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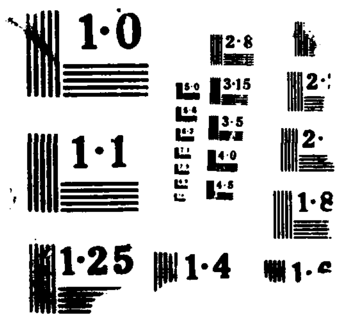
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Fraunhofer-Institut für Kurzzeitdynamik

Ernst-Mach-Institut

Abteilung für Ballistik

VISCOUS MODELING OF THE INTERIOR BALLISTIC CYCLE

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Third Periodic Report

October 1987 - March 1988

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Outline

In the third period, the study of algebraic turbulence models was continued: A series of experimental data on boundary layers were measured by J. H. Whitelaw and his co-workers [1] by experiments with low pressure gun simulators. We have run the DELTA code with the same input data and have obtained a good agreement with the experimental data. For a better display of the results, the graphics software was extended.

A mathematical model for the turbulent compressible gas phase of interior ballistics flows was developed. For this the k-ε model has been employed which is the most widely used and tested model of the present turbulence models besides the algebraic type of models.

During this period

1) J. Garloff has attended a lecture course entitled "Numerical Methods of Fluid Dynamics and Heat Transfer" at the University of Erlangen-Nürnberg, October 27-30, 1987.

2) R. Heiser visited the U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, November 2-5, 1987 to report the progress made by our ongoing activities.

Numerical Results

In [1] Measurements of pressure, projectile and flow velocities in a subsonic gun simulator with an inert single-phase flow are reported. The model gun is of constant diameter and of preburned-propellant type and allows a travel distance of the projectile of about 1 m inside the tube and an exit velocity of 40 m/s. The projectile is 250 mm long and weighs 0.953 kg. The measurements were performed with nitrogen gas pressurized within the initial volume to 8 bar above atmospheric pressure (gauge pressure); silicone oil droplets were added to the gas to represent the gas velocity. Flow velocity measurements were obtained at four axial stations by laser Doppler anemometry. computerized simulation, WEST GERMANY. (JES)

Figures 1 to 4 show the results of our numerical simulation using the DELTA code. The algebraic turbulence model employed is the Baldwin-Lomax model. In Figure 1, the axial distribution of the boundary layer thickness (marked by □) and the boundary layer displacement thickness (marked by Δ) at 26 ms is displayed. Special emphasis was put on the simulation of the transition from laminar to turbulent flow. The flow under consideration becomes turbulent at a late part of the cycle. This is a significant difference to the situation observed in the test case of the 20-mm caliber to which our computations reported in the second periodic report refer.

Figure 2 shows the projectile velocity travel curve over distance of breech. It was stated in [1] that the friction between the projectile and the tube wall is negligible. Therefore, the friction force was neglected in our test runs. However, it seems that the small overprediction of the projectile velocity may be due to this negligence.

In both figures, crosses indicate the measurements reported in [1] and show a good agreement with our computations. Details and comprehensive numerical results will be presented in a forthcoming report [2].

Our graphics software for an improved post-processing of the computational results was extended: Plots of the velocity vectors for a given radial and axial position at a given time are now available. Figure 3 shows the axial velocity components at some selected positions at time 26 ms (where the distance of the projectile from the breech is 1.078 m and its velocity is 41.8 m/s). For a better display of the results the graphics package DISSPLA was bought by our institute. This package allows us to run G2DELT and G3DELT, the postprocessors of the original BRL-DELTA version, for 2-D and 3-D plots, respectively. Figure 4 shows the axial gas velocity over the computational domain at time 26 ms using the DISSPLA software.

Mathematical Model for the Turbulent Compressible Gas Phase

To incorporate a more advanced turbulence model into the DELTA code, we have studied several turbulence models employing transport equations for turbulent quantities. Special emphasis was put on compressibility effects. These effects are neglected in most models presented in the literature. If one tries to take these effects into account it turns out that some compressibility terms appearing in the exact transport equations cannot be modelled up to now or can be modelled only under restrictive assumptions. At present, the effort of many researchers is directed to the modelling of these terms. We have greatly benefited by the lecture course on modelling of turbulence at the von Karman Institute mentioned in the first periodic report and the above mentioned lecture course on numerical methods in fluid dynamics and heat transfer at the University of Erlangen-Nürnberg. Many references to the 'grey literature' given there were very helpful.

To this periodic report we have attached a preliminary draft of an extended report [3] which points out in detail our efforts to develop an adequate model for the turbulent compressible gas phase of interior ballistics flows. In this report, we derive the governing equations for modeling the effects of viscosity, heat conduction and turbulence in the compressible gas phase. The underlying averaging procedure is described in detail. As advanced turbulence model, the k-ε model is employed. The model presented also includes near wall effects to facilitate future investigations on heat transfer to the gun tube wall, and real gas effects by using the Noble-Abel equation of state. However, it is noted that the model has to be carefully checked against experimental data so that the equations and modeling correlations listed in the report should not be considered as final.

Future Work

At present, we are incorporating the model described in the attached report into the DELTA code. This modification affects a large part of the code. We will continue to validate the turbulence models (algebraic and k-ε model) used in running the code with inputs from experimental measurements. We expect additional measurements on boundary layers obtained by F. Seiler from the Franco-German Research Institute in Saint-Louis (ISL), France, with the shock tube accelerator.

References

[1] A. F. Bicen, L. Khezzar, J. H. Whitelaw
Subsonic Single-Phase Flow in a Gun Simulator
Imperial College of Science and Technology, Mechanical Engineering Department, Fluids Section, London, Report FS/86/03, April 1986

[2] J. Garloff
Comparison of Two Algebraic Eddy Viscosity Models for Turbulent Modeling of Interior Ballistics Flows
Fraunhofer-Institut für Kurzzeitdynamik, Ernst-Mach-Institut, Abteilung für Ballistik (EMI-AFB), Weil am Rhein, Report to appear in spring 1988

[3] J. Garloff, R. Heiser
Turbulence Modeling of One-Phase Interior Ballistics Flows by a Two-Equation Model
Fraunhofer-Institut für Kurzzeitdynamik, Ernst-Mach-Institut, Abteilung für Ballistik (EMI-AFB), Weil am Rhein, Report No. 1/88 (to appear May 1988)

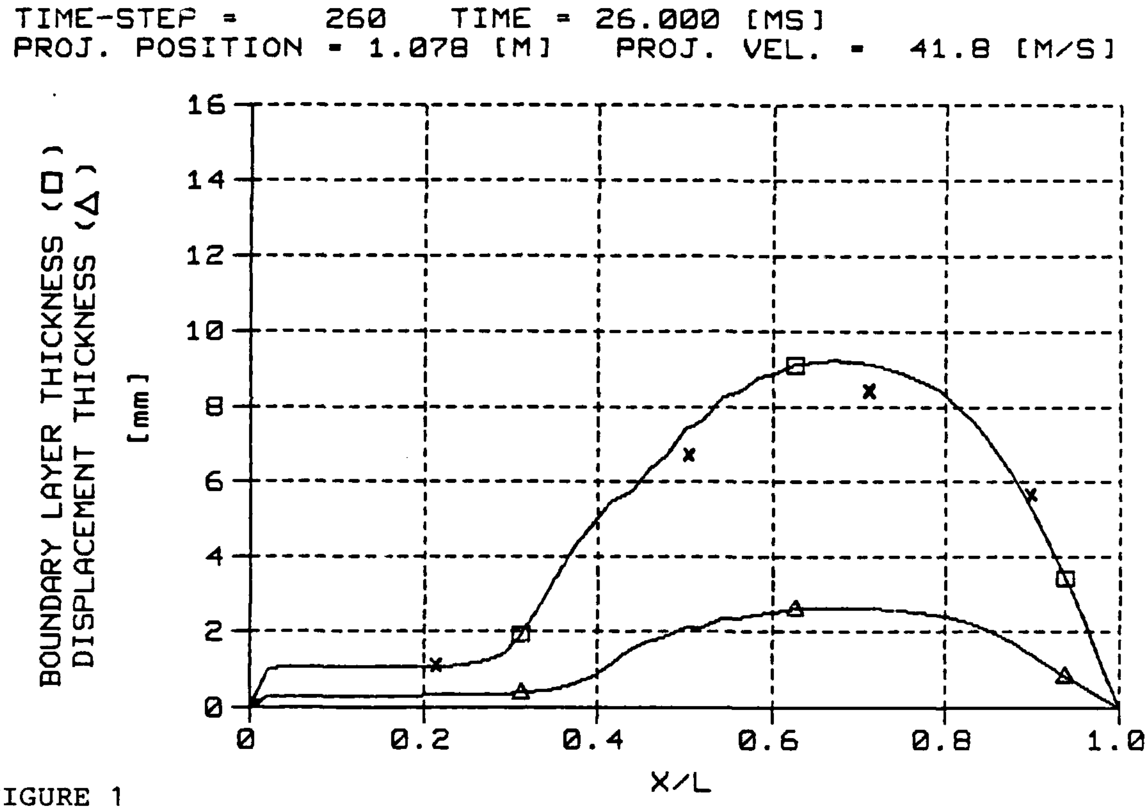

FIGURE 1

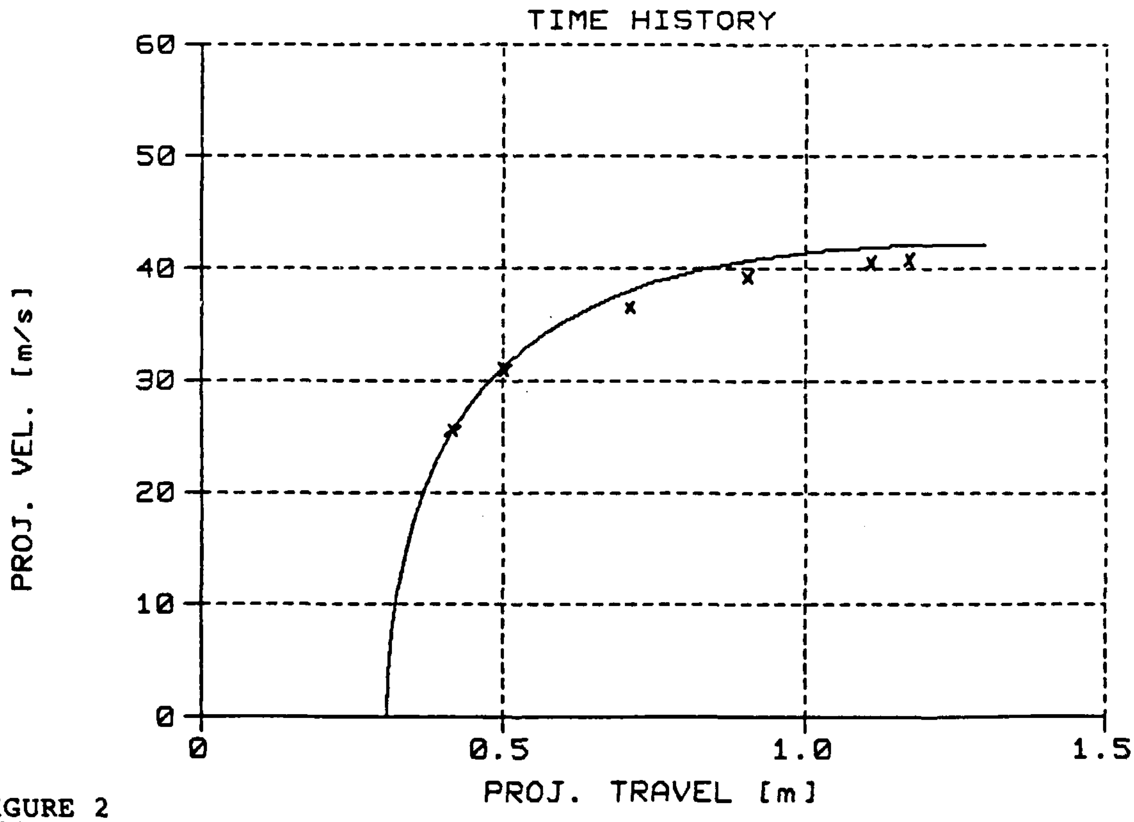

FIGURE 2

FIGURE 3

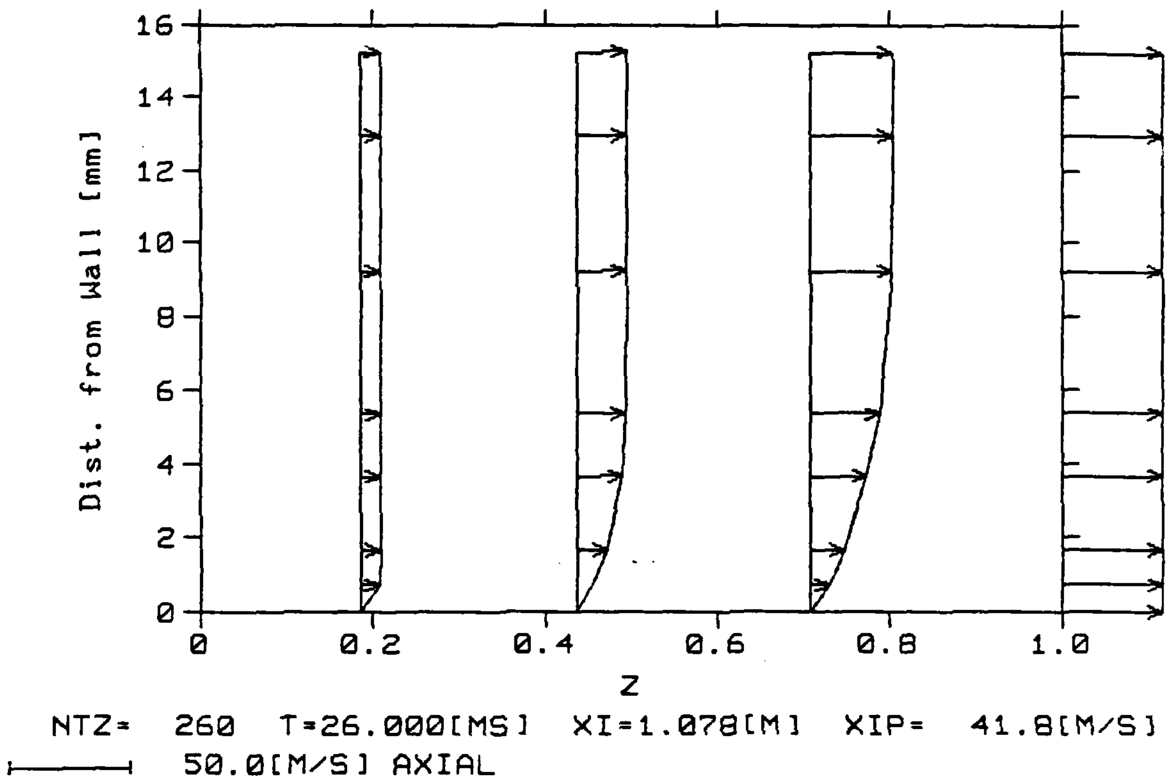
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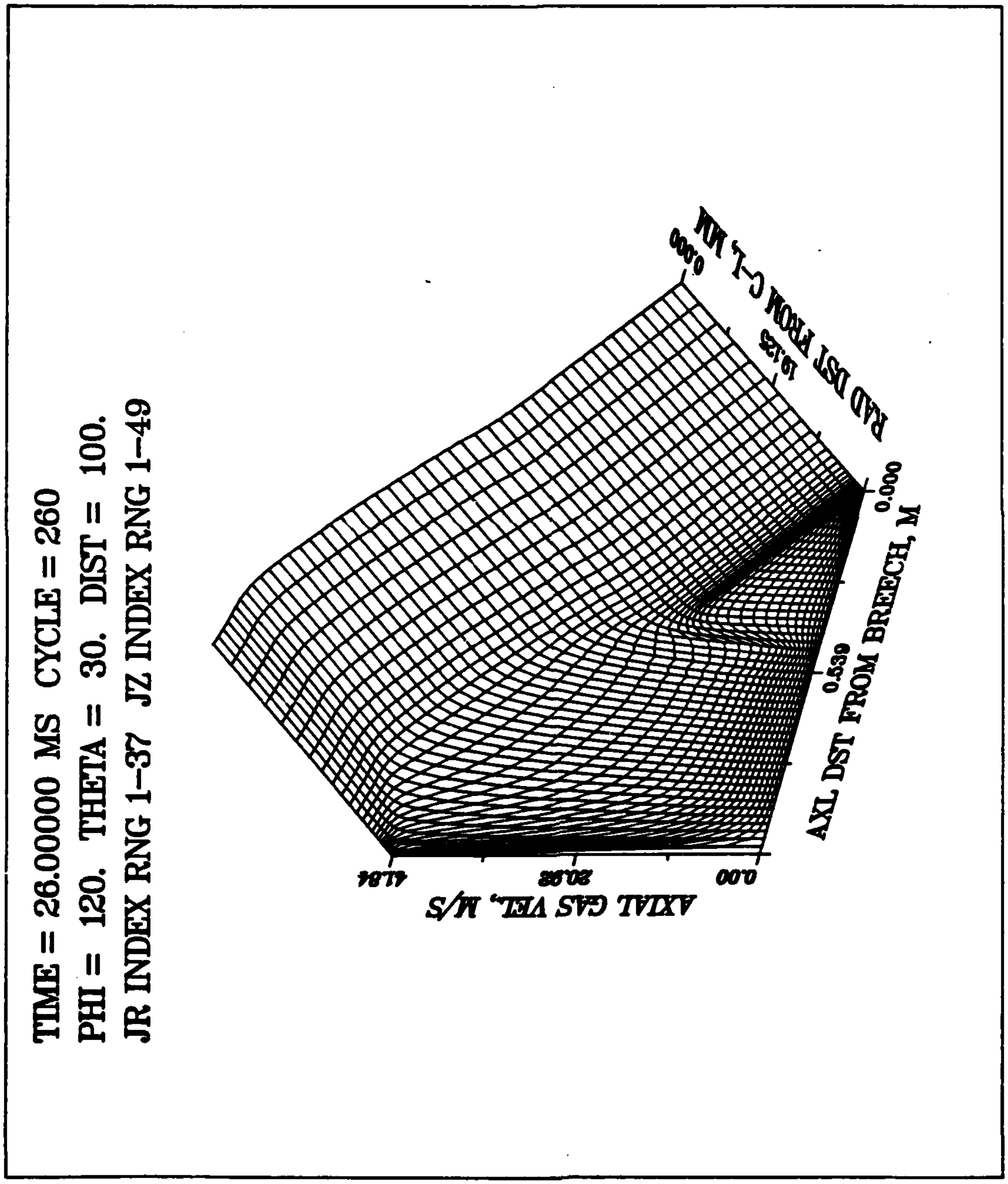
FIGURE 4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RAD DST FROM C-L, MM
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