Development of modular-built strip-tillage implement for minimum tillage experiments in Hungary

Péter ZWIERCZYK¹, János RÁDICS¹, Balázs VIDOVICS¹, István JÓRI J.¹, László FARKAS²

¹Budapest University of Technology and Economics, Department of Machine and Product Design, Műegyetem rkp. 1-3. H-1111 Budapest, Hungary, (e-mail: peter.zwierczyk@gmail.com)
²Metalwolf Fémpipari és Kereskedelmi Kft., Tavasz utca 12. H-6334 Géderlak, Hungary

Abstract

In the region, including Hungary, the extreme weather is also becoming more frequently seen. As a consequence certain periods of heavy rains or drought can be observed at times. This extreme weather is caused by the climate change. This weather requires new tillage systems which have not been used previously in the region. The strip-tillage is an environment friendly tillage system, basically known and used in North-America. By using this method, we can minimize the resources we use for the tillage as well as, being able to realize the biological and physical harmony of the soil itself. In this project, we had been designed a strip-tillage implement, which allows us to introduce this tillage technology in Hungary with the help of the tools of systematic machine design. As a result of our work, we designed a tillage unit with modular structure, which will help to conduct successfully - according to our hopes - this technology in the Hungarian agriculture.

Key words: strip-tillage, minimum-tillage, environment friendly tillage

Introduction

The result and experience of the domestic and foreign studies shows, strip-tillage is a possible technology which reduce the harmful effects of the climate change. Strip tillage, which is a type of minimum tillage, combines no tillage and full tillage to produce row crops. The cropped strips are 150-200 mm wide but sometimes occur wider (250-300 mm). The depth of the strips varies between 100 and 250 mm. The area between the tilled rows left undisturbed. Often both types of fertilizer (liquid or dry granulate fertilizer) are injected into the rows during the tilling operation. Strip-tillage operations can be performed in the spring. The strip-tillage consists of a number of consecutive operations. An ordinary strip-tillage implement involves the following components. These components are the front coulter blade, the row cleaners, the tillage shanks, the berm discs and optional rubber packing wheels or berm reels (the last two components are not equipped in all of the machines) (Birkás, 2000).

Coulter blade cuts through the soil and residue ahead of the tillage shank. Ordinary these blades diameter varies between 508-610 mm. The coulters require special mounting that allows flexible movement over stones to avoid the crash of the implement. The diameter of the blades influences the cut efficiency. Row cleaners’ function to clear the cut residue away from the front of the tillage shank. The cleaners are usually fitted behind the cultural blades but there are some manufacturer who mounted it directly in front of the front blades. The residue which was removed from the tilled strips covers the untilled areas. This residue cover protects the soil against losing their moisture content. One of the most important part of a strip-tillage implement is the tillage shank which penetrates and loosens soil. Normally it is designed with a fertilizer injection tube to make it possible to use liquid or dry granular fertilizers during the strip tillage operation. Tillage depth is dependent on the soil type and conditions and the specific crop to be planted. Berm discs are mounted on each side behind the tillage shank. The discs are mounted that way that the stripes made by the
shank should be covered preventing the moisture level of the soil from drying in the spring or, alternatively, mounted to create a slight depression in the soil to catch snow and rain to increase soil moisture for the next crop. The last part of the strip-tillage operation is the soil surface conditioning. Berm reels are mounted behind the shank and the berm discs to break soil clods and smooth the soil surface. There are several types of baskets available in the strip-tillage equipments (solid, straight tooth, arrow tooth, etc.). Some manufacturers use rubber packing wheels instead of conditioning baskets (sometimes without berm discs) (Nowatzki et. al., 2008).

In Table 1. we collected the most important advantages and disadvantages of strip-tillage. The strip-tillage used effectively for corn and soya bean production.

The domestic application of this tillage technology requires a strip-tillage unit which meets the inland demands. Therefore we set an objective to design an implement which satisfies this requirement.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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<tr>
<td>Reduce soil erosion</td>
<td>Possible dependence on herbicides</td>
</tr>
<tr>
<td>Cost-effective automation</td>
<td>Cold seed bed when seeding</td>
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<tr>
<td>Effective soil moisture conservation</td>
<td>Necessary precise work schedule</td>
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<tr>
<td>The tilled areas warm earlier in spring. This helps the germination and plant emergence.</td>
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**Materials and methods**

As a first step in our work we collected the most relevant information e.g. the customers' demands, previous experience, market and technical information. In this work, we paid great attention to the examination of the following areas: patents, analysis of the North-American market and a former domestic investigational report (Kurucz, 1966). We examined the performance and structure of the equipments available in the USA. Some of the overseas solutions are displayed in Picture 1.

**Table 1. Advantages and disadvantages of strip-tillage. (Birkás, 2000)**

Using this information, we set up a detailed list of requirements and we found that the machine to be developed has to achieve the following operations:

- preliminary row cleaning (optional)
- soil opening
- row cleaning
- soil loosening
- soil surface conditioning
- soil surface compression (optional)

In the next step - following the systematic machine design - we have started to elaborate our concepts according to the list of requirements. We have chosen to generate concepts for each sub-function and then we used the Morphological Chart (MC) method to generate logically suitable concepts aiming to fulfill the most requirements. Our morphological chart can be seen on Picture 2.
After we examined that the concepts operate as anticipated, with reasonable further development, which is a primary goal in concept development, we refined enough them to evaluate the technologies needed to realize them, to evaluate their basic architecture, and - with limited degree - to evaluate their manufacturability. Our process was special, since we used CAD representations from the very beginning, trying to incorporate each and every bit of information about the design knowledge at the time. Picture 3. shows our concepts.

The difficulty in concept evaluation and decision-making is that we must choose which concepts to spend time developing, when we still have limited knowledge and data on which to base this selection. Ideally, we should have enough information about each concept before committing to one of them. This requires resources; spread among many concepts and possibly, inadequate development of any one of them. Many companies generate only one concept and then spend time developing it. Others develop many concepts in parallel, eliminating the weaker one along the way.

We followed the second way. We have developed more than one concept parallely, but instead of using the former methods, we tried to combine the solutions of a certain concept, by building a modular system product. This approach was fostered by both the MC method, and the fact that the preliminary CAD models contained the function-solution fit information (Ullman, 2010)
Results

By thinking on the elaborated conceptions, we laid down the final plans of the strip-tillage implement. When elaborating the details, we greatly emphasized the modular structure, which makes it possible, to design later versions of the unit. Other key considerations were the most possible use of commercial items - e.g.: the front coulter blade, the discs’ hubs etc. - which helps reducing the manufacturing cost, and time. The final equipment, and the subassemblies are displayed in Picture 4.

Picture 4. The final strip-tillage design

The equipment is made in two different forms. The first one, the more complex, seed-bed-preparing unit presents all the elements of the above displayed strip-tillage procedure. In this version, after cutting the residue, clearing the row and getting the chemical fertilizer in the ground with the tillage shank, there is a ridge. And finally, after the set of operations, the berm reel will spread the overturned big clods. The second, simpler version misses the berm reel and discs in the back, instead a few simple rubber packing wheels are integrated behind the shank. To decrease the downtime task and the number of unique parts, both strip-tillage implements have a common frame, to which the different hind adapters can be directly connected by two bolts. This setup makes it possible to easily change the adapters, according to the changing demands of the users, and there is no need to buy a new unit. In Picture 5. the different adapters and the common frame are displayed.

Picture 5. The modular system

During the development of the final equipment, we gave high notice to make the cultivator unit adoptable to all kinds of soil. To achieve this, we developed a parallelogram lever structure, on which the hold-down force can be adjusted by discreet values in a range of 0-2500 N, to guarantee the optimal holding-down matching in the circumstances given. During the design process, we aimed to give scope to adjust the sub-assemblies in the biggest possible range. Due to this, the built in, 330 mm diameter uniquely developed row cleaner discs are adjustable in 100 mm range and the tillage shank in 250 mm range. This adjustment possibility makes it achievable the adequate row cleaning and the nutrient supply of soil in the desired depth by grained fertilizers. 100 mm deep, even hack-depth is ensured by a depth-limiter edge on the 500 mm diameter front coulter blade.
We aimed the biggest possible adjustment range in the case of the 400 mm diameter berm discs too. Besides adjusting vertically and horizontally it is possible to adjust the angular offset by discreet values in a 0-15° range.

We used a special tension-spring device, which is evenly holding down the berm-reel, this way ensuring an even 500N hold-down force while working. A similarly developed tension-structure gives similar hold-down force to the rubber packing wheels. The berm-reel had been given an arrow-shape-rib to ensure balanced running.

**Conclusions**

Setting up the requirements and the help of the Morphological Chart method we determined the most important components of our strip-tillage unit. We found that the modular design is the only way which satisfies economically the wide range of domestic demands.

The modular development makes it possible to get liquid fertilizers into the soil later, by connecting a simple adapter to the frame. For carrying strip-tillage implements, and the nutrition supply, we are developing a complete carry-frame, which makes it possible to assemble a whole compound with 4,5 m work-width. We plan to conduct field measurements in next spring, the results of which will confirm our expectations concerning the cultivating technology.

**References**

Birkás, Márta. (2000). Energiatakarékos, talajvédő és kímélő talajművelés, Szent István University, Gödöllő

Horák, P. (2010). Gyártmánysorozatok, építőszelekény rendszerek fejlesztése oral presentation, Budapest University of Technology and Economics

Kurucz, L. (1966). Előzetes jelentés a minimum tillage című kutatási témáról, Mezőgazdasági Gépkísérleti Intézet


sa2011_0540