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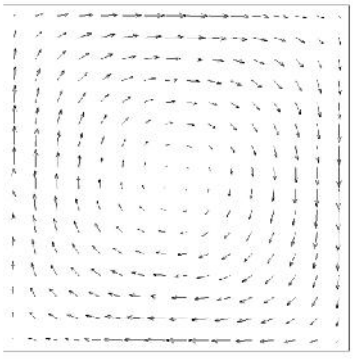
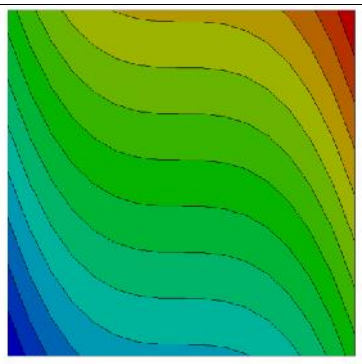
| **Verification type** | Manufactured Solutions |
| **Database reference** | MAN-1 |
| **Topic / Application** | Manufactured Solution<br>Numerical Solutions<br>Error Norms<br>Grid Convergence Study |
| **Physics** | Steady Laminar Incompressible |
| **Summary** | The Method of Manufactured Solutions is applied to the quantitative verification of a code. A highly accurate numerical solution is also used for verification. |
| **Description** | The paper concerns the verification of a code, primarily via MMS, but also via comparison with an accurate numerical solution. The Code undergoing verification is CFDLIB, while the reference numerical solution is generated by Fluent. Both codes are formally second order.<br>Formal quantitative error norms are used to quantitatively determine the error as a function of a grid refinement study. |
| **Case Title** | A Method of Code Comparison for CFD Verification |
| **Authors** | Thomas Reid , Jean-Yves Trepanier and Martin S. Aube |
| **Year** | 2009 |
| **Online reference** | 47th AIAA Aerospace Sciences Meeting Including The New Horizons Forum and Aerospace Exposition 5 - 8 January 2009, Orlando, Florida |
| **Case image** |   <br>Example of manufactured velocity (left) and temperature contours (right) in the verification test case deployed |

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| **Governing equations** | $$\begin{aligned} \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} &= 0 \\ u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + \frac{1}{\rho}\frac{\partial p}{\partial x} &= \nu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) \\ u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + \frac{1}{\rho}\frac{\partial p}{\partial y} &= \nu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) \\ u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} &= \alpha\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right) \end{aligned}$$ |
| **Results** | The authors conclude that the uncertainty in the reference code (Fluent in this case) need to be clearly understood to retain the value of verification via this means. Code comparisons based on qualitative metrics cannot be considered as an appropriate verification method and, thus, may lead to over confidence. |