Contents

1 Introduction **1**
- 1.1 Isogeometric Analysis and refinable splines . . . 1
- 1.2 Geometry Independent Field approXimation: decoupling of the field and geometry . . . 2
- 1.3 Error estimators and Adaptive refinement . . . 3
- 1.4 Selected applications . . . 4
  - 1.4.1 Time-harmonic acoustics . . . 4
  - 1.4.2 Kirchhoff–Love thin plates and fracture mechanics . . . 6
- 1.5 Introduction to the present work . . . 7
- 1.6 Objectives and Statement . . . 8
  - 1.6.1 General Objective . . . 8
  - 1.6.2 Specific Objectives . . . 8
  - 1.6.3 Statement and Thesis Scope . . . 8

2 Methodology **9**
- 2.1 Literature review . . . 9
- 2.2 PHT-Splines GIFT code . . . 9
- 2.3 Adaptive refinement strategies . . . 9
- 2.4 Applications on wave propagation problems . . . 10
- 2.5 Applications on fracture mechanics on thin plates . . . 10

3 Theoretical background **11**
- 3.1 Isogeometric Analysis . . . 11
  - 3.1.1 Non Uniform Rational B-Spline (NURBS) . . . 11
- 3.2 Polynomials Splines Over Hierarchical T-meshes . . . 17
  - 3.2.1 T-meshes . . . 17
  - 3.2.2 Hierarchical T-meshes . . . 17
  - 3.2.3 PHT-Splines Space . . . 18
  - 3.2.4 PHT-Splines Surfaces . . . 18
- 3.3 Geometry Independent Field approximaTion (GIFT) . . . 19
  - 3.3.1 Formulation of GIFT . . . 21
- 3.4 Error estimators and Adaptive refinement . . . 21
  - 3.4.1 Residual-based error estimator . . . 22
  - 3.4.2 Recovery-based error estimator . . . 23
  - 3.4.3 Marking strategies . . . 24
- 3.5 Helmholtz equation . . . 25

3.5.1 Boundary-value problem (BVP) . . . 25
3.5.2 Weak Form . . . 26
3.5.3 A posteriori error-estimates for the Helmholtz equation . . . 27
3.6 Kirchhoff-Love plate theory and fracture mechanics . . . 28
3.6.1 Strong Form . . . 29
3.6.2 Weak Form . . . 30
3.6.3 Vibration of plates . . . 31
3.6.4 XGIFT: Extended formulation for GIFT . . . 32
3.6.5 Computation of Stress Intensity Factors (SIF) . . . 36
3.6.6 J-Integral and Interaction Integral . . . 38
3.6.7 A posteriori error-estimates for the Kirchhoff-Love equation . . . 40
3.6.8 Dynamic analysis and adaptive refinement . . . 42

4 Numerical results: Helmholtz equation 43
4.1 2D Numerical Examples . . . 43
4.1.1 The L-shape domain . . . 43
4.1.2 The thin plate example . . . 51
4.1.3 The star-shaped geometry . . . 56
4.2 3D Numerical Examples . . . 59
4.2.1 The unit cube problem . . . 59

5 Numerical Results: Fracture Mechanics of Kirchhoff-Love plates 67
5.1 Numerical Examples: Bending of plates with cracks . . . 67
5.1.1 Square plate with an edge crack . . . 67
5.1.2 Square plate with a central crack . . . 73
5.1.3 Square plate with a central crack subjected to constant pressure loading 76
5.2 Vibration of plates with cracks . . . 79
5.2.1 Square plate with central crack . . . 79
5.2.2 Clamped circular plate with a central crack . . . 81
5.2.3 Clamped annular plate with 2 symmetric cracks . . . 84

6 Conclusion 86

Bibliography 88

Appendix 100

Appendix A Geometry Parameterization employed in the Numerical Examples 100