A BINDING SCHEME TO MINIMIZE THINNING OF FORMED TAILOR WELDED BLANKS

By

Mahmoud Samir Ahmed El-Sayed Seyam

A Thesis Submitted to the
Faculty of Engineering at Cairo University
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Under the Supervision of

Prof. Dr. Abdalla S. Wifi
Department of Mechanical Design
and Production Engineering
Faculty of Engineering, Cairo
University

Assoc.Prof. Alaa El-Mokadem
Department of Mechanical Design
and Production Engineering
Faculty of Engineering, Cairo
University

Assoc.Prof. Mostafa Shazly
Mechanical Engineering Department
Faculty of Engineering,
The British University in Egypt

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

Engineer's Name: Mahmoud Samir Ahmed El-Sayed Seyam
Date of Birth: 14/11/1989
Nationality: Egyptian
E-mail: Mahmoud.s.seyam@cu.edu.eg
Phone: +201094589646
Address: 369/12 St/Alfardows Gardens/October City/Giza

Registration Date: 1/10/2013
Awarding Date: …./…./2018
Degree: Master of Science
Department: Mechanical Design and Production Engineering

Supervisors:

Prof. Dr. Abdalla S. Wifi
Assoc.Prof. Alaa El-Mokadem
Assoc.Prof. Mostafa Shazly
(Faculty of Engineering, The British University in Egypt)

Examiners:

Porf. Dr.Abdalla S. Wifi (Thesis main advisor)
Prof. Dr. Mohammed M. Megahed (Internal examiner)
Prof. Dr. Mahmoud Mohamed M. Nemat-Alla (External examiner)
(Deen of the Faculty of Engineering, Kafr El-Sheikh University)

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A Binding Scheme To Minimize Thinning of Formed Tailor Welded Blanks

Key Words:
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Summary:

The present work suggests a new binding scheme to reduce the thinning and weld line movement of TWBs. This scheme combines weld line constraining via counter pins while applying a lower BHF on the weaker side as compared to the stronger side via segmented binders to achieve minimum thinning in the final product. Adopting this scheme, an analytical model was developed for the plane strain 2D draw bending and the 3D box deep drawing processes to determine the required BHF and counter pin force values. Laboratory and numerical experiments were conducted to examine the developed analytical model and compare the proposed controlling scheme with other schemes. The experimental results showed that the new scheme is physically applicable and capable of providing reasonably accurate force values that sufficiently eliminate the weld line movement and enhance formability (substantial reduction in thinning).

The present study showed the merits of implementing the proposed scheme in cases where large thickness and/or strength ratio of the sheets comprising the TWB exist. In such cases, conventional segmented binders along with weld line clamping technique without any variation in the applied BHF at each side cannot prevent.

Acknowledgments

I would like to express my grattitude to my parents, my wife and the rest fo my family, thank you all for your limitless support. A special grattitude also goes to my supervisors for the valuable guidance.

Dedication

I dedicate this work to all interested and knowledge eager folks.

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Nomenclature

F	Tensile force along the deformed profile (normal to the sheet thickness)
BHF_s	Blank holding force on the stronger side
BHF_w	Blank holding force on the weaker side
F_{pin}	Clamping force along the weld line
μ_p	Friction coefficient at the weld line
μ_s	Friction coefficient at the stronger side
μ_w	Friction coefficient at the weaker side
K	Strength coefficient (in the maximum principal direction)
n	Strain hardening exponent
L_o	Original length (for each parent sheet s & w)
t_o	Original thickness (for each parent sheet s & w)
L	Current length (for each parent sheet s & w)
t	Current thickness (for each parent sheet s & w)
$\Delta L_{s_{tot}}$	Total increase in the original length (the total elongation) of the stronger parent sheet
$\Delta L_{w_{tot}}$	Total increase in the original length (the total elongation) of the weaker parent sheet
c	Die/Punch clearance
R_d	Die corner radius
R_p	Punch corner radius
Y	Punch current vertical position
Θ	Wrap Angle
M	internal bending moments
X_w	Initial Weld Line Position
σ	Effective stress
ϵ	Effective strain
α	Stress ratio $\frac{\sigma_2}{\sigma_1}$
β	Strain ratio $\frac{\epsilon_2}{\epsilon_1}$

Abstract

Die-Forming of Tailor Welded Blanks (TWBs) is currently used to produce body panels by the majority of automotive manufacturers. The high material utilization and structural rigidity combined with weight reduction and controlled crash behavior are some of many reasons behind the fast spread of this non-traditional technique. Processing of TWBs has been subjected to intensive research over the past four decades. Still, the field is frequently updated with new ideas and innovations for better utilization of such inherently inhomogeneous Blanks.

This work presents a new force scheme to minimize thinning and Weld Line Movement (WLM) during TWBs die forming. The scheme is applied by means of weld line counter-pins and blank holding segmented binders. An analytical model is developed to provide the required set of forces (Binders and counter pins forces) depending on the TWB properties and die geometry. The model is developed for the U-Draw Bending and Rectangular Box-Shaped Deep Drawing processes following the Marciniak's 2D and 3D stamping approaches. Given the blank geometry/material properties, tool geometry, and the input Blank holder force (binder force) at one of the parent sheets, the model provides the remaining binder forces and the minimum required counter pin force. Depending on the strength of each parent sheet, the estimated forces produce identical elongations in each parent sheet normal to the weld line direction in order to prevent the WLM.

Two different die sets were custom-manufactured for the application of segmented binders and counter-pins. The Die sets were used to verify the new force scheme by applying the predicted forces from the analytical model as inputs in a series of U-Draw Bending and Box-Deep Drawing laboratory experiments. Additional experiments and finite element simulations were used to present the advantage of the new force scheme over other existing schemes.

The experimental results demonstrate the practical feasibility of the new force scheme and validate its capability to minimize thinning as well as WLM. The laboratory experiments and Finite Elements (FE) simulations based on the proposed force scheme also show significant improvement in formability when compared to separate use of either weld line clamping pins or the segmented binders, and show that it can prevent eminent potential failure of the drawn part.

Chapter 1 : Introduction

1.1. Historical Background

By the end of the First World War, steel sheets were gradually replacing wood in the production of vehicles external bodies. Back then, all automobiles were manufactured based on a concept known as body-on-frame (BOF). A powertrain was assembled by chassis manufacturers on a rigid frame as an independent drivable unit while the remaining of the vehicle, the upper body, was separately made by coachbuilders in internal body shops. The two units were later assembled to produce a finished car like the Ford T-Coupe in Figure 1.1. The BOF concept is still adopted by some SUVs and pickup trucks manufacturers but rarely seen in smaller passenger cars at the present time [1][2].

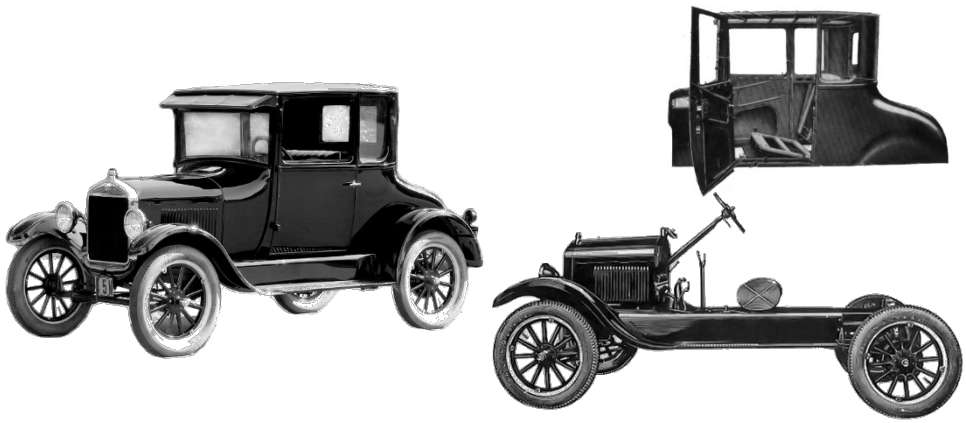

Figure 1.1: Ford Model-T Coupe, 1926[2]

In developed countries, the increasing demand for higher top speeds and less power consumption during the interwar era (between both World Wars) was forcing the automotive industry toward light-weight bodies with higher structural integrity. After the Second World War, vehicles designs started to shift from BOF concept to the unitized body concept. In which, the upper body and chassis were replaced by a single integral skeleton covered by various die-formed steel panels (aka monocoque chassis) as shown in Figure 1.2. The technology was developed early in the 1920s by European manufacturers in collaboration with the USA Budd Company. However, it wasn't until the late 1950s for the technology to be widely used in association with certain advances in sheet metal welding technology. Soon after, unitized body designs became standard for most commercial passenger-cars [1][3].