BUREAU OF RECLAMATION

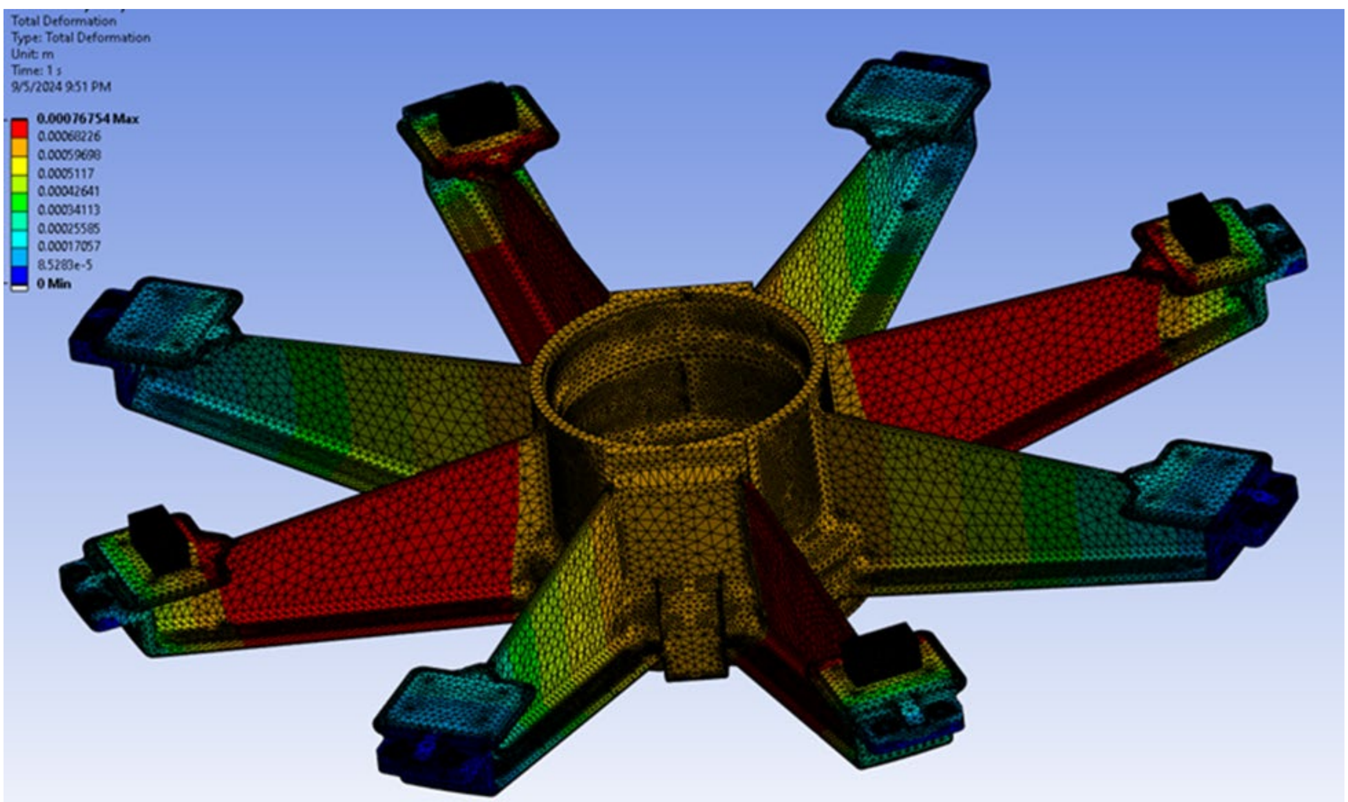
Final Report No. ST-2024-21091-01

Evaluation and Validation of Fatigue on Aging Hydro Mechanical Components using Finite Element Analysis

Research and Development Office

Science and Technology

Research Program



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14. ABSTRACT The goal of this project was to evaluate and validate the effect fatigue has on aging mechanical components using Finite Element Analysis (FEA). FEA is a method of calculating and predicting how complex systems react to real-world forces with the aid of a computer system. This project analyzed several mechanical components from Reclamation Powerplants using a developed FEA process. This report will provide results of the analysis, outline the processes used, and make recommendations for further FEA studies.			
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Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; honors its trust responsibilities or special commitments to American Indians, Alaska Natives, Native Hawaiians, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Disclaimer

Acknowledgements

The Science and Technology Program, Bureau of Reclamation, sponsored this research. LDV Consulting provided training and support on FEA topics, and PADT provided training and support on Ansys Software use. Thanks to the Reclamation facilities that partnered with researchers to provide projects, scoping, and support.

Cover Image – Three-dimensional digital rendering of a hydroelectric generator thrust bracket with a fine mesh overlayed onto the structure. The image is color graded to display total deformation from blue to red. (Bureau of Reclamation)

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Peer Review

Bureau of Reclamation
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This document has been reviewed under the Research and Development Office Discretionary peer review process, consistent with Reclamation Policy CMP P14. It does not represent and should not be construed to represent the Bureau of Reclamation's determination, concurrence, or policy.

Acronyms and Abbreviations

ASME	American Society of Mechanical Engineers
ASTM	American Society Testing and Materials International
BPVC	boiler and pressure vessel code
CAD	computer-aided design
ft^3/s	cubic feet per second
FEA	finite element analysis
ft	foot
ft-lbs	foot-pounds
GCPO	Grand Coulee Power Office
HP	horsepower
in	inch
lbf	pound-force
lbs	pounds
mils	thousandths of an inch
OEM	original equipment manufacturing
PADT	Phoenix Analysis and Design Technologies, Inc
psi	pounds per square inch
Reclamation	Bureau of Reclamation
ROI	regions of interest
TSC	Technical Service Center
U.S.	United States

Symbols

=	equal to
%	percent

Contents

Tables

Figures

Appendix

Executive Summary

Many of the Bureau of Reclamation's (Reclamation) hydroelectric powerplants were designed in the early to mid-20th century. Engineers of that era did not have the advanced engineering modeling tools or computing capacity to perform fatigue analysis that are available today. As these hydro units continue to operate 70 years later there are increasing signs of fatigue failure such as cracking and broken weld joints. It is important to ensure that existing mechanical components are able to withstand the changes in dynamic forces as these units are overhauled with new runners, uprated windings, increased power output, operational changes, and other modifications to the original design.

The goal of this project was to evaluate and validate the impact of fatigue on aging mechanical components. This was accomplished by using finite element analysis (FEA). Finite element analysis is a method of calculating and predicting how complex systems react to real-world forces with the aid of a computer system. Elements of a system are broken into a mesh (small solvable portions of a larger component) and run through a solver, such as Ansys, to gain usable data and information. The results from FEA are used to analyze and predict characteristics of existing hydropower equipment such as high-stress concentrations, abnormal vibration resonances, or modes of failure like fatigue.

In order to increase Reclamation's ability in the above, it was proposed to instrument the thrust bearing bracket of a vertical Francis hydro unit with strain gauges prior to a turbine runner replacement. An FEA model was created to estimate fatigue life and predict the future stresses that would be experienced with the new runner. Following the runner replacement, the model would be validated by taking a final set of empirical thrust bracket data. Due to unforeseen circumstances during the unit overhaul, this portion of the research was unable to be performed as planned. The research team adapted by generating five finite element models of hydro components: two (2) thrust brackets, a single turbine shaft, a mechanical seal, and a piping wye branch.

The findings and capabilities from this research are expected to have far-reaching and lasting effects on Reclamation's ability to proactively prevent catastrophic failures and reduce unplanned downtime. Inspections can be more targeted and effective by identifying specific high-stress areas. Advanced computational analyses will facilitate precise calculations and estimations that were previously reliant on assumptions and approximations, optimizing initial designs and corrective repairs with fewer iterations. This program is intended for expansion to include permanently installed cranes, large gates/valves, bearing brackets, operating rings, head covers, generator rotors, stator frames, and much more. Leveraging these new capabilities, Reclamation anticipates significant cost savings through reduced construction expenses from iterative designs, avoiding the need to contract these services to third parties, increased unit availability, and enhanced operational safety.

Appendix A

Finite Element Modeling Flow Charts

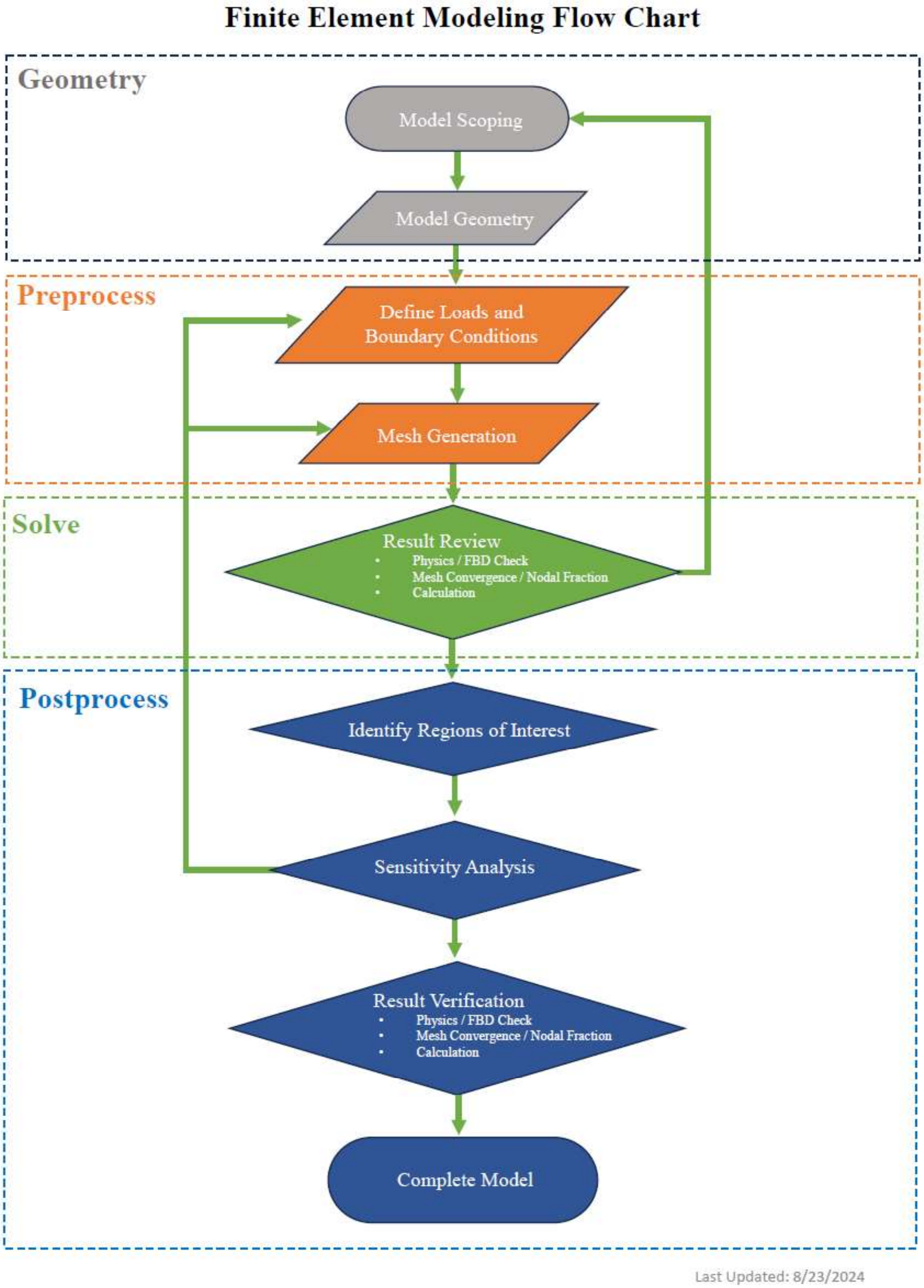

Figure A-1.—Finite element modeling flowchart.

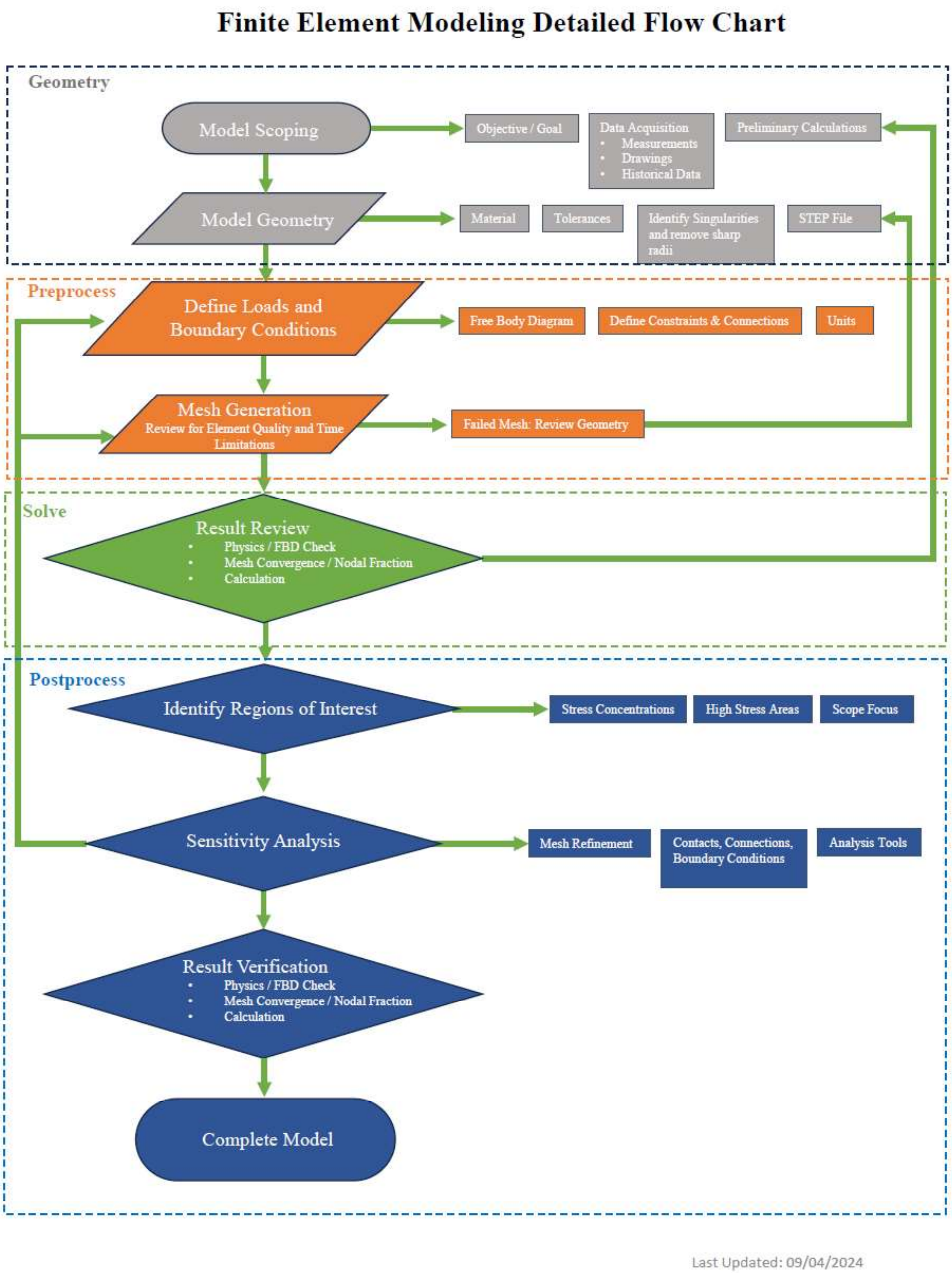

Figure A-2.—Detailed finite element modeling flowchart.