Dramatically reducing noise

Technique to design optimum blade shapes

Shape is a crucial factor in machine design. In the development of an aircraft, for example, the shape must satisfy requirements such as high safety, light weight, and low noise at takeoff and landing. A technique called "optimization," a design technique recently used in various fields, seeks to identify the most suitable and efficient shape capable of satisfying the design requirements. Optimization using Computational Fluid Dynamics (CFD) requires a huge computing power. The requirements are so high that the technique has only become available with the recent advances in computer technology.

In research and development on a low noise passenger airplane capable of travel at supersonic speed, JAXA is applying an optimization design technique for an experimental aircraft design.

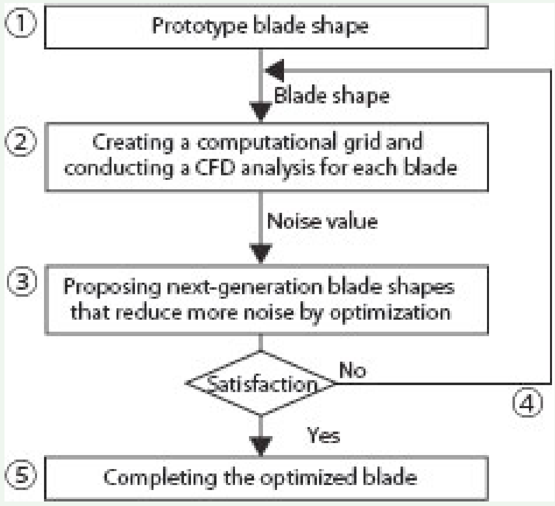
In 2007, the Numerical Analysis Group commenced joint research with Tohoku University and Pusan University of South Korea to introduce a design technique for reducing helicopter noise by optimization.

Reducing HSI noise by optimization

Two types of noise generated from the rotor blades pose major problems for helicopters (refer to here). The first is Blade-Vortex Interaction (BVI) noise, a rattling sound generated at takeoff and landing. The second is a High-Speed Impulsive (HSI) noise generated during high-speed flight.

JAXA has been conducting researches to reduce helicopter noise for many years. Top-class results on a global standard have been achieved through the agency's earlier work to clarify the mechanisms responsible for these two types of noise and to investigate the method to reduce the noises. In coming years, JAXA aims to obtain even better results by introducing the optimization design technique into its research on HSI noise reduction.

In earlier studies on conventional noise reduction, we have worked out blade shapes using parametric study, and found suitable shapes through CFD analyses and evaluations by wind tunnel experiments. It hasn't been easy, however, to determine the specific shape which can truly reduce the noise most. To obtain the most suitable shape, we combined CFD analysis with optimization technique using genetic algorithms(*) (Fig. 1).



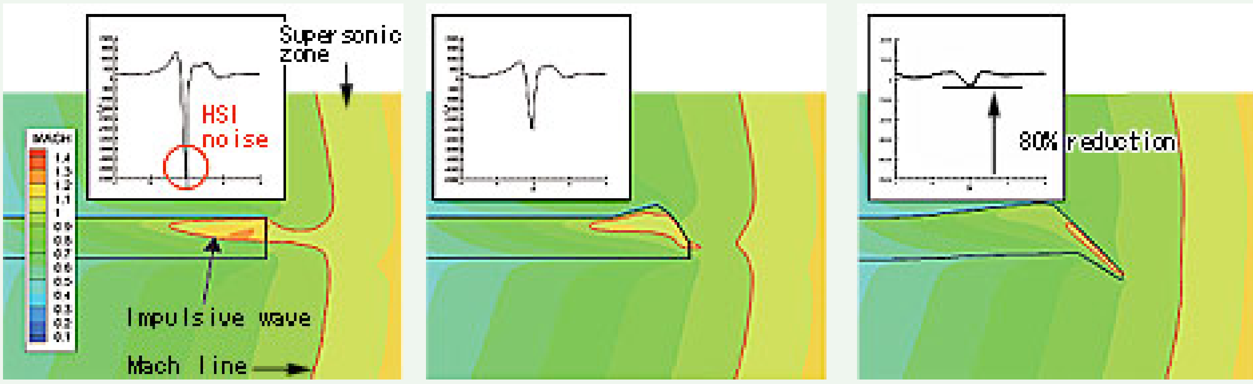
1. Randomly change the design variables that determine the shape of a blade and make several prototype blades. There is no need to consider whether the prototypes can reduce noise or not.
2. Create a computational grid and conduct a CFD analysis for each blade to obtain the noise value.
3. Have the computer analyze the noise tendency according to the blade shape, based on the value obtained in step (2). Next, have the computer propose next-generation blade shapes that reduce more noise.
4. Conduct a CFD analysis for the next-generation blade shapes proposed by the computer. If the result has yet to meet the noise-reduction targets, program in the CFD analysis values and conduct optimization again. Have the computer propose several blades with suitable shapes. (Decrease the number of proposed blades on each occasion.)
5. Obtain the blade shape that suppresses the most noise by repeating steps (2) to (4). Figure 2 shows the shape obtained and the noise characteristics. Earlier research led to a 60% reduction of the HSI noise generated from a rectangular blade. In the current research, we obtained a shape capable of reducing the noise by 80%. This far exceeds even our most successful result in the past.

Fig.1 Procedure for optimization

Future research and development

The first step of our research was to obtain the blade planform most suitable to reduce HSI noise. In the future, we aim to establish the three-dimensional optimum blade design method focused on various factors such as performance, BVI noise, and structure, besides the HSI noise reduction itself.

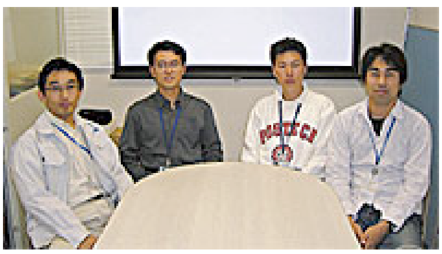
(*) Genetic algorithm : a heuristic algorithm simulating the process of an organism's adaptation to the environment and evolution through an engineering approach.



Rectangular blade | Shape obtained previously | Shape obtained from this research

A helicopter's blade rotates counterclockwise, as seen from above. The speed of the inflow colliding with the blade tip reaches its highest value when the blade occupies the three o'clock position relative to the forward movement of the helicopter in the 12 o'clock direction during high-speed flight. A supersonic (Mach) zone appears above the blade as a result, causing an impulsive wave. A strong HSI noise is generated when this supersonic zone is connected to the outer supersonic zone seen from the rotating blade. With the shape obtained from the present research, these two supersonic zones are disconnected and the magnitude of the generated impulsive wave itself is suppressed.

Fig.2 Comparison of analysis results



[Numerical Analysis Group]

(from left) Takashi Aoyama, Sanghyun Chae, Choongmo Yang, Atsushi Hashimoto

Intermission Break

Helicopter noise

Unlike airplanes, helicopters can take off vertically, without long strips of land for runways. For this reason, helicopters can be mobilized for important disaster-management tasks impossible to accomplish via overland transport routes such as roads or railroads. 'Doctor helicopters' fly in medical personnel, while other helicopters dust crops or take news photographs from the sky. Yet the big noise of helicopters is an obstacle to operation in densely populated areas and during nighttime. This prevents us from bringing the potential of helicopters into full play.

Helicopters generate various types of noise (Fig. 1). Especially problematic are the HSI noise generated during high-speed flight and the BVI noise noticeable at landing. A helicopter obtains lift and thrust from a rotor rotating directly above the cabin. The rotor consists of two to six plate-like wings, or blades. The rotation of the rotor blades generates a strong vortex (wing tip vortex) from the wing tip. BVI noise is characterized by a flap-flap sound generated by the slashing of the wing tip vortex by the blade.

JAXA is researching air currents around helicopters and aerodynamic noise through CFD analysis (Fig.2). We are making the most of the results obtained through our CFD analysis to design low-resistance airframes, develop methods to analyze noise, develop noise-reduction technologies, and so on. In one project, we are using CFD analysis results to research a blade shape that can reduce HSI noise (refer to page 1) In another, we are designing a next-generation low-noise blade to drastically reduce BVI noise and effectively suppress helicopter vibration.

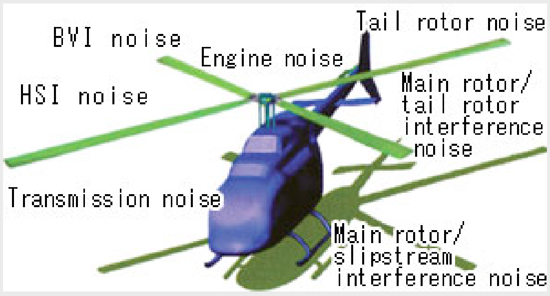
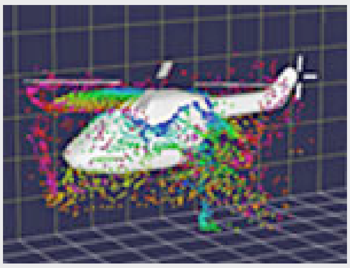
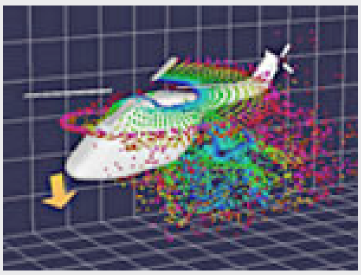


Fig.1 Various types of noises generated by helicopters


Fig.3 MUPAL- ε , an experimental helicopter

It will be possible, as a matter of course, to reduce noise by carefully designing the blade shape. We can also reduce noise, in relative terms, by choosing a specific flight path. If we can set a flight path based on land usage conditions and avoid densely populated areas, particularly those with noise-sensitive institutions such as hospitals and schools, we can control the level of noise experienced by people on the ground. Thus, we have developed a system to optimize a flight path in real time to reduce helicopter noise for ground dwellers, and to display the flight path and guide the aircraft accordingly. MUPAL-e(upsilon), an experimental helicopter owned by JAXA, plays an important part in this research and development (Fig.3).


Hovering


Transitional flight

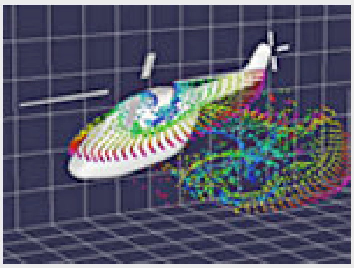

Advancing flight

Fig.2 View of a flow field around the whole airframe of a helicopter