventional blowers. The reduction in the fan noise principally contributes to the reduction as a whole.
(3) Air volume has been increased by 10% as compared with conventional blowers by optimizing the shapes of the flexible hose and blower air intake.

New blowers incorporating these features were introduced in the US market in November, 2001 and have been highly rated by our customers. We plan on applying the simulation techniques introduced in this thesis to the development of each new product in order to achieve an ever-lower level of exhaust gas and noises.

Introduction of the writers

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[A few words from the writers]

In actuality, incorporating analysis results as well as the fruits of technological development activities into a new product development process is a far more difficult job than it appears to be on the surface. To reach the level of success achieved in the development work for this product, the Analysis Group and the Product Development Group collaborated more closely than ever before.

We successfully completed our original development objective by sustaining our original motivation and “never-give-up” persistence, while suppressing the conflicting interests of our respective groups. Our high motivation level and unbroken persistence eventually bore fruit. It was indeed an irreplaceable experience to us as the engineers concerned.

It is our desire to fully utilize the advanced analysis techniques as well as expertise, and develop a new product that gives such a surprise and excitement to customers all over the world that they will utter their pleasure, saying “After having used this product, I don’t feel like using any other now”