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Reduction of vibrations in blanking by MR dampers

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ABSTRACT

The break through shock during sheet metal blanking operations generates uncontrolled high reverse loads, mechanical vibrations and loud noise that may cause problems such as fatigue cracks in the press components, premature wear in tooling and great discomfort for press operators.

In this paper, the application of magneto-rheological (MR) dampers to reduce the shock response of press systems is considered with the aim of evaluating, through full-scale experiments, feasibility and practicability of their implementation and understanding the potential benefits in comparison with conventional dampers.

1. Introduction

Blanking and, more generally, shearing operations are the most common operations in the process chains for sheet metal parts. Looking at a typical punch force vs. penetration curve in blanking (Fig. 1), two main phases can be distinguished. In the first phase (from A to B in Fig. 1), the punch penetrates the material causing the sheet metal to deform, first elastically and then plastically, until the pressure at the cutting edges starts the shearing. Initially, the punch force increases steadily due to both the deformation and strain hardening of the material and, then, at the onset of shearing, it decreases due to the progressive reduction in the cross-section despite the strain hardening. In this phase, the press and die set store up elastic energy. In the second phase (from B to C in Fig. 1), the shear strength of the material in the shearing zone is exceeded and a fracture starts causing the sudden release of the energy that dissipates through the high frequency oscillations shown in the tail end of the curve in Fig. 1. This break through shock generates uncontrolled high reverse loads, mechanical vibrations and loud noise that may cause serious problems such as fatigue cracks in the ram, drive linkage, crown, housings and, in the bed of the press, premature wear in punches and dies and great discomfort for press operators. To withstand the harmful effects caused by break through shocks, mechanical and hydraulic presses can be oversized (an over tonnage of 50% is usual for continuous blanking and punching of high strength materials) or equipped with cushions or hydraulic shock dampers that absorb part of the shock energy. However, if, on the one hand, over sizing the press may not be practical from an economical point of view, on the other hand, the required additional load capacity, fluid elasticity and limitations in the working stroke represent the main drawbacks of cushions and hydraulic dampers.

The break through shock in blanking operations has been considered by a number of researchers, most notably for modelling the ductile fracture that causes the sheet metal separation and the associated energy release [1–3] or for correlating the stiffness of the system components (press, stripper and die set) and their vibrations during the break through [4–6]. However, few contributions in the scientific literature have dealt with new possible solutions to effectively reduce the reverse load, vibrations and noise. Murakawa [7] developed a "hydraulic inertia damper" that proved to be effective in lowering the punch force reduction rate, thereby causing a reduction in vibration and noise. Osakada [8] demonstrated that the noise level accompanying the break through shock can be significantly reduced if an accurate control of the punch motion – such as that allows by servo controlled presses – is combined with a "continuous two-step blanking", where the punch is stopped just before the fracture starts.

In this paper, the application of magneto-rheological (MR) dampers to reduce the shock response of press systems during blanking operations is considered. In recent years, many research projects have demonstrated that MR dampers can be profitably utilized to control the vibrations of civil structures, vehicle suspensions and biomedical systems as well (e.g. see Refs. [9–11]). The principal aim of the investigation described in the paper was to evaluate, through full-scale experiments, the feasibility and practicability of implementing MR dampers and to understand the potential benefits when they are used in a semi-active manner in comparison with conventional dampers. In the first part of the paper, the design and construction of the MR dampers utilized in the experiments are presented together with the testing that was carried out to evaluate their damping force characteristic. The second part focuses on the experiments, which aimed at evaluating the press system response to the break through shocks generated

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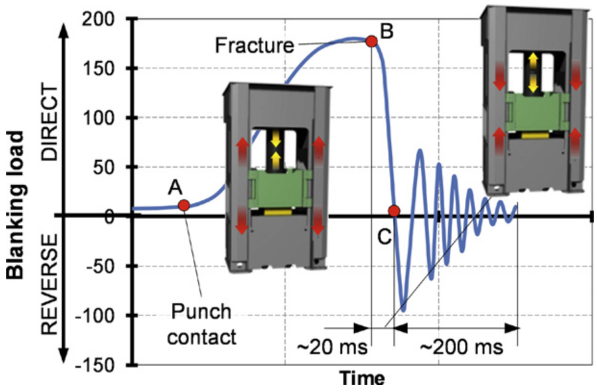

Fig. 1. The reverse load phenomenon in blanking.

Table 1
MR dampers specifications.

MR device	
Nominal damping force	400 kN
Stroke	±125 mm
Cylinder bore	178 mm
Inner annular orifice	1 mm
Axial active length	240 mm
Coil resistance	15 Ω
Coil inductance	0.34 H
Copper wire diameter	0.87 mm
Current intensity range	0–3 A
MR fluid	
Particles size	10^{-5} to 10^{-7} M
Density	2.98–3.18 g/cm^3
Viscosity	0.092 ± 0.015 Pa
Solids content by weight	80.98%
Flash point	>150 °C
Operating temperature	40–130 °C

during blanking operations. After describing the experimental apparatus, which basically consists of a long-stroke hydraulic press equipped with the die set and the dampers and of a data acquisition system, the performance of the press equipped with the MR dampers is presented in the time and the frequency domains. These results are also contrasted with those achieved with the same press equipped with conventional shock dampers.

2. MR dampers for metalworking presses

Compared to most conventional dampers, which are passive hydraulic devices, MR dampers are semi-active devices where the damping capacity can be modulated either gradually or in real time based on the system response. Thanks to this feature, MR dampers are expected to offer effective performance over wide ranges of amplitude and frequency, as demonstrated most notably for applications to control the low-frequency and large-amplitude vibrations of civil structures. Although the working principle does not change, the characteristics of MR dampers for metalworking presses are quite different from those that are used for civil structures. The vibrations of metalworking presses caused by break through shocks are high-frequency and small-amplitude vibrations. Furthermore, long working strokes can be required, especially for hydraulic presses, which are equipped to carry out in one stroke a set of sheet metal working operations including blanking.

2.1. Design of the MR dampers

The MR dampers developed at the DIMEG lab to withstand the break through shock generated during blanking in a long-stroke hydraulic press are single-hand dampers where the piston rod is connected to the press ram and the cylinder liner is fixed to the press bed. A schematic section of the MR dampers is given in Fig. 2 left. A 1 mm thick annular orifice between the piston rod and the liner allows the fluid to flow through the entire annular region as the piston moves. The inner shaft prevents possible misalignments from arising due to high-frequency vibration and reverse load and, at the same time, works as a volume compensator to balance the volume change during the rod stroke. The electrical coils embedded into the piston generate a uniform magnetic field across the 240 mm long gap and perpendicularly to the direction of the MR fluid flow. Fig. 2 right shows the four dampers in the working area of the press. The main mechanical and electrical features of the MR dampers are given in Table 1 together with the physical characteristics of the MR fluid. Details on the design and manufacture of the dampers are in Ref. [12].

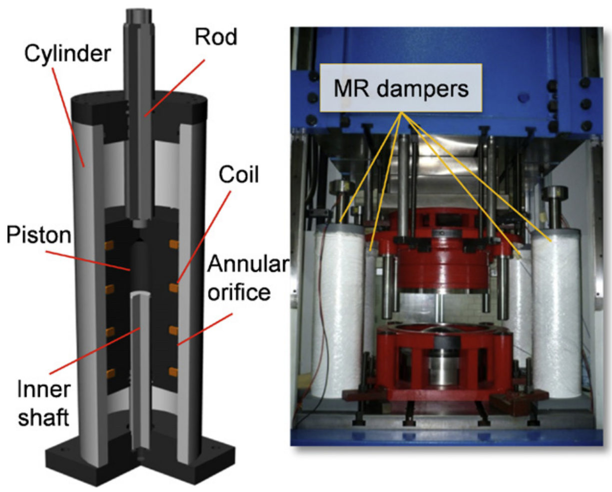

Fig. 2. Sketch of the MR damper on the left and MR fluid dampers on the right.

2.2. Damping force of the MR dampers

The damping force of the four MR dampers for different values of the current intensity and the punch speed were measured through experiments carried out on a 1000 kN servo-hydraulic INSTRON testing machine. Fig. 3 shows the curves of the force vs. current intensity of the MR dampers for a fixed value of the punch speed. For the four dampers, the damping characteristics are very similar: the damping force is constant along the entire testing stroke and presents a good linearity with the current intensity. These features make the dampers suitable to be easily controlled during the entire stroke of the press.

3. Experiments

This section presents the experiments carried out to evaluate the press system response to the break through shocks that were

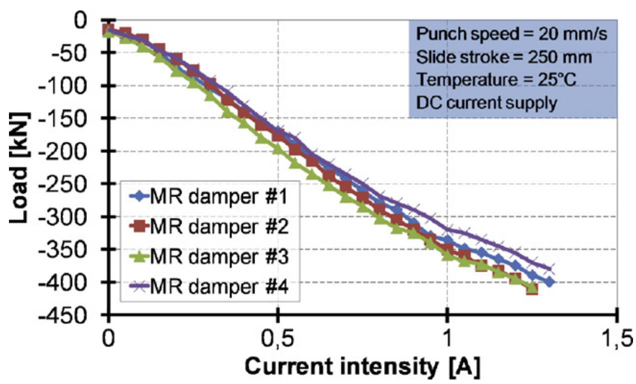

Fig. 3. Force vs. current intensity curves of the MR dampers for a fixed value of the punch speed.