McLaren 2023 F1 Front Wing FSI Analysis - Setup Guide

Complete installation and setup guide for the fluid-structure interaction analysis pipeline.

System Requirements

Hardware Requirements

- **CPU**: 8+ cores recommended (Intel i7/AMD Ryzen 7 or better)
- **RAM**: 16GB minimum, 32GB recommended
- **Storage**: 50GB+ free space (SSD preferred)
- **Network**: Internet connection for package downloads

Software Requirements

- **OS**: Ubuntu 20.04+ (primary), CentOS 8+, or WSL2 on Windows
- **OpenFOAM**: Version 11
- **CalculiX**: Version 2.20+
- **Python**: 3.8+
- **Git**: Version control

Installation Steps

Step 1: Install OpenFOAM 11

Ubuntu/Debian Installation

```bash
# Add OpenFOAM repository
sudo sh -c "wget -O - https://dl.openfoam.org/gpg.key | apt-key add -"
sudo add-apt-repository http://dl.openfoam.org/ubuntu

# Update package list
sudo apt update

# Install OpenFOAM 11
sudo apt install openfoam11

# Source OpenFOAM environment
echo "source /opt/openfoam11/etc/bashrc" >> ~/.bashrc
source ~/.bashrc

# Verify installation
foamInstallationTest
```

Alternative: Docker Installation

```bash
# Pull OpenFOAM Docker image
docker pull openfoam/openfoam11-paraview56

# Run container with volume mounting
docker run -it --rm -v $(pwd):/workspace openfoam/openfoam11-paraview56
```

Step 2: Install CalculiX

Ubuntu/Debian Installation

```bash
# Install CalculiX packages
sudo apt update
sudo apt install calculix-ccx calculix-cgx

# Verify installation
ccx_2.20 -h
cgx -h
```

Manual Compilation (if needed)

```bash
# Download CalculiX source
wget http://www.dhondt.de/ccx_2.20.src.tar.bz2
wget http://www.dhondt.de/ccx_2.20.test.tar.bz2

# Install dependencies
sudo apt install gfortran libblas-dev liblapack-dev libspooles-dev libarpack2-dev

# Extract and compile
tar -xjf ccx_2.20.src.tar.bz2
cd CalculiX/ccx_2.20/src
make

# Add to PATH
echo 'export PATH=$PATH:/path/to/CalculiX/ccx_2.20/src' >> ~/.bashrc
```

Step 3: Install Python Dependencies

```bash
```

```
# Update pip
python3 -m pip install --upgrade pip

# Install project dependencies
pip install -r requirements.txt

# Verify critical packages
python3 -c "import vtk; print('VTK version:', vtk.vtkVersion.GetVTKVersion())"
python3 -c "import numpy; print('NumPy version:', numpy.__version__)"
```

Step 4: Install Additional Tools

ParaView (Visualization)

bash

```
# Ubuntu installation
sudo apt install paraview

# Or download latest version
wget "https://www.paraview.org/paraview-downloads/download.php?submit=Download&version=v5.11&type=
```

Git LFS (Large File Support)

bash

```
# Install Git LFS
sudo apt install git-lfs

# Initialize in repository
git lfs install
```

Project Setup

Step 1: Clone Repository

bash

```
# Clone the repository
git clone https://github.com/yourusername/McLaren-2023-Front-Wing-FSI.git
cd McLaren-2023-Front-Wing-FSI

# Initialize Git LFS (if using)
git lfs pull
```

Step 2: Verify Project Structure

bash

```
# Check directory structure
tree -L 2

# Should show:
# ├── config/
# ├── docs/
# ├── geometry/
# ├── scripts/
# ├── fea-analysis/
# ├── cfd-analysis/
# └── results/
```

Step 3: Test Installation

```bash
# Test OpenFOAM
which blockMesh
which snappyHexMesh
which rhoCentralFoam

# Test CalculiX
which ccx_2.20

# Test Python environment
python3 scripts/test_installation.py
```

Configuration

Step 1: Environment Variables

```bash
# Add to ~/.bashrc
export FOAM_RUN=$HOME/OpenFOAM/run
export WM_PROJECT_USER_DIR=$HOME/OpenFOAM/$USER-11

# Source OpenFOAM
source /opt/openfoam11/etc/bashrc

# Add CalculiX to PATH (if needed)
export PATH=$PATH:/usr/bin

# Reload environment
source ~/.bashrc
```

Step 2: Configure Parallel Processing

```bash
```

```
# Set number of processors for parallel runs
export OMP_NUM_THREADS=8

# For MPI runs (if using)
export OMPI_MCA_btl_vader_single_copy_mechanism=none
```

Step 3: Verify Configuration

bash

```
# Check OpenFOAM environment
foamInstallationTest

# Check available solvers
ls $FOAM_SOLVERS/compressible/

# Verify rhoCentralFoam
rhoCentralFoam -help
```

Quick Test

Test Basic Functionality

bash

```
# Navigate to project directory
cd McLaren-2023-Front-Wing-FSI

# Run quick test
python3 scripts/run_analysis.py --config config/quick_test.yaml --step validation

# Expected output:
# - OpenFOAM installation: OK
# - CalculiX installation: OK
# - Python dependencies: OK
# - Project structure: OK
```

Test Mesh Generation

bash

```
# Test simple mesh
cd cfd-analysis/rigid-wing
blockMesh

# Should complete without errors
```

Test Streamlines Function

```bash
# Test streamlines setup
python3 ../../scripts/post_process.py . --streamlines-only

# Check for output:
# - Streamlines function added to controlDict
# - foamPostProcess completed successfully
```

Troubleshooting

Common Issues

OpenFOAM Not Found

```bash
# Check installation
dpkg -l | grep openfoam

# Re-source environment
source /opt/openfoam11/etc/bashrc

# Check PATH
echo $FOAM_APPBIN
```

CalculiX Permission Denied

```bash
# Check executable permissions
ls -la /usr/bin/ccx*

# Fix permissions if needed
sudo chmod +x /usr/bin/ccx_2.20
```

Python Package Conflicts

```bash
# Create virtual environment
python3 -m venv mclaren_env
source mclaren_env/bin/activate

# Install packages in isolated environment
pip install -r requirements.txt
```

Memory Issues

```bash
```

```
# Monitor memory usage
free -h

# For large cases, increase swap
sudo fallocate -l 8G /swapfile
sudo chmod 600 /swapfile
sudo mkswap /swapfile
sudo swapon /swapfile
```

WSL2 Specific Issues

File Permission Problems

bash

```
# Mount with proper permissions
sudo umount /mnt/c
sudo mount -t drvfs C: /mnt/c -o metadata,uid=1000,gid=1000
```

Display Issues for ParaView

bash

```
# Install X11 server for Windows
# Download and install VcXsrv

# Set DISPLAY variable
export DISPLAY=:0

# Test with simple X application
xeyes
```

Additional Resources

Documentation

- OpenFOAM User Guide
- CalculiX Documentation
- Python VTK Examples

Tutorials

- OpenFOAM Compressible Flow Tutorial
- CalculiX Examples

Community Support

- OpenFOAM Discourse
- CalculiX Forum

Verification Checklist

Before running the analysis, verify:

- [ ] OpenFOAM 11 installed and sourced
- [ ] CalculiX ccx_2.20 accessible
- [ ] Python 3.8+ with all dependencies
- [ ] Project cloned and structure verified
- [ ] Quick test passes
- [ ] Sufficient disk space (50GB+)
- [ ] Adequate RAM (16GB+)

Next Steps

Once setup is complete:

1. **Read the theory documentation**: `docs/theory.md`
2. **Review the configuration**: `config/default.yaml`
3. **Run the full analysis**: `python3 scripts/run_analysis.py`
4. **Explore results**: `results/` directory

For advanced usage and customization, see the API Reference.