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# Structural design and analysis of a servo crank press

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ABSTRACT

Due to precision, flexibility, simplicity in construction, easy control, higher speed and lower energy consumptions, servo presses have recently become popular in metal forming applications. Servo press technology combines the advantages of hydraulic and conventional mechanical presses without their drawbacks. This study presents design, construction and demonstration of a servo crank press system for metal forming operations. The research involves structural design and analysis with dynamic considerations of the servo press. A design and manufacturing guide is offered. The press used in this work has a load capacity of 500 kN and stroke capacity of 200 mm. Structural CAD model is constructed, and Finite Element Analysis (FEA) of press parts are performed within safety limits. Experimental studies are performed on this machine. Satisfaction at the output is seen.


## 1. Introduction

Design is either formulation of a plan for needs or a solution for a problem, in which some parameters are desired like functionality, safety, reliability, manufacturability, and marketing consideration. A design must have some processes such as identification of need, definition of problem, synthesis, analysis, optimization, evaluation and presentation. Design can involve more than one discipline of mechanical engineering such as dynamics, fluid mechanics, heat transfer and manufacturing technology [1–3]. The structural design in mechanical analysis can be applied by Finite Element Method (FEM), which is a numerical technique for finding approximate solutions to boundary value problems for differential equations. FEM allows detailed visualization of where the structures bend or twist, and indicates the distribution of stresses and displacements [4].

Several studies on structural design and analysis of machine parts and tools are found in the literature [5–11]. FEM simulations are performed by using Ansys® software [12,13] although other software firms have started to provide dedicated analysis packages (e.g. SolidWorks®) in recent years. SolidWorks® allows 3D CAD, FEA, motion analysis, and simulation modules. Some studies on use of SolidWorks® are also reported in design and analysis [14–18]. Crank presses are assembly of slider crank mechanisms [19]. The following studies involve crank press or slider crank design, manufacturing, and FEA. Doege [20] designed a crank press with a noncircular gear for deep drawing stroke motion. The study showed mechanical modernizations for the desired motion of press by changing gears. Spiewak et al. [21] studied on predictive monitoring and control of the cold extrusion process. A crank press and its mechanisms were defined under high loading at high speeds. They developed a multicomputer system to present the results showing feasibility of predictive monitoring, diagnosis and control.

Chang and Joo [22] presented a study to support design optimization of engineering products, including High Mobility Multipurpose Wheeled Vehicle (HMMWV). In proposed environment, Pro/engineer® and SolidWorks® were employed for product model representation, Dynamic Analysis and Design System (DADS) was employed for dynamic simulation of mechanical systems including ground vehicles, and Design Optimization Tool (DOT) was included for a batch mode design optimization. In their research, the overall finite difference method was adopted to support design sensitivity analysis. A simple slider-crank mechanism and HMMWV were optimized to demonstrate feasibility and effectiveness of the proposed system. Having applied optimization is rod length/crank length ratio is found 5. Abdullah and Telegin [23] studied dynamic analysis of a hot-crank press. Definition of the slider-crank mechanism (size, mass, inertia, etc.) and deformation analyses were given for each mechanism part. Zheng and Zhou [24] described a flexible coupling model of the slider-crank mechanism because of

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its accuracy by using Adams®. The dynamic simulation results of mechanism with clearance under no-load and piling conditions were presented.

Servo presses driven by servo motors have recently come into prominence for sheet metal forming operations due to their flexibility, controllability, and simplicity. Kutuk and Dulger [25] studied on motion design of a hybrid servo press. The press has two cranks are driven by one servo motor and one constant velocity motor. Halicioglu [26] has then presented a complete study on design, synthesis, manufacturing and control of servo crank press.

A design guide involving system dynamics, load types, and capacities are defined. Pre-strength analysis is put into rule, which should be specified and applied. In this study, the design guide of a servo crank press is prepared, and its structural 3D CAD model is constructed. FEA of all parts are investigated using SolidWorks®. Manufactured press is presented herein.

## 2. Description of the servo press and design methodology

A servo crank press mechanism is similar to conventional crank press mechanism without flywheel and clutch-brake. Its parts are servo motor with controller panels, mechanisms (crank-connecting rod-ram), gears (pinion and main gears), bearings, and structural body (as C frame and mono-block). Sketch of the model is given in Fig. 1. It includes body and mechanism, in which the crank length, the crank angle, the rod length, the rod angle, and the slider (ram) position are represented by $r$, $\theta$, $l$, $\beta$, and $y$, respectively. TDC and BDC refer to Top Dead Center and Bottom Dead Center. The rod-to-crank ratio is taken as 7 [26]. Dimensional specifications of press are given in Table 1. Table 2 presents choice of materials for the parts of press machine referred to Coskunoz Metal Form [27].

A design approach is considered as design guide is given in Fig. 2. The requirements are given by press users by specifying dynamic expectations. Having performed the dynamic analysis, loads and motion parameters are used for the machine parts; dynamic and static. The machine parts are designed in accordance

**Table 1**
Press specifications.

| In CE standards C type crank press | |
|---|---|
| Load capacity | 500 kN |
| Stroke | 200 mm |
| Stroke-ram adjust | 150 mm |
| Ram (in TDC)-bolster distance | 500 mm |
| Bolster plate size | 800 × 500 $mm^2$ |

**Table 2**
Chosen materials for the press parts.

| Tool part | Material | Yield strength (MPa) | Tensile strength (MPa) |
|---|---|---|---|
| Ram | St52 | 360 | 530 |
| Connecting rod | St52 | 360 | 530 |
| Crankshaft | 42CrMo4 | 750 | 1000 |
| Pinion shaft | 42CrMo4 | 750 | 1000 |
| Main body | St37 | 275 | 370 |
| Bolster plate | St37 | 275 | 370 |
| Main gear | GS52 | 360 | 530 |
| Pinion gear | 30CrNiMo8 | 1050 | 1250 |

with a satisfactory engineering design that is necessary for 3D CAD design. The steps on machine parts are analyzed by FEM.

The previous studies present kinematic and dynamic analysis of crank press mechanism [26,28,29]. This study includes some dynamic parameters that are found based on information given in the previous studies. Press motion and dynamic loading were represented in the previous studies. The motion profile is defined based on ram. The most preferred scenarios are chosen for its operation. It is considered that the rated force on slider is applied less than 7 mm stroke position for mechanical structure design.

## 3. Bearing design

The press mechanism's joints are created by using hydrodynamic sleeve bearings, roller bearings, and slide ways. Roller

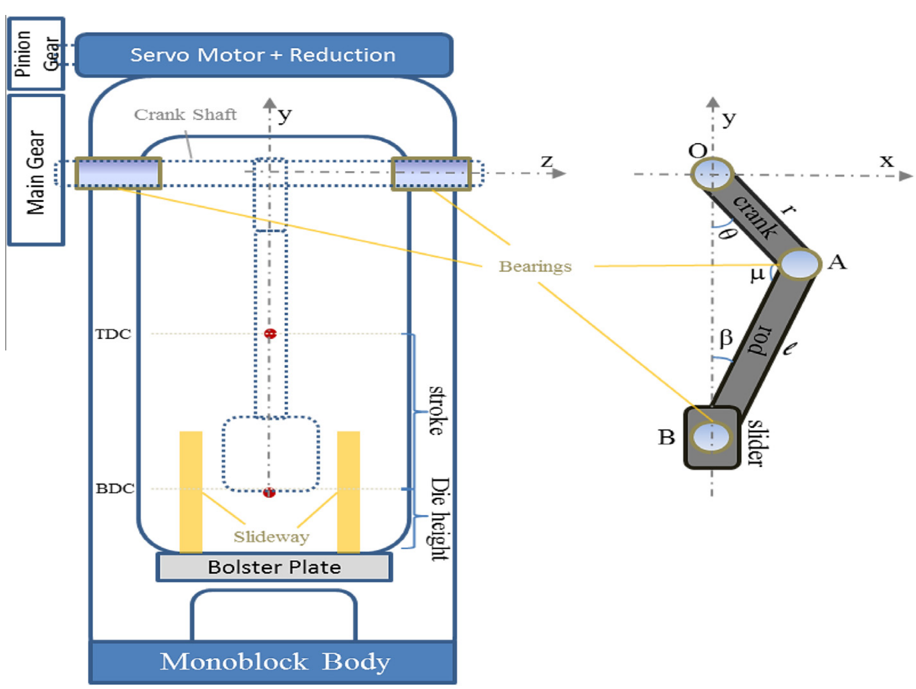


**Fig. 1.** Sketch of the press structure.

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