Implicit-dynamic vibration of a three-dimensional beam

Table of contents

1 Objective

Verify direct implicit-dynamic time integration for native Abaqus, body-fitted Coreform IGA, and immersed Coreform IGA discretizations. The six-case study exercises both the `TRANSIENT_FIDELITY` and `MODERATE_DISSIPATION` Abaqus application shortcuts [1].

2 Geometry

The model is a rod of length $L = 10$ aligned with the x axis and a 2×2 square cross-section.

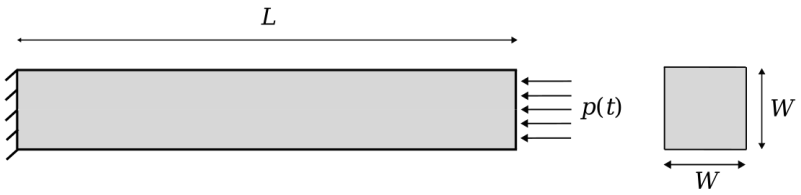

Figure 1: Vibrating-beam geometry and boundary conditions.

3 Material

The rod is linear elastic with Young's modulus $E = 1 \times 10^{6}$, density $\rho = 1 \times 10^{-6}$, and Poisson's ratio $\nu = 0$ in a dimensionally consistent unit system. The zero Poisson's ratio makes the response effectively one-dimensional.

4 Loading & boundary conditions

The $-x$ face is fixed, and the lateral faces are free. A pressure on the $+x$ face rises smoothly from zero to its peak during one analytical fundamental-mode period, returns smoothly to zero during the next period, and then remains zero. The free-vibration comparison starts after the load has been removed.

5 Mesh & discretization

The native reference uses structured `C3D8R` elements with nominal size $h = 1$. Both Coreform IGA discretizations use quadratic, C^1 splines with the same nominal size; one is body-fitted and the other is immersed.

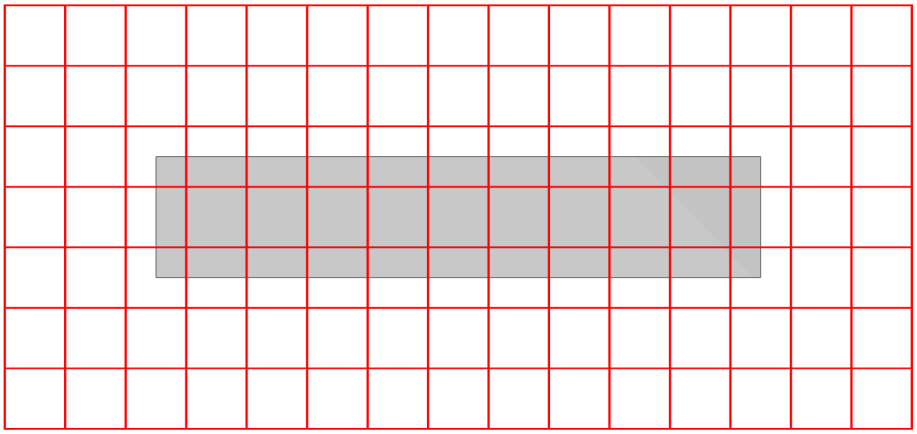

Figure 2: Background mesh used by the immersed Coreform IGA model.

All cases cover $0 \le t \le 2 \times 10^{-3}$ with an initial increment of 1×10^{-6} and a maximum increment of 2×10^{-6}. Axial displacement, velocity, and acceleration are recorded at every accepted increment and averaged over the free end.

6 Reference & accepted solutions

The fundamental axial frequency of a fixed-free rod is

$$f_1 = \frac{1}{4L}\sqrt{\frac{E}{\rho}} = 25,000.$$

Each case must predict f_1 within 2%. Each Coreform IGA history is also compared with the native Abaqus history using the same application shortcut.

Quantity	Acceptance criterion
Fundamental-frequency relative error	< 0.02
Normalized displacement-history RMS error	< 0.01
Free-vibration phase RMS error	$< 0.2\ \mathrm{rad}$
Amplitude-decay-ratio difference	< 0.03
Energy-decay-ratio difference	< 0.05
Accepted-increment count ratio	≤ 1.10
Samples per fundamental-mode period	≥ 19.9

7 Results

7.1 Fundamental frequency

Table 1: Implicit-dynamic vibrating-beam verification results.

Application	Discretization	f_1	Relative error	Accepted increments
`TRANSIENT_FIDELITY`	Native Abaqus	24745.6	1.02%	1003
`TRANSIENT_FIDELITY`	Body-fitted Coreform IGA	24767.1	0.93%	1003
`TRANSIENT_FIDELITY`	Immersed Coreform IGA	24766.9	0.93%	1003
`MODERATE_DISSIPATION`	Native Abaqus	24681.0	1.28%	1002
`MODERATE_DISSIPATION`	Body-fitted Coreform IGA	24702.4	1.19%	1002
`MODERATE_DISSIPATION`	Immersed Coreform IGA	24702.2	1.19%	1002

The maximum normalized displacement-history RMS error is 2.21×10^{-3}, and the maximum free-vibration phase RMS error is $0.155\,\mathrm{rad}$. The maximum amplitude- and energy-decay-ratio differences are 304×10^{-6} and 1.11×10^{-3}, respectively.

7.2 Representative displacement field

The final recorded `TRANSIENT_FIDELITY` immersed result is shown using the same CTest result database that supplies the verification evidence.

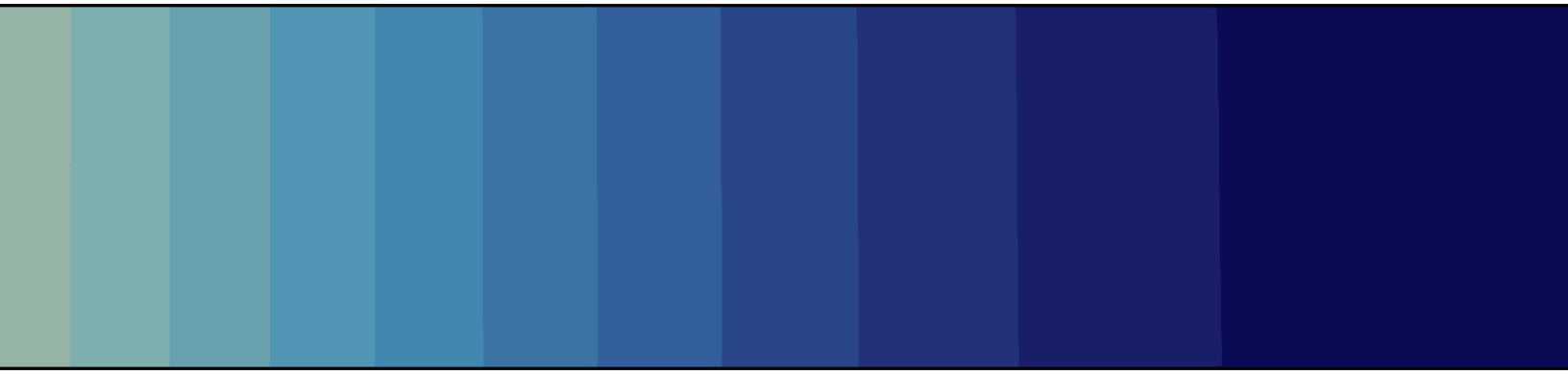

Figure 3: Axial displacement in the immersed Coreform IGA vibrating-beam model.

8 Discussion

Every spatial discretization and application shortcut predicts the analytical fundamental frequency within the enforced tolerance. The body-fitted and immersed histories track their matching native Abaqus references without using more accepted increments. The sampling criterion confirms that agreement is not obtained by taking substantially smaller time increments.

References

[1] *Abaqus analysis guide*, 2026 FD03. Dassault Systèmes, 2026.

Appendix

8.1 Download artifacts

Download artifacts are available from the HTML version of this page.

8.1.a Geometry CAD files

Geometry CAD downloads are available from the HTML version of this page.

8.1.b Abaqus/CAE journal files

Individual journal downloads are available from the HTML version of this page.

8.2 Provenance

The records below identify the six simulation CTests and their cross-case study CTest.

ℹ Test_abaqus_verification_vibrating_beam_3d_tf_native

Parameter	Value
Evidence type	Numerical verification
CTest result	Passed (Release)
Verification result	Passed — 1/1 enforced criterion passed
Test date	10-Sep-2026 16:03:33
Operating system	Ubuntu 22.04.4 LTS
Coreform IGA version	`2026.9+69838`
Source revision	`d88163e59ac0`
Abaqus version	`Abaqus 6.26-4`

ℹ Test_abaqus_verification_vibrating_beam_3d_tf_bodyfit

Parameter	Value
Evidence type	Numerical verification
CTest result	Passed (Release)
Verification result	Passed — 1/1 enforced criterion passed
Test date	10-Sep-2026 15:55:40
Operating system	Ubuntu 22.04.4 LTS
Coreform IGA version	`2026.9+69838`
Source revision	`d88163e59ac0`
Abaqus version	`Abaqus 6.26-4`

Test_abaqus_verification_vibrating_beam_3d_tf_immersed

Parameter	Value
Evidence type	Numerical verification
CTest result	Passed (Release)
Verification result	Passed — 1/1 enforced criterion passed
Test date	10-Sep-2026 15:56:41
Operating system	Ubuntu 22.04.4 LTS
Coreform IGA version	`2026.9+69838`
Source revision	`d88163e59ac0`
Abaqus version	`Abaqus 6.26-4`

Test_abaqus_verification_vibrating_beam_3d_md_native

Parameter	Value
Evidence type	Numerical verification
CTest result	Passed (Release)
Verification result	Passed — 1/1 enforced criterion passed
Test date	10-Sep-2026 15:57:14
Operating system	Ubuntu 22.04.4 LTS
Coreform IGA version	`2026.9+69838`
Source revision	`d88163e59ac0`
Abaqus version	`Abaqus 6.26-4`

ℹ Test_abaqus_verification_vibrating_beam_3d_md_bodyfit

Parameter	Value
Evidence type	Numerical verification
CTest result	Passed (Release)
Verification result	Passed — 1/1 enforced criterion passed
Test date	10-Sep-2026 15:57:11
Operating system	Ubuntu 22.04.4 LTS
Coreform IGA version	`2026.9+69838`
Source revision	`d88163e59ac0`
Abaqus version	`Abaqus 6.26-4`

ℹ Test_abaqus_verification_vibrating_beam_3d_md_immersed

Parameter	Value
Evidence type	Numerical verification
CTest result	Passed (Release)
Verification result	Passed — 1/1 enforced criterion passed
Test date	10-Sep-2026 15:56:20
Operating system	Ubuntu 22.04.4 LTS
Coreform IGA version	`2026.9+69838`
Source revision	`d88163e59ac0`
Abaqus version	`Abaqus 6.26-4`

Test_abaqus_verification_study_vibrating_beam_3d_core

Parameter	Value
Evidence type	Numerical verification
CTest result	Passed (Release)
Verification result	Passed — 26/26 enforced criteria passed
Test date	10-Sep-2026 16:03:45
Operating system	Ubuntu 22.04.4 LTS
Coreform IGA version	`2026.9+69838`
Source revision	`d88163e59ac0`
Abaqus version	`Abaqus 6.26-4`