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Draining machine concept

Koncepcja urządzenia drenarskiego

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The article contains a draft of a device for laying drainage pipelines. The project was made in a CAD environment. The article contains basic strength calculations of the device structure elements. The main assumptions that the device fulfills is the simple operation and high repairability of the machine element.

KEYWORDS: drainage, construction, 3D model, CAD

Draining is the process of spreading the drainage pipeline in properly prepared recesses, and then - on its backfill. In order to facilitate the work, devices are used to excavate the recess, position the pipeline and fill the groove [1].

Machines of this type, available on the market, have solutions based on the principle of straw drain plows - a similar method of operation is used in agricultural subsoilers [2]. These devices, after passing, leave a small groove, which is removed during cultivation. The manufacturer's offer includes machines hooked onto agricultural and self-propelled tractors. These often have a track drive and are usually used in more difficult terrain and for deeper grooves [3]. In older solutions, hooking structures were used for the agricultural tractor and with a shaft hitching under the PTO, which allowed direct filling of the groove immediately after the drainage pipe was installed.

Design assumptions of the device

During the formulation of design assumptions, both the criterion of manufacturing and exploitation costs as well as the ease of placing the hose in the prepared recess were taken into account. Due to the price of the project, all electronic devices have been eliminated, e.g. GPS system or laser height sensor [7]. The device will cooperate with an agricultural tractor, so it should be hooked using a three-point system of suspension or - in justified cases - a field catch. In addition, to expand its application, it must have connections to peripheral devices

An important criterion is the depth of placing the drainage pipe. It must be large enough that the pipelines are not damaged during the agricultural operations, and the water in it does not freeze under the influence of a negative temperature. This depth was adopted at the level of 80÷100 cm [4].

Another assumption was to create a layer that would allow the water to seep into the pipeline and would not cause the siltation of the hose. In order for the device to work in a continuous mode, there is a place for a drainage hose that would be taken from the tray. The device should not provide proper hose position (it can not be bent) and thus proper drainage of water [5].

Initial calculations

In order to determine the durability of the device under the effect of maximum loads, strength calculations of selected structural elements [6] were made, which are the most exposed to mechanical damage. Thus, we analyzed:

- drawbeam,
- length of the weld to the hinge,
- main frame.

The maximum force of the agricultural tractor at 38 kN was taken into account in calculations [3]. Because the device can be subjected to forces exerted by two tractors during operation, the force F_u = 80 kN has been assumed for calculations.

■ **Drawbeam**. The drawbeam is shown in fig. 1. It consists of a closed profile in the shape of a square and from mounting brackets.

Output data for calculations: force exerted on the beam F_u = 80 kN, beam length l = 850 mm (TUZ cat. II + width of the tractor arms), wall thickness of the profile 10 mm. Assumed $a = b$ (fig. 1) and material: steel St4 (k_{gj} = 94 MPa).

The dependencies were used in the calculations:

$$\sigma_g = \frac{M}{W_x} \leqslant k_{gj} \quad (1)$$

$$\sum F_y = 0 \Rightarrow F_u = R_A + R_B \quad (2)$$

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$$\sum M_A = 0 => R_B \cdot l = F_u \cdot \frac{1}{2} l => R_A = \frac{1}{2} F_u ; R_B = \frac{1}{2} F_u \quad (3)$$

$$M_g(x) = R_A x - F(x - \frac{1}{2}) \quad (4)$$

$$M = M_g\left(\frac{1}{2} l\right) = \frac{1}{2} F_u \cdot \frac{1}{2} l - 0 = \frac{1}{4} F_u \cdot l = 17 MNmm \quad (5)$$

$$W_x = \frac{a \cdot h^2}{6} - \frac{(a-20)(h-20)^2}{6} = \frac{a^3-(a-20)^3}{6} = \frac{60a^2-1200a+27000}{6} mm^3 \quad (6)$$

After substituting (1) the values of k_{gj} = 94 MPa and M = 17 MNmm and taking into account the expression (6), we obtained:

$$a^2 - 20a - 17635 \geqslant 0 \quad (7)$$

It was finally accepted that:

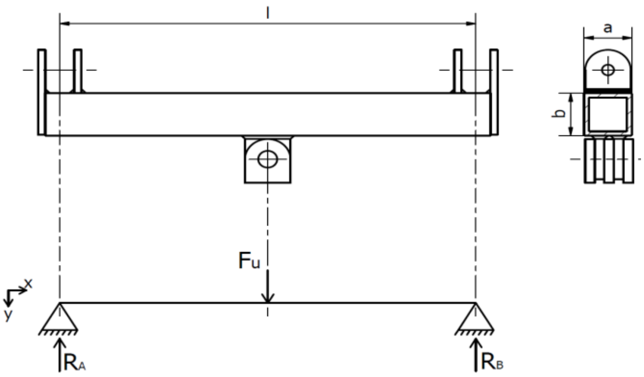

Fig. 1. Sketch of the drawbeam [5]

■ **Weld length for the fastening element.** This assumes the following assumptions (fig. 2): tensile force connection P = 80,000 N; joint thickness g = 20 mm; coefficient of static weld strength x' = 0.8; on-permissible stress of the material of combined elements k_{tj} = 60 MPa; weld size a = 0.4 g = 8 mm. The sought length of the weld was marked as 1. The calculations were made on the basis of the data contained in the mechanic's guide:

$$l \geqslant \frac{F_u}{0{,}4 \cdot g \cdot x' \cdot k_{tj}} \quad (8)$$

After substituting for the formula (8), the values obtained were:

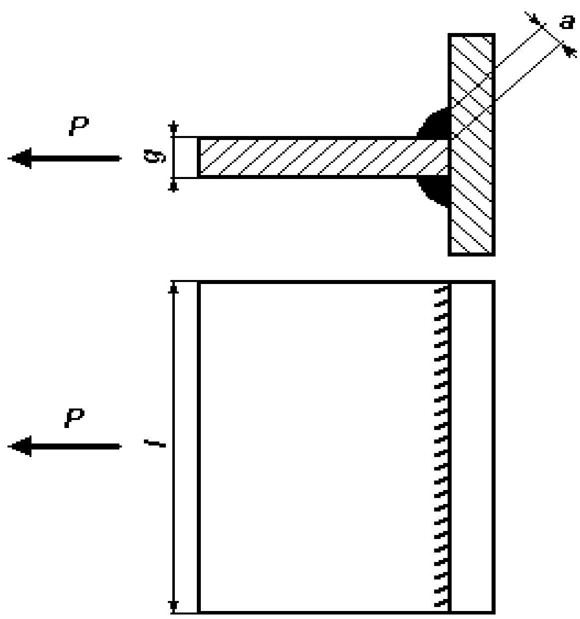

Fig. 2. Sketch for the calculation of the weld [5]

■ **Main frame.** The main frame (fig. 3) is the beam bent with the focused moment MA. For its calculation, it was assumed that q = 80 N/mm (thus: q × 1000 mm = 80,000 N), and the equation $\sum M_A = 0$ was used. It was:

$$M_A = 80000\ N \cdot 5600\ mm = 448\ MNmm \quad (9)$$

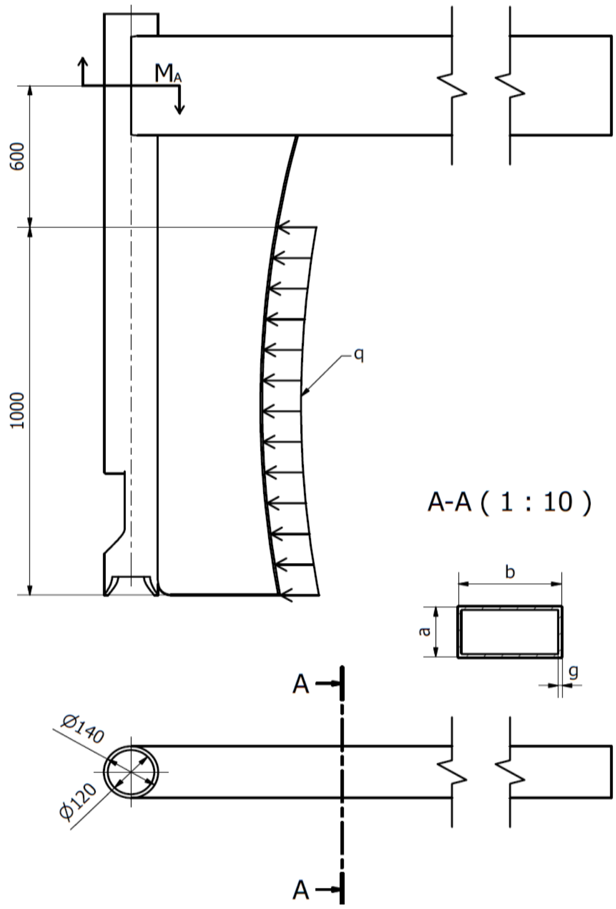

Fig. 3. Sketch of the main frame [5]

Then the dependence was used:

$$\sigma_g = \frac{M_A}{W_x} \leqslant k_{gj} => W_x \geqslant \frac{M_R}{k_{gj}} \quad (10)$$

Because M_A = 448 MNmm, and k_{gj} = 94 MPa (for St4 steel), therefore W_x > 4,765,957 mm³, and at the same time:

$$W_x = \frac{a \cdot b^2}{6} - \frac{(a-20)(b-20)^2}{6} \quad (11)$$

After substituting (11) the values of a = 140 mm and W_x = 4,765,957 mm³, we obtained: b = 277 mm. This profile dimension was taken as b = 300 mm

CAD design

After determining the boundary conditions, a design was made in the CAD environment. In order to meet the assumed requirements, a machine attached to a three-point fastening system was designed. The project is an alternative to expensive devices available on the market. The vehicle is suitable for snakes with a diameter of ⌀100, which is the kind of drainage arms commonly called sludge. Computer control and expensive electronic devices have been abandoned - thanks to this the vehicle is fully mechanical and can be repaired at home. In order to determine the driving path of the agricultural tractor, places that will leave a trail during the journey are marked. The machine has an additional coupling for the next tractor, useful in harder conditions.

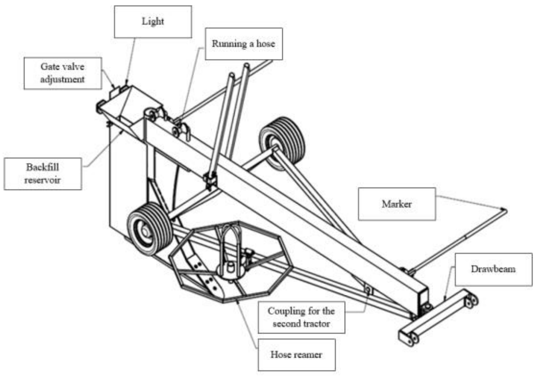

Fig. 4. Machine design [5]
Zasuwa regulacji warstwy obsypki – Gate valve adjustment
Zasobnik obsypki – Backfill reservoir
Oświetlenie – Light
Prowadzenie węża – Running a hose
Znacznik – Marker
Belka zaczepowa – Drawbeam
Sprzęg dla drugiego ciągnika – Coupling for the second tractor
Rozwijarka węża - Hose reamer

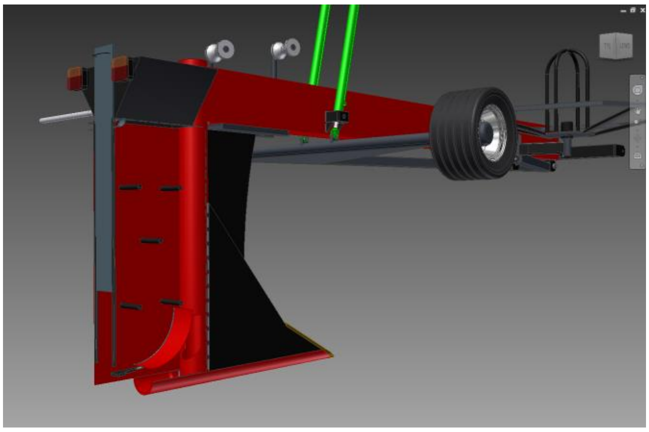

Fig. 5. Machine in the working position with the exposed container for the filter material [5]

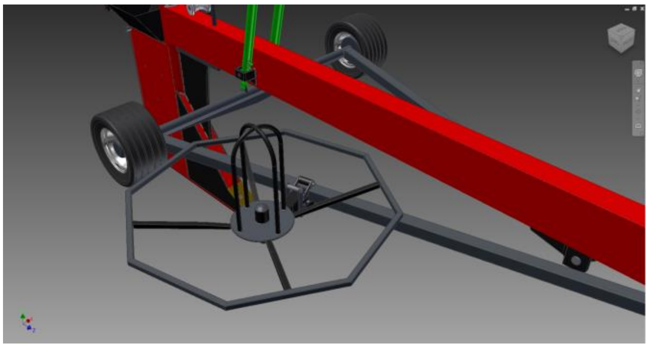

Fig. 6. Hose reamer [5]

The CAD design of the device is shown in figs. 4-6. The powder is fed into the upper part of the machine, the height being adjusted by means of a latch located in the rear part of the machine. It is set with screws located at both ends of the blade stand.

The hose is pressed by the backfill when it is laid by the machine. The hose reamer is attached to the side of the machine. It has a lightweight and simple structure, ensuring easy feeding of the hose to the groove (without creases and blockages).

Conclusions

The construction model met the assumed edge conditions. The designed device can effectively compete with the solutions available on the market. The calculations confirmed that the device will work in difficult field conditions. The CAD design is the basis for producing the actual model of the device and testing in real operating conditions.

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