

Version-Bounded Verification of a Nondimensional Taylor–Green Vortex Reconciliation

Independent derivations, executable defect controls, and revision requirements

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Editorial status: Authorized publication edition. The original-version findings and targeted version-2 revision check are complete. This edition adds publication links, licence terms and metadata; it contains no new scientific analysis or audit.

Abstract

We report a version-bounded validation study of a manuscript that reconciles apparently conflicting nondimensional forms of the decaying two-dimensional Taylor vortex. The original article distinguishes the side length of an assumed square domain, the trigonometric vortex scale, and the reference length used in a Reynolds number. Its central claim is that two periodic profiles can carry different numerical Reynolds labels while representing the same physical field at matched viscosity, with $Re_D = 2\pi Re_\ell$ when $D = 2\pi\ell$. We tested that claim together with the translated exact solution, pressure convention, full-period invariants, periodic compatibility, Fourier support, and two numerical fingerprints.

The review combined direct componentwise derivations, dimensional analysis, source inspection, counterexamples, and a newly authored standard-library executable using exact Gaussian-rational Fourier coefficients for normalized spatial identities. All 28 recorded checks completed successfully. The checks included deliberately wrong pressure signs and factors, a wrong decay rate, omission of the density factor from the physical-pressure Poisson equation, omission of moving-phase differentiation, pressure-only periodicity on a half-size box, and a shifted-window counterexample to an overstrong averaging statement. High-precision decimal references independently reproduced the reported pressure and energy fingerprints to the stated tolerance.

The central analytical reconciliation in frozen version 1.0 is supported, but the original manuscript was not validatable as an unqualified whole. It required explicit dimensional-to-nondimensional mapping, complete numerical normalization, clearer attribution of the periodic box as an analysis assumption, an

energy-per-unit-depth qualification, positive finite-Reynolds scope, qualified historical provenance, and figure corrections. A subsequent targeted revision check confirmed those corrections in byte-identified version 2.0 and found no outstanding scientific correction within that bounded check. No audit credit is transferred automatically across versions. The work does not validate a numerical solver, establish an official Airbus interpretation, demonstrate turbulence or industrial-flow performance, or constitute external human peer review. The review was human-directed and AI-assisted, using procedurally separated contexts from one AI provider within organisations and journals under common ownership or control.

Keywords: Taylor vortex; Taylor–Green vortex; nondimensionalization; Reynolds number; exact solution; pressure Poisson equation; periodic boundary conditions; reproducibility; software-assisted verification; version-bounded validation

1. Introduction

An exact analytical solution can remove discretization error from a verification problem, but it does not remove ambiguity from notation. The viscously decaying two-dimensional vortex associated with Taylor's 1923 work is historically distinct from the later three-dimensional Taylor–Green construction, although modern usage often joins the names [3–5]. In this analytical family, three lengths may have the same physical dimension while serving different roles: the side D of a computational domain, the phase scale ℓ appearing inside trigonometric functions, and the reference length L_{Re} used to define a Reynolds number. Conflating them changes the numerical viscosity attached to a Reynolds label and can also make a locally exact field incompatible with an assumed periodic box.

The research article under review addresses that ambiguity by reconstructing a translated viscous vortex, separating physical pressure from kinematic pressure, and comparing two nondimensional profiles [1]. The principal conclusion is deliberately modest: when a periodic square contains one full velocity wavelength, $D = 2\pi\ell$, a box-based Reynolds number is 2π times a vortex-scale Reynolds number at the same speed and viscosity. Two profiles evaluated at the same numerical label therefore decay differently, while the profiles coincide after their labels are mapped to the same physical viscosity.

Validation of such a claim requires more than agreement with the article's final formulas. The derivation must expose which parameters are held fixed, dimensional interfaces must be consistent, counterexamples must distinguish the proposed result from plausible incorrect alternatives, and the exact version examined must remain identifiable. It is equally important not to turn a successful check of a bounded analytical family into a claim about numerical solvers, turbulent flow, industrial geometries, or the intent of the source authors.

This study therefore asks four questions:

1. Do the proposed velocity and pressure fields satisfy the stated constant-density incompressible equations?
2. Are the periodicity, invariant, Fourier-support, and Reynolds-mapping claims correct under their stated assumptions?
3. Can a fresh executable detect representative sign, factor, decay, density, translation, and boundary-condition errors while reproducing the article's numerical fingerprints?
4. Which conclusions apply to the frozen original manuscript, and which require a new closure check after revision?

The answer to the first three questions is affirmative within the scope defined below. The answer to the fourth is necessarily version-specific: the core mathematics of version 1.0 is supported, and a targeted same-provider AI revision check subsequently confirmed the specified corrections in the byte-identified

version 2.0 research source and PDF. That check does not convert the audit into external human peer review or whole-paper certification.

2. Materials, versions, and questions tested

2.1 Frozen original article

The primary object of the completed audit was the frozen version-1.0 Markdown manuscript, 17,936 bytes, SHA-256

e8bf95f686889a9ac75a8593f33a8ad2e76b76ea5da62907a826ba22abb71a51.

Its six-page PDF was also inspected visually against the source equations, tables, and figures. The associated DOCX was inventoried but was not independently rendered during the fresh audit. These identifiers establish which bytes were reviewed; they do not establish authorship, historical read order, or correctness.

The version-2.0 research article retains the title *Reconciling Nondimensional Forms of the Decaying Taylor Green Vortex* and the subtitle *A reproducible symbolic and dimensional verification*. The frozen prepublication editable source supplied for targeted closure contains 27,710 bytes and has SHA-256 4e2d4b10bec450bbba85c1c0ff835cb631911ac290a7edf456b027facdf50752. Its ten-page rendered PDF contains 540,196 bytes and has SHA-256 9e12911375ceb434f404a867d75a9a15add8164e1251fe5d35d4fe4c872ad008. Version 2.0 is a revision of the frozen version 1.0, not a replacement of the original audit record. The revision disposition in Section 6 attaches only to these exact prepublication version-2.0 identities and the claims examined.

The linked publication edition retains the scientific content of those reviewed files while adding journal links, licence terms, exclusions and publication metadata. Its source and PDF bytes therefore differ. The publication release ledger records these successor identities separately; the editorial repackaging is not a new scientific revision or audit and does not broaden the review disposition.

For publication correspondence, the research edition of 16 October 2026 has a 29,469-byte Markdown source, SHA-256 9da64e82d07f757d0c5b1a70ce350fb2d66d3c2a5d8fd95a20dfa1c61d33f212, and an eleven-page PDF of 544,803 bytes, SHA-256 07501ca97379ee2484c0f806474a1f9c2d53f5f825aa7fa14de73291ebd55bca. These are publication artifact identities, not additional audit targets. The final validation identity is recorded in the same release ledger.

2.2 Primary challenge source

The review consulted a locally retained inspected copy of a publicly posted Airbus challenge statement, version vF, especially pages 6–9 [2]. Its inspected file had SHA-256

4a2e084dd25d49343c98475091eede479513779c4306e90260f9b9cf518f77c6.

The source uses physical pressure in the momentum equation, omits the density factor in a displayed pressure-Poisson form, and includes density in the stated pressure field. It also uses the same length symbol in roles that the research article separates. The source supplies $V_0 = 1$, $U_c = 1$, $V_c = 0$, $\rho = 1$, $p_0 = 0$, a domain length 2π , and a viscosity formula based on that domain length. It does not, however, unambiguously declare every later analytical assumption made in the research article. In particular, the periodic square and the choice $\ell = 1$ are analysis assumptions rather than source-authenticated boundary data.

The publicly posted source was used as reference evidence. Public access does not itself authorize redistribution. No source page, screenshot, or logo is reproduced here, and the present public Airbus programme page [8] is not treated as the immutable historical challenge document or as an endorsement of either article.

2.3 Claims selected for validation

The validation target was not “the paper” as an indivisible object. The following material claims were separated and tested:

- continuity and both components of momentum for the translated decaying field;
- the physical- and kinematic-pressure forms of the pressure-Poisson equation;
- mean velocity, mean pressure, specific kinetic energy, dissipation rate, vorticity, and pressure extrema under full-period averaging;
- the velocity-periodicity criterion on an axis-aligned square and the distinction between local PDE validity and boundary compatibility;
- the $Re_D = 2\pi Re_\ell$ conversion at matched physical parameters;
- different decay at equal numerical labels and exact coincidence at matched viscosity;
- fixed continuous spatial Fourier support under translation and viscous decay;
- two analytical numerical fingerprints under the complete challenge normalization;
- the actual meaning and documentary limits of historical archived check counts; and
- the manuscript's boundary, solver, turbulence, industrial, rights, and provenance limitations.

3. Methods

3.1 Review design and procedural separation

The fresh audit used five recorded high-reasoning AI contexts from the same provider: one coordinating context, three specialist contexts, and one distinct final-review context. The specialists covered (i) PDE identities and dimensions, (ii) invariants, periodicity, Fourier content, and numerical arithmetic, and (iii) source, reference, and documentary provenance. Initial specialist assessments were recorded before cross-challenge. The final reviewer assessed the consolidated report, readable validation article, claims table, executable, results, and relevant source and manuscript renderings.

This design provided procedural separation of tasks and fresh derivations, not institutional independence. It was not external human peer review, provider diversity, or a native consensus-kernel adjudication. Records describe staged read separation for some historical work, but no trusted external chronology was examined that independently proves every historical read order or authorship assertion. Agreement among the contexts is therefore not treated as a vote that establishes truth. The evidential warrants are the derivations, source observations, discriminating controls, executable results, and explicit limitations.

3.2 Direct analytical derivation

Let

$$\mathbf{u} = \mathbf{c} + \mathbf{w}, \quad \mathbf{c} = (U_c, V_c),$$
$$\mathbf{w} = (B \sin X \cos Y, -B \cos X \sin Y),$$

with

$$X = \frac{x - U_c t}{\ell}, \quad Y = \frac{y - V_c t}{\ell}, \quad B(t) = V_0 \exp\left(-\frac{2vt}{\ell^2}\right).$$

For constant $\rho > 0$, $v \geq 0$, $\ell > 0$, and constant U_c, V_c, V_0 , we differentiated the field componentwise. The derivation did not divide by B , so the local cancellation remains meaningful in the zero-amplitude limit. Physical pressure was taken as

$$p = p_0 + \frac{\rho B^2}{4} [\cos(2X) + \cos(2Y)],$$

with kinematic pressure $q = p/\rho$. We then checked continuity, momentum, pressure-Poisson compatibility, exact moments on whole periods, boundary traces, and Fourier support.

3.3 Reynolds and nondimensional interfaces

The two Reynolds numbers were defined only after their reference lengths were named:

$$Re_\ell = \frac{V_0 \ell}{\nu}, \quad Re_D = \frac{V_0 D}{\nu}.$$

The finite-ratio comparison assumes $V_0 > 0$, $\nu > 0$, and shared physical speed, geometry, units, and time. The inviscid case is an infinite-Reynolds limit, and the zero-amplitude field is a degenerate constant-velocity solution rather than a nondegenerate Reynolds-ratio example.

For a self-contained nondimensional statement, a fixed length $L_* > 0$ and speed $V_* > 0$ are needed:

$$x^* = \frac{x}{L_*}, \quad t^* = \frac{tV_*}{L_*}, \quad \mathbf{u}^* = \frac{\mathbf{u}}{V_*}, \quad \nu^* = \frac{\nu}{V_* L_*}, \quad q^* = \frac{p - p_0}{\rho V_*^2}.$$

The original manuscript did not collect this mapping and the complete example normalization in one reproducible statement. That omission was treated as a reporting defect requiring revision, not as evidence against the central algebra.

3.4 Fresh executable checks

A reviewer who had not adopted an older checker authored a new Python standard-library script. The script represents normalized spatial Fourier polynomials using exact pairs of rational numbers for complex coefficients. It performs exact addition, multiplication, differentiation, Laplacian, and zero-mode extraction. General time dependence and parameter scaling remain warranted by the hand derivation; the finite executable is not presented as a universal symbolic proof engine.

The 28 recorded checks comprised:

- exact normalized identities for continuity, two nonlinear pressure balances, two velocity Laplacians, pressure Poisson, zero means, specific energies with and without translation, mean-squared vorticity, pressure support, non-unit-density physical pressure, and moving-phase cancellation;
- expected rejection or exposure of wrong pressure sign, wrong pressure factor, wrong decay rate, density-free physical-pressure Poisson form, stationary phase with nonzero mean, a pressure-periodic but velocity-incompatible half-period box, phase-sensitive averaging on a shifted half-window, and the literal one-radian box trace;
- eight-decimal reproduction of the pressure and energy fingerprints, together with a binary floating-point matched-viscosity check at absolute tolerance 10^{-17} ; and
- relative-error comparisons with independently computed 100-digit decimal references at tolerance 2×10^{-14} .

The high-precision reference computed π independently through a Machin arctangent identity and used decimal exponentiation. It was not an interval-certified transcendental proof. The script also printed the source byte count and hash but did not count that printout among the 28 checks.

3.5 Source and documentary review

Relevant source pages were text-extracted and visually inspected. Public bibliographic and technical sources were checked within access limits. The historical verification archive was examined only as documentary evidence of what its files record. No historical checker was rerun or adopted as the fresh acceptance oracle.

The archive contains 132 recorded true checks; 203 further true records decomposed as 6 clean controls, 57 negative controls, and 140 integrity records; and 42 true assumption/source records decomposed as 23 assumption records, 18 source bindings, and one aggregate check preserving ten conflict qualifications. These totals are not counts of independent theorems, PDE experiments, or physical validations. Matching hashes establish current byte correspondence, not historical authorship, chronology, institutional independence, or organizer approval.

4. Results

4.1 Exact PDE balance

Direct differentiation gives

$$\nabla \cdot \mathbf{w} = 0, \quad \nabla^2 \mathbf{w} = -\frac{2}{\ell^2} \mathbf{w},$$

and

$$(\partial_t + \mathbf{c} \cdot \nabla) \mathbf{w} = -\frac{2\nu}{\ell^2} \mathbf{w}.$$

The time derivative of the moving phase cancels advection by the constant translation, and the derivative of $(B(t))$ cancels viscous diffusion. The perturbation self-advection is

$$(\mathbf{w} \cdot \nabla) \mathbf{w} = \frac{B^2}{2\ell} (\sin 2X, \sin 2Y).$$

For the stated physical pressure,

$$\frac{1}{\rho} \nabla p = -\frac{B^2}{2\ell} (\sin 2X, \sin 2Y),$$

so nonlinear advection and the pressure-gradient term $\nabla p/\rho$ cancel when the momentum equation is written with all terms on the left-hand side. Equivalently, the advective acceleration is balanced by the physical-pressure force $-\nabla p/\rho$. No sign, coefficient, or Galilean-translation defect was found in the core field.

4.2 Physical and kinematic pressure

If

$$Q = \nabla \cdot [(\mathbf{u} \cdot \nabla) \mathbf{u}] = \frac{B^2}{\ell^2} [\cos(2X) + \cos(2Y)],$$

then the dimensionally consistent interfaces are

$$\nabla^2 p = -\rho Q$$

for physical pressure and

$$\nabla^2 q = -Q$$

for $q = p/\rho$. At $\rho = 1$, the numerical fields coincide and a missing density factor is hidden. At non-unit density, the distinction is observable. This physical/kinematic pressure convention is also documented in the cited OpenFOAM technical documentation [6,7]. The fresh executable verified the physical equation at $\rho = 3$ and rejected the density-free physical-pressure equation. This supports the research article's identification of an interface ambiguity in the challenge source, without establishing the source author's intended convention.

4.3 Full-period invariants and a necessary wording correction

On a rectangle containing whole axial velocity periods, orthogonality yields

$$\begin{aligned}\langle u \rangle &= U_c, \quad \langle v \rangle = V_c, \quad \langle p \rangle = p_0, \\ K &= \frac{U_c^2 + V_c^2}{2} + \frac{B^2}{4}, \quad \frac{dK}{dt} = -\frac{\nu B^2}{\ell^2}, \\ \omega &= \frac{2B}{\ell} \sin X \sin Y, \quad p_{\min, \max} = p_0 \mp \frac{\rho B^2}{2}.\end{aligned}$$

These are continuous spatial identities. Multiplying specific kinetic energy by ρ gives energy density; integrating it over a two-dimensional area $L_x L_y$ gives energy per unit out-of-plane depth. For the square, the area is D^2 . The original paper's unqualified “integrated energy” wording therefore required correction.

Whole periods guarantee the stated mean identities independently of phase, but they are not logically necessary for every accidental equality on a smaller window. At zero phase and zero translation, the square $[0, \pi\ell]^2$ happens to reproduce several listed averages even though its velocity traces are incompatible. Shifting both phases by $-\pi/4$ produces nonzero perturbation means $\pm 2B/\pi^2$. The audit therefore replaced “require a full-period average” with the more exact claim that full-period averaging is a sufficient, phase-independent guarantee.

4.4 Local validity and periodic compatibility

For a nonzero perturbation on an axis-aligned square, velocity periodicity requires and is ensured by

$$\frac{D}{\ell} = 2\pi n, \quad n \in \{1, 2, 3, \dots\}.$$

Translation changes phase but not this condition. Pressure has half the axial period of velocity, so pressure periodicity alone cannot establish velocity compatibility. A square of side $\pi\ell$, for example, can make the pressure periodic while leaving a velocity-trace mismatch of $2B$ at a suitable boundary point.

The literal identification $D = \ell = 2\pi$ advances phase by only one radian across the box. At $t = 0$, $u(D, 0) - u(0, 0) = V_0 \sin 1$, which is nonzero for nonzero V_0 . The field remains a local solution of the differential equation, but it does not meet the assumed periodic boundary condition on that square. Because the challenge source does not itself unambiguously declare that periodic square, the finding is conditional on the analysis assumption and must not be attributed as an Airbus-declared boundary failure.

4.5 Reynolds-label reconciliation

When $D = 2\pi\ell$, $V_0 > 0$, and $\nu > 0$,

$$\frac{Re_D}{Re_\ell} = \frac{D}{\ell} = 2\pi.$$

At the same numerical label R , the vortex-scale convention assigns $\nu = V_0\ell/R$, whereas the box-scale convention assigns $\nu = V_0 D/R = 2\pi V_0\ell/R$. Their decay rates differ because they describe different viscosities. At matched viscosity the labels obey $Re_D = 2\pi Re_\ell$, and the physical fields coincide when the remaining scales, units, and time are also matched. This is an exact relabelling identity, not an independent experiment.

The nonconstant velocity support remains at angular wavevectors $(\pm 1, \pm 1)/\ell$; nonconstant pressure remains at $(\pm 2, 0)/\ell$ and $(0, \pm 2)/\ell$. Translation changes phases and viscous decay changes amplitudes.

Neither operation creates additional spatial modes in this exact family. The result does not support a claim about turbulent cascades or numerical mesh demands.

4.6 Numerical fingerprints

Under the complete example normalization $V_0 = 1, U_c = 1, V_c = 0, \rho = 1, p_0 = 0, \ell = 1, D = 2\pi$, and $Re_D = 100$, the domain-based viscosity is $\nu = 2\pi/100$. The pressure extremum magnitude at $t = 1$ is

$$\frac{1}{2} \exp\left(-\frac{8\pi}{100}\right) \approx 0.3888838395858945135 \dots,$$

and the mean specific kinetic energy at $t = 10$ is

$$\frac{1}{2} + \frac{1}{4} \exp\left(-\frac{80\pi}{100}\right) \approx 0.5202506480394857822 \dots$$

The checker's binary floating-point outputs were 0.3888838395858945 and 0.5202506480394857. Their relative errors against the independent decimal references were approximately 1.29×10^{-17} and 9.99×10^{-17} , respectively, below the declared 2×10^{-14} tolerance. The source plots are qualitatively consistent with values near ± 0.4 and 0.52, but the eight-digit values are analytical evaluations, not measurements digitized from those plots.

4.7 Defect sensitivity

The negative controls were chosen to answer whether agreement could survive plausible wrong formulas:

Seeded or exposed defect	Discriminating result
reverse the pressure sign	leaves a nonzero momentum residual
multiply the pressure contribution by the wrong factor	leaves a nonzero momentum residual
use $\exp(-\nu t/\ell^2)$ instead of $\exp(-2\nu t/\ell^2)$	leaves residual $\nu B/\ell^2$ at a discriminating point
omit ρ from the physical-pressure Poisson equation	fails at non-unit density
keep translated phases but omit moving-phase differentiation	leaves uncanceled mean-advection terms
infer velocity periodicity from pressure on a half-size box	contradicted by a velocity-trace difference
treat half-window averages as phase-independent	contradicted after a phase shift
identify $D = \ell = 2\pi$ on the assumed periodic square	produces the nonzero one-radian boundary trace

Passing these controls demonstrates sensitivity to the specified defects. It is not a security proof, a sampling estimate of all possible errors, or evidence that no untested error exists.

5. Findings on frozen version 1.0

The audit's disposition was neither rejection nor blanket validation. The mathematical core was retained, while publication-quality reporting required substantive correction.

Area	Version-1.0 finding	Required version-2.0 action
translated PDE solution	supported by direct derivation and fresh exact checks	retain equations and their bounded assumptions

Area	Version-1.0 finding	Required version-2.0 action
physical versus kinematic pressure	core distinction supported	state $\nabla^2 p = -\rho Q$ and $\nabla^2 q = -Q$; cite pressure convention in the body
nondimensionalization	incomplete as a self-contained mapping	define L_* , V_* , starred variables, and all example constants
periodic box	mathematical criterion supported conditionally	identify the periodic square and $\ell = 1$ as analysis assumptions, not source-declared facts
energy	specific-energy formula supported	describe 2D area-integrated energy as per unit out-of-plane depth
averaging	whole-period formulas supported	say whole periods guarantee phase-independent identities; avoid universal necessity wording
Reynolds mapping	supported for common finite positive physical parameters	state endpoint restrictions and distinguish physical changes from relabelling
numerical fingerprints	supported to quoted rounding	collect full normalization and label values analytical, not plot measurements
source interpretation	source ambiguity supported	do not infer organizer intent; cite the inspected challenge copy precisely and the public programme page only for context
figures	scientific intent supported	correct the displaced periodicity endpoint marker; add numerical time ticks and time normalization to the decay figure
historical counts	archive contents documented	decompose denominators and do not use totals as counts of independent scientific proofs
procedural independence	records support separated workflow descriptions	disclose same-provider AI contexts and the limits of chronology evidence
scope	analytical family supported	retain exclusions for solver validation, turbulence, industrial flow, hardware advantage, and official endorsement

No mathematical basis was found for an unqualified statement that every sentence or artifact in version 1.0 had been validated. Equally, no sign, factor, or translation error was found that overturns the central convention-reconciliation result.

6. Revision closure and non-transfer of audit credit

Version 2.0 applies the audit corrections while preserving version 1.0 and its audit record. The revision includes the explicit dimensional-to-nondimensional map and full normalization; assumption-qualified periodicity; positive finite-Reynolds scope and endpoint treatment; density-correct pressure interfaces; per-unit-depth energy language; phase-independent sufficiency wording for full periods; removal of unexplained workflow terminology; qualified plot consistency; accurate decomposition of historical checks; same-provider AI disclosure; and corrected figure specifications.

A targeted same-provider AI revision check against the completed fresh audit confirmed that the identified scientific and method-reporting corrections are implemented in the revised research source (27,710 bytes; SHA-256 4e2d4b10bec450bbba85c1c0ff835cb631911ac290a7edf456b027facdf50752), with a matching ten-page PDF (540,196 bytes; SHA-256

9e12911375ceb434f404a867d75a9a15add8164e1251fe5d35d4fe4c872ad008). The corrected numerical page was independently inspected, and the approximate values, classification of the floating-point check, dimensional convention and qualified time interpretation were confirmed against the existing evidence. The bounded analytical reconciliation remains supported, and no outstanding scientific correction was identified within this revision check.

This was same-provider AI scrutiny, not external human peer review, institutionally independent endorsement, a new full audit or native-consensus adjudication. Rights clearance, journal editorial acceptance and public-release decisions are separate from the scientific review. The publication package records its version identifiers and the research and validation documents' post-render identities in its release hash ledger.

The resulting status is:

- **version 1.0:** central analytical claims supported, with manuscript revisions required;
- **version 2.0:** the specified corrections are confirmed in the exact source and PDF identified above; publication consideration remains bounded by the stated limitations and separate rights/editorial decisions; and
- **this validation article:** scientifically complete for the original-version findings and the targeted version-2.0 revision check; the publication edition's final artifact identities are recorded separately in the release ledger.

This boundary prevents “audit laundering,” in which a favourable result on one byte-identifiable version is silently applied to another.

7. Interpretation

The value of the result is methodological rather than sensational. A Reynolds number is not a property of a field without a declared reference length. A domain side is not a trigonometric scale merely because the same source symbol is used for both. A pressure field can satisfy the momentum equation while a displayed Poisson interface is dimensionally misstated. A local exact solution can fail a chosen periodic boundary condition. A plot can be consistent with a formula without measuring its displayed digits.

The study also shows why controlled negative cases matter. Direct substitution establishes the correct formulas; seeded wrong formulas establish that the verification is capable of distinguishing several nearby alternatives. Neither replaces a clear statement of assumptions. The decisive evidence remains the combination of explicit derivation, source-grounded normalization, exact normalized checks, discriminating counterexamples, and bounded conclusions.

The fixed Fourier support deserves particular caution. In this exact smooth family, raising a consistently defined Reynolds number slows viscous decay but does not add spatial wavevectors. This says nothing general about turbulent flows, numerical truncation, or the complexity of industrial CFD. Similarly, the matched-viscosity identity is a change of label, not a new empirical confirmation of fluid mechanics.

8. Limitations

This validation study is limited in the following ways:

- It addresses a smooth, constant-density analytical family and its notation, not a numerical discretization or experimental flow.
- No solver trajectory, mesh-refinement study, convergence test, matched-accuracy comparison, or finite-volume benchmark was run.
- The 28 checks cover specified normalized identities and defects; they do not constitute 28 independent physical experiments or a universal proof system.
- The decimal transcendental comparison is high precision but not interval certified.

- The periodicity result assumes an axis-aligned square and a nonzero perturbation; the zero-amplitude constant field is an exception.
- Whole-period formulas are continuous spatial averages and do not automatically certify arbitrary grids, cells, truncated windows, or moving windows.
- The challenge's official intended nondimensional convention is unresolved.
- Source hashes identify inspected bytes but do not prove authorship, permission, chronology, or correctness.
- The historical archive was reviewed documentarily; no historical checker was rerun in this audit.
- Publication and redistribution rights for the publicly posted challenge document and internal evidence remain separate from scientific correctness and public accessibility.
- All fresh review contexts used the same AI provider. Procedural separation does not create external institutional or human independence.
- The version-2.0 closure check was performed by a same-provider AI context against the existing audit evidence; it was not external human peer review, institutionally independent validation, or a new full audit.

9. Authorship, relationships, conflicts, and AI assistance

Haivian Technology is the sole corporate author of this validation article and the provider of the audit service described here. Richard Janutka is the author of the related research article, with affiliation Qonduit Limited NZ, and provided responsible human direction and oversight for the commissioned audit and publication workflow. The research author, the audit service, and the Research and Validation Journals are under common ownership or control. The validation article is therefore not an arm's-length institutional review, and readers should not interpret journal placement as independent external endorsement.

AI systems assisted with evidence indexing, direct mathematical derivation, executable-check authorship, source and reference review, cross-challenge, drafting, and final-review preparation. The fresh process used procedurally separated contexts from one provider. No external human peer reviewers or independent institutions participated in the completed fresh audit. Responsible human oversight included defining scope, assigning the disclosed authorship, commissioning the review, and retaining the final publication decision. The corporate author is responsible for ensuring that the final published text accurately reflects the evidence and that unresolved version-closure and rights conditions are not omitted.

Airbus did not review, approve, or endorse this validation article. No ORCID, DOI, journal index status, or third-party credential is asserted here.

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10. Data, code, and materials availability

The fresh standard-library checker, captured output, audit report, claims table, specialist reviews, and final-review record are preserved in a private evidence archive. A sanitized reproducibility package has been prepared for owner release review but has not been published. Therefore this article does not claim that its code or evidence bundle is publicly available. Any later public release should remove private operational metadata, include bundle-relative instructions and a hash ledger, and receive rights review.

The publicly posted challenge statement is reference evidence; its locally retained inspected copy is not distributed with this article. Public access does not itself authorize redistribution. Equations, tables, and

figures in the related research article are independently prepared rather than reproduced as source-page images. Access to private internal audit materials, if any, is subject to the owner's release decision and applicable rights.

11. Conclusion

The fresh audit supports the core analytical result of the frozen research manuscript: once the domain side, vortex scale, and Reynolds reference length are separated, two apparently conflicting nondimensional descriptions are reconciled exactly. The translated vortex satisfies the stated constant-density incompressible equations; physical and kinematic pressure obey distinct density-aware Poisson interfaces; the assumed square is velocity-periodic only at the appropriate phase advance; and the box- and vortex-based Reynolds labels satisfy $Re_D = 2\pi Re_\ell$ at matched physical parameters.

Support for that core does not justify blanket validation. Frozen version 1.0 required substantive corrections to normalization, assumption attribution, energy dimensions, scope, provenance language, and figures. The 28 fresh executable checks and their wrong-formula controls strengthen specific mathematical findings, but they do not validate a numerical solver, establish organizer intent, or create external peer review. A targeted revision check confirmed the specified corrections in the exact version-2.0 source and PDF identified in Section 6; that bounded closure does not expand the audit's scientific scope.

The bounded conclusion is therefore both positive and precise: the mathematical reconciliation is supported; the original reporting defects are real; and validation attaches only to the exact version and claims actually examined.

References

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