# A Conceptual Design of Active Tab for Mach scaled Model Blade Installation

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## ABSTRACT

JAXA has researched Active Tab as one of the active techniques for helicopter BVI (Blade/Vortex Interaction) noise reduction. A conceptual design study of Active Tab installed in a Mach scaled assumed blade is carried out. A single stacked piezo actuator stored in a casing inside the blade generates a linear reciprocal movement, which is magnified by an amplifier. Then, Active Tab is driven via a pivot in a rotational reciprocal direction. The drive mechanism of Active Tab has a practical size to be completely stored inside the assumed blade. Consequently, the conceptual study result of Active Tab system applicable to the 2m radius and 0.12m chord blade is obtained.

## INTRODUCTION

Among the noises generated by helicopters, the BVI noise causes significant damage and cannot be well reduced by passive techniques such as airfoil/tip shape improvement. In order to resolve this BVI noise problem, many research organizations and helicopter manufactures have been working to research/develop BVI noise reduction techniques for these decades as one of the high priority technical tasks [1]-[19].

JAXA (Japan Aerospace Exploration Agency) and Kawada Industries Inc. have been working to research and develop a new active technique for helicopter noise reduction which is available to ICAO defined flight patterns, namely approach, fly over and take-off [20]. This new technique is referred as "Active Tab" [21]-[24]. The schematic view of the active tab is shown in Fig.1. The active tab is installed in the aft portion of the airfoil and driven back and forth dynamically to reduce BVI noise and the vibration by the blade circulation control due to the variable blade area effect.

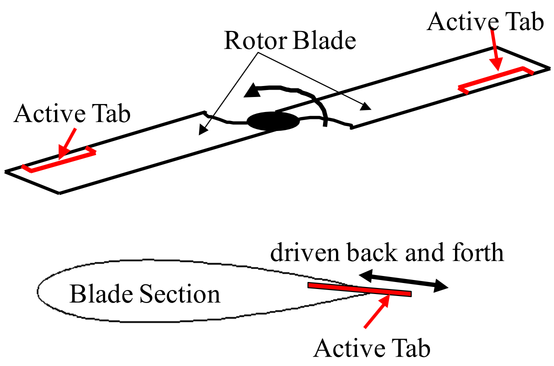



Figure 1: Active tab concept

The outline of this research program is depicted in Fig.2. We started in 2002 to study the fundamental tab aerodynamic property by a 2D static wind tunnel test, then proceeded to 2D dynamic wind tunnel test in 2003 to examine the tab dynamic effect. This step of the study showed that a realistic size and anhedral of the active tab has sufficient aerodynamic capability equivalent to the potential for rotor noise reduction. CFD analysis simultaneously started to propose aerodynamically effective tab geometry [25].

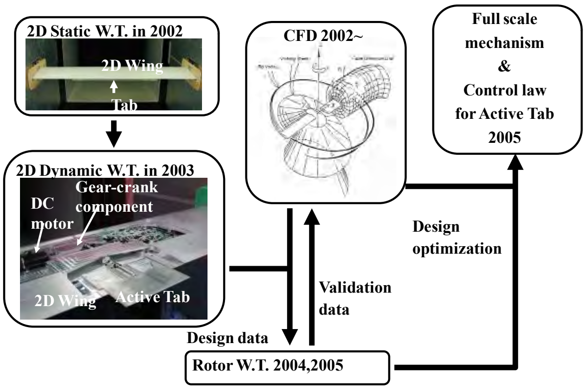



Figure 2: Active Tab research program

In 2004 and 2005, the rotor wind tunnel test using one-bladed rotor system as shown in Fig. 3 was carried out in a rotor configuration with on-blade active tab to evaluate the active tab effect on rotor noise reduction and to provide the validation data for CDF code development.

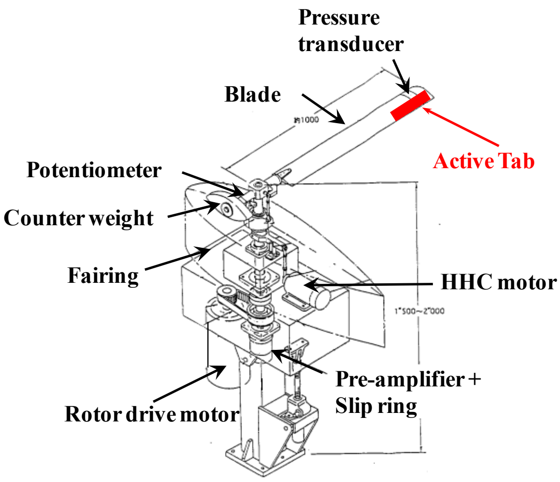


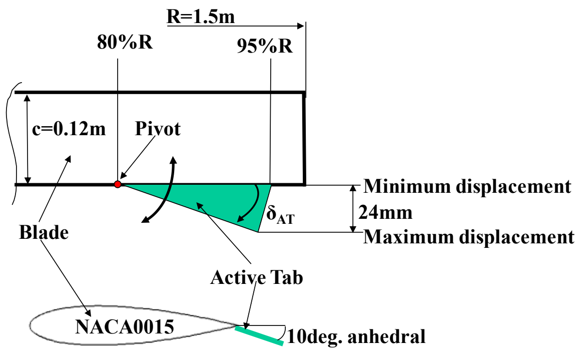

Figure 3: One-bladed rotor system with Active Tab

It is demonstrated by this wind tunnel test in a rotor configuration that Active Tab has the efficient capability to control the rotor noise about 3dB and that Active Tab is one of the promising techniques for rotor noise reduction.

The next step is established to demonstrate Active Tab capability on a Mach scaled condition because the above mentioned rotor wind tunnel test was carried out by a one-bladed rotor system as the first step to evaluate Active Tab performance on low subsonic test conditions where the blade tip speed is less than 100m/sec. This paper presents a conceptual design study of Active Tab in order to be installed in a Mach scaled assumed blade.

## ASSUMED BLADE AND ACTIVE TAB GEOMETRY

Based on the achievement of wind tunnel test by one-bladed rotor system, the features of Active Tab for the Mach scaled blade are defined and its schematic drawing is shown in Fig.4.




Rotor speed : 1333rpm
Rotor radius : 1.5m
Blade chord : 0.12m
Plan form : rectangular
Airfoil : NACA0015
Twist : -8deg. linear

Figure4: Active Tab installation

The tab is fan-shaped so that the extended area generated by the tab operation is made larger in the outer portion of the blade. A 10deg. anhedral angle is put to the tab so that the tab effect to the blade lift increment is augmented. This active tab is pivoted at its apex to 80%R location of the blade. NACA0015 is selected as the airfoil of the blade in order to provide as large thickness to store the drive mechanism of Active Tab as possible without significant disadvantage to the maximum lift of the blade.

## REQUIREMENTS

Based on the experimental results, the requirement for Active Tab is set up as follows.

Active Tab :

Span length : 80-95%R
Displacement : 24mm
Frequency : 2/rev

Instrumentation :

Active Tab displacement
Hinge moment

## CONFIGURATION SELECTION

### Types of drive mechanism

As the initial step of the conceptual design, four types of the drive mechanism are considered and merits and demerits of each type are discussed to select the proper solution for Active Tab system.

### The first type

is the piezo actuator with elastic hinges as shown in Fig.5. The displacement generated by the piezo actuator is augmented by the double armed amplifier. There is a difference in stiffness between the two arms, which transforms a liner movement from the actuator into a rotary displacement of the arms around the pivot and Active Tab is driven back and forth. A counter weight is connected on the opposite side of Active Tab across the pivot in order to cancel the centrifugal force acting about the pivot.

The merit of this type is that the elastic hinge can significantly reduce the free play which can be easily generated by the conventional mechanism such that using bearings. Another merit is that the target Active Tab displacement can be obtained by the lower actuation power. The challenging part is that the size (thickness) of the piezo actuator must be less than the blade thickness which is 0.12m *0.15=0.018m, although this challenge can be accomplished by using the existing stack piled piezo unit.

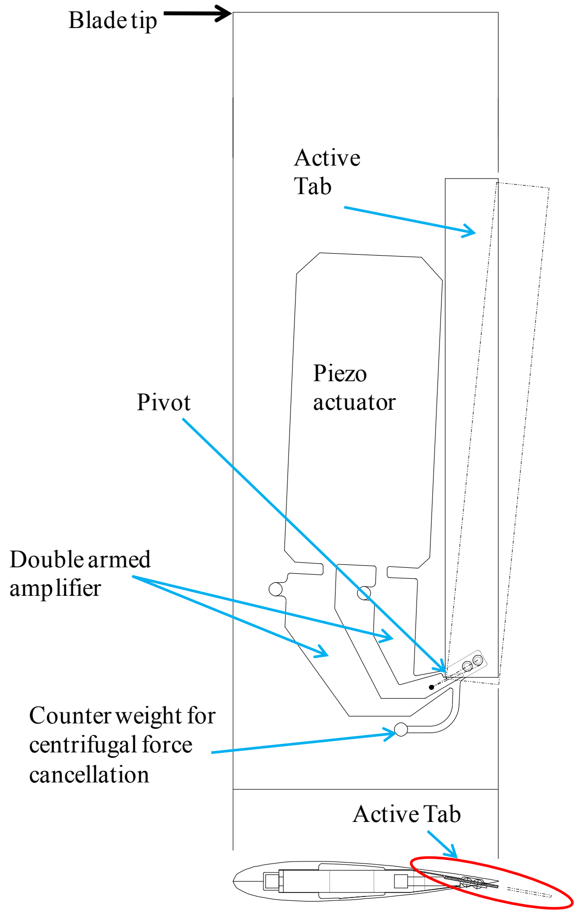



Figure 5: Drive mechanism : piezo actuator with elastic hinges

### The second type

is the servo motor with an eccentric cam as shown in Fig.6. The inner eccentric cam rotated by the two servo motor generates a linear reciprocal movement which is transmitted to the outer eccentric cam via. the ball bearing. The push-pull linkage connected to the outer eccentric cam drives Active Tab around the pivot. A counter weight is installed on the opposite side of Active Tab across the pivot in order to cancel the centrifugal force acting about the pivot.

The advantage of this type is availability for high frequency movement of Active Tab. The drawbacks are some free play caused by the couplings between the servo motors and the axle and by the ball bearing between the inner and the outer eccentric cams. The bearing on the end of the push-pull linkage may yield free play. Furthermore, it is also a disadvantage that the only pre-set Active Tab displacement depending on the eccentricity of the cam can be applicable.

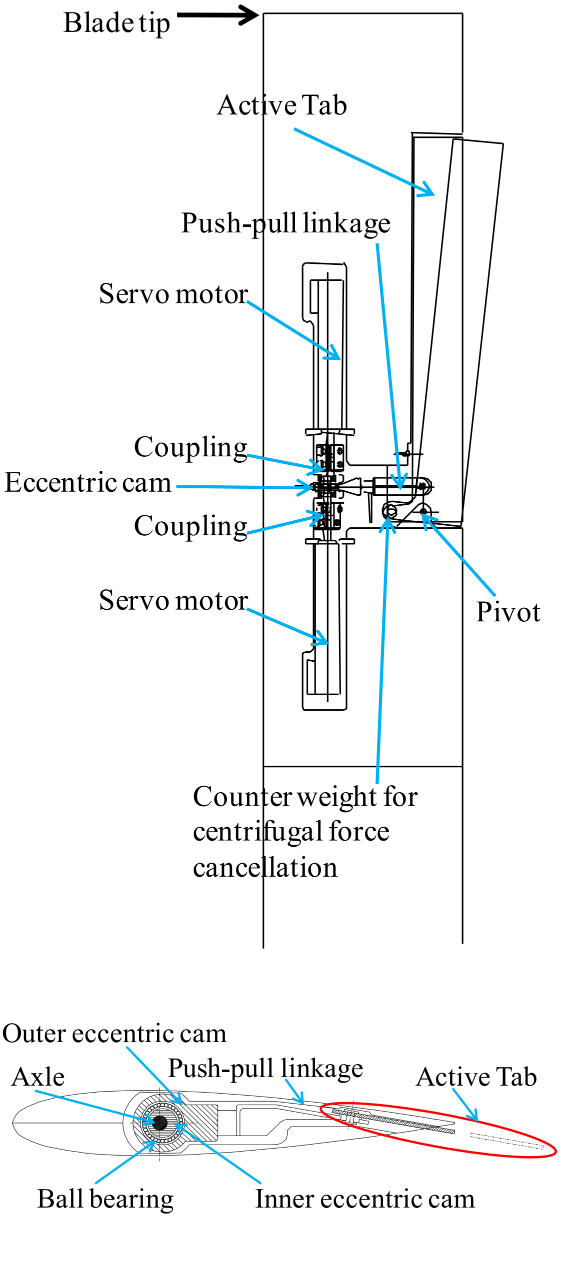



Figure6: Drive mechanism : servo motor with eccentric cam

**The third type**

is the bell crank driven by linear motors as shown in Fig. 7. The displacements generated by the four linear motors are combined into and amplified by the bell crank. The push-pull linkage connected to the bell crank transmits this movement to Active Tab.

The advantage of this type is that the drive mechanism can be very conventional. The drawback is some free play caused by bearings put in the bell crank and on the both ends of the push-pull linkage.

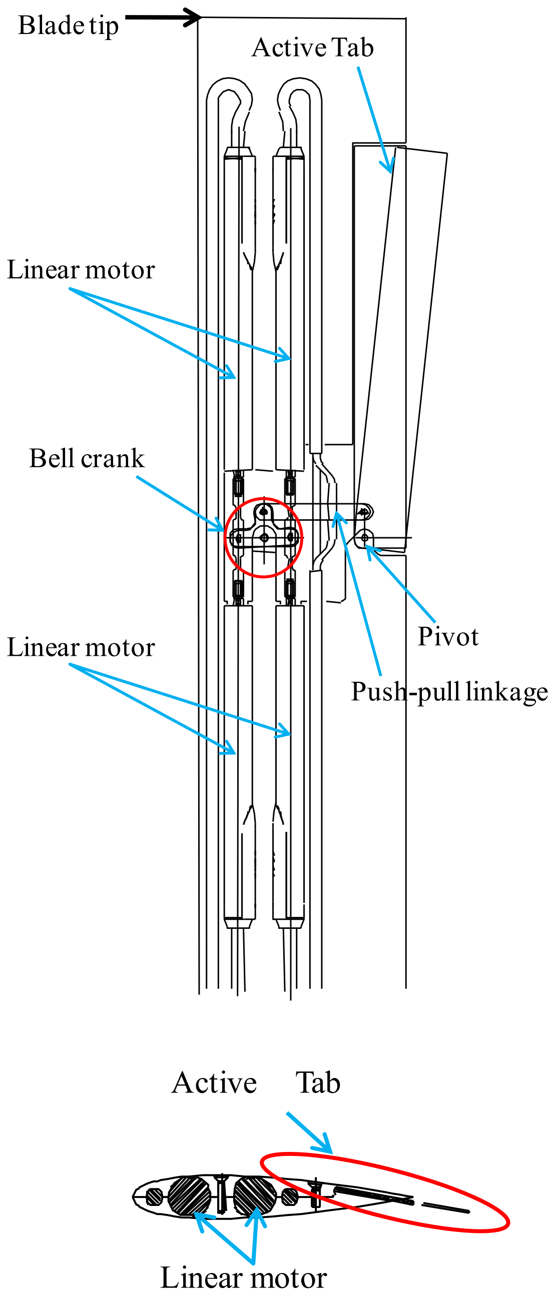



Figure 7: Drive mechanism : linear motor with bell crank

**The fourth type**

is the electro-magnetic solenoid with a sheet spring as shown in Fig. 8. The actuator plunger in the solenoid transmits the movement to the sheet spring which is connected between the actuator plunger and Active Tab. A counter weight is coupled with the actuator plunger in order to suppress the blade spanwise vibration generated by the actuator plunger oscillation. The advantage of this type is that the drive mechanism can be very conventional and the free play can be almost eliminated. The drawback is difficulty in operability at the high frequency region because of the large inertia of the actuator plunger supplemented by the counter weight. Furthermore, the signals from sensors may be contaminated by the electro-magnetic solenoid which may generate EMI (Electro-Magnetic Interference).

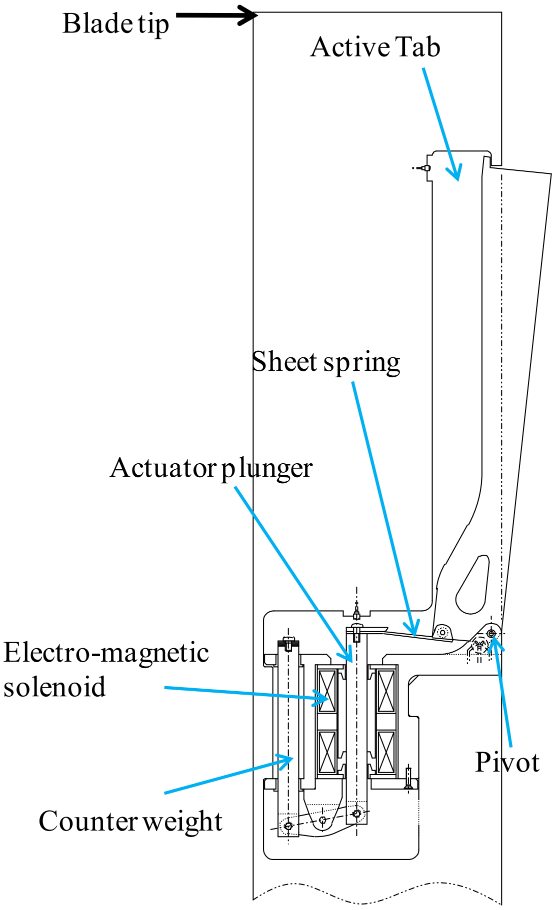



Figure 8: Drive mechanism : electro-magnetic solenoid with sheet spring

**Trade off**

The trade off to select the proper type of Active Tab drive mechanism among the four is carried out with respect to the following points of view;

- operability at high frequency
- tolerance to centrifugal force
- controllability of Active Tab displacement
- size to be installed in the blade

As above mentioned merit/demerit or advantage/disadvantage description for each type of Active Tab drive mechanism, the first type, the piezo actuator with elastic hinges as shown in Fig.5 is considered the best among the four candidates. Especially, the small amount of the free play by the elastic hinges of this type is the most important factor to realize Active Tab drive mechanism to be stored in the blade.

## SYSTEM DESIGN

The selected drive mechanism of Active Tab is shown three dimensionally in Fig.9.

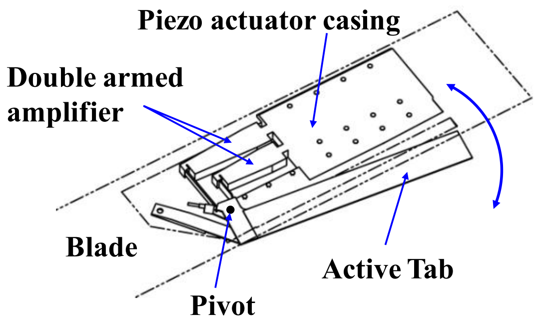



Figure9: Drive mechanism of Active Tab

A single stacked piezo actuator stored in a casing generates a linear reciprocal movement, which is magnified by the double armed amplifier. Then, Active Tab is driven via a pivot in a rotational reciprocal direction.

**Counter weight for centrifugal force cancellation**

The counter weight is connected to the amplifier arm in order to cancel the centrifugal force acting about the pivot as shown in Fig.10.

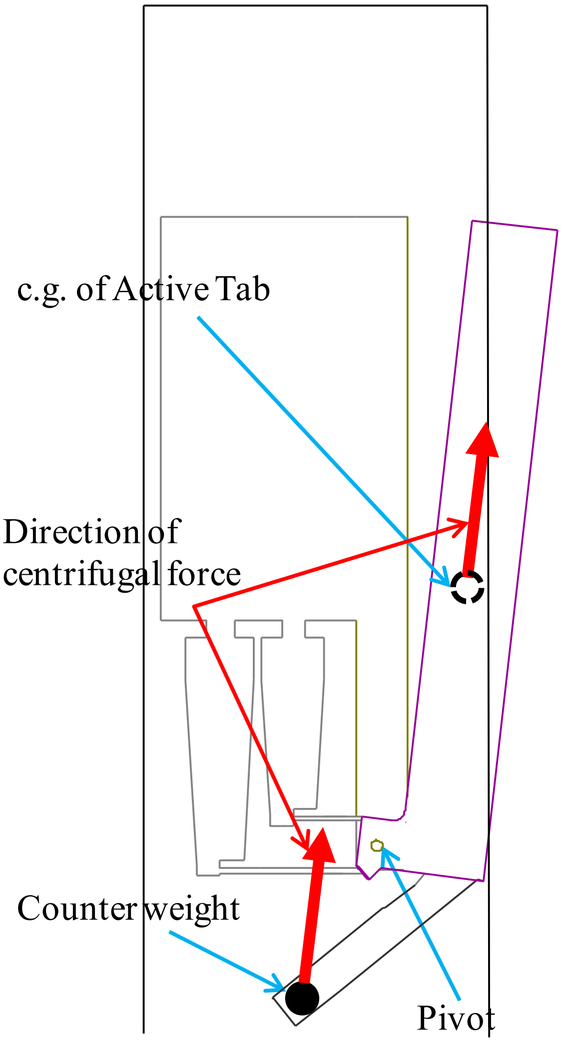



Figure10: Counter weight installation

The centrifugal force is reduced by the counter weight at the cost of increased inertia. As the centrifugal force is one of the dominant factors for constructing the drive mechanism, the counter weight can be an essential component of the drive mechanism.

**Instrumentation**

Fig.11 shows the instrumentation of the Active Tab drive mechanism satisfying the requirements as described above. The hinge moment is measured by the strain gauges on the two arms of the amplifier. The difference between the two gauge output is reduced to quantify the hinge moment. The output displacement of the double armed amplifier is also measured by these strain gauges. The eddy current displacement sensor measures the unsteady Active Tab displacement.

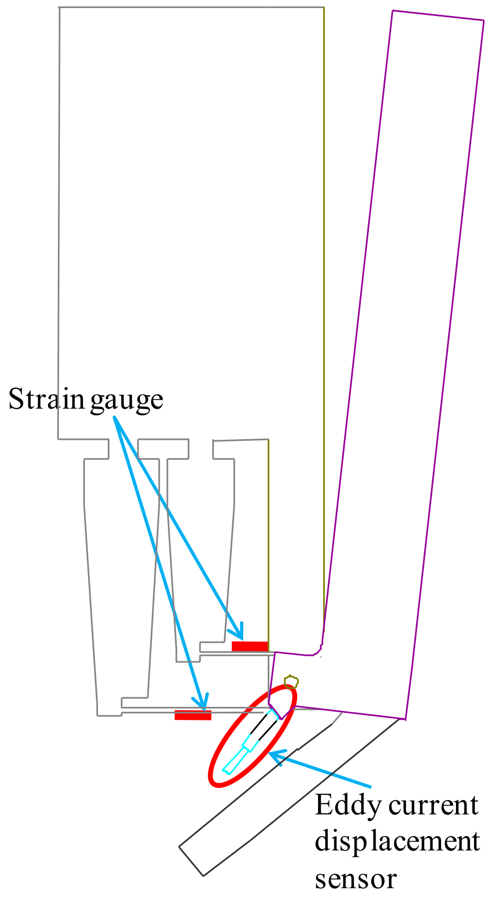



Figure11: Instrumentation

**Friction reduction for Active Tab operation**

Fig.12 shows the opening of the trailing edge part of the blade near Active Tab with the friction reduction measure. The aerodynamic lift acts on Active Tab, which pushes up/down Active Tab to the inside structure of the blade. The friction force acting between Active Tab and the inside structure may prevent the smooth operation of Active Tab or even causes the abrasion damage on Active Tab. In order to reduce this friction force, Teflon film is put on the surfaces of the inside structure of the blade. The advantage of this solid lubrication measure is free from lubrication maintenance such as oiling and greasing.

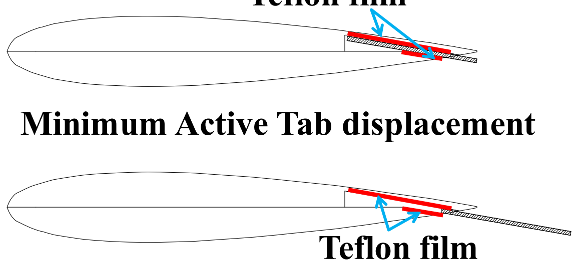



Figure12: Friction reduction measure for Active Tab operation

## CONCLUSIONS

Summarizing the results, the followings are concluded by this study.

1. The four types of the drive mechanism are considered and merits and demerits of each type are discussed to select the proper solution for Active Tab system, namely, the piezo actuator with elastic hinges, the servo motor with an eccentric cam, the bell crank driven by linear motors and the electro-magnetic solenoid with a sheet spring.

2. The piezo actuator with elastic hinges is selected as the drive mechanism of Active Tab by the trade off carried out with respect to the following four points of view;
   -operability at high frequency
   -tolerance to centrifugal force
   -controllability of Active Tab displacement
   -size to be installed in the blade

3. Based on the conceptual design to achieve 24mm displacement at 2/rev (44Hz) for BVI noise reduction, the drive system is designed including the piezo actuator with the elastic hinges to suppress free play to obtain target amplitude by lower actuation power. The drive mechanism of Active Tab has a practical size to be completely stored inside the assumed blade.

4. In order to reduce the friction force acting between Active Tab and the inside structure of the blade, Teflon film is put on the surfaces of the inside structure of the blade.

## FUTURE WORKS

In order to validate the result of this conceptual design, a prototype of Active Tab system is to be built up and the bench test is performed in the next step.

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