Dimensioning Mechanical Press Architecture for Improved Dwell using Advanced Algebraic Techniques

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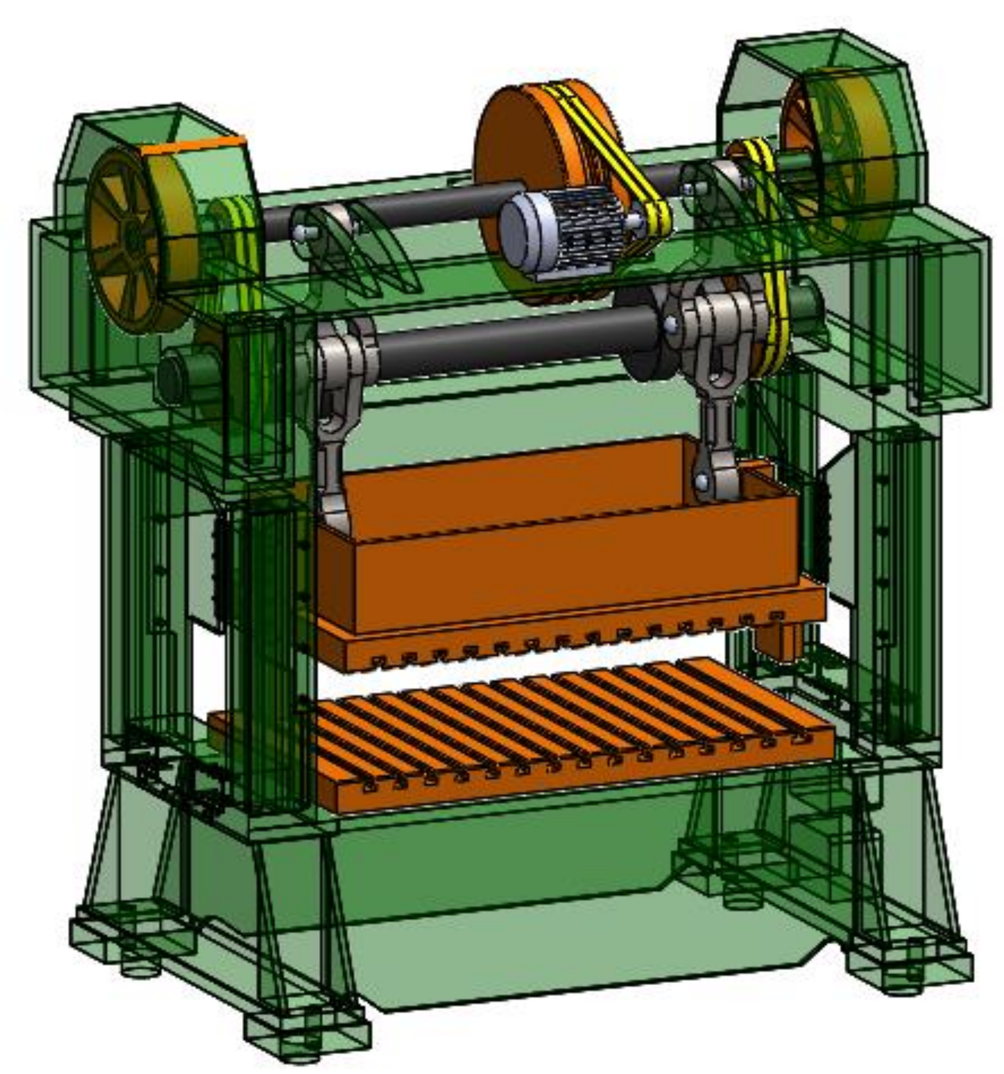
Objective: To determine a knuckle press design with maximized dwell.

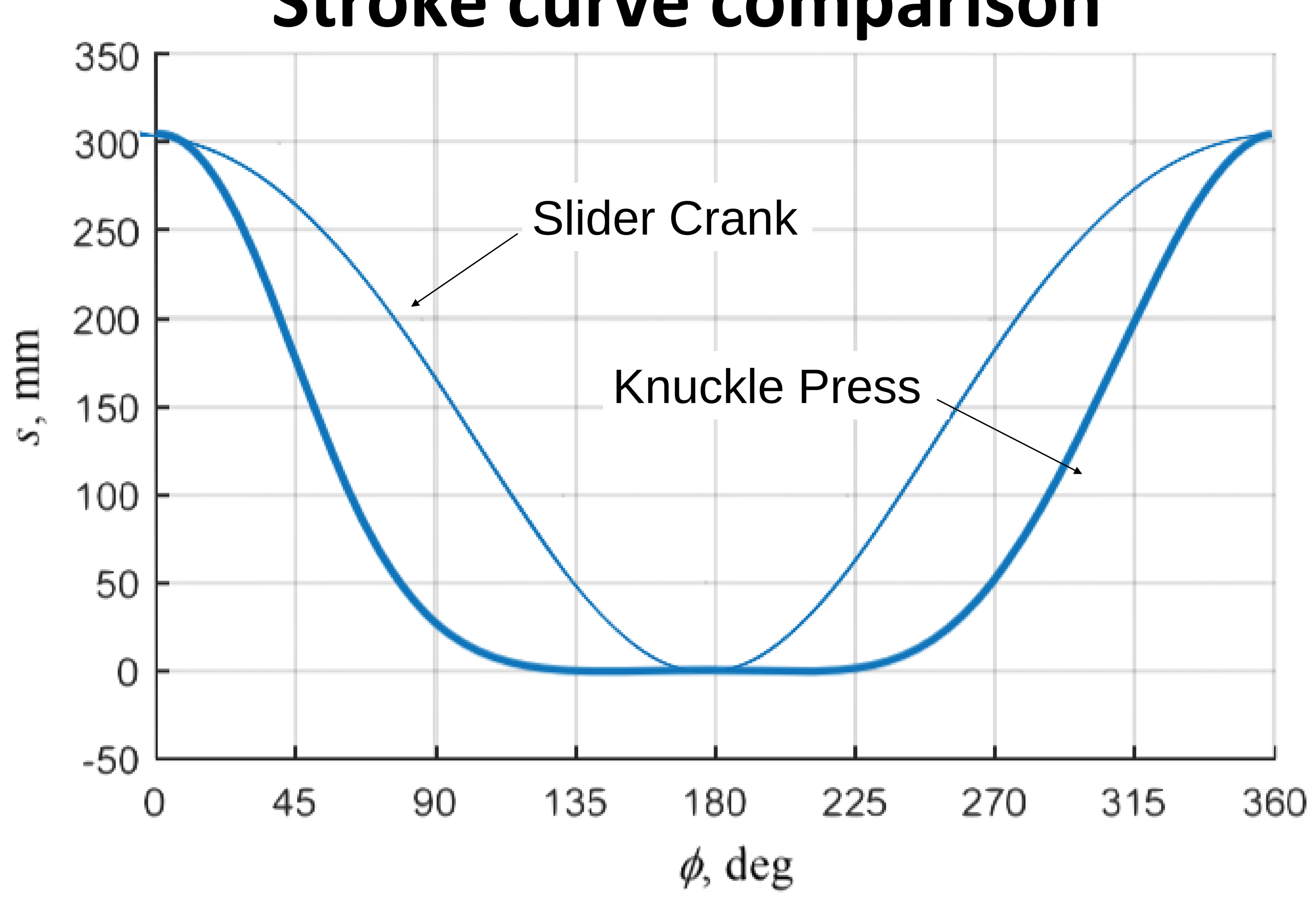
Introduction

A mechanical press is a machine that shapes parts by driving a ram into metal and deforming the material into a desirable shape. As this is an incredibly common process for forming metal parts, from pop cans to car fenders, presses see significant use in industry. This research project seeks to develop a numerical algebraic method for determining mechanical press dimensions from a desired dwell displacement pattern. This dwell pattern occurs when the ram lingers near the bottom of the stroke while the rest of the press stays in motion. Longer dwell produces improved part forming at no additional cost. This study focuses on knuckle presses architectures to test the proposed method on a variety of systems and to produce the most feasible design. Numerical algebraic methods are particularly relevant here due to their capacity to accurately describe mechanical press architectures while allowing solutions via current numerical methods that guarantee the determination of all solutions to a set of algebraic equations.

Knuckle Joint Driven Press Driven

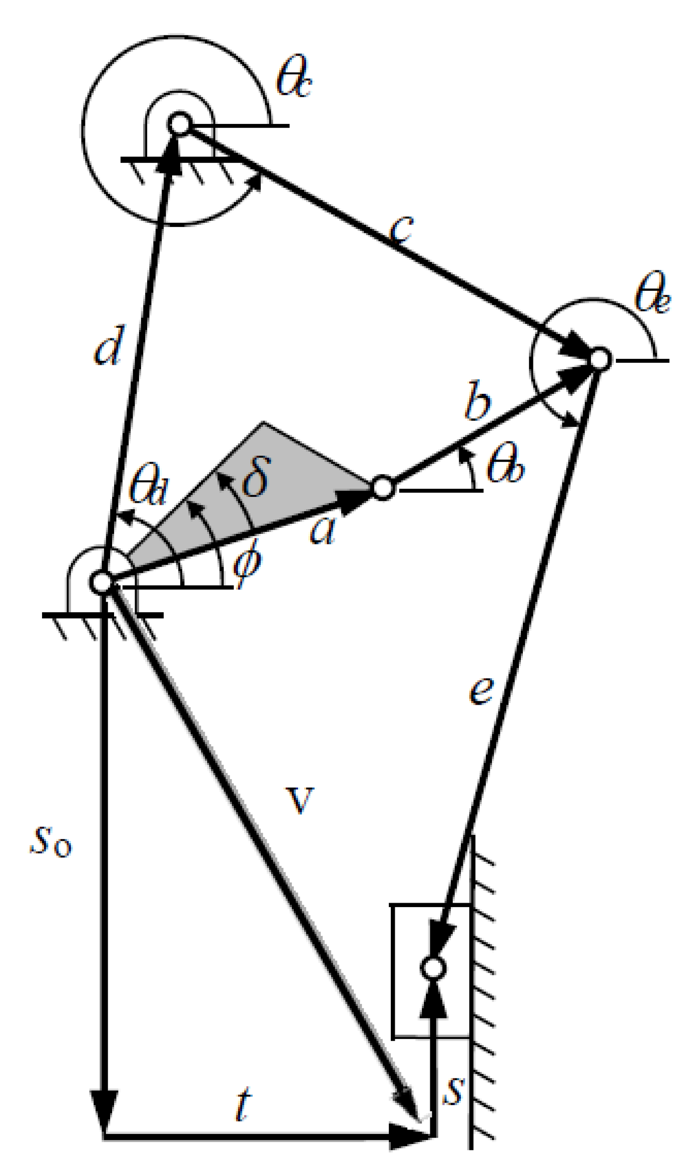


Stroke curve comparison

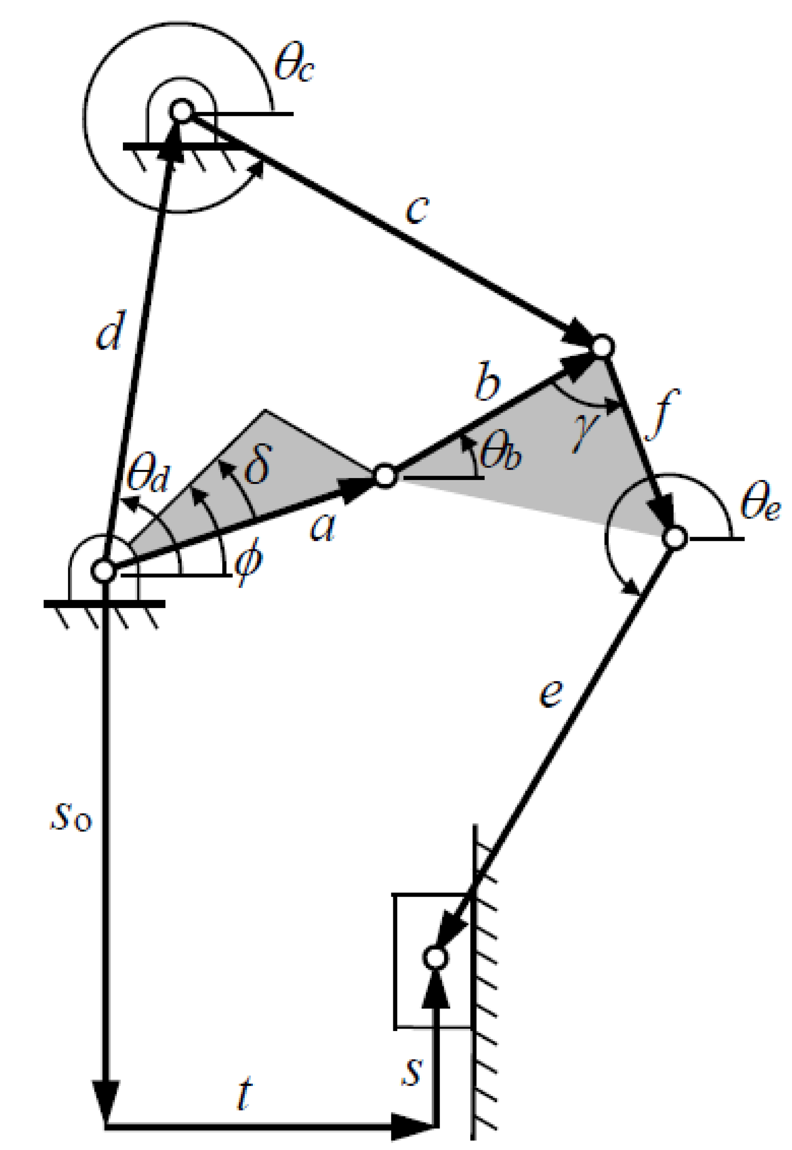


Vector Diagrams

Knuckle Press



Knuckle Press with Ternary Link



The vector diagrams above are the mathematical abstraction of the press shown to the left. These vector diagrams are used to generate the listing of equations to the right. Isotropic coordinates are a little used formalism being promoted by mathematicians in the mechanical engineering sector because they are well suited to numerical algebraic techniques.

Knuckle Press Position Equations

$$\begin{cases} a*c(\phi_i+\delta)+b*c(\theta_{bi})-c*c(\theta_{ci})-d*c(\theta_d)=0 \\ a*s(\phi_i+\delta)+b*s(\theta_{bi})-c*s(\theta_{ci})-d*s(\theta_d)=0 \end{cases}$$

$$\begin{cases} a*c(\phi_i+\delta)+b*c(\theta_{bi})+e*c(\theta_{ei})-v*c(\theta_v)=0 \\ a*s(\phi_i+\delta)+b*s(\theta_{bi})+e*s(\theta_{ei})-v*s(\theta_v)-s=0 \end{cases}$$

In Isotropic Form

$$\begin{cases} aT_{\phi i}T_\delta+bT_{bi}-cT_{ci}-dT_d=0 \\ a\bar{T}_{\phi i}\bar{T}_\delta+b\bar{T}_{bi}-c\bar{T}_{ci}-d\bar{T}_d=0 \end{cases}$$

$$\begin{cases} aT_{\phi i}T_\delta+bT_{bi}+eT_{ei}-vT_v-si*I=0 \\ a\bar{T}_{\phi i}\bar{T}_\delta+b\bar{T}_{bi}+e\bar{T}_{ei}-v\bar{T}_v+si*I=0 \end{cases}$$

where

$$T_j=e^{i\theta_j}=cos\theta+sin\theta i$$
$$\bar{T}_j=e^{-i\theta_j}=cos\theta-sin\theta i$$

Velocity Relationships

$$\begin{bmatrix} -b*s\theta_b & 0 & c*s\theta_c & 0 \\ b*c\theta_b & 0 & -c*c\theta_c & 0 \\ -b*s\theta_b & -e*s\theta_e & 0 & 0 \\ b*c\theta_b & e*c\theta e & 0 & -1 \end{bmatrix} * \begin{Bmatrix} \omega_b \\ \omega_e \\ \omega_c \\ \omega_s \end{Bmatrix} = \begin{Bmatrix} a*s\theta_a \\ -a*c\theta_a \\ a*s\theta_a \\ -a*c\theta_a \end{Bmatrix}$$