Development of a machine learning model to determine the forces on the piston in the pump-tube of a two-stage gas gun deforming due to a taper

Benjamin Alheit*[1, 2]

[1] *Centre for Research in Computational & Applied Mechanics, University of Cape Town, 7701 Rondebosch, South Africa*
[2] *Department of Mechanical Engineering, University of Cape Town, 7701 Rondebosch, South Africa*

September 23, 2021

Abstract

Abstract here.

1 TODO

1. Get output parameters
2. Model automation
3. Mesh optimization

2 Introduction

- We will use: ton, mm, s, N, MPa, N-mm

2.1 Gas gun design

2.1.1 title

3 Finite element simulation

3.1 Material models

3.1.1 ABS

1. Yield stress: 48.26 MPa from https://peer.asee.org/tensile-comparison-of-polymer-specimens-produced-with-different-processes.pdf

*alhben001@myuct.ac.za

MASS	LENGTH	TIME	FORCE	STRESS	ENERGY	Steel Density	Steel Modulus	G - Gravity Constant
kg	m	s	N	Pa	Joule	7.83E+03	2.07E+11	9.81
kg	mm	ms	kN	Gpa	kN-mm	7.83E-06	2.07E+02	9.81E-03
g	cm	s	dyne	dyne/cm^2	erg	7.83E+00	2.07E+12	9.81E+02
g	cm	us	1e7N	Mbar	1e7 N-cm	7.83E+00	2.07E+00	9.81E-10
g	mm	s	1e-6N	Pa	1e-9 J	7.83E-03	2.07E+11	9.81E+03
g	mm	ms	N	Mpa	N-mm	7.83E-03	2.07E+05	9.81E-03
ton	mm	s	N	Mpa	N-mm	7.83E-09	2.07E+05	9.81E+03
lbf-s^2/in	in	s	lbf	psi	lbf-in	7.33E-04	3.00E+07	3.86E+02
slug	ft	s	lbf	psi	lbf-ft	1.52E+01	4.32E+09	32.2

Figure 1: Consistent units for Abaqus. From https://www.researchgate.net/post/What-are-the-Abaqus-Units-in-Visualization

2. (Modelled as perfect plasticity)
3. Poisson's ration: 0.35 from http://www.goodfellow.com/A/Polyacrylonitrile-butadiene-styrene.html
4. Young's modulus: 2.1-2.4 GPa from http://www.goodfellow.com/A/Polyacrylonitrile-butadiene-styrene.html
5. Density 1.05×10^{-9} ton/mm^3 from http://www.goodfellow.com/A/Polyacrylonitrile-butadiene-styrene.html

3.1.2 Steel

1. Poisson's ration: 0.3 from http://www.matweb.com/search/datasheet.aspx?bassnum=MS0001&ckck=1
2. Young's modulus: 200 GPa from http://www.matweb.com/search/datasheet.aspx?bassnum=MS0001&ckck=1
3. Density 8×10^{-9} ton/mm^3 from http://www.matweb.com/search/datasheet.aspx?bassnum=MS0001&ckck=1

3.2 Single test simulation

3.3 Mesh optimization

Parameters

1. ratio of element expansion for piston
2. ratio of element expansion for tube
3. n elements

Objective function

1. Min elements

Constraint

1. Force
2. Dissipation

4 Machine learning surrogate model

4.1 Feature engineering

Predictive features:

1. Coefficient of friction: μ
2. Taper angle: α
3. Velocity: v
4. Distance between piston front and taper start: x_{taper}
5. Pressure difference between piston front and back: Δp
6. Piston length: l_p
7. Piston density: ρ_p
8. Accumulative plastic strain in the piston: γ

Dependent variables:

1. Axial force on piston due to taper: F_z
2. Increment in accumulated plastic dissipation: $\Delta\gamma$

4.1.1 Non-dimensional analysis

4.2 Experimental input parameters

In order of importance:

1. Initial velocity: v_0
2. Pressure path: p_{path}
3. Piston length: l_p
4. Coefficient of friction: μ

4.3 Experimental results

4.4 Model

5 Packaging of model for use in 1D code

5.1 PIP

5.2 Usage example