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# SOP Starter Kit

Standard Operating Procedures  
for Finite Element Analysis

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*Ready-to-Use Checklists, Framework & Implementation Guide*



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Companion resource to the FEA Academy webinar:  
*Standard Operating Procedures for FEA*

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## About This Document

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This SOP Starter Kit is a companion resource to the FEA Academy webinar on Standard Operating Procedures for Finite Element Analysis. It translates the webinar content into a practical, ready-to-use toolkit that you can adapt and implement in your own engineering practice.

### What You Will Find Inside

- A concise summary of the 6-Stage FEA SOP Framework
- Stage-by-stage checklists you can print and use immediately
- A quick-reference table of the Top 10 Common FEA Mistakes and the SOPs that prevent them
- A practical 6-step implementation roadmap for rolling out SOPs in your team or organization
- Blank templates for project-level SOP tracking

### How to Use This Kit

This document is designed to be practical, not theoretical. Every section contains actionable items you can implement today. Whether you are an individual engineer looking to improve your own process, or a team lead establishing standards for a group, the approach is the same: start small, start now, and iterate.

**Practical Tip:** *Print the checklists from Stages 1 through 6 and keep them at your workstation. Use them on your very next FEA project. A checklist used imperfectly is infinitely more valuable than a perfect manual that stays on a server.*

## Why SOPs Matter in FEA

If two analysts independently build an FEA model of the same component (same loads, same material, same geometry) how different would their results be? In most organizations, the answer is: meaningfully different. Not because the analysts are incompetent, but because the process has no standard. The result depends on the analyst as much as on the physics. That is a fundamental quality problem.

SOPs address this through four interconnected pillars:

Pillar	Why It Matters
<b>Error Prevention</b>	Inconsistent practices are the primary source of preventable FEA errors: wrong boundary conditions, incorrect material data, poor mesh quality. SOPs eliminate entire classes of error through simple, mandatory checks.
<b>Team Consistency</b>	Without SOPs, every analyst has their own workflow. Results vary with the engineer, not with the physics. SOPs compress this variation and raise the baseline.
<b>Review Efficiency</b>	When deliverables are standardized, review time drops significantly. Reviewers know where to find the mesh quality report, the free body check, the acceptance criteria, every time.
<b>Confidence &amp; Trust</b>	SOPs give auditors, customers, and certification bodies a traceable, reproducible process they can interrogate. This builds trust, and trust is a competitive differentiator.

**Key Principle:** *SOPs are not bureaucracy. They are engineering disciplines applied to processes. The same rigor you apply to your physics should apply to your method.*

## The 6-Stage FEA SOP Framework

The framework below organizes the entire FEA process into six sequential stages. Think of them as a pipeline, not a checklist: each stage feeds the next. Contamination introduced at Stage 1 propagates through every subsequent stage. This is why SOPs must exist at every gate, not just at the output.

Stage	Scope
<b>1 – Model Creation</b>	Geometry simplification, idealization decisions, coordinate system convention, unit consistency, file naming and versioning
<b>2 – Material Data</b>	Centralized material library, source traceability, validation against references, temperature range documentation
<b>3 – Loads &amp; BCs</b>	Load case definition and sign-off, boundary condition rationale, symmetry exploitation, load introduction method
<b>4 – Meshing</b>	Element type selection and justification, mesh quality thresholds, convergence study procedure
<b>5 – Solving</b>	Solver configuration, pre-run checklist, convergence monitoring, error and warning adjudication, post-solve QA
<b>6 – Result Interpretation</b>	Result extraction protocol, pre-defined acceptance criteria, post-processing standards, deliverable package

**Key Principle:** *A QA check at Stage 6 cannot catch an error introduced at Stage 1. You need upstream intervention. SOPs at every gate.*

## Stage 1 – Model Creation Checklist

Model creation is deceptively complex. Decisions made here (what to simplify, what to suppress, what coordinate system to use) set the foundation for everything downstream. A bad idealization decision at Stage 1 cannot be rescued by a better mesh at Stage 4.

✓	Model Creation Checks
<input type="checkbox"/>	Unit system (SI, mm-N-MPa, etc.) specified at project outset and documented in the analysis plan
<input type="checkbox"/>	CAD file revision tracked and linked to the FEA model version
<input type="checkbox"/>	Geometry idealization decisions documented: features suppressed, simplifications made, and rationale recorded
<input type="checkbox"/>	De-featuring tolerances defined and approved before meshing begins
<input type="checkbox"/>	Global coordinate system convention defined (e.g. X-forward, Z-up) and documented
<input type="checkbox"/>	All local coordinate system definitions documented with rationale for their orientation
<input type="checkbox"/>	Model file naming convention applied: project ID, component, revision, analyst initials
<input type="checkbox"/>	Folder structure follows the team standard; all files stored in the correct location
<input type="checkbox"/>	Idealization sign-off obtained from the responsible engineer before meshing begins
<input type="checkbox"/>	Unit consistency verified at every import/export step (CAD to FEA, FEA to post-processor)

**Practical Tip:** *The sign-off gate before meshing is critical. Once you have spent hours meshing a complex assembly, the psychological cost of going back to fix the geometry is enormous. Enforce the right sequence.*

## Stage 2 – Material Data Checklist

Material data management is frequently the weakest link in the FEA process. Material cards copied from model to model with no traceable source, properties used outside their validated temperature range, and proprietary data with no archived test report are all common findings. Unlike mesh errors (which tend to be conservative), material errors can be non-conservative in unpredictable ways.

✓	Material Data Checks
<input type="checkbox"/>	All material properties sourced from a centralized, version-controlled material library
<input type="checkbox"/>	Every property value traced to its source: datasheet revision, test report number, or applicable standard
<input type="checkbox"/>	Validated temperature range documented for each material entry
<input type="checkbox"/>	Date and author of the last review recorded for each library entry
<input type="checkbox"/>	Any extrapolated or assumed values explicitly flagged with uncertainty markers
<input type="checkbox"/>	Usage conditions (temperature, environment, strain rate) confirmed to fall within the validated range
<input type="checkbox"/>	Cross-check performed: at least one property independently verified against an alternative reference
<input type="checkbox"/>	Material card linked to the FEA model file for full project traceability
<input type="checkbox"/>	Senior review completed for all material inputs used in safety-critical analyses
<input type="checkbox"/>	Access controls in place: nominated data custodians control additions to the library

**Key Principle:** *No source, no entry. If you cannot trace a material property back to a documented source in under 30 seconds, the property is unverified.*

## Stage 3 – Loads & Boundary Conditions Checklist

Loads and boundary conditions are where the physics of the problem interfaces with the numerical model. They are also where the most consequential engineering judgements are made, and where the most dangerous errors hide. A wrong boundary condition can produce plausible looking but completely wrong results.

✓	Loads & Boundary Conditions Checks
<input type="checkbox"/>	Every load case documented: source, magnitude, direction, combination rules, and applicable design factors
<input type="checkbox"/>	Load source traced to a requirements document, test report, or specification
<input type="checkbox"/>	Load application method specified and justified (RBE2 / RBE3 / CBUSH / distributed, etc.)
<input type="checkbox"/>	Potential for unrealistic stress concentrations at load introduction points assessed
<input type="checkbox"/>	Every boundary condition accompanied by a written statement of the physical behaviour it represents
<input type="checkbox"/>	Sensitivity of results to boundary condition assumptions qualitatively assessed
<input type="checkbox"/>	Over-constraining reviewed: no unnecessary constraints that artificially stiffen the model
<input type="checkbox"/>	Symmetry and periodicity conditions defined with rules; validated against full-model spot checks
<input type="checkbox"/>	All load and BC data signed off by the responsible structural engineer before the run
<input type="checkbox"/>	Load sensitivity or parametric sweep requirements defined where applicable

**Practical Tip:** *The most common BC error is not a load magnitude mistake, it is a conceptual error in what the constraint represents. Bolting a component to a rigid ground when it is actually connected to a flexible substructure will produce plausible but incorrect results.*

## Stage 4 – Meshing Checklist

Meshing is the stage most engineers associate with FEA skill. But skill without standards is inconsistent. The mesh quality on Monday morning differs from the mesh quality on a Friday afternoon before a release deadline. SOPs remove that variability.

✓	Meshing Checks
<input type="checkbox"/>	Element type justified: solid, shell, beam, or connector, with rationale documented
<input type="checkbox"/>	Element order specified: linear vs. quadratic, with justification based on analysis type
<input type="checkbox"/>	Element technology selected: full or reduced integration, documented with rationale
<input type="checkbox"/>	Interface and contact formulations defined and documented
<input type="checkbox"/>	Mesh quality thresholds defined for the project (aspect ratio, skewness, warpage)
<input type="checkbox"/>	Mesh quality report generated, reviewed, and archived before analysis submission
<input type="checkbox"/>	All elements outside tolerance flagged, documented, and accepted with justification
<input type="checkbox"/>	Mesh density in regions of interest consistent with expected stress gradient
<input type="checkbox"/>	Mesh convergence study performed: minimum 3 mesh densities, key output quantity plotted
<input type="checkbox"/>	Convergence target met: less than 5% change in key output between medium and fine mesh
<input type="checkbox"/>	Chosen mesh density documented with justification; convergence plots archived

### Recommended Starting Thresholds

These are not universal standards. They are a starting baseline appropriate for many structural analyses. Your SOPs should define thresholds appropriate to your specific analysis types, element technologies, and solver. You will find more details in the book *Practical Finite Element Analysis for Mechanical Engineers* by Dominique Madier – 2020 – FEA Academy.

Metric	Recommended Threshold
Aspect Ratio (shells, regions of interest)	< 5:1
Skewness	< 60°
Warpage (shell elements)	< 15°
Convergence criterion	< 5% change between medium and fine mesh
Minimum mesh densities for convergence study	3

**Key Principle:** A mesh convergence study is not optional for any structural analysis where quantitative results are used to make design decisions. If your results have not converged, you do not know what they mean.

## Stage 5 – Solving Checklist

The solving stage is where most engineers stop paying attention, and where some of the most damaging silent failures occur. The solver runs, you see “SOLUTION COMPLETE,” and you go straight to post-processing. That is not an acceptable workflow.

### Pre-Run Checklist

Every pilot runs a pre-flight checklist before take-off. The pre-run checklist for FEA serves exactly the same purpose. These checks take approximately fifteen minutes and catch roughly 30% of significant analysis errors before the solver ever runs.

✓	Pre-Run Checks
<input type="checkbox"/>	Model total mass verified against hand calculation or reference value
<input type="checkbox"/>	Degree of freedom count confirmed as reasonable for this model type
<input type="checkbox"/>	Free body balance confirmed: applied forces and moments sum correctly
<input type="checkbox"/>	Estimated run time assessed: hours or days, and resources allocated accordingly
<input type="checkbox"/>	Solver version and settings documented: precision, tolerance, max iterations
<input type="checkbox"/>	All pre-run items signed off by the analyst before job submission

### Post-Solve QA Checks

✓	Post-Solve Checks
<input type="checkbox"/>	Convergence criteria verified: force residuals, displacement norms, energy criterion as applicable
<input type="checkbox"/>	Reaction forces balance confirmed against applied loads
<input type="checkbox"/>	Free body diagram check performed post-solve
<input type="checkbox"/>	Rigid body motion check completed (no unexpected unconstrained modes)
<input type="checkbox"/>	Energy ratio reviewed (for dynamic/nonlinear analyses)
<input type="checkbox"/>	All solver warnings reviewed and adjudicated: explained and documented, or corrected
<input type="checkbox"/>	No result accepted if any critical warning remains unexplained
<input type="checkbox"/>	Solver log archived as part of the project deliverable package

**Key Principle:** *No result may be accepted if unexplained critical warnings exist in the solver log. Every warning must be reviewed. Every warning must be adjudicated. No exceptions.*

## Stage 6 – Result Interpretation Checklist

Result interpretation is the most intellectually demanding stage and the one most vulnerable to cognitive bias, confirmation bias in particular. SOPs here enforce rigor at the exact point where human judgement is most fallible.

✓	Result Interpretation Checks
<input type="checkbox"/>	Acceptance criteria defined and approved in the analysis plan before the run was submitted
<input type="checkbox"/>	Result extraction method standardized: stress averaging method, coordinate system, critical location ID
<input type="checkbox"/>	Results compared against pre-defined pass/fail criteria for each load case
<input type="checkbox"/>	Color scale range standardized for all fringe plots in deliverables
<input type="checkbox"/>	Fringe plot orientation, result quantity, and unit labels clearly visible on all plots
<input type="checkbox"/>	Analysis assumptions explicitly documented in the report
<input type="checkbox"/>	Model limitations and applicability envelope of results stated
<input type="checkbox"/>	Sensitivity to key inputs assessed and documented
<input type="checkbox"/>	Peer review checklist completed by an independent reviewer
<input type="checkbox"/>	Sign-off record completed and archived with the deliverable package

### Mandatory Deliverable Package Contents

The final output of any FEA project is not a number. It is a documented evidence base. The following items constitute the minimum deliverable package:

1. Analysis plan (including acceptance criteria, approved before the run)
2. FEA model files (archived at the version used for the final results)
3. Mesh quality report
4. Mesh convergence study with archived plots
5. Solver log
6. Result plots with standardized formatting
7. Acceptance criteria comparison table
8. Assumptions and limitations section
9. Peer review checklist (completed and signed)
10. Sign-off record

**Key Principle:** *Acceptance criteria must be defined and approved before you look at the results. Not during. Not after. Before. If you define criteria after seeing results, you are not doing engineering, you are doing post-hoc rationalization.*

## Top 10 Common FEA Mistakes & Their SOP Preventions

The table below distills decades of FEA review experience into ten mistakes that occur repeatedly across organizations and industries. For every mistake, there is a specific, implementable SOP that prevents it.

#	Common Mistake	SOP Prevention
01	Wrong unit system at model import	Unit SOP mandated at project kick-off; checks at every import/export
02	Unverified material data from old models	Centralized, source-traced material library with custodian control
03	Over-constrained boundary conditions	BC rationale documented and peer-reviewed for every constraint
04	No mesh convergence study performed	3-density convergence SOP with archived plots as a mandatory gate
05	Solver warnings ignored or unlogged	Mandatory warning adjudication checklist: no unexplained warnings accepted
06	Acceptance criteria set after seeing results	Pass/fail criteria defined and approved before the analysis run
07	Loads not traced to a source document	Load case sign-off SOP with source reference field required
08	No free body diagram check post-solve	Post-solve QA checklist with FBD balance as a mandatory item
09	Ambiguous result plots in deliverables	Post-processing standard: defined scale, labels, coordinate system, units
10	Analysis assumptions never documented	Mandatory assumptions and limitations section in every report

**Practical Tip:** *Print this page and pin it next to your monitor. If you prevent even two of these mistakes on your next project, this document has already paid for itself.*

# Implementing SOPs in Your Organization

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SOPs do not need to be comprehensive before they deliver value. A one-page checklist for the pre-run review, completed and signed, will prevent more errors this month than a 200-page quality manual that is not finished for another year. Start with the minimum viable SOP and iterate.

## 6-Step Implementation Roadmap

### Step 1 – Audit Your Current Practice

Before writing anything, map your current practice. Interview your three most experienced analysts. Where do they agree? Where does each person do something different? That divergence is your priority SOP list.

### Step 2 – Start with a Template Library

Build reusable SOP templates for checklists, report covers, and result tables. The fastest path to SOP adoption is a template people actually use: a pre-run checklist in a shared folder, a standard result plot configuration, a mesh quality report in a familiar format. These feel useful immediately.

### Step 3 – Engage Your Team

SOPs created top-down are ignored. SOPs written by the engineers who do the work are followed. Identify your most respected technical leads and make them co-authors. Their credibility transfers to the document.

### Step 4 – Version & Govern

Your first SOP will not be your best SOP. That is expected. What matters is traceability: what changed, when, and why. A shared folder with version numbers and a change log is sufficient to start. Assign a document owner and define a review cycle.

### Step 5 – Train & Validate

The highest-leverage moment for SOP adoption is onboarding. A new engineer who learns the SOP as the default way of working will follow it naturally. Build SOPs into your technical onboarding curriculum. Include SOP compliance in peer review checklists.

### Step 6 – Iterate Continuously

After every major project, run a 30-minute lessons-learned session specifically focused on the FEA process. What worked? What failed? What should the SOP say differently? SOPs are living documents, they must evolve with your experience.

**Practical Tip:** *Commit to one action this week: identify the single SOP you will write, or have written, before Friday. It does not need to be comprehensive. It needs to exist.*

## Go Deeper with FEA Academy

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FEA Academy provides in-depth training, mentoring, and consulting to help engineers and engineering teams build rigorous, consistent FEA practices. The resources below are available at [fea-academy.com](https://www.fea-academy.com).

### Online Courses

<https://www.fea-academy.com/index.php/services/training>

- Practical Basic FEA
- Practical Nonlinear FEA
- Model Debugging in FEA (coming soon)

### Mentoring & Coaching Programs

<https://www.fea-academy.com/index.php/services/coaching>

- Monthly mentoring plans for individual engineers
- Annual subscriptions for engineering teams in companies

### Books

<https://www.fea-academy.com/index.php/all-books>

- Practical Finite Element Analysis for Mechanical Engineers – Dominique Madier – 2020
- Harness the Power of Finite Element Analysis – Dominique Madier – 2025

### Free Resources

<https://www.fea-academy.com/index.php/resources>

Visit the Free Resources page at [fea-academy.com](https://www.fea-academy.com) for additional guides:

- Good Modeling Practices
- The Fundamentals in Mesh Generation
- The FEM Theory in Depth
- This SOP Starter Kit

### Stay Connected

- **LinkedIn:** <https://www.linkedin.com/in/dominique-madier> (46,000+ followers)
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