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Diffraction of waves by obstacles and inhomogeneities in fluids: a report on Euromech Colloquium 271

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This first Euromech Colloquium to be held in Kiev attracted 74 participants including 19 from outside the USSR: from Austria, Bulgaria, France, Germany, Italy, Japan, Norway, Poland, Portugal and the United Kingdom. Despite unexpected absences or delays for some participants due to travel difficulties, a full programme of talks, each followed by a lively discussion, was maintained throughout the entire three and a half days of the Colloquium. In addition considerable space was set aside for posters, which ensured that the discussions were not confined to the lecture theatre. The colloquium was dominated by two major areas of interest: scattering of acoustic waves by elastic shells or bodies, and problems of surface gravity-wave diffraction. Also presented was a selection of widely varying topics within the general area of wave diffraction. A summary of the presented talks is given below.

1. Acoustic scattering by elastic shells or bodies

V. T. Grinchenko (Kiev) described work on scattering by thin elastic rectangular shells whose dimensions were small compared to a wavelength. The problem was solved using matched eigenfunction expansions appropriate to the different regions, enabling criteria to be established for the control of acoustic characteristics of a two-layer active elastic grid using a varying elastic field.

V. M. Babich† & A. P. Kiselev (Leningrad) illustrated a 'non-geometric' phenomenon in wave propagation which is not revealed from simple ray theory. Using as an example the point-source problem for two acoustic homogeneous media separated by a plane interface for which an explicit solution is possible, they used asymptotic analysis to reveal a further wave in addition to the expected incident, reflected and refracted waves. The introduction of complex eiconal functions with a small imaginary part provided a modified ray theory which was able to describe these extra waves and which could be applied to situations where no explicit solution exists.

Ray theory was used by V. S. Buldyrev & M. A. Pookhov (Leningrad) to calculate the waves diffracted by an elastic spheroid, whilst E. L. Shenderov (Leningrad) considered the differences between the fields scattered by an elastic layer when excited first by a point source and then by an incident plane wave. On the same theme M. V. Fedoryuk (Moscow) discussed the scattering of an acoustic field by an arbitrary elastic solid immersed in a liquid and showed that in certain parameter ranges the usual system of four two-dimensional integral equations with rapidly oscillating kernels can be replaced by two well-behaved one-dimensional integral

† This symbol indicates the presenter of each talk in cases of multiple authors.

equations which can easily be computed. (It was a great shock to learn of Fedoryuk's sudden death so soon after the colloquium had ended.)

A. Klauson† & J. Metsaveer (Tallinn) showed how stiffening members in a thin cylindrical elastic shell can cause creeping modes in addition to the usual scattered field when excited by an incident plane pressure pulse. An asymptotic method valid in an intermediate frequency band was used by D. G. Markushevich, E. V. Nolde & D. G. Vasil'ev† (Moscow) to consider the scattering of a plane acoustic wave by a thin empty arbitrary convex shell of revolution.

G. Maze†, J. L. Izbicki & F. Lecroq (Le Havre) described a method developed by Maze & Ripoche in 1981, the Method of Isolation and Identification of Resonances (MIIR), which enables plots to be made of the backscattered spectrum and the resonance spectrum when elastic cylinders or shells immersed in water are excited by acoustic plane waves. J. Ripoche (Le Havre) explained how MIIR can be used to widen the scope of experimental research in acoustic scattering of elastic targets to include both passive targets such as solid cylinders, empty or liquid-filled cylindrical shells and also active targets excited for example by an internal source.

Further work in this general area of scattering of acoustic waves by elastic bodies was presented by A. Goldenveizer, J. Kaplunov† & S. Korsunskiy (Moscow) who considered scattering by a cylindrical shell, and N. D. Veksler (Tallinn) who considered both spherical and cylindrical shapes.

2. Surface wave diffraction problems

A composite model was described by Yu. I. Shokin, G. S. Khakimzyanov & A. I. Urusov† (Krasnoyask) to investigate the effect of nonlinear surface waves approaching a surface body. In a domain external to the body, equations similar to the Boussinesq equations were used whilst a fourth-order elliptic equation for the potential was used under the body. Calculated results for a partly submerged parallelepiped showed good agreement with both experimental data and computation based on a full three-dimensional potential flow model.

S. R. Massel (Gdansk) used an extension of Berkhoff's mild-slope equation to include dissipation due to wave breaking in estimating wave motions over a shoaling bottom, whilst J. Grue (Oslo) constructed a model for nonlinear waves approaching a shallow underwater ridge and showed that up to 25% of the incoming energy is transferred to the second harmonic waves. The model used full shallow-water theory above the obstacle and deep-water linear theory upstream and downstream of the obstacle. Linear theory was used by G. Flaten & E. Palm† (Oslo) to determine the dissipation and diffraction of an incoming plane wave by a submerged, long horizontal porous circular cylinder. Darcy's law was assumed to hold in the porous region and it was proved that, up to second-order in amplitude, the reflection coefficient was identically zero.

Both A. Clement (Nantes) and Yu. A. Egorov† & I. A. Molotkov (Leningrad) considered the effect of a solitary wave against a rigid boundary, in the former case a surface obstacle and in the latter case a slowly varying bottom topography; a generalized ray theory approach was used by P. Borejko† & F. Ziegler (Vienna) to study the scattering of sound sources in the ocean by a submerged sea-mount, and Y. Tsuji (Tokyo) described a theory to explain the loss in energy and momentum in a tsunami approaching the Japanese coastline. Using a Gaussian representation of both the initial wave and a sea-mount the theory predicted that 40% of the initial energy will be transferred into scattered wave energy.

S. Yu. Dobrokhotov† & P. N. Zhevandrov (Moscow) described asymptotic solutions to a number of problems of wave propagation in water over a slowly varying bottom including diffraction by bottom inhomogeneities, trapping of waves by arbitrary bottom topography, and the Cauchy–Poisson problem for one- and two-layer fluids including surface tension effects.

C. M. Linton (Bristol) presented a simplified but exact formulation of the scattering of an incident plane wave by any number of vertical circular cylinders of arbitrary size and spacing, and showed how both the mean drift force and the free surface elevation could be calculated in a straightforward way.

3. General topics

R. I. Nigmatulin & A. A. Gubaidullin† (Tallinn) described models of unsteady wave motions in a two-phase gas–liquid medium having a bubbly structure. The principal mechanism determining shock-wave evolution in low-viscosity liquids with bubbles about 1 mm in size appears to be heat dissipation arising from non-equilibrium heat transfer between the gas in the bubbles and the surrounding liquid. Shock-wave propagation can be either damped or amplified with the help of a bubbly source by suitable choice of parameters.

J. Stefaniak (Posnai) discussed magnetoelastic waves in viscoelastic material, whilst I. Molotkov & S. Vakulenko† (Leningrad) considered autowaves in inhomogeneous nonlinear dissipative media, where liquid movement is described by a reaction–diffusion equation modelling changes in the internal structure of the medium.

S. Rybak (Moscow) considered the consequences of using a model dispersion relation which may be appropriate for liquids with bubbles or for modelling internal waves. The corresponding partial differential equation modelled both resonant dispersion and quadratic nonlinearity and produced solitary wave solutions.

A method for determining properties of the internal waves which occur in an exponentially stratified liquid was presented by Korobkin (Novosibirsk). The method, which appeared to give explicit results for simple geometries such as a vertical shelf or barrier, makes extensive use of complex function theory.

I. D. Abrahams (Keele) and G. R. Wickham (Manchester) described matrix Wiener–Hopf techniques applied to scattering of acoustic waves by staggered infinite plates. The resulting infinite system of equations was shown to be uniquely solvable in the space of l_2 infinite sequences, and a variety of numerical results for the scattered field were presented.

Stationary phase techniques were used by C. J. Chapman (Cambridge) to show that the diffraction pattern in the near acoustic field of a supersonically rotating many-bladed propeller was confined to a limited region of space near the propeller tips.

L. M. B. C. Campos (Lisbon) described a class of wave equations, namely those having exponential coefficients, for which a simple criterion can be given for the determination of the cutoff frequencies. The equations applied to a wide range of wave phenomena including oblique waves in a uniform horizontal or vertical magnetic field, as well as to vertical waves in an obliquely magnetic field.

W. Möhring (Göttingen) showed how to extend a technique by W. E. Williams for solving acoustic scattering by half-planes with soft, hard or more general impedance conditions by using combinations of source solutions and their derivatives both with respect to the source point and in a direction along the plane. For certain such problems it turns out that the scattered far field can be determined for all angles of incidence once it is known for certain specific angles of incidence.

D. V. Evans† & C. M. Linton (Bristol) proved the existence of trapped acoustic waves in the vicinity of a small circle symmetrically placed in a waveguide, and presented numerical results both for this case and also for the case of a symmetrically placed rectangle in the guide, whilst S. Sukhinin (Novosibirsk) used functional analysis to prove general results for trapped waves in the vicinity of periodic submerged bodies where linear shallow-water theory applies. The theory would appear to apply to acoustic problems also.

Finally, I. Selezov (Kiev) co-chairman of Euromech 271, surveyed a wide range of topics currently under investigation. These included perturbation methods in general wave scattering problems involving an extension of the Born approximation used in optics; the interaction of a heart wave pulse with a stenosis, using a simplified hydraulic model; the reflection of a solitary wave over a sloping beach of arbitrary slope, using multiple scale analysis, and the diffraction of an acoustic wave by an arbitrary array of circular cylinders. It will be of interest to compare the results of this last problem with those of C. M. Linton.

4. Conclusion

Throughout the Colloquium a high standard of both presentation and scientific content was maintained, and those participants who did not present a paper went to considerable trouble to prepare illuminating material for the poster sessions. Notable amongst these was the poster of T. S. Krasnopolskaya & N. P. Podchasov (Kiev), who considered the free-surface deformation arising when a vertical cylinder of liquid is excited by the rotations of a slightly eccentrically mounted internal vertical cylinder driven by an electric motor. Numerical studies revealed a transition from a limit cycle to chaotic motion in certain parameter regimes.

What emerged clearly from Euromech Colloquium 271 was the immense wealth of talent in the Soviet Union in the general field of wave diffraction. The same is undoubtedly true in other areas. With the arrival of *glasnost*, for the first time opportunities now exist for collaboration and exchange visits between scientists in the Soviet Union and elsewhere. But the lasting impression which remains is not just confined to the breadth and depth of the scientific ideas, but extends both to the overwhelming friendliness of the Soviet participants and to the warmth and hospitality of the Ukrainian hosts towards their foreign visitors.