REPORT ON EUROMECH COLLOQUIUM 261

GORTLER VORTEX FLOWS

held on 11-14 June 1990 at ISITEM- University of Nantes - Nantes - France

The Colloquium brought together , *for the first time* , researchers working in the general area of the Görtler instability .
The Görtler instability is one of the most interesting flows displaying 3-dimensional perturbations in the form of streamwise vortices.
From the fundamental point of view , this instability belongs to the "open flow" systems where the control parameter (the Görtler number) of the instability grows with the boundary layer thickness, so every single vortex undergoes a succession of laminar, transitional and turbulent regimes.
At the same time the instability is strongly influenced by the nature of disturbances in the incoming flow.
This instability plays an important role in many industrial and aeronautical problems. Gaz turbine designers are interested to know the heat transfer modifications on the pressure side of the blades when Görtler vortex appears. Designers of airfoil profiles with concave regions and designers of re-entry space vehicles (such as Hermes) have similar preoccupations. In the recent years a great development in the studies of the Görtler vortex flow was prompted in relation to the design of nozzles in quiet tunnels.
Almost *90 %* of scientists active in this field attended this meeting and this proves the success in the previous publicity and advertising process.
This EUROMECH Colloquium provided a very useful forum for a review of the current state of knowledge of the Görtler instability, an exchange of information about projects being currently carried out at different laboratories and identification of the open questions that should be addressed in the future.
The meeting was successful in bringing together specialists from different fields. We obtained the participation of key specialists of the Fluid Mechanics (M.Morkovin, H.Bippes, J.Ginoux, W.S.Saric, E.Hopfinger,...), in the Physics of Chaos and Nonlinear problems (P.Manneville, P.Huerre, H.Brand,...), in the Mathematics of Differential Equations (P.Hall, Th.Herbert, K.Kirschgassner,....) and scientists representing the industry (Avions M.Dassault, SNECMA, High Technology Corp.) and representatives of public organizations as the national aeronautical laboratories (NASA-USA-, ONERA-France-, DFVLR-FRG-, V.Karman Inst. -Belgium).
The distribution of the participants was as follows:
Belgium 1 , Denmark 3, France 18, Federal Republic of Germany 12, Democratic Republic of Germany 2, Italy 1, Norway 1, United Kingdom 8, Sweden 1,Switzerland 2, USSR 5, and other countries 12.
Almost all the participants and the scientific committee appreciated the policy of giving the opportunity to people coming from different points of view and experiences, to express their opinions without rigid dogmas .
An other goal of this EUROMECH Colloquium was also to assure the presence of the senior and more experienced scientists in the subject, together with young researchers (including students). We were glad to receive in this meeting the full teams from important laboratories working in the subject, as was the case of the groups from the University of Exeter(UK), the University of Southern California(USA) and the Ecole Supérieure de Physique et de Chimie de Paris(France).
A special effort was made by the directors of the EUROMECH 261 to obtain financial aides from different organizations to cover the meeting expenses, full coverage of the expenses of the Scientific Committee and participants from eastern European countries, financial aide (travel and lodging expenses) to young participants and those who had not enough travel fund. In this way we could satisfy almost all justified financial demands of the participants who needed, without increasing the others fees.

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The scientific programme was designed in order to alternate theoretical and experimental contributions.It ran perhaps with a strenuous rhythm; the price to pay for the first colloquium on the subject with speakers revisiting even old works. The oral contributions ran between 25' and 35' . In addition a poster session (very efficiently conducted by E. Hopfinger) provided the possibility of short oral discussion of all the posters.
In this Colloquium we revisited the state of the art of the Görtler instability. The main topics discussed were as the following:
§ Linear theory of instability: The neutral curve of instability is strongly dependent on the initial conditions. The effect of pressure gradients and compressibility is known. Open problems are related to the effect of roughness and the role of the freestream disturbances known as the problem of receptivity. The existence of convective type instability in special cases (constant thickness boundary layer) need to be extended to more realistic flows.
§ Nonlinear interactions and secondary instabilities : The stages of the nonlinear development of the Görtler vortex and the temporal secondary instabilities are subjects where many problems are still open. The results of the Dean instability (the centrifugal instability of the Poiseuille flow in curved channels) can shed some light on the more complex Görtler problem, however the direct numerical simulation of the Dean and in the Taylor - Couette problems imply the hypothesis of no growth or periodical disturbance structure in the flow direction.
The experiments show that secondary instabilities concentrated in the regions where low momentum fluid flows away from the wall forming "mushroom" structures ,which induce local inflectional points in the spanwise distribution of the streamwise velocity (spanwise gradients of the same order of magnitude as the normal to the wall gradients).
Regarding this topic, one of the observations of the Colloquium was that the Görtler instability is still experimentally "young" compared to the Tollmien-Schlichting instability.
§ Interaction with transverse waves : The interaction of the longitudinal Görtler vortex and the typical transverse Tollmien-Schlichting waves is an important subject in transition to chaos and turbulence. This interaction can become a model problem of nonlinear resonance between different spatial modes of instability.
It is interesting to note that it has been commonly believed tthe presence of streamwise vortices strongly accelerate transition to turbulence. The picture emerging from the experimental and numerical results presented during this meeting show that it is not so. This problem needs, therefore, further clarification.
§ Applications : Successful application of the linear theory coupled with the commonly applied e^N criterion on the concave walls, needs theoretical support.
The Colloquium observed that a large gap exists between fundamental results and industrial needs where the Görtler instability appears.
The effects of the instability on heat transfer can not be quantified at present. Some reported experiments show strong effects. This issue is of most interest to the industry in relation to the problems of film cooling of gaz turbine blades and in the overheating of space vehicles at re-entry to the earth atmosphere.

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The strong participation, heavy rhythm and different origin of the participants did not impede the generation of interesting discussions. Indeed in the context of the conference perhaps only two or three papers did not prompt questions and discussions. In this regard, we like to acknowledge M. Morkovin who remaind, through his constructive comments, one of very active animators of the workshop. W.S. Saric summarized the papers which were presented during the three and a half days of work and the Colloquium terminated by a panel discussion led by P.H.Alfredsson, H. Bippes , J.C. Floryan, P. Hall and M. Morkovin. The panel concluded with some suggestions that will be presented at the end of this report.
The concentration of the participants in principally two hotels, very near one to the other, allowed numerous informal discussions. Also during the lunches taken together and during the social banquet and welcome reception the exchanges of information and discussions were strong.

We also like to acknowledge the authorities of the ISITEM (of the University of Nantes) especially its Director J.P.Bardon, who provided us with the very modern facilities of the new building of his Institute (in fact this building was inaugurated two weeks before the EUROMECH 261).

As this meeting was the first on this subject and with consideration of the interests of this conference the panel and almost all the participants strongly recommended the idea of the continuation of this event. As a conclusion of the panel the Directors of this EUROMECH Colloquium were mandated to coordinate the organization of a next meeting in around three years. At the same time we were mandated to coordinate a network of scientific exchange on the subject and permanent contact between the research workers in this area. We are studying a special project in order to put in action this proposition.

We are also confident that in this meeting people from different countries established solid bases of future collaboration.

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§ Directions for future : A new and modern generation of experiments is needed in this field. Experiments carried out at different facilities should be coordinated. Experiments should concentrate on few selected geometries and configurations to make meaningful comparisons possible. The same geometries could also be used for numerical simulation. The scientific committee of this EUROMECH Colloquium could undertake the mission of the model selection, and the directors of this Colloquium were mandated to establish a permanent secretariat in order to facilitate and encourage the communication and the coordination in this regard among the scientific community.