Improved Pressure-Velocity Coupled Algorithm For Compressible Flow

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Abstract

In this research, an improved pressure-velocity coupled computational fluid dynamics algorithm for numerical analysis of compressible flow with the discontinuous phenomena as like shock waves was described.

Introduction

The pressure-velocity coupled algorithm to analyze at various flow speeds was studied by Drawish[1]. In that paper, they demonstrated that the developed algorithm works well in flow fields at various speeds. The other hand, the pressure-enthalpy coupling scheme for the simulation with high change of enthalpy was performed Emans[2]. This algorithm was adapted to analyse for engine flow problems.

Kraposhin[3] has applied the Kurganov-Tadmor flux splitting scheme, which is mainly used in density-based solvers, to the pressure-based algorithm of OpenFOAM. In that study, they proved that flux splitting schemes are appropriate to interpret the discontinuous flow phenomena as a pressure-based algorithm.

In this study, the Kurganov-Tadmor flux splitting scheme, developed by Kraposhin[3], was applied to a developed coupled algorithms and a verification analysis of compressible flow problems were performed using the developed solver.

Methods

The Original pressure-velocity & pressure-enthalpy coupled algorithm

- The coupled algorithm in pressure based solver is a way of simultaneously updating the flux on cell faces and the pressure gradient in iterative calculation
- The pressure based coupled solver has than the segregated pressure based solvers but this way is required more computation resources
- To analyze the flow with a large change in density induced by enthalpy in the pressure-velocity coupled algorithm, an internal iterations has to be performed for density convergence
- The pressure-enthalpy coupled algorithm was employed for the phenomena that has large density change induced by energy change

An improved pressure-velocity-enthalpy coupled algorithm

- The two coupled algorithms have some disadvantages to perform analysis the flow with high energy and velocity change as like shock tube and nozzle problem
- To solve this problem, an improved algorithm by combining the above two methods with flux splitting method studied by Kraposhin[3] was developed

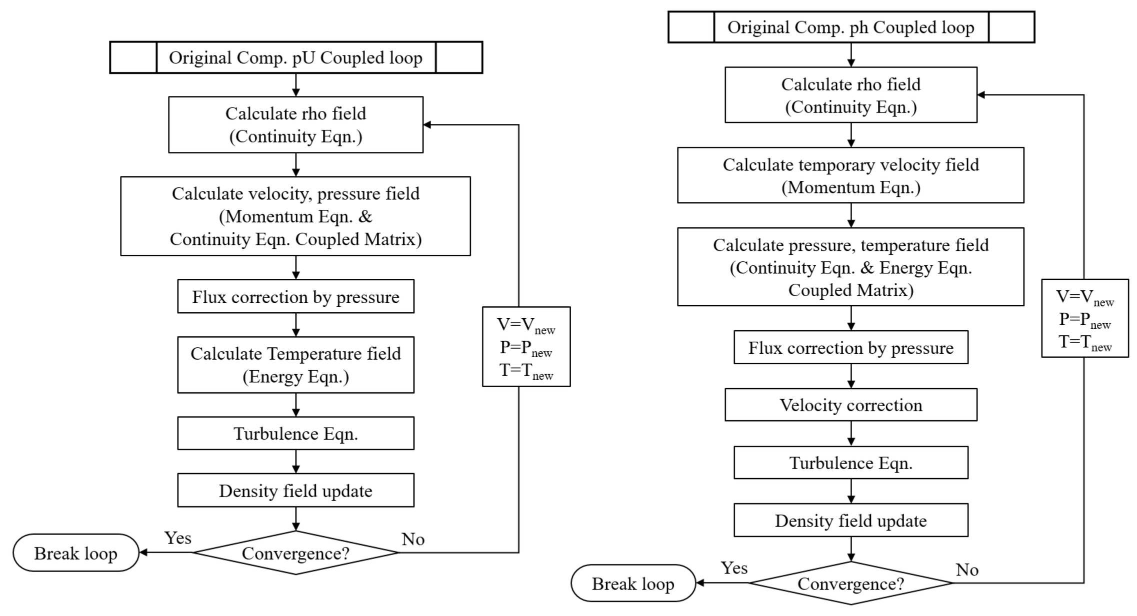

Figure 1. The original algorithms of coupled numerical analysis.

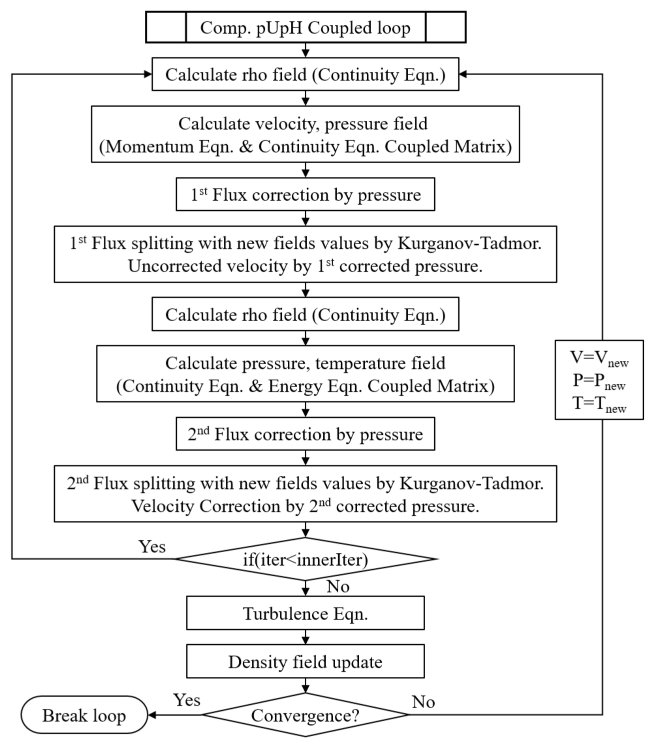

Figure 2. The developed algorithm of coupled numerical analysis.

Results

Some flow cases was employed to verify the developed solver.

1D Shock problems

- There is 3 shock problem – Sod(Figure 3), Lax(Figure 4), Shu & Osher(Figure 5) cases
- The analyzed results by developed solver are comparatively similar to other in-house and experimental results
- Through the analysis of the these cases, the analytical ability of the developed solver by improved algorithm for the flow with discontinuous flow phenomenon can be verified

JPL nozzle Problem

- Over-expended nozzle case was employed(Figure 6)
- Various mach number region was appeared through in converging-diverging regions
- Through the JPL over-expended nozzle case, the analytical ability of the developed solver by improved algorithm for the flow with wide mach number range can be validated

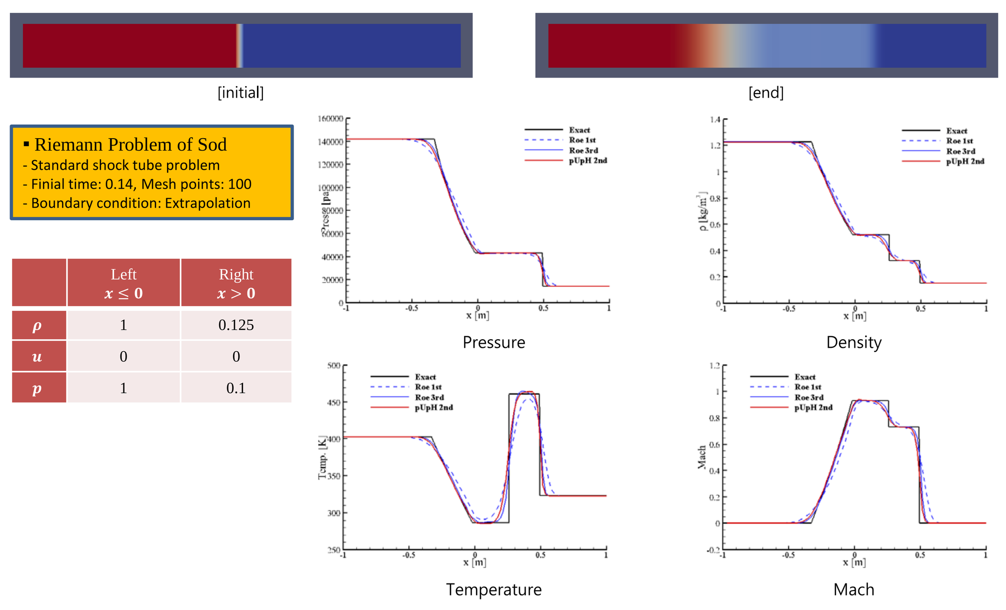

Figure 3. 1D Sod problem conditions and results.

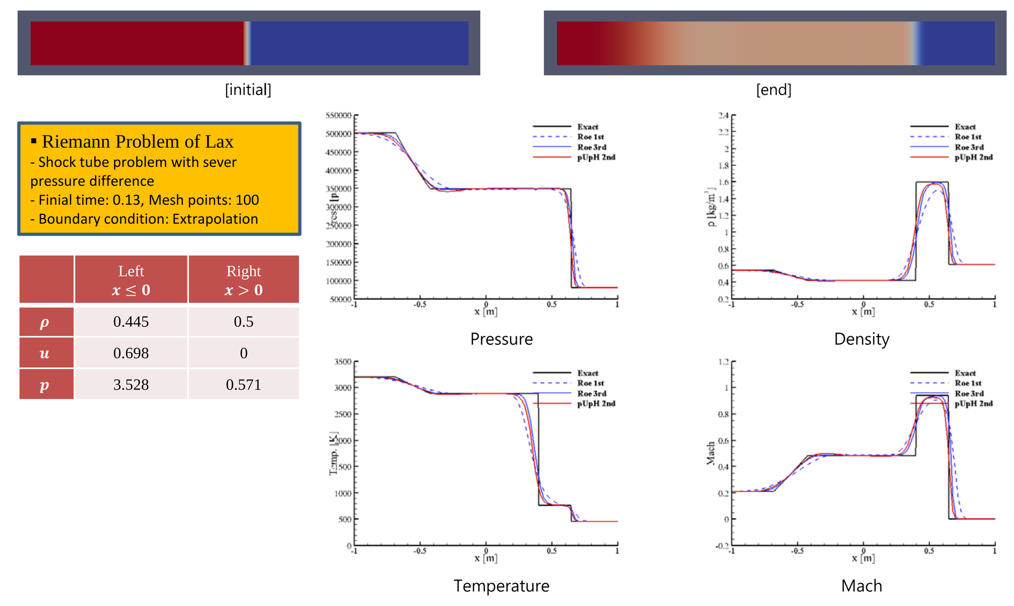

Figure 4. 1D Lax problem conditions and results.

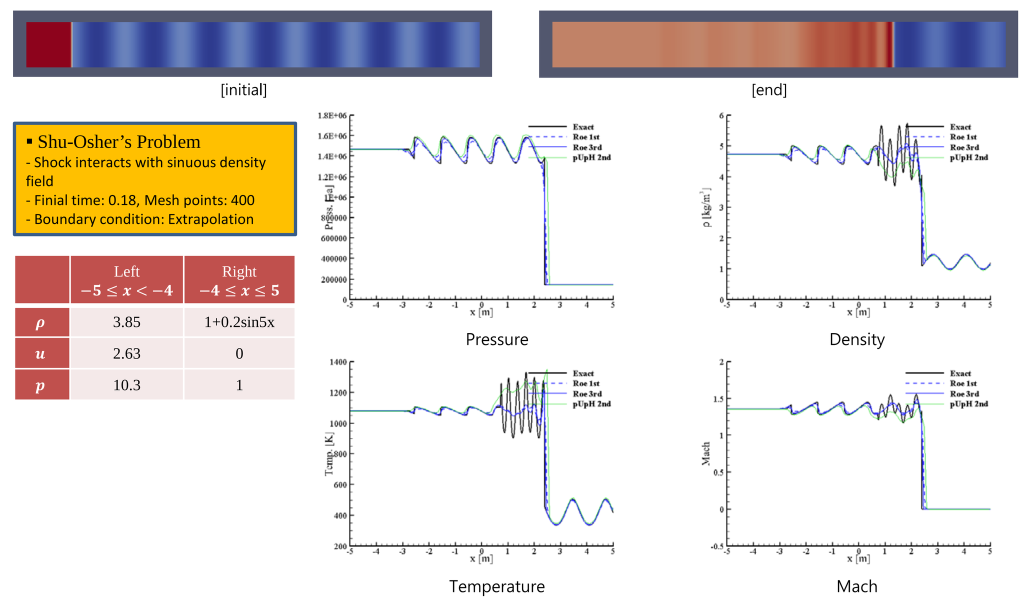

Figure 5. 1D Shu & Osher problem conditions and results.

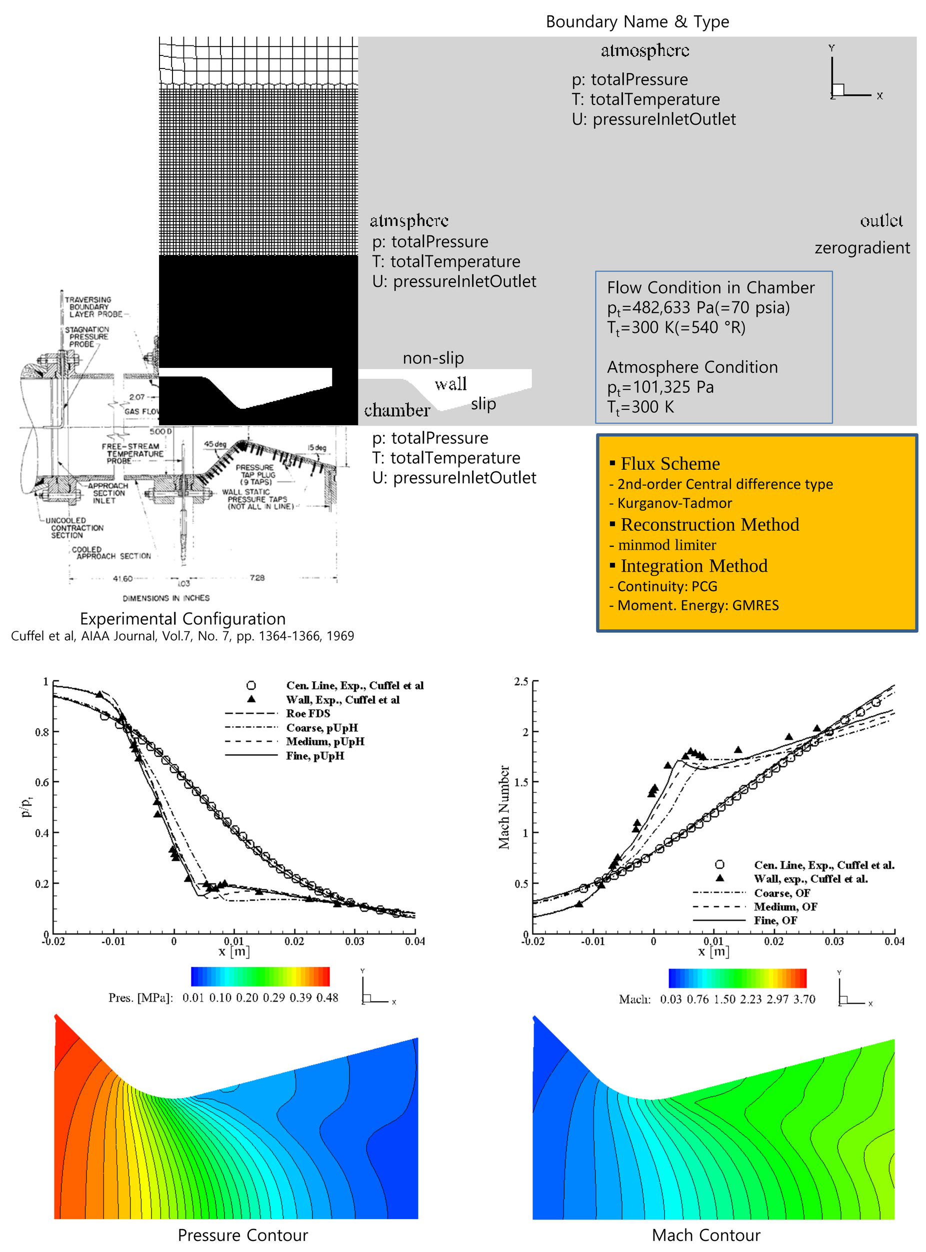

Figure 6. JPL Nozzle conditions and results.

Conclusions

It was confirmed that the developed solver had the similar analytical ability with that of the other numerical codes through the analysis of the shock wave induced problems in the supersonic flow region.

In order to verify the analytical ability for the all mach number flow region of the developed solver, the nozzle flow problems were analyzed and compared with results of experiments and other numerical analysis codes. It is confirmed that the analytical ability of developed solver in the high speed flow region such as supersonic and transonic is similar to the other density based in-house codes.

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