“Hydraulic Cushion” Type Overload Protection Devices
Usable in Mechanical Presses. A Patent Study

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Abstract. The possible consequences of machine-tool overload are well-known. In order to
prevent such, machine-tools are equipped with various overload protection devices. Mechanical
presses, intensively strained machine-tools, are typically equipped with three protection systems:
against accidental access to the working area during machine deployment, against torque overload
and force overload. Force overload protection systems include either destructible parts and are used
in small to medium nominal force mechanical presses, or non-destructible ones used mostly in
medium to large nominal force (H-frame) presses. A particular class of force overload protection
systems without destructible parts are “hydraulic cushion” type devices. While such systems do not
necessarily cause the machine to stop, the slide’s stroke does not reach the initial dead centre and
consequently cannot exert the designed technological force on the workpiece. By a patent study
referencing 19 relevant patents the paper captures both the diversity of the constrictive solutions of
“hydraulic cushion” type protection devices and their positioning modalities within the structure of
a mechanical press. An important aim of the study is to highlight the reserve of creativity existing
in this field, at least from the viewpoint of the hydraulic cushion positioning, as well as to
emphasize the essential requirement of a relative motion between the mobile and the fixed parts of
the tool, a motion of opposite sense to that of the slide-crank mechanism.

1. Introduction
Like any technical system, a machine-tool is designed and built to sustain a certain maximum strain
level, most often depending on a maximum admissible force, which is a quantity indicated in the
technical specifications of the machine. The possible consequences of machine-tool overload are well-
known [1], concerning mainly the risk for the human operator and the possible deterioration or even
destruction of the machine. In order to prevent such, machine-tools are equipped with various overload
protection devices.

This paper deals strictly with mechanical presses, intensively strained machine-tools which are
typically equipped with three protection devices:
- a protection device that prevents access to the working area during machine operation (the space between
  the table and the slide, which is actually the space between the fixed and mobile parts of the tool);
- a torque overload protection device;
- a force overload protection device.

The protection device against access to the working area during machine operation is mainly aimed
at protecting the human operator against accidents. A press can be equipped with two or more such
systems, usually of different kind, also having a warning function.
The torque overload protection device is aimed at protecting the main shaft and the transmission of the machine against any strain caused by a torque greater than the maximum admitted value taken into consideration for designing the machine [2]. Torque overload appears when the opposing force at the slide generates in the main shaft an opposing torque greater than the maximum admitted torque to be transmitted by the main shaft. If the press is endowed with a friction clutch, this has to be dimensioned [3] such as to ensure the necessary protection against this type of overload.

Thus the clutch will slip every time the opposing torque at the main shaft of the machine, and implicitly the torque at the clutch shaft exceed the admitted limit. If the friction clutch of the machine does not ensure this function, then the main linkage of the press will include a distinctive dedicated subassembly. Constructions of this type are similar to clutches, an example being the constructive solution proposed by patent US 5542884 [4].

Force overload occurs when the opposing force at the slide exceeds the nominal force taken into account in the design and construction of the machine. Essentially, most force overload safety systems allow the machine to continue its operation, thus the rotation of the main shaft (or of the main shafts, as the case may be), but compensates the relative motion between the mobile and the stationary parts of the tool. Thus the opposing force of the workpiece to the action of the slide is limited or even cancelled. The protection device stroke length needs to be at least equal to the maximum capable load stroke length of the press.

Force overload protection devices include either destructible parts [2] and are typically used in small to medium nominal force mechanical presses, or non-destructible ones used mostly in medium to large nominal force (H-frame) presses.

Protection systems with non-recoverable parts are achieved by placing a calibrated destructible part subject to shearing in the slide assembly, between the slide and seat of the joint that links it to the rod. The press will not cease operation, but will not be able to exert a technological force upon the workpiece. An example is offered by the constructive solution proposed by patent US 3014420 [5]. In case the safety part is destroyed, easy access to it is evidently required. In some cases destructible parts are used designed to shear by two concentric circular contours [2].

An important group of force overload protection systems not deploying destructible parts are those based on measuring the elastic deformation of a reference component of the press structure. The most frequently selected reference component is the frame, part of it or a tie bar used for assembling the frame. These protection systems interrupt the operation of the press, which remains strained pending the intervention of the human operator. The elastic deformation is measured electric contacts, tensometric gauge systems, laser measurement systems, special displacement sensor systems, etc. A fairly recent example of tensometric gauge protection system is proposed in patent US 5125332 [6].

A special class of destructible part free force overload safety systems is that of “hydraulic cushions”. While more complex as to their construction, these systems are reliable and highly efficient. In addition the value of the force that triggers the protection system is easily adjusted, and integration of the hydraulic protection system into the automatic control and operation system of the machine is fairly simple. While the system does not necessarily cause the machine to stop, the slide’s stroke does not reach the initial dead centre and consequently cannot exert the designed technological force on the workpiece. By a patent study the paper captures both the diversity of the constrictive solutions of “hydraulic cushion” type protection devices and their positioning modalities within the structure of a mechanical press.

2. “Hydraulic cushion” type protection systems placed between the slide and the rod seat

The typical position of many overload protection systems, including the ones with destructible parts is between the slide and the seat of the join linking it to the rod [7], directly or indirectly. This approach is found in a pioneer patent in this field, US 1808606 (figure 1), but also in many subsequent ones, like US 2936055 (figure 2), US 3426873 (figure 3), US 4030336 (figure 4), US 4085669 (figure 5), US 4166415 (figure 6), and US 4827839 (figure 7). To be noticed in the solution out forward by patent US 2936055 is the cylinder membrane used for packing the hydraulic cushion, as well as the mechanism
responsible for adjusting the slide position, consisting of an electric motor –cylinder gear – bevel
gear – rotating screw nut. Interesting and somewhat atypical is the constructive solution for the
adjustment of the slide position presented in patent US 4166415 [8], figure 6.

Figure 1. Force overload hydraulic protection system with a hydraulic cushion placed
between the seat of the rod nut and the slide, according to patent US 1808606 [9].

Figure 2. Force overload hydraulic protection system with a hydraulic cushion
according to patent US 2936055 [10].

Figure 3. Force overload hydraulic protection system with a hydraulic cushion placed directly between the
seat of the rod nut and the slide, according to patent US 3426873 [11].

Figure 4. Force overload hydraulic protection system with a hydraulic cushion placed between the
seat of the rod nut and the slide, according to patent US 4030336 [12].
Although preferable, “hydraulic cushion” type safety systems do not necessarily disrupt the driving of the slide under overload. Such stopping is included explicitly by the solution proposed by patent US 3426873, figure 3, where the overload causes the clutch to disengage.

In order to use “hydraulic cushion” overload protection systems of the described or similar type in two-crank presses, one such system has to be provided for each rod, the two devices being connected to an adequate general hydraulic circuit. Suggestive examples are offered by patents US 2937733 (figure 8) [13], US 3481171 (figure 9) [14] and US 5638748 (figure 10) [15].

A more particular constructive solution of a force overload hydraulic safety system placed between the slide and the seat of the joint linking it to the rod, designed for forging presses is put forward by patent US 3948077 [18], figure 9. Under overload the tilted slide placed between the press slide and seat of the joint linking it to the rod is displaced, moving the screw that adjusts the position of the slide stroke and of the attached hydraulic piston. Also to be noticed is the particular construction of the rod.

3. “Hydraulic cushion” type protection systems with different locations

Placing the hydraulic cushion between the slide and the seat of the joint linking it to the rod is not the only possible solution. Of the essence is, that between the mobile and stationary parts of the tool a relative motion is generated of opposite direction to the one developed by the crank-rod-slide mechanism. In other words, the protection system needs to induce a relative motion between the supporting face of the machine table and the main shaft axis, thus between the inferior and superior parts of the frame. Translation can be carried out by:
- the rod screw in relation to its body;
- the rod in relation to the main shaft;
- the main shaft in relation to the frame;
- the table in relation to the frame;
- the superior part of the tool in relation to the slide;
- the inferior part of the tool in relation to the table.

**Figure 8.** Hydraulic cushion protection system for two-crank mechanical presses according to patent US 2937733 [13].

**Figure 9.** Force overload protection system with a translatable slide and a translatable hydraulic piston according to patent US 3948077 [18]

**Figure 10.** Force overload hydraulic cushion protection system placed between the body of the rod and its screw, according to patent US 2491279 [19].

Positioning the hydraulic cushion between the body of the rod and its screw requires an intermediary assembly assuming the role of a translatable piston. Constructive solutions of this type are put forward, for example, by patents US 2491279 [19] (figure 10) and US 3892143 [20] (figure 11).

To date no patent of a protection system could be identified that entails the translation of the rod in relation to the main shaft. Research in this direction is worth conducting, and this possibility is to be noted as an interesting reserve of technical creativity.
Figure 11. Force overload hydraulic cushion protection system placed between the body of the rod and its screw, according to patent US 3892143 [20].

Placing the hydraulic cushion between the frame and the main shaft entails a supporting slide for the latter, enabling it to translate in relation to the frame. Such a solution is given in patent US 2236154 [21], figure 12.

Figure 12. Force overload hydraulic cushion protection system placed between the frame and a main shaft supporting slide according to patent US 2236154 [21].

If the hydraulic cushion type protection system is placed between the table of the press and its frame, the table will behave like a large hydraulic piston. An example in this respect is given by the solution put forward by patent US 2389818 [22], figure 13.
A hydraulic cushion type protection system enabling the translation of the superior part of the tool in relation to the slide, or of the inferior part of the tool in relation to the table can be integrated in either a distancer plate, a “banking plate” if placed on the machine table, under the stationary inferior part of the tool, or even on the superior or inferior part of the tool, respectively. Placing the protection system in one of the parts of the tool is possible, but increases the cost of the tool and no strict correlation with the maximum admitted value of the force for a given press is achieved; such solutions have not been explicitly identified, but the idea is to be noted and can be a source of innovation. The protection system placed in a distancer plate can be found in the current state of technology, an example being patent US 3487772 [23], figure 14. Actually, the patent proposes a module-system of this type, machine-independent, but attachable to any mechanical press as an intermediary element between the tool and the slide or between the tool and the table of the press. Evidently, the solution is applicable also in two-crank mechanical presses, generally in presses with large slides with great surface areas of the superior plate of tool. In such cases two or more independent protection systems of the discussed type can be deployed, ensuring their adequate hydraulic connection.

Figure 14. Independent force overload protection hydraulic cushion module-system, attachable to the inferior surface of the slide, according to patent US 3487772 [23].

4. Conclusions
In order to prevent the undesired consequences of possible overload, machine-tools are equipped with various overload protection devices. In presses one of the overloads is by force, when the opposing force at the slide significantly exceeds the nominal force for that the machine was dimensioned and built. In essence, the majority of force overload safety allows the further functioning of the machine, without, however, a useful relative motion between the mobile and the stationary part of the tool.
Reliable and most efficient are “hydraulic cushions” type force overload safety systems, not including destructible parts. In such systems the force at that the protection device can be easily adjusted, and the integration of the hydraulic safety system into the automated control and operation system of the machine is also fairly simple to achieve.

Typically “hydraulic cushion” type protection devices are placed between the slide and the rod, directly or indirectly, as illustrated by the relevant examples given in the paper. Such positioning is, however, not the only alternative. Of essence is that between the mobile and stationary part of the tool a relative motion of opposite direction to the one developed by the crank-rod-slide mechanism occurs. In other words, the protection device needs to induce a relative motion between the supporting surface of the machine table and the main shaft axis, thus between the inferior and superior part of the frame. Constructive solution were identified that ensure the translation of the rod screw in relation to its body, of the main shaft in relation to the frame, of the table in relation to the frame, of the superior part of the tool in relation the slide, and of the inferior part of the tool in relation to the table.

Further possible constructive solutions would be those ensuring the translation of the rod in relation to the main shaft, or of the inferior part of the rod body in relation to its superior part. A study of the current state of technology has not revealed any existing solutions in this sense, which could represent interesting reserves of creativity.

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