Development of a drivehead for the coupling between power take off drive shaft and operating machine within the project CRA-ING and MED S.A.S.[(1)]

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Abstract
Connecting and disconnecting the PTO-drive-shaft to the Power-Input-Connection (PIC) of an operating machine is often made difficult by the presence of most protection models. The locking system of the PIC yoke is actuated by means of both the hands and can be reached through a narrow space between the PTO-drive-shaft cone of guard and the PIC protection: sometimes, it is necessary to disassemble one of them. The aim of the project was to develop a protection that, through a proper opening, could simplify the connection/disconnection between PTO-drive-shaft and PIC, keeping in compliance with the requirements of the ISO EN 12100-2: 2003, ISO EN 4254-1:2005 and EN 953 1997. In the first phase of the project, the standards' general requirements for the product-design and construction of fixed and mobile guards have been studied. It emerged that a mobile guard was needed, planned for frequent accesses to the danger zone, with the following requirements: 1) it can be opened only by means of a proper tool; 2) if opened, it must keep solid to the operating machine; 3) it must automatically close and lock itself without any tools; 4) the type of risk against which it has been developed has to be shown on it.
As a consequence of the characteristics of its components, the prototype is in compliance with the mobile guards standard requirements. A further contribution to the increase of safety level is represented by a device determining the automatic closure of the guard.
Finally, the prototype allows to completely cover the PTO-drive-shaft transmission system. It makes easier the connection/disconnection between PTO-drive-shaft and PIC and the maintenance of the PTO-drive-shaft. It could hopefully contribute to reduce the frequency of accidents.

Key words: protection, Power-Input-Connection, prototype.

Introduction

Agricultural tractors are commonly used as mobile power sources driving operating machines in for the execution of a wide range of operations.

The power transmission from the power-take-off (PTO) to the power-input-connection (PIC) of the operating machine is made by means of a PTO-drive-shaft. With the aim of avoiding dangerous detachments of the PTO-drive-shaft during the rotation, its extremities can be equipped with different kinds of safety locking devices, such as button victaulic coupling, conic bolt coupling, sprag clutch coupling, etc.

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(1) The prototype has been developed within the 12th ENAMA project upon the experimental activity on innovative mechanic devices for agriculture, in accordance with the MiPAF

The connection and the disconnection between the PTO-drive-shaft and both operating machines PIC and tractors PTO yokes often represent difficult operations, even for effect of most of the drivehead models present in the market, that leave a narrow space in which unlock the above mentioned safety locking devices. In particular, as regards the PIC yoke, these operations require to operate, with both the hands, inside the space between the drive-shaft cone of guard and the PIC protection: sometimes it is necessary to tear down one of them.

The access to the coupling zone is also requested for the normal maintenance operations on the PTO-drive-shaft: the PIC-yoke bore must be kept in good conditions, periodically cleaned and lubricated, avoiding excessive wear and rust formation; the safety locking system must be lubricated and perfectly working in order to be easily actuated for locking or releasing the PIC-yoke from the bore, respectively during the connection and the disconnection of the drive-shaft.

In the present paper the aspect of the driveheads for the PIC of the operating machines has been studied with the aim of developing a prototype of protection system capable to provide a complete isolation of the connection zone and allowing, at the same time, the execution of all the operations of maintenance, connection and disconnection of the PTO-drive-shaft.

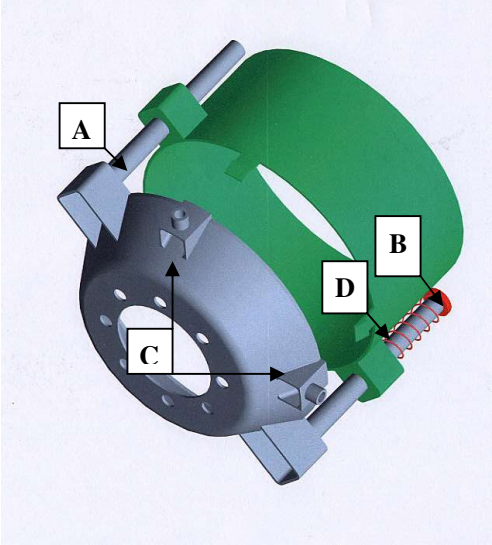

Figure 1. Three-dimensions sketch of the prototype of guard developed according to the requirements of safety and functionality.
(A) Sliding system with cylindrical guides;
(B) End-stop removable only by means of a suitable tool;
(C) Protection against accidental opening;
(D) Spring system for the automatic locking of the guard.

Project design and development

The work started with an examination of the existing standards on the matter. In particular, the EN 953: 1997 provides the general requirements for the design and realization of fixed and mobile guards. Considering that a guard is defined as an "element of a machine aimed at providing protection by means of a physical barrier", the subject of the work could be considered a guard, according to the standard. In particular, among the foreseen different kinds of guards, it seemed to better adapt to the definition of "mobile guard", capable to facilitate the locking and unlocking manoeuvres of the safety device of the PTO-drive-shaft under safety conditions.

- The standard requirements of mobile guards, aimed at guarantying the safety f the operators are the following:
- The guard can only be open by means of a voluntary action;
- When the guard is open, its mobile part must be solid to the fixed part;
- The elements keeping solid the mobile part and the fixed part can be removed only by means of a suitable tool;
- The guard locking must occur without any tool, automatically.

Further aspects of the mobile guard took into consideration were its working mode, its lifetime and the characteristics of the work environment in which it should be used.

After having defined the guard requirements according to the standards, among different technical possibilities, it has been chosen the solution that also seemed capable of better guarantying the functionality of the system.

Particular attention has been paid to the system that must allow the access to the danger zone, that have to occur only through a voluntary action and not accidentally. As a consequence, it has been chosen a wedge shaped locking system allowing, on one hand, the guard opening only with a voluntary action and, on the other, the automatic locking of the system, when the intervention is concluded, by means of a spring system avoiding that the guard could remain open during the rotation of the PTO-drive-shaft.

As to the dimensions of the access opening, the project-design based on the indications reported in the EN 547-2:1996 reference standard, also considering the points of action of the automatic locking system on the operator's hands.

The choice of the guard material has been based on the impact strength, the stiffness, the thermal stability, the resistance to the vibrations, the time life of the cylindrical guides, the prevision of the sliding system efficiency, the presence of cutting edges, the colour.

The previous considerations are synthesized in the 3-D sketch of fig. 1, in which the main elements are represented by: a sliding system (fig. 1-A) that must by capable of high performances under the sever condition typical of agricultural work (presence of dust, mud, plant residues, vibrations, etc.); a stop-end that can be removed only by mean of a proper tool (fig. 1-B); a system protecting against the accidental opening of the guard that can be unlocked by mean of a sharpened tool as well (fig. 1-C); a spring based system operating the automatic locking of the guard as soon as the hands are taken out (fig 1-D).

Basing on the characteristics determined in the preliminary study, the work proceeded with the realization of a prototype that underwent the first experimental test at CRA-ING in Monterotondo (RM, Italy).

Finally, in order to facilitate the series production by means of dies, the guard has been divided into three main components.

Figure 2. Particular of the die for the production of the bottom of the guard

Tests

The first prototype of the guard has been mounted on a series of operating machines (a stump grinder with horizontal axis, a rotary harrow, a two-axle trailer, a spading machine, a ditch cleaner on a slewing arm) and tested with the aim of verifying the correct installation and working and its adaptability to the different types of machines. The tests results suggested some modifications of the structure and shape of the prototype (aimed at increasing the stiffness of the automatic locking system) and of the section of the guides of the sliding system (that became cross-shaped, instead of cylindrical, in order to reduce the friction surfaces, increasing the efficiency of the system).

The realization of the dies for the series production started after these modifications on the prototype (fig 2). The lash-ups produced represented 2nd level prototypes, the

behaviour of which has been observed in further experimental tests under operating conditions similar to those describe for the first series of tests.

The tests regarded the evaluation of the correct use of the protection and its functionality, verifying both the effectiveness of the sliding system and of the automatic locking and the actual simplification in the connecting and disconnecting operations of the PTO-drive-shaft from the PIC-yoke and the resulting increased comfort (fig. 3).

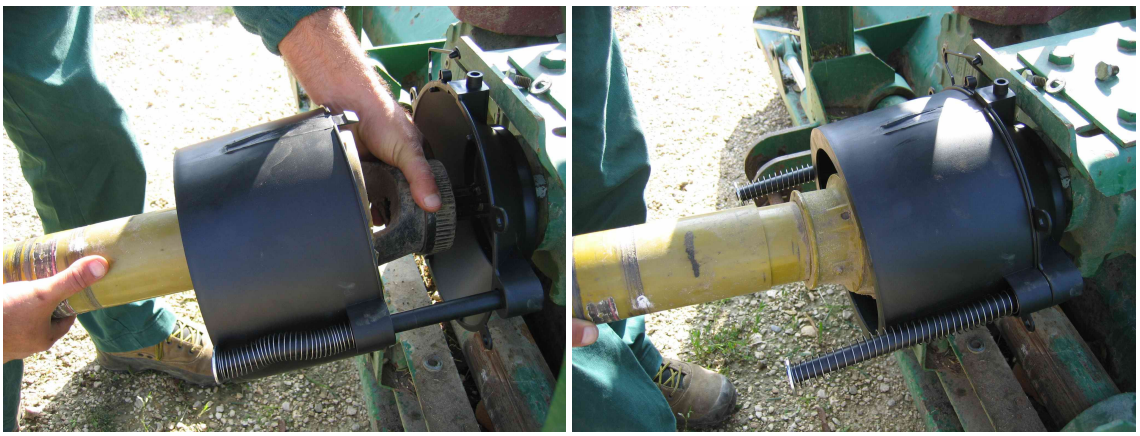

Figure 3. Tests on the functionality of the 2nd level prototype of the guard. Left: guard open for the connection of the PTO-drive-shaft to the PIC-yoke. Right: guard automatically locked by the spring system

Observing the performances of the 2nd level prototype during the tests, provided indications about the effectiveness of the modification on the first prototype and for the alignment of important details such as the maximum length of the sliding guides and the correct working of the automatic locking system.

Figure 4. The prototype has been tested under different working conditions such as the chopping of poplar residues with a stump grinder (left) and soil refinement with a rotary harrow (right)

Basing on these indications, the first exemplars have been realized and tested at CRA-ING. The first series of tests has been made in laboratory and had the goal of verifying the effectiveness of the safety hook against the accidental opening. If the locking system has not been unlocked voluntarily by means of a sharpened tool, the opening can also occur by applying on the safety hook a force of at least 9.3 daN.

Then the guards have been used with different operating machines and tested during the execution of normal works in field. The operating machines were a stump grinder, a rotary harrow, a rotary cultivator and a slurry spreader.

In particular, the use with the stump grinder (fig. 4) represented a severe test for the guard. It has been executed in a field with forestry woody residues, that determined high vibration levels and important shocks on the tractor-operating machine system. Such conditions, in one case only, caused the breakdown of the guard

No troubles arose from the remaining utilizations of the guard, testifying its reliability.

Conclusions

The final version of the guard is shown in fig. 5. The prototype resulted functional, coming up to the project's expectations. The tests evidenced that, after a short training, the operators become capable to easily perform the connection and the disconnection of the PTO-drive-shaft with the PIC-yoke of the operating machines, under significantly increased conditions of comfort. At the same time, the aspects of safety are guaranteed by the described devices aimed at avoiding that the guard could be accidentally opened if not requested, or could be forgotten open after the end of the intervention. All the operator involved in the tests expressed positive evaluations about the different aspects of the use of the prototype (safety, functionality and comfort).

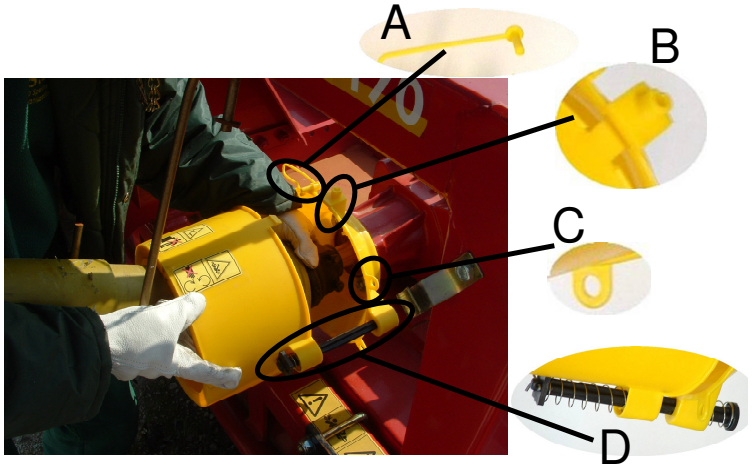

Figure 5. Main components of the drivehead: A) pin locking the guard closure; B) guard locking system; C) hooking holes for the PTO-drive-shaft retraining chain; D) automatic closure system

At the end of the study, an evaluation of the residual risks, determined by the use of the guard, has been made, revealing the necessity of applying a series of pictograms warning, for instance, about the danger of entangling with the PTO-drive-shaft during the rotation, prohibiting to get on the guard itself, etc.

Possible improvement of the prototype guard could be represented by shielding the sliding guides by means of a further external protection or directly realizing them inside the guard.

References

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EN ISO 4254-1: 2005 - Agricultural machinery — Safety — Part 1: General requirements

EN 953: 1997 - Safety of machinery - Guards - General requirements for the design and construction of fixed and movable guards

EN 547-2: 1996 - Safety of machinery - Human body measurements - Principles for determining the dimensions required for access openings.