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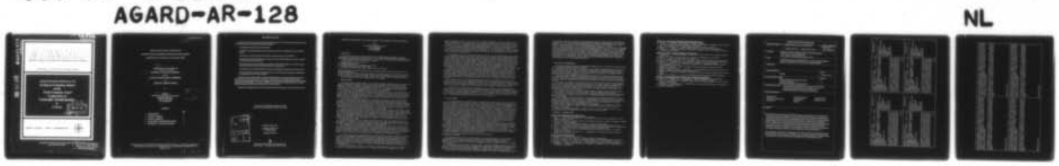

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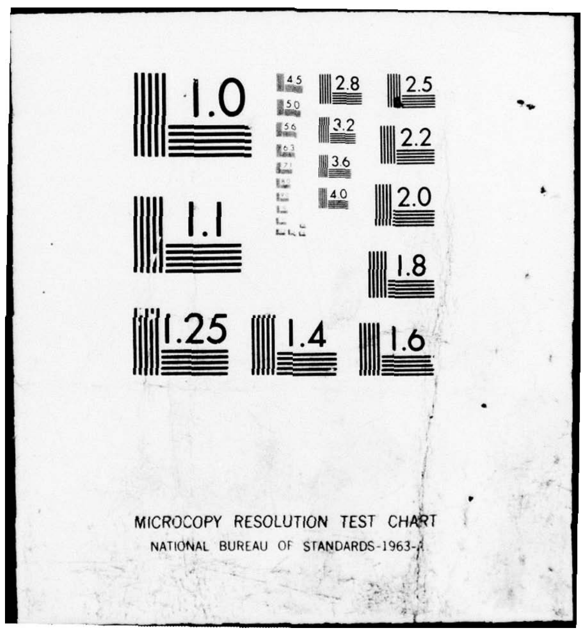
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Technical Evaluation Report on the Fluid Dynamics Panel Symposium on Unsteady Aerodynamics

by

H. Bergh

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on the
FLUID DYNAMICS PANEL SYMPOSIUM
on
UNSTEADY AERODYNAMICS

by

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The Netherlands

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The Proceedings of the AGARD Fluid Dynamics Panel Symposium on Unsteady Aerodynamics, which was held in Ottawa on 26–28 September 1977, are published as AGARD-CP-227, February 1978.

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– Providing scientific and technical advice and assistance to the North Atlantic Military Committee in the field of aerospace research and development;

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1. INTRODUCTION

From 26-28 September 1977 the Fluid Dynamics Panel of AGARD arranged a Symposium on "Unsteady Aerodynamics" at the Government Conference Centre, Ottawa, Canada. This Symposium was organized by an international Programme Committee headed by Prof. A.D. Young, who also chaired the Round Table Discussion.

The programme consisted of the following 5 sessions:

I Unsteady Subsonic and Supersonic Flow
II Unsteady Transonic Flow
III Unsteady Non-Separated and Separated Boundary Layers
IV Viscous-Inviscid Interactions, Dynamic Stall
V Unsteady Flows Associated with Rotors, Cascades and Turbo Machinery.

These 35 papers and the Round Table Discussions are published in AGARD Conference Proceeding No. 227, "Unsteady Aerodynamics".
As the proceedings are already available the evaluator has refrained from a detailed review of the lectures and has restricted his task to an attempt to sketch the main developments in each field to which a session was devoted, to consider their mutual relations and to present conclusions and recommendations.

The views expressed are the sole responsibility of the evaluator.

2. GENERAL OVERVIEW

The various items of research conducted in a certain field may be considered as ships on a river. All ships are sailing from the origin of "basic research" through passages called "increasing knowledge", "attempt of modeling", "development and testing of prediction methods" to the wide sea of "practical application". The various stages of development are revealed by a time exposure as different positions of the ships on the river. As a symposium provides us with such a time exposure, we may evaluate the present situation in "Unsteady Aerodynamics" on the basis of our symposium.

At a first glance, we see distinct differences in the positions on the river, not only between the research ships of one problem fleet, but also between the various problem fleets. Looking more closely, it becomes evident that the ships belonging to session I "Unsteady subsonic and supersonic flow" are sailing ahead on our river, while some ships already seem to have reached the sea. For these speed regimes our knowledge about the aerodynamic forces acting on harmonically oscillating surfaces in inviscid attached flow is certainly well developed [1, 3, 5, 9].

In his review paper [1] Ashley considered also the capability of linearized theory for harmonically oscillating lifting surfaces, slender bodies and interfering configurations. He warned against further refinement of the linearized tools ("misplaced efforts") and pointed to possibilities for calculating small but arbitrary motions. In this respect he believed that Edwards' work will provide a sound basis for modifying existing prediction methods for harmonic motions. A a future goal he sketched his dream of an unified computational fluid dynamics for steady and unsteady 3-D flows, capable to predict accurate results for various types of motions of practical configurations in all speed regimes.

In an attempt to bring this future to the present, Morino and Tseng [3] marched in with SOUSSA, a computer program for Steady Oscillatory and Unsteady, Subsonic and Supersonic Aerodynamics. Recent improvements were reported together with some results. An interesting question is whether such a general computer program with its continuous adaption process to latest developments is sufficiently flexible in application to compete with more pragmatic approaches. A good example of the latter was presented by Roos et al.,[9] who verified the applicability of their NLRI method on a complete aircraft with external stores. For such a configuration calculated flutter characteristics were shown to be in good agreement with flutter tests in a wind tunnel and in free flight.

Another experimental check on the validity of linearization, at least for incompressible flow, was given by Patel [4] who measured lift and pitching moment on two finite model wings in vertical gusts. The aerodynamic force response to gusts with two harmonic frequency components were shown to be in close agreement with a superposition of corresponding responses to single components.

This satisfactory situation existing in subsonic and supersonic flow applies only for attached flow. As soon as we are dealing with separated flows, our theoretical means fail in practical situations and our wind tunnel experiments may suffer seriously from limitations in Reynolds number. There is one exception. Wings with leading edge separation (in steady and unsteady flows) can be treated quite well with a nonlinear discrete vortex method, as was shown by Kandil [2] et al. Their general method, not restricted to small or harmonic motions, was applied to delta wings and gave good agreement with experimental results.

As could be expected from the greater complexity of their problems, the ships of session II "Unsteady transonic flow" are lagging far behind those of the previous session. But driven by the strong need for safety of a new generation of aircraft and stimulated by increased physical understanding [10], some ships seem to be steering a good course. In this problem area the experimental work, mainly devoted to two-dimensional attached flow, has played a guiding part. Our physical understanding of shockwave behaviour and of the strong influence of the steady flow field on unsteady aerodynamics was improved considerably by Tijdeman's experiments directed to special flow features [10]. Additional contributions were presented during the Symposium [8, 13].

In recent years prediction methods for 2-D flow have achieved impressive results. A good example [illegible]s presented at this Symposium by Yoshihara et al [14], showing the potential of such methods for aeroela[illegible] optimization purposes. However, it is a pity that the calculation method was not used to study the applicability of superposition in this speed range. As recent physical observations stressed the importance of shock wave motions, it is not surprising that this phenomenon got much attention in newly proposed calculation methods. An efficient procedure for handling shock wave motion in 2-D flow was demonstrated by Seebass et al.[11]. This shock-wave treatment was also discussed extensively in the promising considerations of Liu and Winther [12] about a mixed kernal function approach for 3-D flow. However, as was stressed by Tijdeman in his review lecture [10], the viscous effects are very important in this speed regime. So there is a strong need for blending the present calculation methods for inviscid flow with some engineering type method that accounts for the main viscous effects.

Looking again at our river, far behind the transonic vessels we see the unsteady boundary layer vessels and the ships dealing with viscous-inviscid interactions near stall conditions. Both groups, guided by helicopters, clearly are sailing in close contact. Yet the research on unsteady turbulent boundary layers seems to lose forward speed in spite of many investigations. As Telionis [16] stated: "Successful modeling of the turbulent boundary layer is a clear challenge to the theoreticians. They will have to invent new models that would take into account the interaction between the organized fluctuations of the outer flow and the random fluctuations of turbulence". Although a certain picture emerges from the experimental evidence, there still remains a strong need for detailed, accurate experimental data with well documented initial conditions. A good example of careful experiments was show in the contribution of the ONERA group [17]. Their continuous effort gradually discloses more details of the turbulent boundary layer and leads to a better physical insight.

The research on the dynamic stall problem has developed rather rapidly in the last decade. Careful experiments have revealed many details of the phenomena occurring during the stall process. Attempts to understand the mechanism and even to model it had some success as long as only the NACA 0012 section was considered. However, as Philippe [21] illustrated in his review paper, stall may be introduced by various causes, depending on several known and unknown circumstances. His conclusions that dynamic stall is still too complex to be understood sufficiently even in the simple case of 2-D airfoils, while at the same time it is questionable whether 2-D observations are useful in 3-D cases, were shared by a large part of the audience.

The contributions [23, 24, 26] concerning numerical solutions of the Navier-Stokes equations did not change the overall view. Impressive results were presented about the flow around airfoils, roughly showing similar features as observed in the experiments of Saxena et al. [22] and Dyment and Gryson [28]. However, as the calculations cover only low Reynolds number (up to 10^4), it remains doubtful whether this way of attack may provide us with useful information for practical applications on helicopters or fixed wing aircraft.

The important field of unsteady flows associated with rotors, cascades and turbo machinery was not covered so well. The two review lectures, one by Byham and Beddoes on unsteady rotor aerodynamics [32] and the other by Platzer on unsteady flows in turbo machines [33], are both excellent surveys of the fields considered but did not get the deserved response, probably due to the limited number of associated contributions. This rather isolated position was emphasized also by the fact, that these subjects were not touched on during the R.T.D. A specialists meeting seems to be better suited for these subjects.

3 CRITICAL COMMENTS

It is not surprising that large differences in development are observed between the various subjects in unsteady aerodynamics, since in general, progress in research depends on two counteractings factors: the need for a solution and the complexity of the problem. The former determines the will to spend money or manpower, the latter is a measure of the severity of the struggle laying ahead. So the various stages in development attained are no more than a result of the weighting factors of the needs and the complexities of the various problems. However, a point of concern is the apparent lack of communication between the groups This stems from the historical development that has gone in an application oriented way: either fixed wing aircraft research or helicopter research. For subsonic and supersonic flutter investigations of fixed wing aircraft unsteady aerodynamics assuming inviscid attached flow appeared to be sufficient. For helicopter rotors, however, operating locally around stall conditions, strong interactions between the inviscid outer flow and the separated or non-separated boundary layer regions exist. As the fixed wing people did not display any interest in viscous phenomena, it is natural that unsteady boundary layer research was devoted almost explicit to problems associated with rotor aerodynamics. To reduce the complexity of the 3-D flow problem near the stall, many studies are dealing with 2-D situations only. This historical development along different lines was reflected also in the programme set up of our Symposium.

However, there are some signs which can be regarded as forerunners of another situation. For example viscous effects are playing an important role in unsteady high subsonic and transonic aerodynamics, not only with regard to flutter aerodynamics but also in the unsteady off-design behaviour (buffeting) of advanced wings, a topic that was not touched upon during the Symposium presentations. On the other hand, as became clear from the RTD, workers on unsteady boundary layer problems have doubts on how to proceed.

Therefore, in my opinion the time has come for considering a better spreading of the total effort spent on unsteady aerodynamics. In stead of having an application oriented approach, we should adopt a problem oriented one emphasizing the following two main problem areas:

a) Attached flow problems, including related viscous-inviscid interactions
b) Separated flow problems

This distribution also allows for a better answer to the intriguing question of the usefulness of 2-D investigations for the study of 3-D problems. As long as the flow remains attached, in many cases a reduction from 3-D to 2-D flow is possible without violating in essence the physics involved.
However, since separation seems to be really a 3-D phenomenon, the study of separated 2-D flows is becoming rather academic.

Also the question of the influence of Reynolds number on unsteady aerodynamic phenomena can be handled better if the proposed division is used. For attached flow we might think of some kind of extrapolation from model test values to free flight. When flow separation is involved Ericsson and Reding [25] consider it as impossible to simulate full scale unsteady aerodynamics in dynamic tests at subscale Reynolds numbers.

A further point concerns the position of unsteady aerodynamics with regard to the AGARD Panels. Prior to

this Symposium, aeroelastic problems and related unsteady aerodynamics have been handled by the SMP. This has worked well, since linearized unsteady aerodynamics may be isolated almost completely from steady aerodynamics. A great advantage of handling unsteady aerodynamic problems in the SMP was the direct contact between the people developing the tools and those applying them to aeroelastic problems.
However, in problem areas where we need a nonlinear aerodynamic approach, e.g. in the transonic speed regime, the steady flow field influences strongly the unsteady aerodynamic loading. Then the tools can be developed better by aerodynamicists with a good knowledge of steady aerodynamics. In some cases, e.g. time dependent calculation methods, the tools are even suitable for both problem areas. So a close liason with the FDP becomes necessary. At the same time the connection between unsteady aerodynamics and aeroelasticity should remain strong to avoid the unwanted situation that the aerodynamic tools developed are not adapted to the requirements of the aeroelasticians. For this reason, though the Programme Committee had foreseen some cross-coupling [27, 31], AGARD should promote a prosperous collaboration between SMP and FDP concerning the interdisciplinary topic called unsteady aerodynamics.

4 CONCLUSIONS AND RECOMMENDATIONS

This symposium clearly demonstrated that unsteady aerodynamics covers a wide variety of research topics that may have quite different stages of development.

A satisfactory situation exists for the subsonic and the supersonic speed regimes as long as the flow remains attached. In that case tools are available for determining the aeroelastic behaviour of complete aircraft with external stores. Prediction methods for calculating on a routine basis arbitrary (small) motions are being developed. In general it can be concluded that computational fluid dynamics offers good possibilities for further progress in the near future.

In unsteady transonic aerodynamics the physical understanding has been improved considerably and for 2-D inviscid flow prediction methods show promising results at least in a qualitative way. For 3-D wings instructive elements for an improved engineering type of approach were shown. It has become clear that a strong need exists for boundary layer calculation methods suitable for inclusion in the existing prediction methods.

In experiments on harmonically oscillating models, more attention should be given to the influence of the tunnel walls on the results; especially in the case of 2-D flow which is subject to a higher blockage ratio. A better understanding of the off-design characteristics of advanced wings with supercritical properties e.g. buffeting is urgently needed. Unfortunately this subject was only touched upon in a very few contributions. As buffet boundaries may affect directly the flight envelope of a new design, more attention should be paid to it in the future.

With respect to the study of attached and separated turbulent boundary layers the need for accurate detailed experimental data with well determined initial conditions emerged during the Symposium.

The question of the influence of Reynolds number in unsteady aerodynamic problems is still unresolved. Transonic facilities for dynamic-testing at high or full scale Reynolds numbers are urgently needed to improve understanding.

A lack of communication and collaboration is observed between the people dealing with fixed wing aircraft and those working on helicopter problems. It is recommended that consideration be given to a more problem-oriented approach which makes a distinction between attached flow and separated flow problems. This may provide a better basis for a more appropriate distribution of the total effort spent in unsteady aerodynamics than the application oriented approach followed so far.

The sessions on unsteady flows associated with rotors, cascades- and turbo machinery got too little attention. It seems worthwhile to consider a separate specialists meeting for such special fields of application in the future.

Finally since unsteady aerodynamics is a field of interest of both the SMP and the FDP, close cooperation between these two AGARD Panels concerning this topic should be assured.

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RTD Round Table Discussion

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14. Abstract

The Symposium demonstrated the different stages of development in the broad field of unsteady aerodynamics. Satisfactory tools are available for the subsonic and supersonic speed regime with attached flow. Understanding has been improved in unsteady transonic aerodynamics, but the need for high Reynolds number transonic facility capability is evident. Difficulty in correlation of work in fixed wing and helicopter attached/separated flow problems is noted. Unsteady flows associated with rotors, cascades and turbomachinery require more attention, and the common interests of structural aeroelasticians in unsteady aerodynamics calls for more collaboration with aerodynamicists.

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