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A Review on Vibration Analysis of Helicopter Rotor Blade

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Abstract: Vibration has always been a major disturbance for helicopter. Vibrations, thus, a threat to components of helicopter. The vibration created by a helicopter draws a great contribution to the reduction in life of the components. Reducing the vibration that creates from helicopter rotor blades, tail rotors is a one step closer to this crisis. Helicopter Vibration control is a topic of research into designing helicopter rotor blade which can be operated more efficiently. The major source of the vibration come from the rotor blade rotation. By trying to upgrade new design in the helicopter main rotor blades and tail rotors reduce the vibration and make the operation more efficient. This paper addresses simulation and analysis of vibration level of rotor blades.

Keywords: drag, rotor, vibration, air foil, blade profile.

I. INTRODUCTION

A helicopter is a type of rotorcraft in which lift, and thrust are supplied by horizontally spinning rotors. This allows the helicopter to take off and land vertically, to hover, and to fly forward, backward, and laterally. These attributes allow helicopters to be used in congested or isolated areas where fixed-wing aircraft and many forms of STOL or STOVL aircraft cannot perform without runway. Helicopter provides plethora of facilities, the vibration from the rotor blades causes some aerodynamic loses. So, reducing the vibration that creates from helicopter rotor blades will reduce some aerodynamics loses. The vibrations of two types: lateral and vertical vibrations. These vibrations can also occur when certain helicopter components fall out of alignment or are in disrepair. Certain imbalances or cracked, loose, or worn-out parts can cause lateral vibrations. And if a rotor blade becomes misaligned, this can cause a vertical vibration. Excessive vibration of main and tail rotors can cause the tail section of helicopters to be physically ripped from the main structural assembly, and result in catastrophe. Severe imbalance in the rotating parts also can lead to instabilities during flight making control difficult, if not impossible. Severe vibration can also affect avionics and navigation equipment onboard the fight deck. To overcome this there can made some changes in the rotor blades or by simulating a new upgraded design may help in proper motion of the helicopter and this paper deals with some ideas on vibration reduction in rotor blades, simulation, and theories on this topic. Fig.1 shows a typical helicopter part.

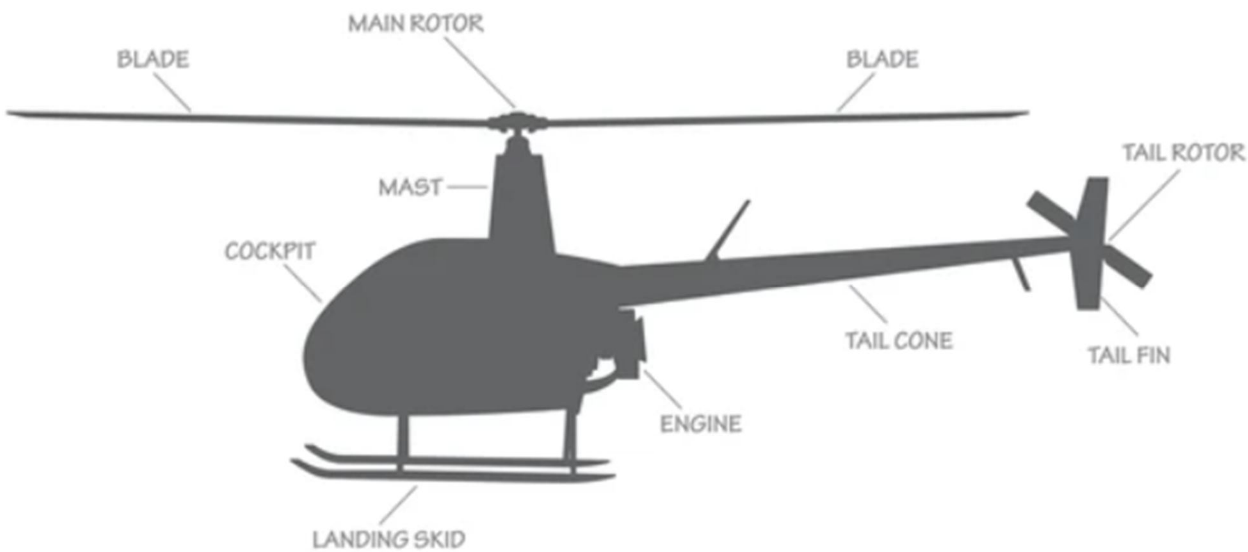

Fig.1 Typical Helicopter Part

II. LITERATURE REVIEW

Noise in helicopters is a major concern, from environmental impact to making enemies alarmed in military helicopters. It can even be a headache for passengers because of the continuous buzzing noise. In this experiment, spoilers attached to the trailing edge of the rotor blades are used to reduce the noise and vibration, thus increasing its efficiency. The rubber spoilers taken are of two types- silicone and neoprene. The noise level (in dB) was measured using IR sensors. The rotor Blades with and without spoilers were measured. Both spoilers (silicone and neoprene rubber) resulted in the reduction of the noise level by several decibels compared to the one without spoilers. Fig 2 shows the proposed design of the helicopter. [1]

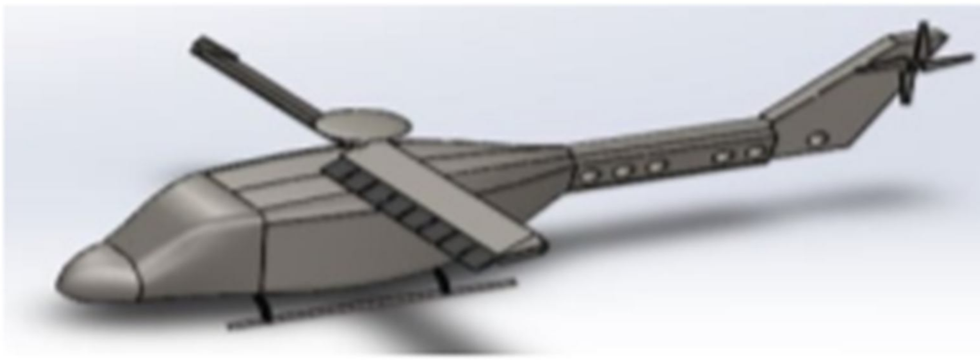

Fig.2 Proposed Design of a Helicopter with spoilers.

Vibration is obvious to nearly all aspects of chopper operation, including fatigue of aviators and to its structural integrity. The vibration characteristics of rotating shafts vary from that of nonrotating shafts due to coupling of elastic distortion and rigid body stir. A dynamic stiffness system was used to determine the vibration characteristics for rotating ray. Vibration characteristics of a multibody system similar as a mortal body, robots, spacecraft, and vehicles can be modelled. The styles to study vibration characteristics of mechanical system are substantially finite element system (FEM), structural modal conflation, and modal analysis. Flap wise climate of copter rotor blades differ from those of other slender shafts because of centrifugal force fields.[2]
The blade pre-twist has been studied considerably and extensively employed in rotor blade design to achieve better performance in hang and further flight. The effect of dynamic blade shape approaches including airfoil morphing, blade twist, variable rotor speed and variable rotor compass on copter rotor performance have been studied. The most representative study is the ATR, which has tested hang and further flight to demonstrate vibration and noise reduction using open- circle and unrestricted- circle control. Other studies use multi-harmonic actuation that consists of variety control factors. To negotiate active twist rotor in field. Fig.3 Two-piece blade concept of PLTC [3]

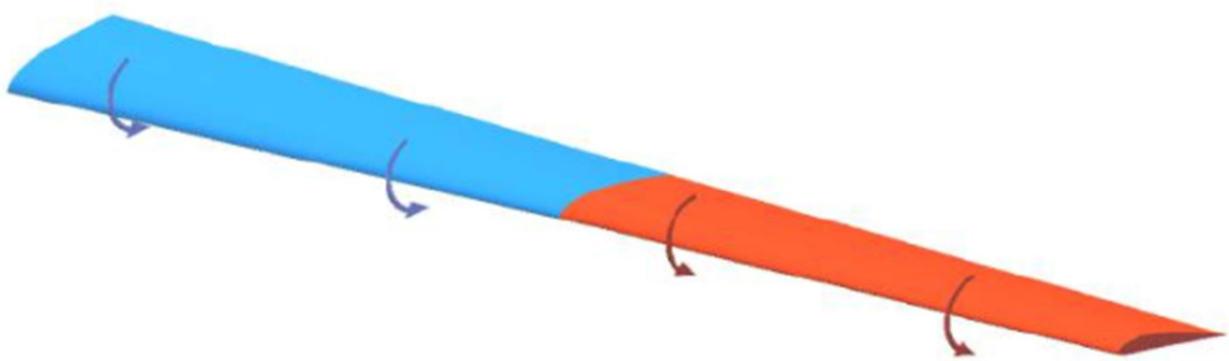

Fig.3 Two-piece blade concept of PLTC

Numerous engineering operations have rotor- blade systems as their main element, for which active control has been an engaging approach to upgrade performance and suppress climate. Passive damping methods aren't suitable to attain advanced effectiveness in a two-dimensional system whose dynamics is periodic. Utmost of the results available in the literature are based on direct time in variant analysis and mixture ways. The rotor- blade system under investigation is a four-blade rotor with tip masses, rotating in a suspended axis. Fig.4 Two-dimensional four-blade rotor system. [4]

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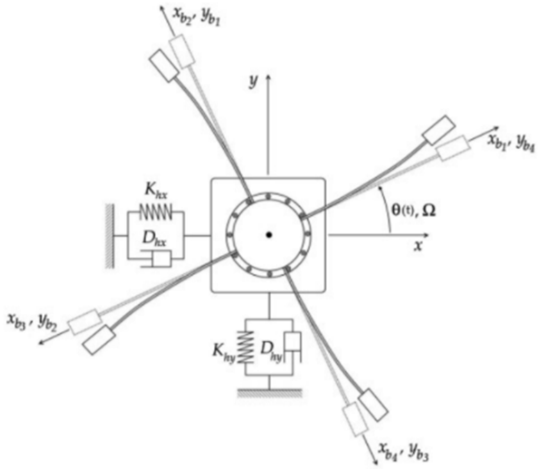

Fig.4 Two-dimensional four-blade rotor system.

The main comfort issues affecting passenger comfort in a turboprop aircraft fuselage are the propeller tonal noise and the affiliated climate. The main noise sources during flight are generated by the propeller's rotational angular velocity, number of blades, power at shaft generating aircraft thrust, and blade configuration. An innovative tolerating bi-tonal device able to optimize the fuselage noise reduction at two different flight administrations has been designed and numerically certified. Due to specific marketable needs, the use of bi-tuned frequency can lead to an unresisting noise reduction with two RPM administrations: 100 at take-off, rise, and approach, and 86 during the cruise, rising, and descent. The vibration of the fuselage of a turboprop aircraft can be tuned at two different frequencies to reduce noise with respect to two different flight administrations. For the two propeller tones, reductions of 32.8 dB and 27.9 dB have been estimated for the two vibration situations. Primary results from this stage encourage the advancement of the disquisition.

This paper deals with the design and numerical simulations of a new unresistant bi-tonal device suitable to be tuned at two different frequencies to reduce the fuselage noise with respect to two different flight administrations.[5]

A helicopter main rotor or rotor system is the combination of a rotary-wing and a control system that generates the aerodynamic lift force that supports the weight of the helo and the thrust that counteracts aerodynamic drag in forward flight. An Active Twist Rotor (ATR) is being developed for the coming implementation of individual blade control for vibration and noise reduction in helos. The rotor blade is integrally twisted by direct strain actuation using active fibre mixes (AFC). 3D models are designed and broken down in CATIA and Ansys. Juan de la Cierva's rotor blade is the basis of the most multi-bladed helo rotor systems. Arthur Young's stabiliser bar was used in several Bell and Hiller chopper models in the 1930s. Alphonse Pénaud's coaxial rotor model chopper toys inspired the Wright brothers to dream of flight. [6]

For a given machine power and RPM input, the most fruitful area for enhancement in effectiveness by propeller design is a reduction in energy losses.

The simple ways to increase the effectiveness are the reduction of blade area, adding cargo near the tip, and taking up a larger periphery with low RPM. Vibration and noise will be the first issues when a developer tries to refine the effectiveness of the propeller. In conclusion, it can be said that the NPT design procedure has been extended to take account of the commerce between the propeller and the housing. A simple system has been developed which can reliably predict pressure impulse situations for different propeller shapes and housing forms during the design process.[7]

Aeroacoustics rotor simulations are based on aerodynamic and aeroelastic tools able to foretell the wake–blade miss distance, which plays a key part in the blade–whirlpool interaction noise discharge. The control law is linked through a numerically effective aeroacoustics solver grounded on logical-numeric sectional aerodynamics modelling. Its revision is the main ideal of the proposed regulatory action. It's grounded in an optimal, multicycle, control approach that exploits distributed torque loads actuated by smart materials to twist rotor blades at the 2/rev frequency (active twist rotor conception). Eventually, the effectiveness of the proposed low-frequency feedback control law for blade–whirlpool commerce noise relief is assessed by the operation of the helo rotor in descent flight. They've developed a control algorithm grounded in ATR control law aimed at reducing copter rotor noise. The proposed noise control methodology seems to be a good candidate for rotor noise relief in real copter flight operations.[8]

For a design detail with given machine power and RPM input, the most fruitful area for enhancement in effectiveness by propeller design is a reduction in energy losses. The simple way to increase the effectiveness is reduction of blade area, adding cargo near the tip and espousing a larger periphery with low RPM. In the last many times orders for over 150 NPT propellers have been secured by SMP, substantially for Far Eastern ockyards, with numerous vessels fated for Western possessors. One intriguing specific of the NPT design was that the relinquishment of the new profile family reduced the optimum periphery below that of the optimum periphery of conventional propellers designed for the same installation. This involves incorporating the housing and propeller commerce factors into the boat design process at an early stage. To completely exploit the eventuality for bettered overall effectiveness and reduced excitation forces the NPT design system was expanded into a further holistic approach where relations with the housing and goods on the housing were considered at an early stage in the propeller design process.[9]

The control law is grounded on a numerically effective aeroacoustics solver grounded on logical – numerical sectional aerodynamics modelling. It exploits distributed necklace loads actuated by smart accoutrements to twist rotor blades at the 2/ rev frequency (active twist rotor conception). A lot of attention is given to noise produced by main rotor when blade – whirlpool relations (BVI noise) do. For BVI noise relief, active control systems feel to be particularly suitable because of the redundant power available to selectors in low- speed flight. Eventually effectiveness of the proposed low- frequency feedback control law for blade – whirlpool commerce noise relief is assessed by operation to copter rotor in descent flight. The IBC approach, in which each blade is controlled in the rotating frame, appears to be more effective than the HHC approach. Downsides include weight and complexity and vulnerability of actuation bias. Starting from these considerations, this work concerns the development of an individual blade control algorithm for reducing BVI noise emitted by copter rotors.[10]

A control calculation fit for both vibration control and in-flight cutting-edge following has been created by DLR and Politecnico di Milano. Air stream tests were completed on a 5-bladed rotor framework at the German Dutch Wind Tunnels. The reconciliation of the control calculation into the ongoing control programming is displayed for the META framework, where, for security reasons, a semi-open circle approach was executed. With the DLR's protected various swashplate control framework (META), it is workable interestingly to acknowledge completely individual cutting-edge control on a rotor with up to six edges. The META went through broad air stream tests in the enormous low-speed office of DNW (Deutsch Niederla¨ndischer Windkanal) in late 2015.[11]

In the early times of helo flight, airman/ passenger comfort was of minimum significance compared with flight safety. This composition offers a new perspective in defining comfortable copter flight along with two results grounded on unresistant and active main rotor morphing. Constrained optimization design problems aimed at minimizing flight control energy and satisfying friction constraints on flight parameters are answered. Details on the calculation of the control energy are given. Copter control is a critical enabling technology; thus, a review of copter control is obligatory. For the first comfort interpretation, when values veritably near to the attainable OVC friction bounds are used, the control trouble needed is veritably large. When active morphing is used for the same purpose (i.e., satisfaction of specified friction constraints on Euler angles) a much larger relative energy saving is observed. When active morphing is used for the same purpose (i.e., satisfaction of specified friction constraints on Euler angles) a much larger relative saving in control energy is observed.[12]

Generally, rotorcraft with variable speed rotors is used to bring fuel consumptions, performance improvement and noise emission, but this is limited because of encountering numerous natural frequencies by which the main rotor can be excited. This paper's objectives are performance improvement, noise reduction and fuel-consumption efficiency. A shift of natural frequencies is occurred at main rotor blade due to various rotor speeds, that's why a concept of an active tendon, a tensile structure is putting into a rotor blade to control its dynamic properties. This mechanism will help to adaptively avoid harmful rotor resonances in various flight regimes. A case study of Bo 105 helicopter, with 60%-120% of its nominal rotor speed, is also presented. Incorporation of a tendon into blade gives two main effects – a shift of natural frequencies and manifestation of tuned vibration absorber through frequency loci veering. It is also hypothesis that this concept can tune the dynamic properties by morphing technologies. Shape Adaptive Blade Rotorcraft Efficiency (SABRE) is an ongoing research project where an investigation of morphing technologies is presented, so that is why this paper’s concept can be theoretically employed to one of the morphing technologies, developed in SABRE project. This paper consists of different sections; one of them presents a mathematical model of coupled blade-tendon system of a Bo 105 helicopter.[13]

This paper describes a passive approach to reduce the vibration and power consumption. During flight operations, blades bend and twist, so altering angle of attack affects power consumption and loads reduction. Aeroelastic effects cannot be avoided in flexible design so that is why it can be used in advantage by tailoring it. If flexible devices are added in blade tip, it can regulate speed in high winds. Same thing can be done by providing desirable twisting on the blade skin.

Effects of aeroelastic tailoring in helicopter rotor and production of potential energy by twist coupling are reviewed here. It's also examined that twist coupling's design can be made by stretching or bending loads. This paper has shown that it is possible to give elastic twisting in rotor blade either centrifugal or flap, which will help in power consumption. The reorientation of fibre in the blade skin to provide either flap load or extension load with blade twist is a cost=effective and reliable aeroelastic tailoring approach. This technique can be utilized in wind turbine blade of helicopter. This technique is multidisciplinary problem dealing with strong coupling properties such as blade elasticity, aerodynamics, dynamics, and control. The improvements used to be seen not sensitive to the wind. Investigation on large angles of twist and changes in large diameter of rotor is presented here. It is observed that the benefits drop off for the larger twist angle.[14]

This paper has studied on Active/Passive optimization of helicopter rotor blades at high advance ratio. The source of vibration levels is the dynamic stall in the flight regime. Active control of vibration and rotor power is implemented with the operation of partial span trailing-edge flaps as per closed loop control algorithm. By Efficient Global Optimization (EGO) algorithm, blade combination is optimized, but due to limitation of functions' compromises, and strong trade-offs between objective functions which are noise reduction and power consumption, as there is no single best configuration, a surrogate based multi-objective optimization is implemented to reach active/passive configurations in vibration and performance characteristics. Though many wind tunnel tests have established that active approach has effective results, passive approaches are implemented in helicopter popularly compared to active approach. In passive approach of structural optimization, vibration reduction is formulated as mathematical problem, that is subjected to constraints which are specified on blade geometry, blade stress, blade stability margin, frequency and autorotational properties. Vibration reduction in this approach has been within the range of 30% to 60% respect to baseline reference. Further studies have shown that modification of blade's geometric mass, stiffness, properties is an effective passive approach towards power consumption for hovering and forward flight. By this approach, 4% to 6% power reduction is possible.[15]

The old methods for vibration reduction were a sluggish approach which was using the vibration isolators and absorbers which were imparting undesirable weight penalties and the reduction was unsatisfactory. So, a new technique was formed. This technique involves active approaches such as Higher Harmonic Control and Individual Blade Control. As the active controls were emerging the Active Twist Rotor (ATR) concept was recommended. To the rotor blade skin actuators were implemented which generate dynamic blade twist and to the flight condition, the camber was adapted. This was altered at any given amount of time. This leads to significant vibration and noise reduction. Not only this but flight performance was also improved. The paper discusses the optimisation methodology that is used for the full-scale rotor blade design. This rotor blade has an active twist which is used to strengthen its potential for vibration and noise reduction. This technique is based on the 3d finite element model. With the help of finite element software ANSYS, the structural static analysis with thermal load using a 3D finite element model is developed for investigating the active twist of the helicopter rotor blade. For conforming to the modelling efficiency experimental values validate the helicopter rotor blades which gives torsion angle. This torsion angle is obtained from the finite element simulation.[16]

We used a 3D finite element framework to model a full-scale multi-laminate composite helicopter rotor blade in this research. Because of its overall stiffness, good strength-to-weight ratio, thermal characteristics, fatigue life, and wear resistance, composites have been employed in helicopter rotor systems for over 30 years. Minimize tip deflection and increase overall helicopter blade efficiency by optimising the aspect ratio and geometry of such composite laminates. A full-scale multi-layered composite helicopter rotor blade was modelled using the FE framework. It agrees with the Abaqus FEA model both quantitatively and qualitatively. Various parameter studies on width/depth ratios, such as carbon / epoxy Glass / Epoxy Laminate on Composite Wing Deformation Behaviour. These variables have a significant impact on the deformation.[17]

The helicopter rotor system operates in a highly dynamic and unsettled environment, resulting in high vibratory loads. Repeated exposure to this high-loading environment might cause damage to the composite rotor blades. Delamination, fibre matrix debonding, fibre breakage, fibre pull out, and matrix cracking are all competing modes of injury for these blades, which are frequently made of fibre bolstered laminated composites. An experiment is carried out to determine the combined effect of damages. The helicopter rotor system operates in a highly dynamic and unsettled environment, resulting in high vibratory loads. Repeated exposure to this high-loading environment might cause damage to the composite rotor blades. Delamination, fibre matrix debonding, fibre breakage, fibre pull out, and matrix cracking are all competing modes of injury for these blades, which are frequently made of fibre bolstered laminated composites.[18]

Engine-propeller power plant aircraft noise reduction problem is determined by ICAO Standard for limiting noise levels generated by light propeller aircraft and special unmanned engine propeller power plant (PP) aircraft. The present paper generalizes the author's research results of engine- propeller PP acoustic characteristics and noise reduction methods. Two-stroke piston engines are a source in engine-propeller PP noise with intake and exhaust channel noise suppressor and silencer absence.

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The active noise dampening system installed in the engine exhaust channels is a critical and important feature. It should be also noted that engine cowling setting requires its vibration damping to avoid greater vibrations. A propeller diameter decreases by 3,3% was found to bring to 300 m distance reduction that a UAV might approach terrain without being detected. European authors believe that one can achieve propeller noise reduction in conditions of real arrangement up to a level lower than that of an isolated propeller. Fig.5 Propeller diameter effect on three-octave sound pressure spectrum (120º, propeller speed 2094 rpm., static condition, distance 30 meters). [19]

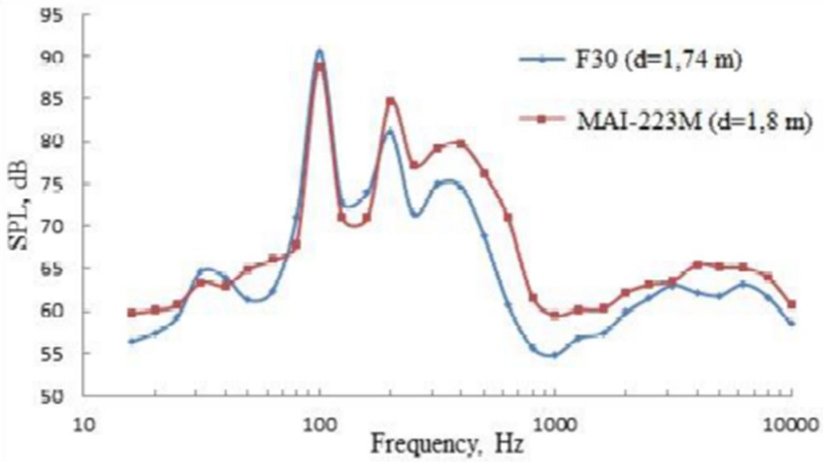

Fig.5 Propeller diameter effect on three-octave sound pressure spectrum

The ProNoVi project aims to deliver reliable tools for predicting different types of propeller cavitation and the dynamics in operation behind a ship hull. Underwater noise due to shipping activities raises the natural underwater background noise level in the frequency range from 10 to 300Hz by an estimated 20 to 30dB. To make noise prediction technology ready for industry, ProNoVi considers the entire ship and propeller system, as well as their interaction. The output consists of recommendations and guidelines for industry, research, and academia, and regulating societies. Four sub-projects aim to advance methods in their area beyond the current state of the art. To reach this objective, the propeller is simulated in open water and behind ship conditions for various loadings and cavitation numbers in model and full-scale, mirroring the model tests. Fig.6 PPTC propeller case (left), vorticity magnitude and resolved tip vortex: hydrofoil case (right) [20]

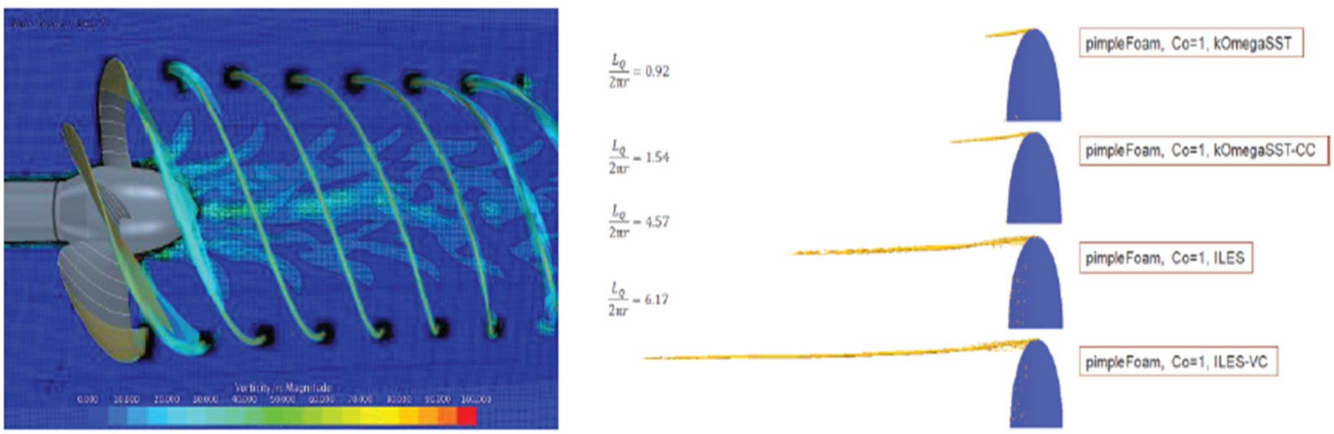

Fig.6 PPTC propeller case (left), vorticity magnitude and resolved tip vortex: hydrofoil case (right).

III.CONCLUSIONS

Among the various aspects of vibration, the impact of vibration on noise generation is significant in helicopter rotor blades. In the field of vibration control, their potential for noise reduction is widely investigated. Extensive research has been conducted using various methods to actively suppress the vibrations of helicopter rotor blades. And the goal of this review is to cover the work that has been reported in these studies.

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