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Improvement of metal forming quality by motion design

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ABSTRACT

Servo presses provide many advantages as formability, accuracy and productivity. A prototype of servo press with 50 ton capacity has been demonstrated by using a metal forming application in this study. The ram motion is programmed to have several desired profiles by introducing different case studies. Only one specific designed motion is included here as an example for sheet metal forming. The motion which is called soft motion is applied experimentally on Cr-Ni steel alloy sheet for material forming. Kinematics and dynamics from the simulations based on the experimental results are given. Soft ram motion with 20 strokes per minute (spm) and constant motor velocities (such as 5 spm, 10 spm and 20 spm) ram motions are experimentally compared. As a result of comparison; soft motion has given higher velocity with higher thickness and better surface quality on the material. Manufacturing performances of servo press are also experimented at 2–50 tons in laboratory. Stroke position error is found as $\pm$ 0.025 mm for the soft motion. This study is provided to be a research on servo crank press having 200 mm stroke.

1. Introduction

Mechanical servo presses are driven by AC servo motors offer good alternatives in industry. Servo-drive presses have been used in sheet metal forming (i.e. bending, stamping, deep drawing, and shearing). Servo presses offer several advantages with ranges from 35–1000 tons. They can be easily configured for different components and/or parts. Servo presses incorporate the most remarkable characteristics of hydraulic presses (i.e. flexibility and full tonnage at any time) and conventional mechanical presses (i.e. accuracy and reliability) [1]. Their production rates are higher than hydraulic and conventional mechanical presses. In a servo press, energy is only consumed when the press is moved. This is an advantage over a conventional press. However servo-driven presses have some drawbacks which require high amount of electric power especially during deep drawing operations. Motor in conventional mechanical presses is mounted to pinion gear via flywheel, clutch and brake. In servo presses, motor can be directly mounted to pinion as servo motors are controllable, providing any torque at any point [2].

Many studies on experimental applications for servo press performance are found in literature. Selected research studies are presented as a way for comparison of the experimental work given here. Hayashi and Nishimura [3] showed sheet metal forming benefits of a servo press. Step forming, coining pressure effects, and rate dependences of material properties are studied. Qingyu et al. [4] presented experimental results with motion optimization on a 2500 ton servo press. Comparison of results between the theoretical loading torque and the actual loading torque of motor are given. He et al. [5] performed four case studies on a designed hybrid actuated servo press with 25 tons of capacity. The same stroke scenarios are used under the cases of 0, 5, 10, and 15 tons of forming loads. Li and Tso [6] constructed a hybrid driven servo press, and then some experiments were performed. A maximum loading force was performed with a dynamometer as 7.5 kN. Iterative Learning Control (ILC) controller was developed and verified on a servo press prototype. Wang et al. [7] performed 2 ton servo crank press prototype by applying Lagrangian dynamics. Experiments were done on the press-hold punching curve.

Majidi et al. [8] used a non-conventional punch motion of a servo press for enhancing drawability of DP780 and TR780 steel sheet. Hata et al. [9] studied on improving sheet metal forming of Al and Mg alloys. Warm forming experiments were conducted using a 110 ton servo press and a heated tool set. Finite Element (FE) predictions with the experimental force results were verified. Ju et al. [10] performed deep drawing simulations and tests of *Al 5182-O* material at room temperature using a 300 ton servo press with a hydraulic cushion. Maeno et al. [11] have examined the filling of metal into the die cavity in the hot impression die forging of Al alloy by a servo press. Die cavity was improved by designing the slide speed. Tamai et al. [12] developed a forming method that was improved formability in stamping of steel sheet by motion control of a servo press. This application is reduced strain localization in pressed panels and improving form limits for frac-

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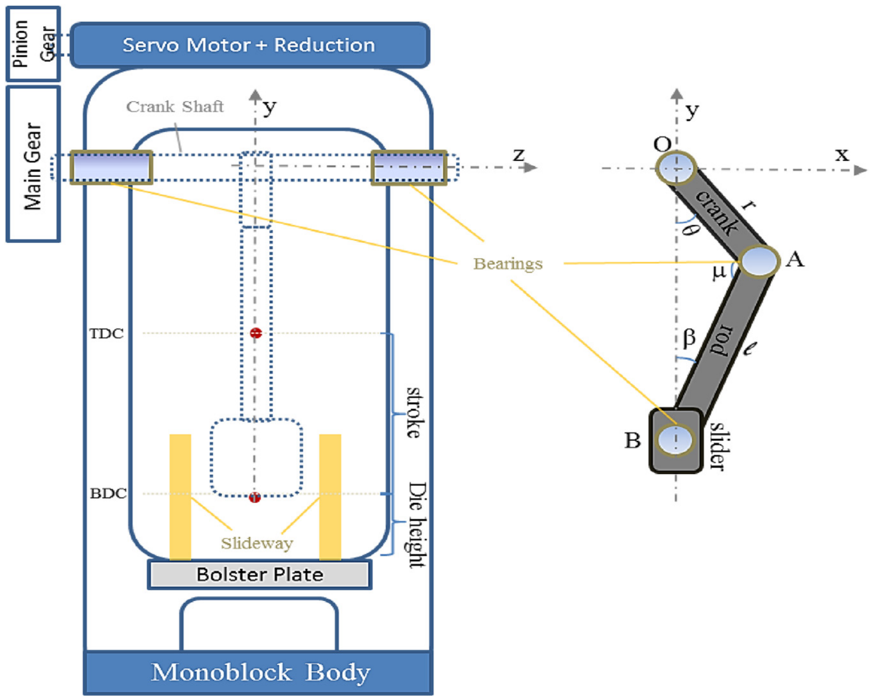
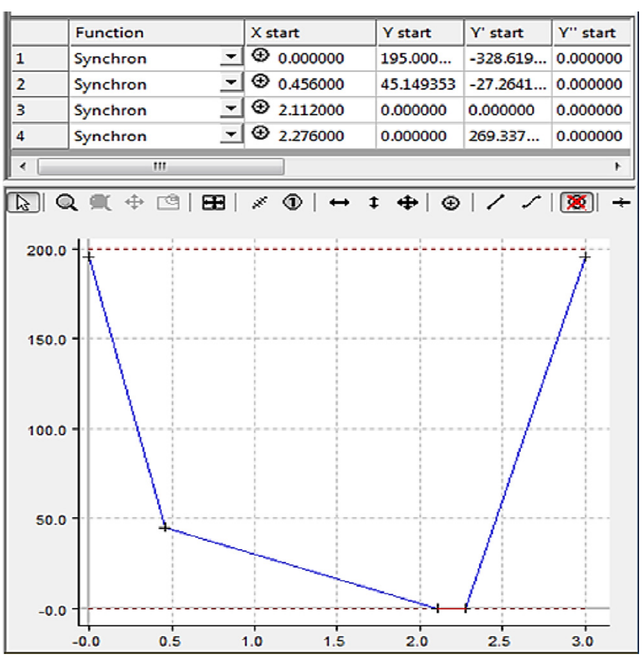


Figure 1. Schematic representation of the press.



	Function	X start	Y start	Y' start	Y'' start
1	Synchron	0.000000	195.000...	-328.619...	0.000000
2	Synchron	0.456000	45.149353	-27.2641...	0.000000
3	Synchron	2.112000	0.000000	0.000000	0.000000
4	Synchron	2.276000	0.000000	269.337...	0.000000

Figure 2. Desired Soft motion with four segments (TwinCAT Cam Design Tool®).

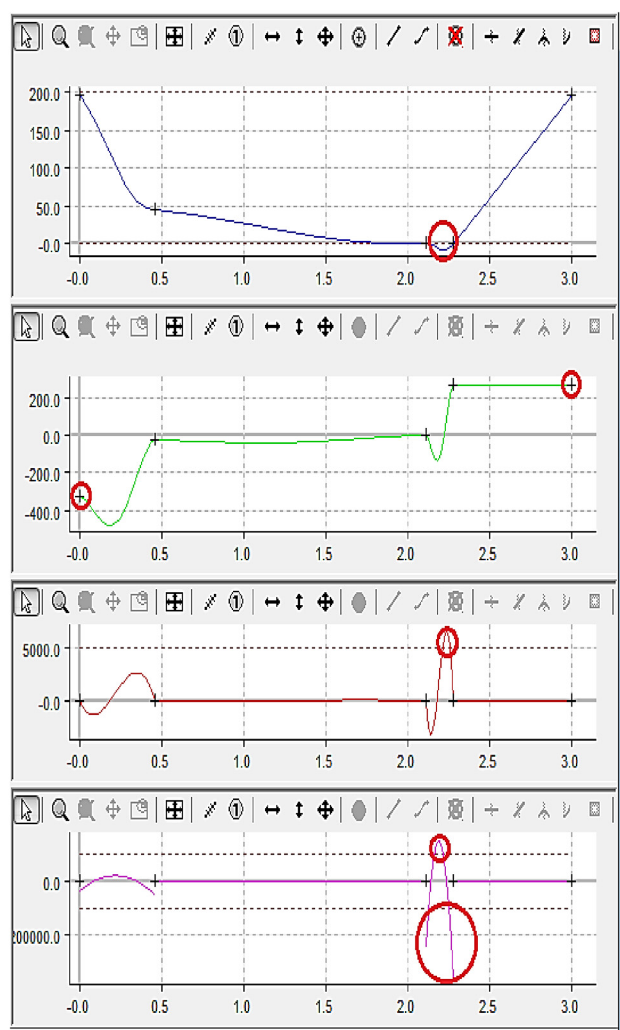


Figure 3. Soft motion design by using "automatic function".

ture. Shiraishi and Nikawa [13] studied on forging of Mg Alloy covers with ribs and flanges. A process is produced for covering by using a servo press. Müller et al. [14] have studied experimental and numerical modal analysis of servo screw presses. Motion control was then performed with direct and indirect classical cascade control in servo presses.

An experimental study is presented by using 50 t servo crank press in this study. It is previously designed and manufactured under a scientific project [15–17]. The experimental hardware is described. A forming process of Cr-Ni steel is carried out for experimental validation. A new developed motion scenario which is in soft motion type is applied for enhancing the forming quality. The results are shown that this press sys-