This paper presents the design and testing of mechanical devices for the suspension of the grab and piler of a conventional sugarcane loader. The grab suspension device permits a horizontal trajectory of the grab tips during the grab's closing movement, in this way avoiding soil penetration. The piler suspension device provides good flotation during cane bundling, significantly reducing soil penetration. The introduction of soil and other extraneous materials during cane loading executed by conventional loaders is significantly reduced. These devices can be adapted to every kind of commercial cane loader without the need to change its original design, implying a minimum additional cost.

Key words: Sugarcane, mechanical loading, extraneous matter, soil.

INTRODUCTION

The most common method of harvesting sugarcane in Mexico is a combination of manual cutting and mechanical loading. The loaders may be self-propelled or tractor mounted. The typical mechanical sugarcane loader uses a pushpiler for heaping up the cane from the ground and a mechanical grab suspended from the boom for picking up the cane and loading it onto trucks.

The main problem in operating mechanical sugarcane loaders is the significant amount of soil and other extraneous materials that are picked up with the sugarcane. Further problems are the pulling up and destruction of stubble by the grab and the pushpiler when they dig into the ground. Soil causes considerable problems during cane processing, as well as involving the transport of thousands of tons of useless material. The solution must be sought in the modification of the mechanical loading. According to studies carried out in Brazil, 40% of the soil is introduced onto the truck because of operating problems and the incorrect position of the cut cane in the field, but 60% is due to the functioning of the machines.

The piler of the conventional sugarcane loaders has rigid design which consists of two vertical plates cut in an elliptic or parabolic shape with the tips in the lower part.
These plates are welded to a frame formed of lateral, longitudinal and diagonal pipes. This frame is articulated to the main structure of the machine and suspended by means of a chain which is in turn connected to an arm activated by a hydraulic cylinder. The lowest position on the piler is limited by the run of hydraulic cylinder and the length of the chain.

During the formation of bundles, the interaction force between the piler and the soil is too high to obtain in flotation of the piler and this causes its tips to dig into the ground. This results in stones and earth being moved into the bundle as well as the uprooting of pieces of stubble.

In order to obtain a better flotation effect of the piler, several designs have been patented. The piler patented by Mello is formed of two parts: a rigid one, as in the conventional case, and a lower part, which is articulated to the superior one. The lower part represents only a part of the total mass of the piler and exerts a very small force on the soil. As only the lower part has to float, the flotation effect in this solution is very good.

The aforementioned patent presents several design options for the divided piler but, in practice, we suggest that this solution has not always been successful due to problems related to the rigidity of the lower part as well as the introduction of stones and soil in the mobile parts. Also, the design represents a large investment for the loader owner, especially if it has to be fitted retrospectively.

Boudreaux, Thornton and Kenneth have designed pilers with active mechanisms which help in the formation of the bundles. These elements can carry out rotatory, lineal and oscillatory movements. The most interesting solution seems to be a rotatory mechanism adapted to a conventional piler in which cogwheels mounted on the piler walls helps in the formation of bunches. With this solution the reaction force of the cane against the piler is diminished and the tip's soil penetration force is reduced. However, these mechanisms are costly because of the need for additional hydraulic motors, etc. Active pilers are not recommended on rocky fields.

A conventional grab is generally made of two curved elements that are articulated at the point of suspension on the boom. During the closing movement, the grab's tips trace a circular path around the point of suspension and tend to dig into the soil if the position of the boom does not change. To prevent the tips of a conventional grab from digging into the ground the operator has to raise the boom as the grab closes, which is a very difficult and not very precise operation. It is not possible for the operator to avoid partial penetration of the ground by activating two hydraulic cylinders, neither can he avoid leaving some cane on the ground if the boom is raised too quickly. The operator must then heap this cane up again which implies both a waste of time and additional soil mixed with the cane.
Some solutions have been introduced in order to reduce the soil penetration by the tips of the piler and increase its flotation effect. One of the most common methods is the use of skids, which diminish the tip's soil penetration and offer a better flotation effect. However, in practice these skids should have a large contact surface between the piler and the soil in order to diminish its penetration. Other methods involve changing the shape of the grab and the separation of the articulation points of the grab's elements, but it has never been possible to avoid some soil penetration.

The most interesting method was devised by Mello. In this case the auxiliary hydraulic cylinder is connected to the hydraulic cylinders of the grab and the boom in such a way that the pressure from the motion of the grab cylinder or the hydraulic fluid expelled during the grab's closing movement drive the auxiliary cylinder, which in turn drives the boom's hydraulic cylinders, thus automatically lifting the grab to the desired height. Another solution from the same researcher consists of the use of a servovalve mounted on the boom or its support. This valve combines the flow to the lift and closing rams during the initial part of the boom's travel.

However, the hydraulic interaction between the grab's and the boom's cylinders does not guarantee the grab's tops will trace a horizontal line because the interaction between the grab and boom cylinders may vary, thus changing the path of the grab's tips. It also implies an additional cost to the machine, especially if the device has to be fitted retrospectively.

DESIGN OF THE NEW GRAB AND PILER SUSPENSION MECHANISMS

Analyzing the attempts of other inventors to modify the functioning of the main working systems of the conventional loaders, the conclusion is that the solution should be the design of mechanical devices which can be easily adapted to the commercial grabs and pilers without the need of any design changes and thus minimize the farmer's investment.

The prototypes described here were designed for a Thomson Hercules loader. Figures 1 and 2 show the mechanisms designed by the authors to re-suspend the conventional grabs on the loader's boom. The conventional grab has an additional two pairs of lugs 3 and 4 welded to the elements 1 and 2 of the grab. The arms 5 and 6 are connected to the lugs 3 and 4 through the bolts. The arms 5 and 6 are articulated at the shaft 9, which is connected to the boom. The grab is set in motion by one or two hydraulic cylinders which work in the same position as in the conventional mechanism. During the grab's closing movement, the elements 1 and 2 move the arms 5 and 6, which raise the grab, giving the desired horizontal path to the grab's tips. Kinematic analysis of the suspension was carried...
FIGURE 1. Suspension mechanism for the grab with one hydraulic cylinder: 1, 2 grab elements; 3, 4 lugs; 5, 6 arms of suspension mechanism; 7 hydraulic cylinder; 8, 9 shafts.

Out in order to obtain the correct position of the articulation points. The use of the cylinders 7 which work in the same way as in the conventional solution permits the reduction of forces on arms 5 and 6 because the piston force represents the internal load of the grab suspension system.

Figures 3 and 4 present the different stages of the closing movement of the conventional grabs suspended directly on the boom(a) and by means of the new suspension mechanisms(b).

Figure 5 shows the side view of the conventional piler suspended through the device shown in Figure 6. The device shown in Figure 6 absorbs between 80 and 100% of the force caused by the weight of the piler and the piled cane giving, as a result, a relatively small contact force between the piler and the soil and ensuring an excellent adaptation of the piler to the land surface.
FIGURE 2. Suspension mechanism for the grab with two hydraulic cylinder: 1, 2 grab elements; 3, 4 lugs; 5, 6 arms of suspension mechanism; 7 hydraulic cylinder; 8, 9 shafts.

Figure 6 presents the longitudinal cross section of the piler suspension. The device 4 is made up of a cylinder 1 in which a previously compressed spring 2 is located. In the spring there is a rod 3 which is connected at one end to the plate 4 and at the other end to fork 5. The fork 6 is connected to the end of the cylinder 1. The forks 5 and 6 permit the connection between the piler and the base of the machine by means of bolts.

When the piler is in operation, the force caused by its weight together with the force caused by the reaction of the piled cane provoke the additional compression of the spring through the plate 4 set in motion by the rod 3, which reduces even more the force between the tips and the soil.

The device can be placed between the grab and the machine by means of a chain in order that the whole system can float very high above unexpected obstacles.

TESTING

Tests of the functioning of the Thomson machine equipped with the two devices
FIGURE 3. Different stages of the closing movement of the grab with one hydraulic cylinder: a) grab suspended directly on the boom; b) grab suspended by means of the suspension mechanism.

FIGURE 4. Different stages of the closing movement of the grab with two hydraulic cylinders: a) grab suspended directly on the boom; b) grab suspended by means of the suspension mechanism.
The cleanliness of the cane loaded onto the truck was analyzed and the results were compared with the impurity content of the cane loaded by the same machine but without any modification. In order to discover
the influence of each one of the devices on the cleanliness of the cane being loaded, additional tests were carried out with the grab and piler suspension mechanisms. The soil digging by the work elements of the loader was observed, as well as the possible destruction of the stubble.

The results of these tests were highly satisfactory. A 60% reduction in the soil content of the cane was observed. This result is considered very good, since when working with the unmodified machine the operator felt pressured to do his job as well as possible because he was being observed by the Sugar Mill Authorities.

Sixty-five percent of the reduction in soil was estimated to be related to the work of the piler and 35% related to the functioning of the grab. Because the piler's soil penetration was very limited and the grab barely dug into the soil, not a single root-protected stool was observed and it was proven that even if the operator wanted to uproot the stools it would have been impossible for him to do so. It was also observed that operation was easier for the operator and the loading cycle was reduced.

CONCLUSIONS

The design of the conventional machines does not necessarily result in picking up soil, but there is a high risk of this happening. The operation is particularly dependent upon the operator's skill. With the devices designed by the authors, the influence of the operator on the work quality is almost completely eliminated. This is a very important aspect, given the working conditions and the number of working hours per day. Presently farmers and loader manufacturers in Mexico have shown great interest in testing and using these devices, especially taking into consideration the large number of machines operating in the country and the low additional investment (about US$1,000). Patent applications are registered in Mexico, U.S.A., Brazil, Australia and Colombia.

REFERENCES

UN SISTEMA PARA REDUCIR LA CANTIDAD DE TIERRA EN EL ALCE MECANICO

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RESUMEN

Se explica el diseño y se habla sobre las pruebas realizadas con un nuevo componente mecanico incorporado a la suspensión de la araña y el apilador de una alzadora convencional. El nuevo componente incorporado a la araña permite una trayectoria horizontal de los dientes durante el cierre, impidiendo la recogida de tierra. El componente en la suspensión del apilador produce una adecuada flotación al hacerse el bulto de caña reduciendo la recogida de tierra. Este nuevo aditamento reduce considerablemente la recogida de tierra y otras materias extrañas en comparación con las alzadoras convencionales.

Palabras claves: Caña de azúcar, alce mecánico, materia extraña tierra. (suelo).