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Reduction of Vibrations in Blanking by MR Dampers

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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 former (from A to B in Fig. 1a), the punch penetrates the material causing the sheet metal to deform until the shearing starts. In this phase, the press and die set store up elastic energy. In the second phase (from B to C in Fig. 1a), the shear strength of the material is exceeded and a fracture starts causing the sudden release of the energy that dissipates through the high frequency oscillations (the tail end of the curve in Fig. 1a). This break through shock generates un-

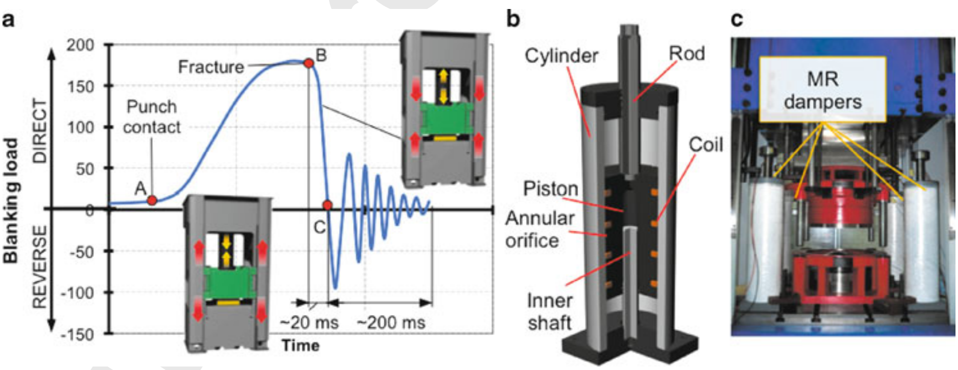

Fig. 1 **a** The reverse load phenomenon in blanking, **b** Sketch of MR damper, **c** MR fluid dampers

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controlled 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. The break through shock in blanking operations has been considered by a number of researchers, most notably for modelling the ductile fracture that causes surface 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-steps blanking", where the punch is stopped just before the fracture starts. In this research, the application dampers based on magneto-rheological (MR) fluids to reduce the shock response of press systems during blanking operations is considered. 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. MR fluids are suspensions of micron-sized ferromagnetic particles in a liquid carrier that presents controllable and reversible changes in its rheological properties, from free flowing linear viscous liquids to semi-solids, having controllable yield strength when activated by an external magnetic field. Thanks to these features, they offer relevant performances in the typical working conditions of metalworking presses, where long working strokes are required and the vibrations caused by break through shocks present high frequencies and small-amplitude vibrations. The 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.

2 MR Dampers

The MR dampers designed and developed by the Authors are presented in Fig. 1b and c (details of the design and manufacture in [9] and [10]). The prototypes consist of single-hand dampers designed to withstand the break through shock generated during blanking in a long-stroke hydraulic press. 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

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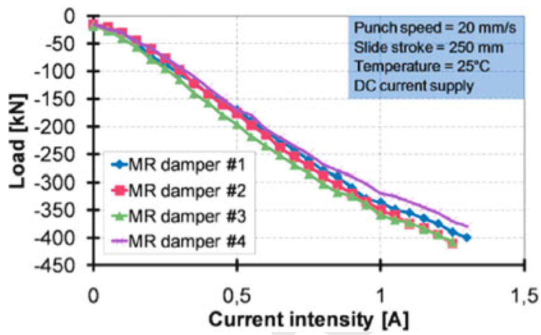

Fig. 2 Force vs. current intensity curves of the MR dampers for a fixed value of the punch speed

direction of the MR fluid flow. Figure 1c shows the four dampers in the working area of the press.

The damping force of the four MR dampers for different values of the current intensity was measured through laboratory experiments. Figure 2 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 force is constant along the entire testing stroke and presents a good linearity with the current intensity.

3 Experiments

In the experiments three damping systems were compared: (a) the MR dampers above described, (b) conventional hydraulic cushions, and (c) commercially available hydraulic dampers. The damping system based on hydraulic cushions consisted of four hydraulic cylinders whose chambers were connected in parallel to a common manifold. The working stroke and maximum counter force were 40 mm and 80 kN, respectively. The system, based on hydraulic dampers, consisted of four shock dampers providing a counter pressure generated by an internal orifice and a flow control valve. The working stroke and maximum counter force were 20 mm and 200 kN, respectively. The experiments were carried out on a four-column double-effect 2500 kN hydraulic press. Figure 3a–c shows the machine and the details and the sketch of the tooling.

Data regarding the pressure and acceleration were acquired during the experiments: the former was monitored inside the manifold of the upper actuator of the press, the latter measured on four points of the frame, respectively located on the die plate, on the ram and on one of the columns of the press. The blanking experiments were conducted on 2 mm and 3 mm thick C40 steel sheets with a constant punch-die clearance of 0.2 mm and two different speeds of the press ram (20 mm/s and 50 mm/s). The experiments were repeated for four different configurations of the press: with no damping device, with MR dampers, with hydraulic cushions and with hydraulic dampers. The experiments with the MR dampers were carried out using four levels of current intensity: 0.4 A, 0.6 A, 1.1 A and 2 A. All the experiments were replicated to assure the repeatability of results.

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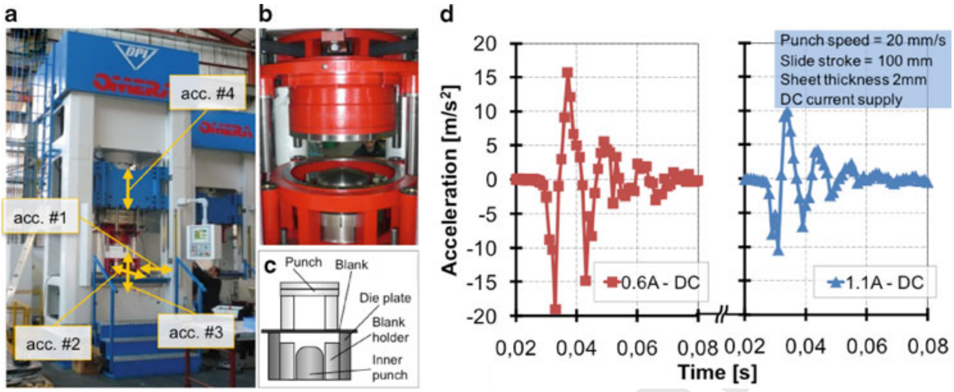

Fig. 3 **a** The 2500 kN hydraulic press with indication of the accelerometers, **b** Detail and **c** sketch of the tooling, **d** Accelerations for different electrical currents with the MR shock dampers

4 Results

Figure 3d shows the effect of the current intensity in the MR damper circuits on the response of the press system to the break through shocks. Damping performance increases with the current intensity until a critical value of 3 A generates the saturation of the magnetic circuit and the permanent magnetization of the particles in the MR fluid. A value of 1.1 A proved to be a good compromise between damping performance and system stability. Figure 4 shows the acceleration-time response over the duration of the break through shock when the press system is equipped with the hydraulic cushions (Fig. 4a), the hydraulic dampers (Fig. 4b) and the MR dampers (Fig. 4c).

Each of the three responses is compared to the one measured on the press without any damping device. Reductions in the peak acceleration are achieved by using both the hydraulic cushions and the MR dampers. Compared to the response of the system equipped

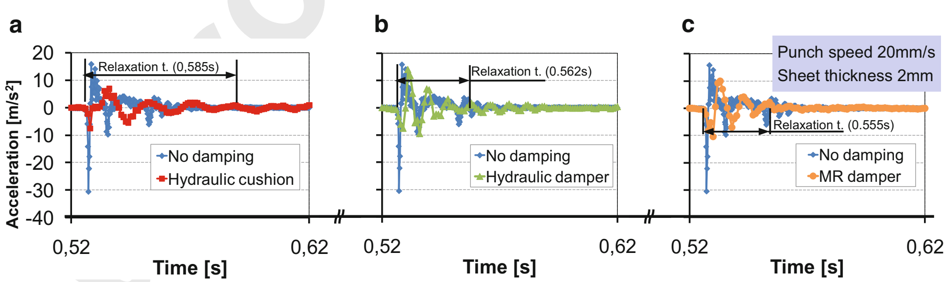

Fig. 4 Accelerations measured at the press ram with **a** the hydraulic cushions, **b** the hydraulic shock dampers and **c** the MR shock dampers

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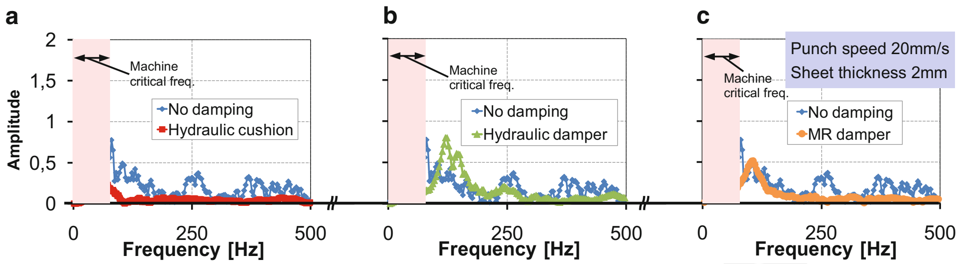

Fig. 5 Amplitude spectra of accelerations at press ram with **a** the hydraulic cushions, **b** the hydraulic shock dampers and **c** the MR shock dampers

with the conventional dampers, the decay of residual vibrations that is observed for the system with the MR dampers is significantly faster (approximately a reduction of 30 % compared with hydraulic cushions and 10 % compared with hydraulic dampers). This is because the damping effect of the highly viscous MR fluid (when the magnetic field is activated) predominates over the unavoidable elasticity of the fluid pressurized in the conventional dampers. Figure 5 shows the amplitude spectrum of the ram acceleration in the frequency domain for the press system equipped with the hydraulic cushions (Fig. 5a), the hydraulic dampers (Fig. 5b) and the MR dampers (Fig. 5c). Each of the three spectra is compared to the one measured on the press without any damping device. As expected, the spectrum for the press without any damper shows a high number of excited frequencies, with the highest values close to 25 Hz. Significant reductions of the number of the excited frequencies and the acceleration amplitudes are observed for the three kinds of dampers. However, the hydraulic cushions behave worse than the other two shock dampers typologies since they are not able to damp the low frequencies vibrations that are typical of the tested hydraulic press. Among the latter, the amplitude of vibrations measured with the MR dampers is approximately 40 % less than the one obtained with the hydraulic dampers.

5 Conclusions

MR dampers were developed for metalworking presses to withstand the break through shock generated during blanking operations. Full-scale experiments were set up to understand the potential benefits of MR dampers compared to conventional dampers. The results show that MR dampers can be effective in damping the vibrations induced by the break through shock and in limiting the number of excited frequencies. Thanks to their short response time they appear suitable to be implemented in processes where multiple blanking operations are required.

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