THE NUMERICAL CALCULATION FOR THE COUPLING OF MULTIPLE PROPELLER DISCRETE NOISE AND ITS INTERACTION WITH THE FUSELAGE BOUNDARY *

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Abstract

This paper presents a numerical method for calculating multiple subsonic propeller discrete noise with the influence of rigid fuselage boundary condition of arbitrary shape , the method described unites the multiple propeller discrete noise coupling effect with the effect caused by its interaction with the fuselage boundary . The interaction of the discrete noise of Y12 scaled propeller model with a cylindrical fuselage model boundary was calcalated. The interpretation of every terms of the governing equation and the discussion of the calculation results illustrated that the mathematical model is reasanable and acceptable . Substantially ,the method can be used to calculate the interaction of any known harmonic sound sources and rigid boundary. The calculation results explained the propellers sychronizer role and its applicable principle.

I Introduction

It has been succesful to calculate subsonic propeller descrete noise propagating in free field by using the formula developed by Farrassat from FW–H Equation, but the sound field created by the coupling of the discrete noise generated from multiple propellers at the same time and its interaction with fuselage boundary condition will be substantially changed. The blocked pressure amplitudes on a cylinder surface can be calcalated from the free field pressure values by the empirically fitted curve found by Magliozzi [1], but it does not work for the phase of blocked pressure. Referance[2] pointed out that unapropriate prediction of the blocked pressure on fuselage is the main cause of the error in studying the noise transmission model of propeller airplane. The study of multiple propeller discrete noise and its interaction with the fuselage is necessary in investigating the effect of sychronizer on noise control. In this respect no successful research works have been published until now. The paper presents a numerical method of calculating multiple subsonic propeller discrete noise with influence of fuselage boundary condition of arbitrary shape and the method links the multiple propeller noise coupling with its interaction with the fuselage boundary. The method is based on the calculation of acoustic load on fuselage surface with FW–H Equation. A singular inhomogeneous Fredholm integral equation is then obtained. By the method given by Lyle.N.Long[3] the singularity of the integral is resolved and the equation is transformed to one in frequency domain. The panel method is used to solve the integral enquation and the problem is reduced to solve a set of linear algebraic equations. Hence the multiple propeller noise coupling effect can be got by simple addition . The paper interprets the meaning of terms in the governing equation and makes the calculation of the discrete noise of a 1 / 4 scaled propeller model of Y12 aircraft (a light propeller aircraft made in china) on a cylinder model just same as that test model used in reference[2]. The result of calculation was discussed and it is satistactory to explain the wave scatter on the boundary. The combined effect of two propellers calculated can be used to explain the role played by sychronizer and its applicable principle.

II Basic Hypothesis

1. The aerodynamic load distribution on a propeller surface is independent of presence of the fuselage, airfoils and sound field radiated from other propellers, it can be calculated by a aerodynamic calculation program.
2. The discrete noise radiated from propeller is determined by FW–H Equation without quadrupole term. The sound source of every propeller is independent of others.
3. The fuselage boundary is rigid , inviscous and no turbulence on it.
4. The velocity of the fuselage is constant.

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the diagram the x-axis is in the negative flying direction, the y-axis is in the peripheral direction and the origin is at the front end of the cylinder.

Both the free field pressure contour and the blocked pressure contour on the cylinder surface caused by the right-side propeller was shown in Fig.4. It is seen that the maximum value of both the free field pressure and the blocked pressure are occuerd in the same position on the cydinder face to the propeller while the blocked perssure level is about 6db higher than that in the free field. It is confomed with the empirically fitted curve used in reference[2]. The contour of the blocked pressure level can be used to explain the diffraction of the sound wave on the cylinder surface. On the left upper part of the cylinder there exists relatively stronger sound pressure level even though where the sound wave can't reach there according to the sound ray propagation principle. But, on the oppsite side of the cylnder to the propeller, there exists very weak sound pressure where the value of sound pressure level is about 50dB lower than the maximum value on the boundary surface. It has illustrated that a sound shadow occurs in that position. The contour of free field pressure level is different from that of blocked pressure level, there exists no shadow anyway.

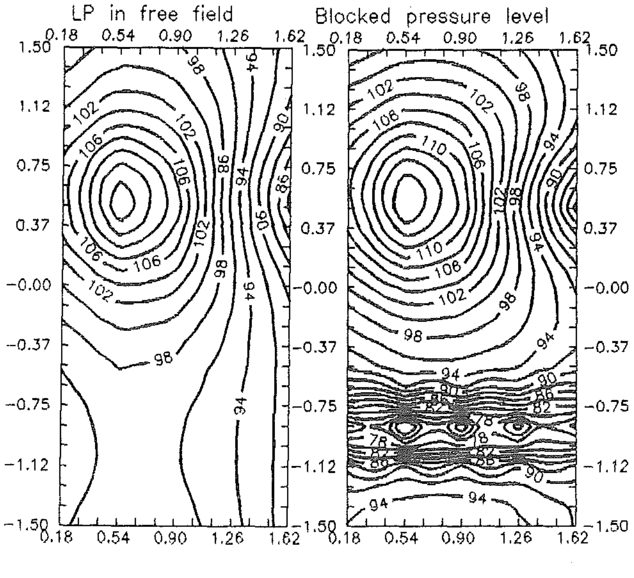


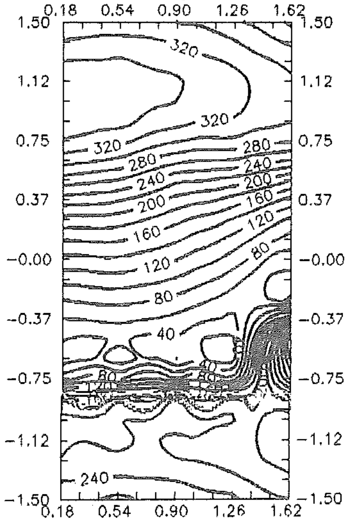
Fig.4 The contours of free field pressure level(left) and blocked pressure lecel(right) by right prop.

The phase contour of the blocked sound pressure has been illusfrated in Fig 5. The contour of both the blocked pressure level and free field pressure level on the right side of the cylinder are somewhat symmetrical to the projection line of the propeller axis, but not for the phase contour(Fig5). It is seen from Fig 5 that the contours are related to the intersection curves of the wave front of sound with the boundary at different instant and showed obviously some regulations which has a propagation pattern of the wave front related to the direction of a right -turn propeller. For demonstrating the relationship of the blocked sound pressure with the diameter of the cylinder and the distance from the propeller to the cylinder, a half-sizd cylinder model was used, and its blocked sound pressure with a right-side propeller was calculated and showed in Fig 5(b). The differences between the two contour maps represented the effects of the relative dimension and distance. For the small size model, the centre of contours has been shifted further to the right of the cylinder. The phase information of the blocked sound pressure is of great importance when studying the sound propagation and interference. This may be the first time that the numerical method was employed to calculate the phase distribution of the blocked sound pressure, excited by harmonic sound sources on the models, and results obtained is satisfactorily.

The calculations in this paper can provide both the magnitude and phase of the blocked sound pressure that was due to the comprehensive input of all the effective physical information of the sound field to the program, where the free field sound pressure was complex which including both magnitude and phase. In addition, the sound frequency, which influences the diffraction and propagation, boundary configuration and the flying speed were also included in the equations. During the discussion of its physical meanings and the analyses of the results it was clearly shown that the calculations are reasonable.

2. The calculation results of dual propeller sound field

The contour maps of the blocked sound pressure of both models, the two propellers with equal phase and the left propeller with a phase retardation of 60° to the right one, were illustrated in Fig.6. There are no significant differences of the sound pressure level distribtions between the two cases. This is because the high sound pressure level regions of the right and left propellers were not superimposed, and the resultant blocked sound' pressure distribution is


a: Phase---original model

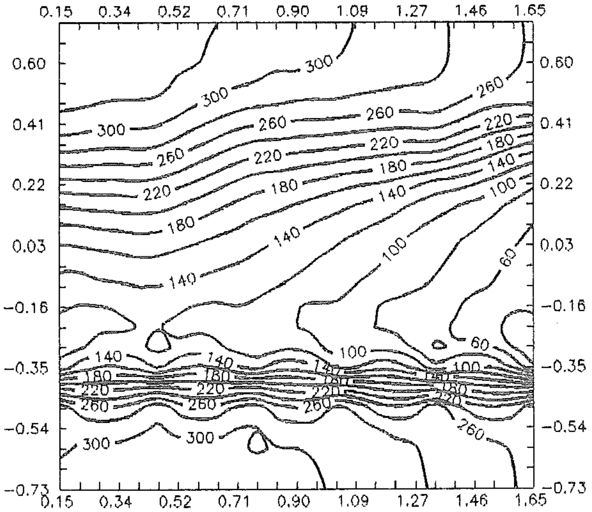

b:Small size model---Phase

Fig.5 The contours of blocked pressure phase
a original model
b small size model.

basically an addition of the two patterns of single propeller each with its own highest sound presure centres. Thus, the sychronizer is not efficient for this case. The situation is quite different for the case of the half-sized cylinder model, in Fig 7, where the relatively high sound pressure regions were superimposed, and the resultant sound field was more sensitive to the phase differences of the propellers, in Fig 8. When the propelles having equal phase the resultant sound pressure was obviously reduced on the top side (Fig. 8 lower) while comparing with the model with the propellers of having 60 Deg phase difference between the right and left propeller(upper). Also, a region of very low sound pressure due to the interference was appeared at the rear left side of

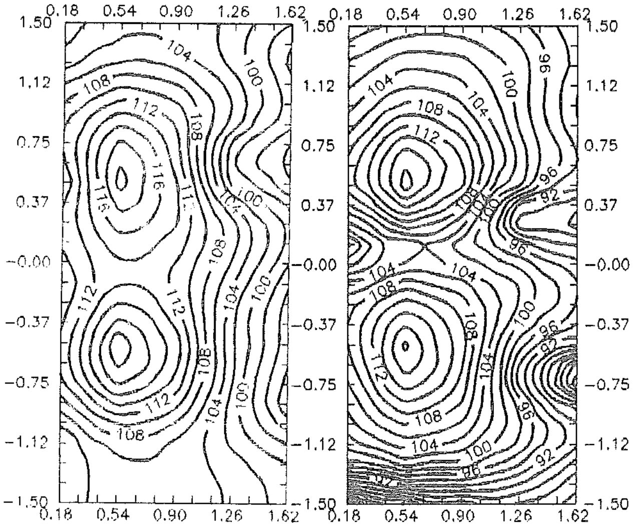
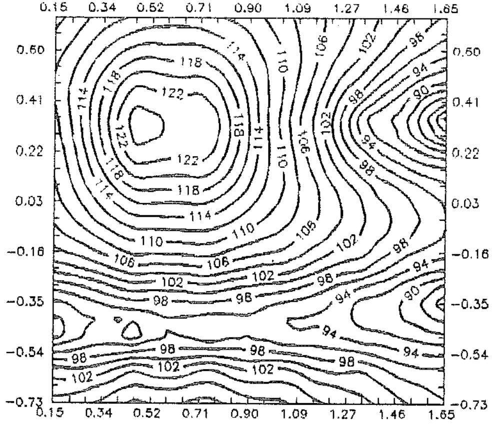

LEFT PROP DELAY 60 DEG SAME PHASE OF TWO

Fig.6 The contours of resultant blocked pressure level of two propellers.
with left prop delay 60 Deg(left)
with same phase(right)


a:Right prop for small size model

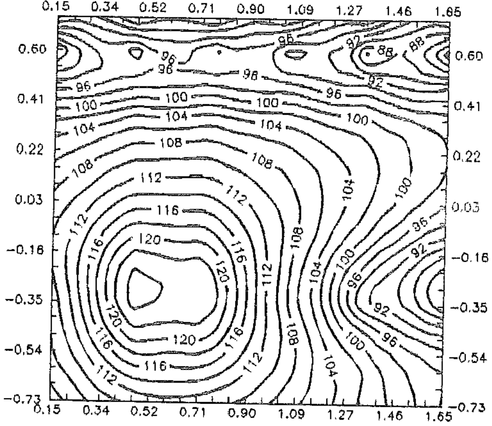

a:Left prop for small size model

Fig.7 The contours of blocked pressure level of small size model from right propeller (upper) and left prop (lower)

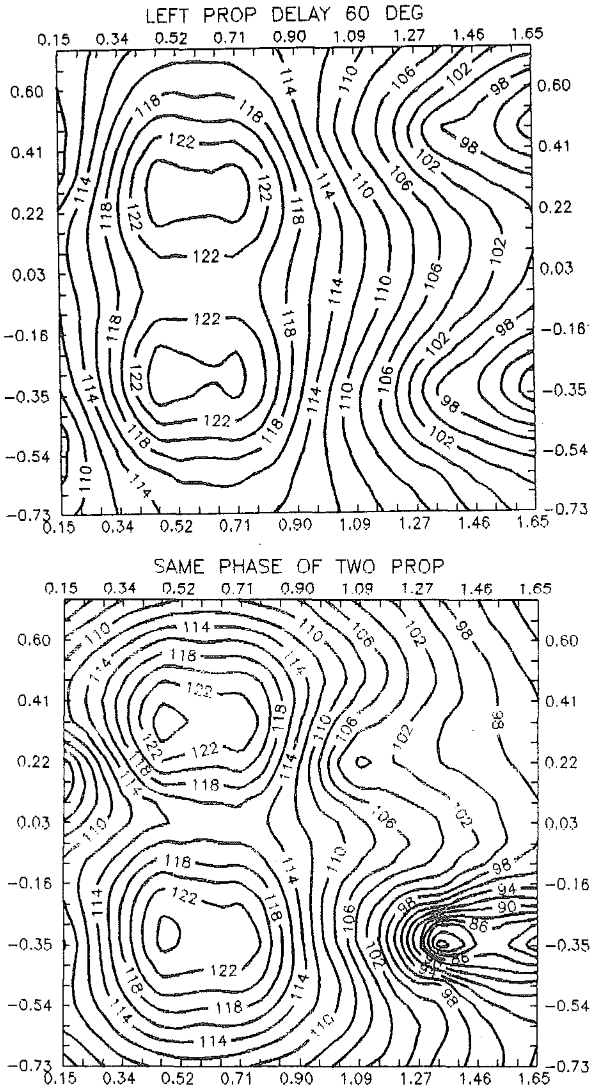


Fig.8 The contours of resultant blocked pressure level of two propellers. for small size model. with left prop delay 60 Deg (upper), with same phase (lowre).

the cylinder body, it was about 44 dB lower than the highest value. It seems to make sense that the synchronizer will be efficient in noise reduction for the this case.

Ⅵ Conclusion

The governing equation of coupled multi-propellers interacted with fuselage derived from FW-H equation is applicable to the calculation of the interaction between free sound field due to any arbitrarily defined harmonic sound source and the fuselage. The equations have clearly physical meanings and the calculation results conform with the rules of propagation and interaction of the sound waves with rigid boundary. This methcd can be used to calculate the blocked sound pressure, including magnitude and phase, of any configuration of fuselage. The calculation results can be used as the basis of studying the propagation of sound from tone sources into the inside of a structure. The results of the sound field with dual propeller illustrated that the sychronizer is only efficient in noise reduction when the blocked pressure fields of the two propellers have the superimposed regions with relatively high pressure.

Reference

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