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Workshop Report for the AIAA 5th Aeroacoustics Conference

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INTEREST in aeroacoustics remains high, as evidenced by the large attendance at the 1979 AIAA Aeroacoustics Conference. Fundamental understanding and technological tools are still being developed at an encouraging rate. But controversies still remain and there is much to be done if proposed and projected noise regulations are to be met.

In order to review the various areas of aeroacoustics and to encourage an open discussion of the controversial topics in these areas, the AIAA Aeroacoustics Technical Committee held a series of workshops at the 3rd Aeroacoustics Specialists Conference. They proved to be highly successful and have become a regular part of the subsequent conferences. Summaries were published in the *Journal of Aircraft*.[1,2] This article summarizes the workshops conducted during the 5th Aeroacoustics Conference which was held in Seattle, Wash. on March 12-14, 1979. The workshop chairmen prepared written summaries of their particular areas. These have been edited and are collected below.

Jet Noise Mechanisms and Suppression

Contributed by
Christopher K.W. Tam, Florida State University

The role of orderly large structures in jet noise generation was the first topic discussed. The question of what were orderly large structures was raised. The consensus of those who expressed an opinion seemed to be that any flow structures which had a spatial coherence on the scale of the thickness of the jet mixing layer fell into this category. Most participants approached this topic very cautiously, indicating that the subject was new and many things were still unknown and unexplored. There was, however, general agreement that orderly large flow structures existed in jets and that they were important with regard to turbulence. For subsonic jets which were foremost in everyone's mind, there were divergent opinions as to whether large structures were responsible for noise generation (directly or indirectly). The issue remained largely unresolved. In contrast, there appeared to be some agreement on the proposition that large structures did play a role in broadband jet noise enhancement (or suppression depending upon frequency) when a jet was excited. Exactly how this enhancement came about was not elaborated upon.

The effect of forward flight on jet noise was the next topic of discussion. Vigorous arguments were put forth about the cause of observed forward flight amplification phenomenon. The framework of a new scaling theory was also briefly presented. A group of the workshop participants believed (or hoped) that they could explain the phenomenon by considering just the forward flight modification of jet mixing noise alone. Some theoretical results and data were presented to support this line of thinking. There was another group holding the point of view that, for flight measurements, the data were additionally influenced by internal noise, installation noise, and airframe noise. It was argued that without including the latter noise elements it was inconceivable that flight measurements and wind tunnel simulation data could be reconciled. The idea of installation noise, which did not seem to have been regarded as important before the meeting, was discussed and demonstrated experimentally in a paper presented at one of the jet noise sessions (Paper 79-0617). After a half hour discussion it was obvious that everyone held fast to his original beliefs.

As a final item of discussion the workshop turned its attention to new noise suppression schemes and devices. A new porous plug nozzle noise suppresor (Paper 79-0673) was the center of interest. Various noise suppression mechanisms associated with the device when operated supersonically were suggested. It was reported that the device was also effective for subsonic jets.

Turbomachinery Noise

Contributed by
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The workshop on turbomachinery noise covered noise sources, (i.e., tones, broadband noise, and shock wave noise), use of the modal approach for noise prediction, and experimental methods. The relevance of these topics is supported by the turbomachinery sessions at the aeroacoustics specialists meeting, which had papers on all of these topics. This summary will concentrate on the workshop discussion as opposed to the papers presented at the sessions. The discussion was organized to define, as much as possible in a large group such as the workshop, a consensus regarding the status of technology and an indication of required future directions for each topic. The following report summarizes this consensus.

Tones, Residual

Discussions of tone noise concentrated on the fan as a source. Two categories of tone noise generation were considered: 1) residual tones or cutoff tones, i.e., cases in which the obvious tone-generating mechanisms such as rotor/stator interaction or direct rotor field are cut off and 2) cut-on tones. This breakdown was made because evidence from static and flyover tests shows that tones exist in fan noise spectra even though the fan is designed to cut off the tone. More subtle mechanisms than the commonly considered ones listed above were believed to be responsible for these residual tones. Some of these mechanisms could include: the interaction of an asymmetric inlet boundary layer with the fan rotor, asymmetric potential flowfields set up by the mounting pylon interacting with the rotor, and interaction of rotor wakes with downstream blade rows that exhibit slight asymmetries due to manufacturing tolerances (Paper 79-0638). The underlying commonality of these mechanisms is connected with the existence of unexpected or previously unaccounted for asymmetries in the turbomachinery blading or flowfield.

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It was agreed that more effort is required to delineate and quantify these sources more accurately. Additional flight data could provide a better definition of residual tone source levels under flight conditions, and the application of modal measurement methods could possibly be used to identify the sources. Use of inflow control structures during static testing (to be discussed in a latter section) is required to insure that masking by spurious noise sources unique to the static test does not occur.

Tones, Cut-On

Cut-on tone generation has been an identified noise source since the early days of jet engine usage in commercial transports. Most of the generating mechanisms are reasonably well defined, and include the direct rotor field, wake interactions with subsequent blade rows (e.g., rotor/stator interaction) (Papers 79-0577 and 79-0579), and interactions between the potential field and blading of closely spaced blade rows. Nonlinear flow effects, not accounted for by existing linear acoustic theories, were identified by the workshop as possible new sources, and their importance, in comparison to other sources, has not yet been settled. Paper 79-0576 presents a discussion of this source.

Models for predicting rotor/stator interaction noise and direct rotor noise exist or are under development, but need to be verified by extensive comparison with appropriate test data. Three-dimensional flow effects, which are dominant in the tip, hub, and shroud regions of fan rotors, give rise to rotor wake characteristics which are different than those of wakes shed from the remaining regions of a blade. It is on this latter area that most of the emphasis of past research on wake structure has been placed. Accordingly, the importance of these three-dimensional flows to the noise generation process should be identified and, if it is important, research to define the details of the wake flowfield and noise generation process should be implemented. The importance of the rotor wake/core engine stator interaction was identified as a potential noise source whose importance should be assessed. Finally, the topic of sum and difference tones, generated by interactions between rotors mounted on the same shaft was raised. The mechanisms that generate these tones and the effects of forward flight on these mechanisms should be the subject of future research.

Broadband Noise

Possible mechanisms for broadband noise generation include:

1) Interaction of the rotor with inlet duct boundary layer turbulence.

2) Interaction of the rotor with the inlet duct boundary layer mean flow profile leading possibly to stalled tip flows.

3) Rotor self noise.

4) Stator self noise.

5) Wake turbulence interaction with downstream blade rows.

The amplitude of peak frequency broadband noise data from a limited number of fans has been correlated against incidence angle, e.g., in Ref. 3 and in Paper 79-0640 presented at this meeting. The data collapsed well when correlated against rotor mean flow incidence angle, suggesting that rotor self noise or rotor/boundary layer interaction noise are dominant mechanisms. Future efforts should be directed toward extending the correlation to include data from many more fans. In this connection, it is possible that forward and aft radiated broadband noises are generated by different mechanisms depending upon the detailed design of the fan. For example, in some fans aft radiated noise may be caused by stator self noise or rotor wake turbulence stator interaction noise. Evidence to support this possibility has been obtained by NASA-Lewis, where changes in stator chord were found to affect the aft radiated broadband noise levels. It was the consensus of the workshop that effort should continue in the correlation of broadband noise data, and that these correlations be tied to appropriate generation mechanisms.

Shock Wave Noise

Shock wave noise (buzz or multiple pure tone noise) is caused by the propagation of rotor shock waves out the inlet of an engine and subsequent radiation to the far field. Comments made by attendees at the workshop indicated that their experience showed that inflow control structures can have an effect on shock wave noise. Additionally, analysis of flyover data showed a reduction in flight of shock noise that was greater than observed by use of ICS's. It was conjectured that inflow cleanup beyond that which exists under static test conditions may be responsible, at least in part, for these effects. Improved models of shock propagation which account for distortions in the mean flow may help in our understanding of these effects, e.g., see Paper 79-0639.

Modal Approaches and Experimental Methods

Use of modal approaches in the design of liners was identified as an area of current interest (i.e., Papers 79-0580 and 79-0581) requiring continued research. This research should include development of techniques for measurement of modes as well as techniques for their prediction by use of source models. Development of modal measurement techniques and analytical liner design and prediction models using simpler approaches for cataloging modal characteristics other than modal indices, e.g., Rice's cutoff ratio approach, should also be encouraged.

Continued development of experimental techniques was recommended by the workshop participants. Use of inflow control structures during static testing have been shown to improve simulation of flight conditions (Papers 79-0654, 79-0655, 79-0656, and 79-0657), but further development is required. In particular, an assessment of the status of current designs is required by comparison to flight data or predictions made with static data obtained with an inflow control structure.

In addition, the duct boundary layer has been shown to influence the noise generation process during static testing (Paper 79-0656). Accordingly, proper simulation during ground testing of the inlet boundary layer is an area requiring further research.

The need to generate a more extensive flyover data base that can be made available to the general acoustic community was identified. In particular, future emphasis should be placed upon providing data specifically for evaluation and improvement of prediction systems and assessment of inflow control structures, by, for example, using multiple microphone measurements and level flyover trajectories.

Summary

The following summarizes the key points of the turbomachinery workshop discussion:

1) More work is required to quantify and identify the generation mechanisms responsible for residual tones.

2) Nonlinear flow effects were shown to be representable as quadrupole noise sources.

3) Direct rotor field and rotor/stator interaction tone noise prediction models require further verification by comparison with appropriate test data.

4) The importance to tone noise generation of three-dimensional wake flowfields needs to be defined.

5) The importance to tone noise generation of rotor wake/core stator interactions needs to be defined.

6) Broadband noise correlations should be extended to include other generation mechanisms and data from a more extensive number of fans.

7) Improved shock wave propagation models should be developed and used to clarify the effects of inflow velocity field distortions on shock wave noise.

8) Development of modal liner design methods (including simplified methods based, for example, upon cutoff ratio) should continue. In addition, development of modal measurement techniques and development of source modal prediction methods should continue.

9) Development of static testing techniques that properly simulate flight conditions should continue.

10) An extended flight data base should be developed to provide data for assessment and improvement of prediction techniques and static testing procedures.

Duct Acoustics

Contributed by
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There were four duct acoustics sessions at the conference. The principal themes of these sessions were: sound attenuation by liners and mufflers, sound propagation within ducts, the application of finite element methods, and the radiation of sound from inlets. The workshop was structured around these topics with remarks on radiation woven throughout the discussion of the first three themes.

Sound Attenuation

The design of duct liners for aircraft engine noise reduction and the ability to predict a liner's acoustic performance depends upon the source characteristics and distribution within the duct, the wall impedance, the length of the duct, the inlet shape, and the flowfield into the inlet and through the duct. All of these quantities must be known with some degree of accuracy. However, the relative importance of these factors for accurate prediction is not clearly established.

The specification of the wall boundary condition for locally reacting liners in terms of impedance is recognized as a considerable simplification of the actual complex sound liner/flowfield interactions which take place at the duct wall. The use of an impedance is generally accepted as the best available way to set the boundary condition and no alternative form was suggested at the workshop. However, there was some feeling expressed that the impedance concept may not be entirely adequate. An alternative expression for the boundary condition which more properly represents the physics—such as an impedancewhich is a function of angle of incidence and nonlinearities due to the effect of high sound pressure levels on material properties—might help reduce the disagreement between theory and experiment. It was noted that variations in the impedance of a given liner segment may occur, due to imperfections in the manufacturing process. Such variations of impedance may have a considerable effect upon the performance of a liner near its design condition where the attenuation can be very sensitive to wall impedance. It was commented that liners with spatially varying properties may nevertheless be locally reacting.

In a duct with an extended reaction liner one must solve a pair of propagation equations—one in the liner and one in the adjacent air—which are coupled through continuity conditions at the interface. The need to develop this analysis for practical situations was expressed.

There was considerable discussion of methods for determining the source distribution. Good definition of the actual noise source in specific applications was felt by some discussants to be a critical need. Methods for defining the source include the use of in-duct sensors to measure either individual modes or groups of modes having similar properties and the use of measurements in the radiation field. The direct measurement of modes within a duct by the use of wall microphones or inflow probes becomes very difficult when many modes are present, as may happen when the sound frequency becomes very high. In these situations the number of microphones required becomes quite large. Since many modes may be cut on in some situations there is a need for developing ways to describe the sound field which do not require dealing with individual modes. One suggestion made for correlating theory and experiment was to work with acoustic pressure distributions without decomposing them into modes. Another approach being explored is to group together modes which have similar attenuation characteristics. Criteria in use for defining modal families are cutoff ratio or angle of incidence. Other discussants felt that such simple criteria may not be complete and would have to be augmented by other data.

The use of far field measurements to deduce information about sources in the duct was mentioned. This approach seems to require some priority assumptions about the modal structure within the duct and require at least an approximate radiation theory for the given geometry and flow conditions. Such an approach must take into account the propagation of sound through the inlet flowfield. The unsteadiness of this flow can create difficulties in applying the method.

It was repeatedly observed that the design of optimal liners depends upon a knowledge of the modal characteristics of the sound field. Hence, work on methods of defining in-duct sources should continue to receive considerable attention.

New duct liner concepts which hold considerable promise for increased attenuation or greater bandwidth of absorption are: bulk absorbers, segmented treatment, variable impedance liners whose impedance might be controlled by bias flow, and active absorption by means of phase cancellation.

Bulk liners were said to be less sensitive to grazing flow and nonlinearities than perforated plate liners. There was some difference of opinion, however, over the practical value of bulk absorbers. It was noted that while they usually performed as expected in ideal flow duct tests, their performance in actual engine tests was inconsistent. Some researchers had observed better than expected performance in engine tests while other researchers had experienced poorer than anticipated performance. It is clearly important to resolve these discrepancies.

Uncertainties in the source and control of wall impedance may compromise the practical usefulness of optimized locally reacting liners which tend to be sharply tuned and have poor off-design performance. It was noted that optimization studies of liners must take into account the inlet geometry and flowfield of the duct, since these factors were shown to have considerable influence upon the optimum.

In addition to these ideas, other concepts considered proprietary by industry were said to be under investigation. At the moment it is felt that a liner must be tested in flight in order to confidently assess its acoustic performance. Since flight tests are very expensive to conduct, better static testing methods are vitally needed.

Another method for community noise reduction is the use of "directional" inlets which will redirect the radiated sound away from the ground through inlet geometry or flow effects. Some of these inlet concepts may also have aerodynamic benefits. This avenue of noise control needs to be explored further. However, achieving a really practical concept is likely to require close interaction between the aerodynamist and acoustician.

Sound Propagation

The need for experimental evaluation of propagation and radiation theories was stressed. There has been some validation of theory by means of high quality experiments carried out under well-controlled conditions in straight ducts without flow. However, careful experimentation becomes very difficult and new problems and phenomena appear when the duct contains flow, especially at high subsonic flow speeds. The need for careful measurements under fairly complex conditions grows as very general numerical methods, which eventually will need validation, continue to be developed. Most of the experimentation so far has made use of pure tone sources. When such an experiment is carried out in an anechoic chamber, the scattering of the tone from objects (such as supports) within the chamber can be a considerable obstacle to making accurate measurements. Several experimental programs for making precise duct acoustics measurements are underway or planned in this country and abroad.

The notion of acoustic energy conservation and production when sound propagates through a rotational flow received considerable discussion. A frequently occurring situation not confined to duct acoustics is the transfer of energy between sound waves and vorticity. When a shear flow is present there are several definitions for acoustic energy and several conservation laws in the literature. Each of these definitions and laws has its adherents. None of these laws has been studied experimentally. Some means of calculating the change in acoustic energy along a lined duct is needed in order to evaluate the attenuation by the liner. Theoretical studies of liners, therefore, require some analytical definition for calculating acoustic energy. Consequently, a fairly general definition of acoustic intensity and energy density applicable to situations in which sound propagates through real shear flow and variable geometry lined ducts which can be accepted throughout the research community is highly desirable. One means proposed for circumventing the current difficulties in defining energy in general flows was to calculate the energy absorbed by a liner directly, using values of the sound pressure and velocity at the liner face.

Finite Element Methods

The use of finite element methods is a fairly recent development in computational acoustics. Much effort is now being directed toward developing very accurate solution methods and comparing various sample calculations with results obtained by other numerical methods and exact solution techniques. Current applications of the finite element method are generally to fairly simple situations; that is, hardwall ducts with uniform cross-sectional areas having no or uniform flow and plane wave or very low order modes as sources. The effort at present is toward laying a very firm foundation from which to handle more realistic problems. A very clear need is to find ways of reducing the computational times which we estimate will be required to solve the very large order systems of equations which come about in complex two-dimensional problems and certainly in three-dimensional problems. It was suggested that at very high frequencies a geometric acoustics approach may be more appropriate and that some effort should be given to developing an analysis along these lines.

The mathematical problem which one solves using the finite element technique can be formulated in various ways, such as the differential equation form of the conservation laws, variation principles which generally involve the use of a velocity potential, and integral equation techniques. Each of the avenues of attack has its relative advantages and disadvantages. For example, the integral equation formulation is very attractive in that it automatically includes the solution for the radiation from the duct. However, the inclusion of a realistic flowfield would seem to present a considerable problem for generalizing this technique. Impedances which cause difficulties in finding solutions to the modal formulation of the problem may also cause difficulties in the corresponding finite element formulation. Numerical experimentation is needed to appreciate and overcome this problem. A marching technique for solving the finite element equations which allows one to treat the problem as an initial value problem is most attractive and certainly deserves careful consideration. So far the choice of a particular problem formulation would seem to be a matter of individual choice. It remains to be seen whether or not any one particular approach will turn out to be generally favored.

It was pointed out that the equations governing sound propagation in a shear flow have unstable exponentially growing solutions. These unstable waves are presumably also contained among the solutions of the finite element equations. Finite element methodologists were advised to be alert for the appearance of such waves in their solutions.

An opinion was expressed that many of the current numerical procedures now available or under development for modeling sound propagation in lined ducts with flow are very complicated to use and are very consuming of computer time. Although these sophisticated computer solutions have an important place in the overall research effort, they are too complex to be used routinely and repetitively. It was therefore suggested that more attention be directed toward the development of somewhat simpler design methods for determining the impedance of a liner for a specific application.

Helicopter Rotor, Airplane Propeller and V/STOL Noise

Contributed by
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This was a well-attended session with good participation in the discussions. The major subjects of discussion were related to helicopter and propeller noise. There was no discussion of V/STOL aircraft noise due to the lack of activity in developing military or commercial aircraft of this type.

In the prediction of propeller and helicopter rotor noise, it appears the nonlinear source and propagation effects are receiving the greatest attention in efforts to obtain correlation between theory and measurements. It was noted that nonlinear effects have been observed in the near field too close for the weak shock propagation theory to explain the results.

Installation effects on propeller or helicopter rotor noise are being investigated in both Europe and the United States. These effects are expected to affect primarily low frequency tone noise.

While the noise control of military helicopters requires an understanding of the noise of rotors operating at high subsonic tip speeds (the blade slap problem), the noise control of commercial helicopters requires an understanding of rotors operating at lower tip speeds. This is particularly important because noise certification of helicopters is now being considered and any additional noise reductions to reach certification levels will have a substantial impact on payload. Recent test experience with wide chord blades having supercritical type airfoils has shown unexpectedly large reductions in tone components of the noise spectrum relative to noise of the conventional rotor.

Because of the progress in reducing helicopter tone noise, broadband noise is now a significant component of the helicopter noise spectrum. This has renewed interest in experimental and analytical work to improve predictions of broad-based band noise. From a certification standpoint, there still appears to be a controversy about the correction to be applied to effective perceived noise level to account for blade slap. Some work has shown that a 6 dB correction is required, while other work has shown that no correction is required. There also appears to be a serious problem in propeller aircraft and helicopter certification, caused by location of the microphone 4 ft from the ground. Since low frequency components dominate the noise spectra of these aircraft, substantial variations in levels occur due to ground reflection which causes cancellation and reinforcement of low frequency tones.

The widespread acceptance of the need for forward flight acoustic testing of propeller aircraft and helicopters has resulted in the development of acoustically treated wind tunnels for model and full-scale testing. New and larger facilities are becoming available and test procedures which allow accurate simulation of full-scale are under development. Also, for full-scale outdoor helicopter rotor noise measurements, the "station keeping" concept is being developed. In this concept, a quiet fixed wing aircraft equipped with microphones and recording equipment flies at fixed locations relative to the helicopter under investigation. This concept eliminates the ground reflection problems mentioned above. Very high quality data have been obtained by use of this concept.

Aircraft Interior Noise

Contributed by
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The discussions commenced by reference to Paper 79-0582 by Dowell which concluded that a general theory of noise transmission analysis is now available and that good agreement between theory and experiment has been shown, at least for simple geometries. Prof. Dowell, furthermore, went on to state at the workshop that the physical mechanisms are known, and with adequate attention the problem of accurately calculating interior noise can be resolved in about 5 years. Other papers presented (79-0583, 79-0585, 79-0643, 79-0645, and 79-0647) indicate that a variety of analytical methods appear to be in reasonable agreement with particular experiments. However, further discussions revealed that several areas require much more attention and that realistic aircraft configurations with complex and not easily predictable noise and vibration inputs will not yield to accurate analysis for a long time to come, at least according to some.

This led to a discussion of the need to conduct more experiments for further verification of theories such as those based on pass band and stop band concepts and factors dealing with model scale testing, better noise source identification, effects of stiffeners on noise control, and finally, what pressures are being applied and by whom for further interior noise reduction. The following represents some thoughts on these issues.

The general feeling appears to be that experiments are particularly needed for more complex aircraft structures, but there was no consensus on exactly what was needed. It was suggested that the half-scale ring-stiffened cylinder model under study at Boeing was appropriate, but it was also pointed out that real aircraft have nonsymmetries in skin thickness, load distribution, and floors that make cylinders unrealistic. Actual aircraft tests were suggested, perhaps using propeller aircraft still in use by some airlines, and perhaps modeled after the test program carried out on the YC-14 MAST aircraft which provided much useful information. The question was asked whether the interior acoustic modes required by some of the theories have been measured. It was indicated that interior acoustic modes of a light aircraft had been defined at frequencies up to approximately 120 Hz, but at higher frequencies the acoustics coupled with the structure modes to form a system too complex to sort out. It was pointed out that some analytical methods average over space and thus avoid the necessity of measuring individual modal details.

There doesn't appear to be much experience on models, i.e., scaling effects. Some 1963 reports describing successful use of scale models for both panels and complex structures were mentioned. Problems with modeling damping and absorption, and with the high cost of carefully scaled and constructed (rivets) models were mentioned. Dr. J. Mixon of NASA is of the opinion that the success of scale models in other fields indicates that models could serve a useful purpose in interior noise.

The basic question of where interior noise comes from was discussed. This statement reflects a concern not only with the original source of noise, but also with the need to find which region of the sidewall is most transmissive, so the control treatment can be appropriately distributed. The partial coherence method of source location presented in Paper 79-0644 was discussed briefly, and the feeling was stated that further work was required before the method could be relied upon. A method that had been used on a helicopter was described. The method involved installation of heavy bulkheads and panels that could be removed singly to measure the noise contribution of the exposed sidewall region.

The effects of stiffeners on noise is not well understood and it was evident that theories for add-on noise control treatments need verification, and that damping of stringers and frames for noise control should be explored. Design of sidewalls for noise control was not extensively addressed in the papers presented at the conference, but the papers seem to have presented extensive theoretical methods which could be applied to interior noise control. It was asked what methods are available for noise control by designers. A facetious response to this question was a comment that designers do not use noise data. This topic could be explored further to examine ways to bring analytical methods, such as those discussed at this meeting, to bear upon important design problems.

Finally, the question of what pressures are perceived to exist for reducing interior noise was discussed. It was indicated that ads for quiet interiors seem to sell airplanes, and that the marketplace takes care of establishing levels (presumably through manufacturers' guarantees to aircraft purchasers or through customer pressure). It was also pointed out that it would be desirable to use less weight for sound proofing, even if the levels were not lowered.

Interior noise in aircraft appeared to be of wide interest as evidenced by the attendance and discussion at the workshop and at the two interior noise sessions. The workshop discussion indicates that additional research is required and that future avenues of research are evident.

General Acoustics, Atmospheric Propagation, and Sonic Boom

Contributed by
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Contributions in the form of an invited review paper (79-0626) on discrete frequency sound generation by shear layers and vortices were timely and stimulating. Some of the important issues which require additional study are the synthesis of an interaction model which contains the essential physics in predicting the amplitude of the disturbance in the shear layer instability/cavity/acoustic field feedback mechanism and the effects of the initial thickness of the shear layer on the stability of the shear layer. Continued research in this area will undoubtedly enhance our understanding of the stability of shear layers, of the appropriateness of the convective wave equation in modeling this phenomena, and the matching of dependent variables across the shear layer in analytical models.

Paper 79-0630 provided comments on the effects of acoustic sources in motion. Several ad hoc models and assumptions were exploited by the author in an attempt to obtain a closed form solution for the acoustic field due to finite source distributions moving in a straight line at constant velocity. The physical implications of his "point-moving" source, his repetitive source and multipole source modeling may best be determined by performing selected experiments. The stated difference between Lighthill's theory and the prediction in Paper 79-0630 also may be resolvable by experimental investigations.

†On leave from the Massachusetts Institute of Technology.

Research continues in the area of sonic boom. Paper 79-0652 included a discussion of an aircraft-shaping method for minimizing the ground level sonic boom and some experimental data which were used to validate the method. The authors concluded that their sonic boom minimization method is valid and is applicable to the design of low boom supersonic cruise aircraft and that Whitham's theory is fairly adequate for predicting near-field pressure signatures of slender, lifting, winged bodies at Mach numbers as high as 2.7. The authors also indicated that boundary layer displacement thickness effects may be significant on small-scale sonic boom models.

Two papers quantifying several aspects of obtaining useful acoustic data in wind tunnel-anechoic chambers were presented. Paper 79-0628 discussed an experimental study of refraction angle amplitude changes associated with sound transmission through a circular, open jet shear layer. This excellent set of experiments demonstrated that significant alterations in far-field noise directivity patterns are possible at test Mach numbers of 0.1 and greater due to sound wave refraction by the open jet shear layer and that refraction angle is independent of shear layer thickness for the range of shear layer thickness investigated. These authors observed an unresolved difference between Amiet's theory and near-field off-axis source data. An extension of this research to include heated free jets would be useful. Paper 79-0649 reported on a study to isolate and to eliminate distortions in sound level in the forward arc of jets with internally generated tones situated in an anechoic chamber. The experiments revealed that the lip of the exhaust collector was the source of the distortion. This distortion was eliminated by modifying the exhaust collector lip with acoustic (foam) wedges.

During the workshop, several comments regarding the need for standardization of noise measurements in the case of airplane flyover were made. This discussion was generated by presentations on airplane flyover noise propagation and measurement (Paper 79-0650) and on the lateral noise attenuation from airplane flyover (Paper 79-0651). Some barriers preventing the establishment of standardized procedures for noise measurements in the case of airplane flyover were discussed. Flight effects, ground attenuation and reflection, calibration (lack of a reference), microphone position, and number of microphone effects were some of the barriers; a determination of the influence of these barriers on the measurement of noise resulting from airplane flyovers would be essential to establishing a standard procedure for such measurement.

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