CUTTERS

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I. INTRODUCTION

The cutter or cutterhead is located at the entrance of the suction tube at the end of the ladder.

PURPOSE

The purpose of the cutter is to cut the soil in such a way that the pieces can be sucked into the suction tube.

There are many types of cutters. Experience in selecting the right type of cutter is very important together with such technical aspects as the sense of rotation of the cutter, the power requirements, and the type of soil.

FORCES

The forces a cutter has to overcome are considerable. The torque developed by the cutter operating in normal soil types can be higher than 300 kN·m.

In this chapter some important aspects of cutters will be discussed, such as selecting a cutter, types of cutters, and maintenance aspects.

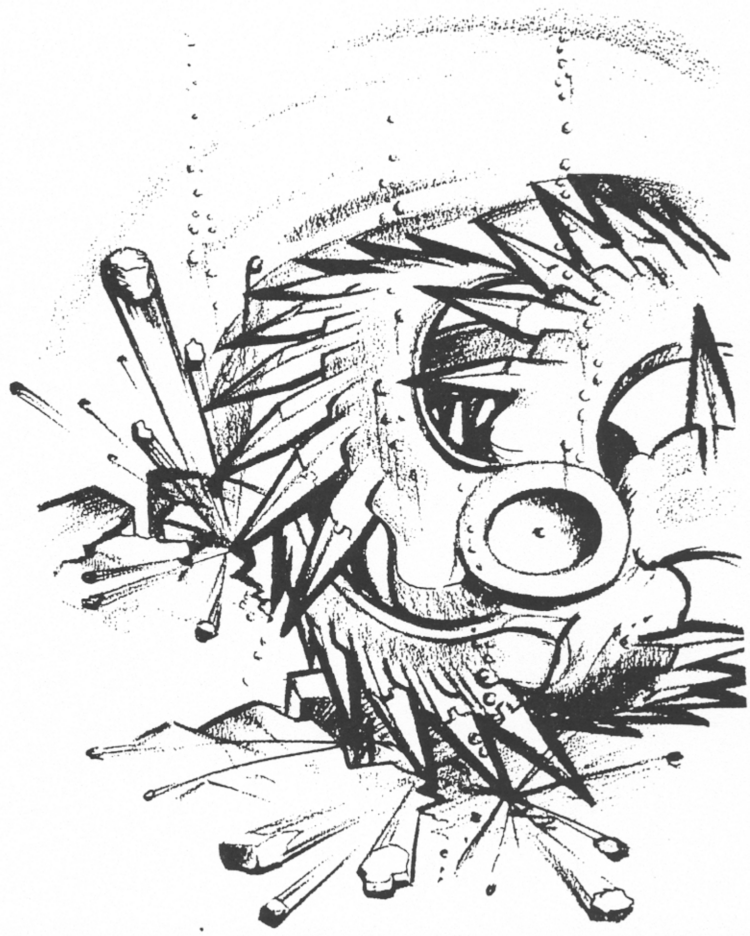

Figure 1 Cutter cutting rock

II. SELECTION OF A CUTTER

Selecting a cutter for a given cutter suction dredger depends to a large extent on the operation that needs to be done.

DATA DREDGER

In the first place specific data of the cutter suction dredger are very important, such as:

- The power of the cutter drive.
- The speed of the cutter (number of revolutions).
- The power required by the swing winches.
- The swing velocity.

All these data should be considered.

SOIL TYPE

The type of soil to be excavated is also of special importance:

- Composition of the soil (Clay, sand, gravel, peat, rock).
- Stratification of the soil.
- Mechanical characteristics of the soil.

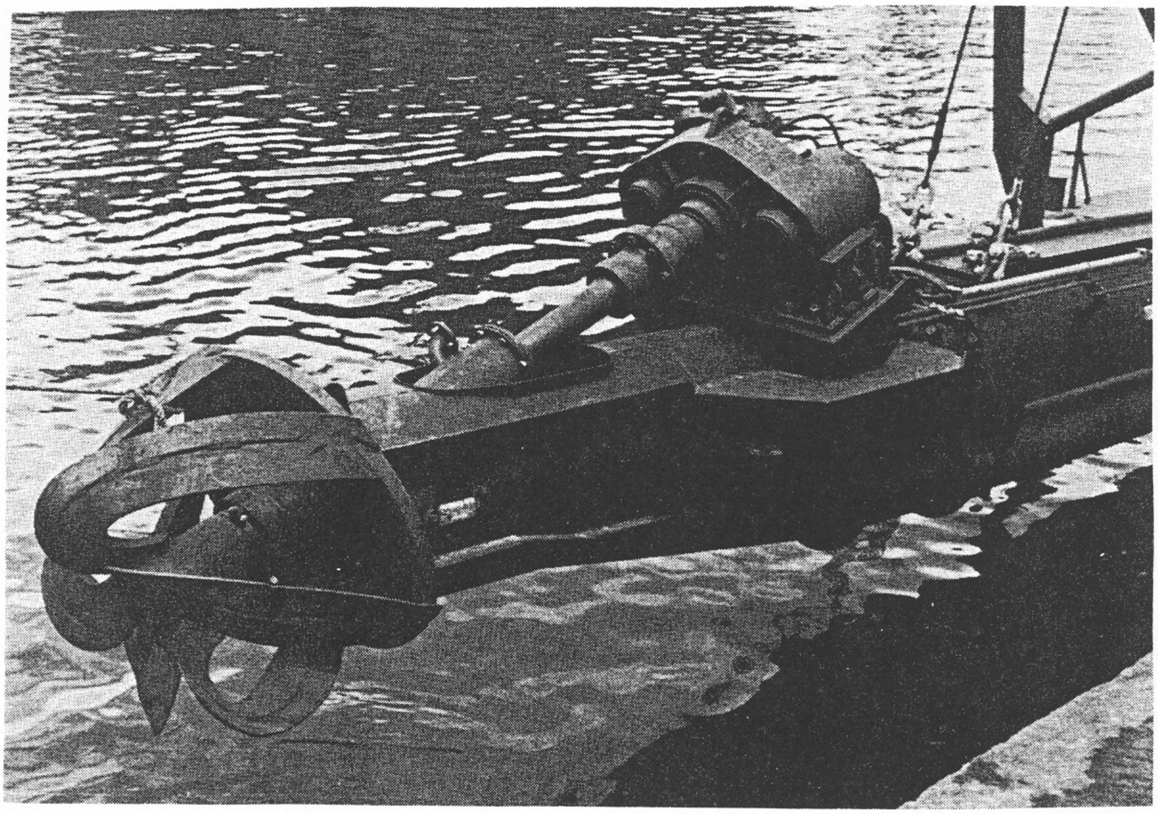

Figure 2 Cutter with cutter drive

POWER

The power of the cutter drive and its speed determine the dimensions of the cutter. Clearly an increase in diameter of the cutter asks for an increase in driving power. Most of the cutter systems can develop 30 revolutions per minute as a maximum. The speed can then be continuously varied between) and 30 r.p.m.

With the power available the force developed can be calculated for any given number of revolutions. When the maximum allowable winch forces are taken into account the maximal value of the cutting force can be calculated as well.

SWING WINCHES

In case of strong swing winches a smaller cutter diameter is already capable of delivering strong cutting forces. This may be important in cutting very hard soil types e.g. rocks.

Figure 3 Cutter on cutter ladder

When the strength of the swing winches is limited the maximum cutting force is limited as well (constant cutting power). Such cutter suction dredgers are not preferred when working in very hard soil.

HARD SOIL

This means that a cutter suction dredger for hard soils should develop a great cutting power and have, among others, strong swing winches for successful application of a cutter with small diameter for developing strong cutting forces. If these specific cutters have work in soft soil, the diameter of the cutter can be increased to achieve a higher production rate. At full load, the swing winch has some reserve in power, provided the swing velocity does not present restrictions.

LOOSE SOILS

In loose soils the behaviour of the cutter is more that of burrowing than of cutting. The forces required for cutting are then moderate and are easily obtained at low speed. The choice is, in these cases, invariably a cutter with a great radial surface having a spherical, basketlike form. This is because the diameter of the cutter cannot be increased or decreased without limits. These limits are related to problems of coupling the cutter to the suction pipe orifice.

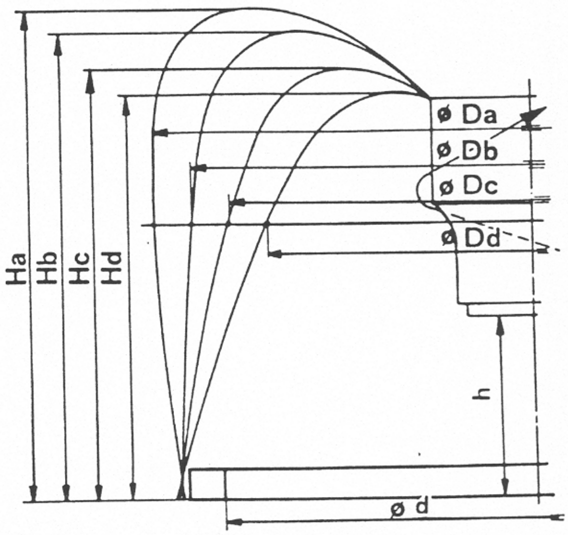

Figure 4 Different cutter forms

COMPACT SOILS

In soils with a high density and with a compact structure, like hard clay etc. the cutter diameter is generally of a smaller size. As the diameter of the ring remains the same, the cutter has a more conical shape. The cutting force is now increased but the rate of production is decreasing in comparison to the rate attained when working in these types of soil, under full load. A very important aim in using a cutter in a compact soil structure is to keep the cutter as “open” as possible.

Considerable space between the consecutive blades of the cutter enhances the passage of big chunks of excavated clay. If the clay is of the “adhesive” type the passage of the chunks between the above blades may be too limited and problems may arise in the cutting operation. There are cases when the foremost portion of the cutter is completely covered by clay excavated by the cutter.

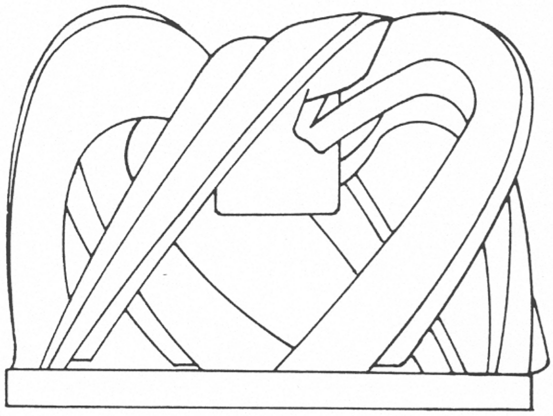

Figure 5 Crown cutter

To improve the operation of the cutter, the cutter to be selected has to have a proper angle of cutting and a proper angle of clearance, together with the right number of revolutions and the proper swing velocity. When working in hard clay the arms of the cutter are provided with either smooth or milled knives. Some knives are even provided with a clay-angle and these knives are extremely useful when working in “adhesive” type of clay.

HARD SOILS

Cutters used in very hard soil types (rocks) have many arms (6 to 7) and these arms are provided with pick-points. The cutting force developed by these cutters is maximal because of the size of the diameter which is selected to be as small as possible. The pick-up points assist in concentrating the cutting forces. The swing winches have to be extremely powerful and stronger than the swing winches found in the average type of cutter dredger.

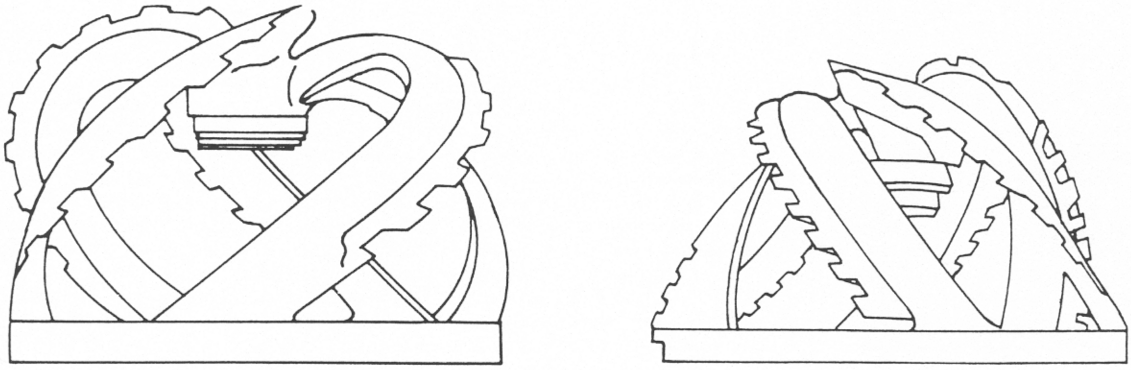

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Figure 6 Basket and modified basket cutter

Figure 7 Rock cutter

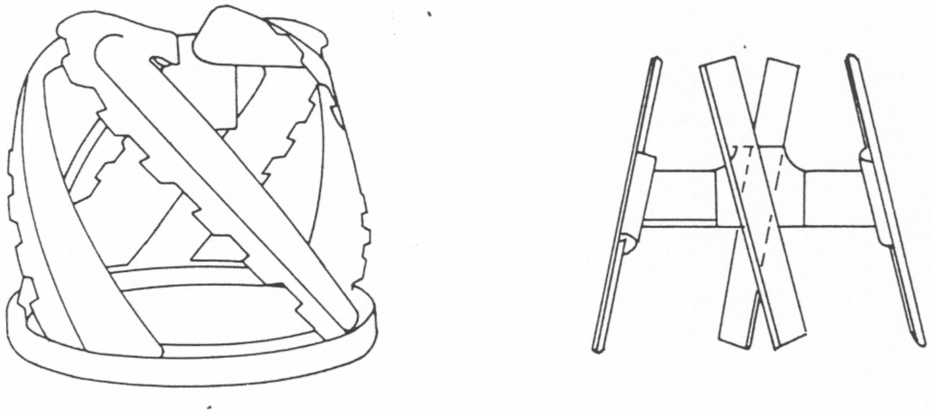

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Figure 8 Close nose basket and straight arm cutter

YIELD

BREAKS IN PRODUCTION

Though the yield in production is low the price of cutting per m^3 is fairly high. Cutters have to be exchangeable as frequent replacement of the operating cutter is required because of increased wear. This frequent replacement of the cutter leads to breaks in production. Efficiency can therefore be increased by replacing the operating cutter swiftly. There are special devices developed for exchanging the cutter but these devices are only used in huge cutter suction dredgers. The time required to replace a cutter by using the above device is about a quarter of an hour. Cutters, when removed, are again provided with sharp pick-points and are ready to be used in a future cutting operation.

III. THE CUTTER

BLADES

In general a cutter consists of a hub a ring connected to each other by a number of blades or arms, usually five or six, sometimes seven or different. The connection is achieved by welding. The cutting arms are not parallel to the cutter axis, but make an angle, which is usually about 45°.

CUTTING EDGES

Cutters can be divided into bladed cutters and toothed cutters. With bladed cutters cutting edges are either welded to the blades or connected to the blades by bolts and nuts. These cutting edges can thus be renewed by simple cutting away the old edges, or dismounting them and putting new edges in position. Several types of cutting edges are available.

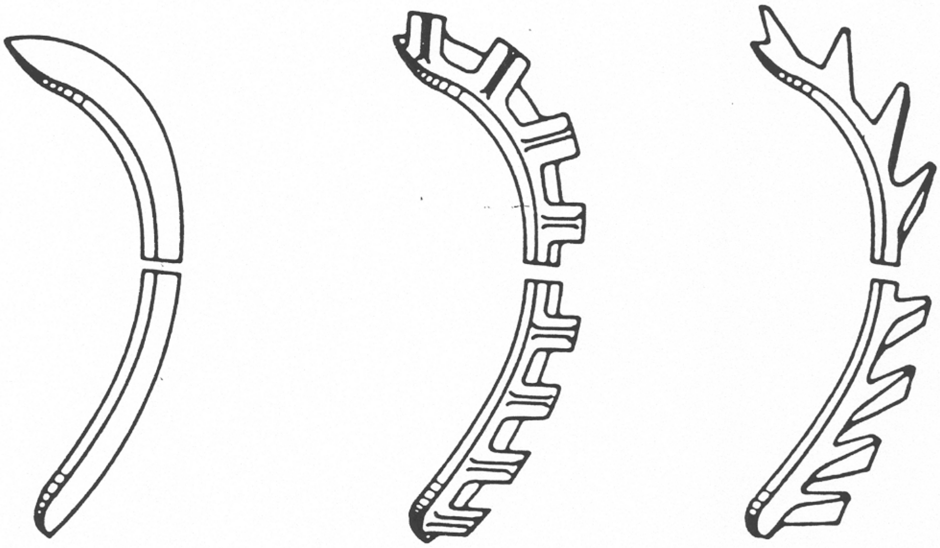
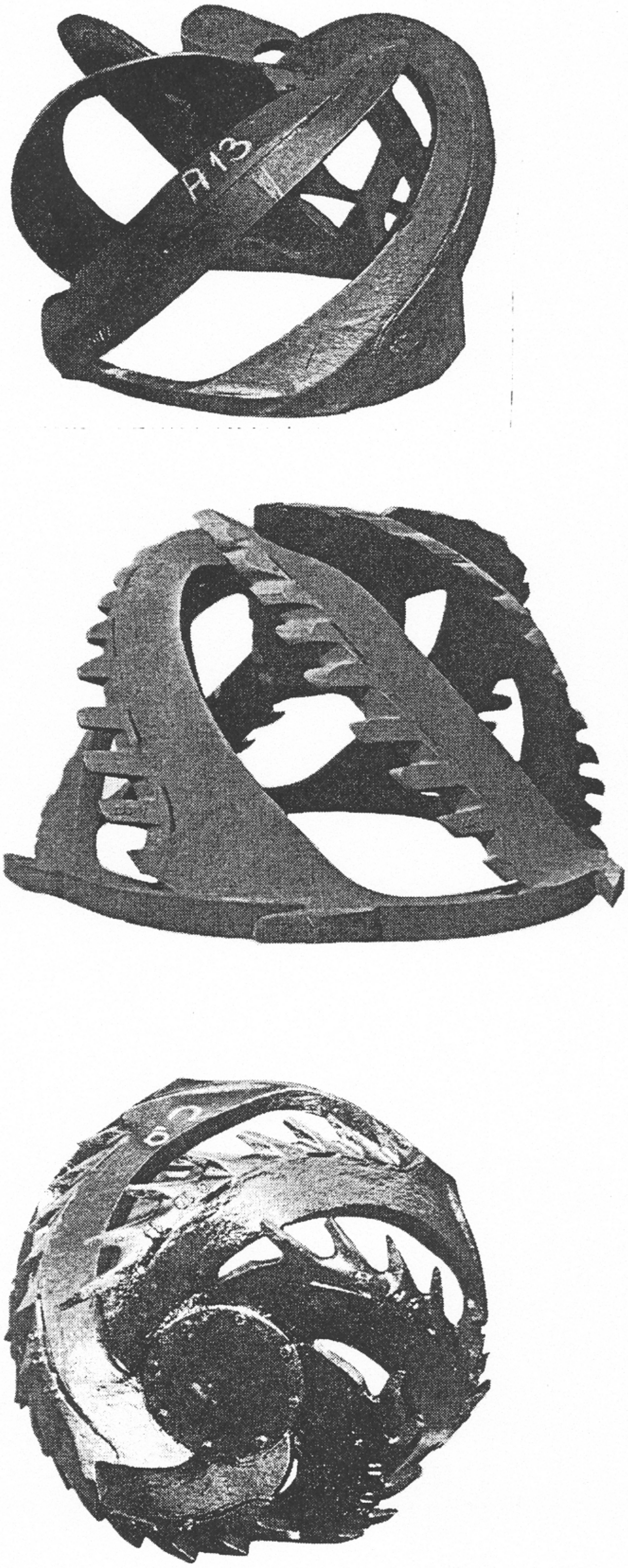


Figure 9 Cutting edges



cutter with plain cutting edges

cutter with serrated cutting edges

cutter with toothed cutting edges

Figure 10 Types of bladed cutters

- Plain cutting edges.
  This type of cutting edge is recommended for medium soil types such as sand peat, and for operations where considerable root growth, steel wires etc. are present, which could foul up a toothed cutter.

- Serrated cutting edges.
  This type of cutting edge exerts a greater specific surface pressure, and is thus more suitable for loosening clay, loam, etc.

- Toothed cutting edges.
  This type of cutting edge is used for hard soils, where great pressure is required for penetration and disintegration. The design and position of this type of edge is such that its teeth operate as chisels.

SECTIONS

The cutting edges are made in two or three sections depending on the size of the cutter. This arrangement makes them easy to handle and moreover enables individual sections to be removed as the wear.

Besides cutters with replaceable cutting edges mounted on blades, toothed cutters are possible. In

TEETH

this type teeth are mounted on regular intervals to the arms, by a tenon and mortise joint.

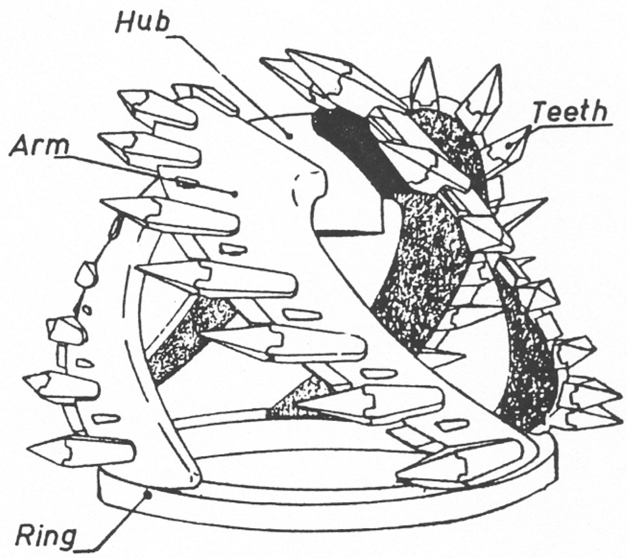


Figure 11 Toothed cutter

The teeth of a toothed cutter consist of two main parts, the adapter and a tooth-like joint. The adapters are welded to the arms. In a view of wear, the teeth

TENON AND MORTISE

are made replaceable by means of the tenon and mortise joint.

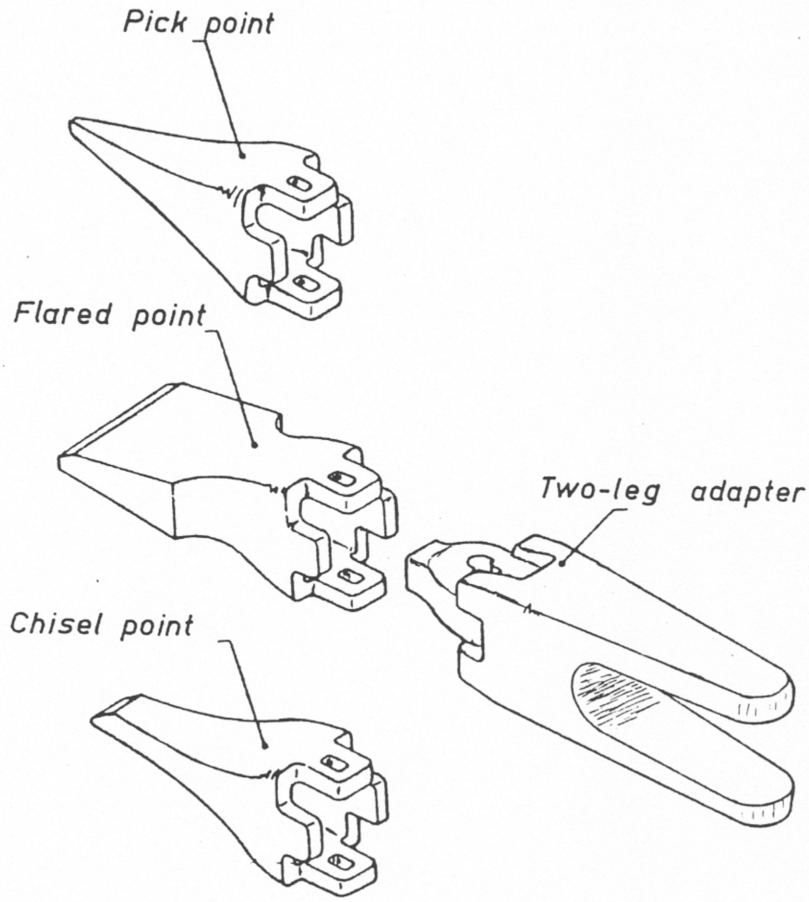


Figure 12 Teeth

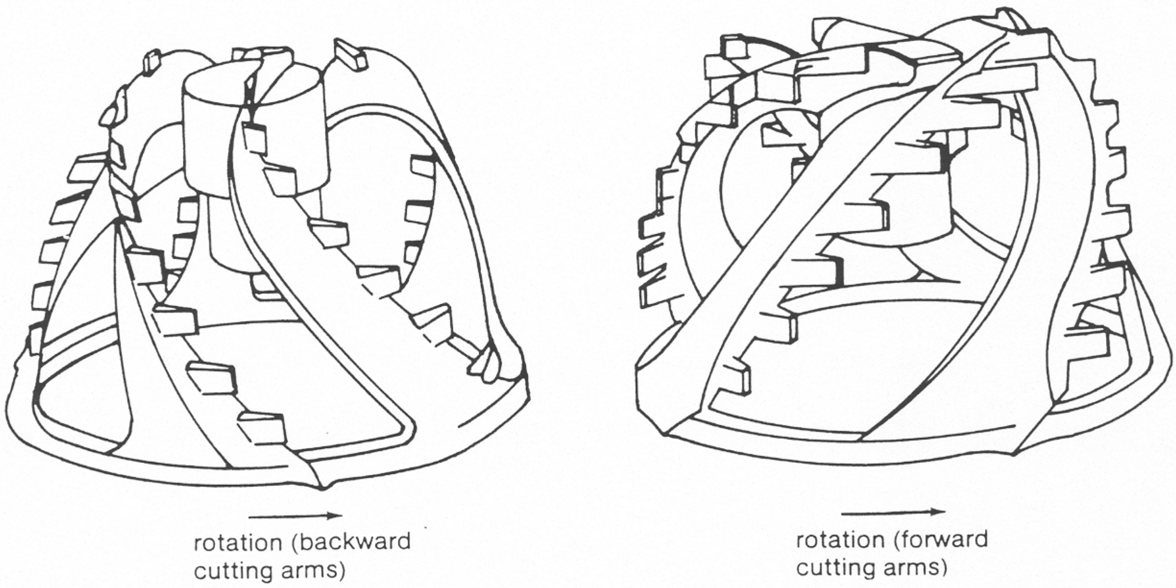


Figure 13 Forward and backward cutting arms.

Several types of points are available, such as:

- Flared points, used in sand and clay.
- Chisel points, used for hard non-porous materials such as lime stone.
- Pick points, used for hard porous materials such as coral.

The type of soil determines the choice between on the one hand the bladed or toothed cutter, and on the other hand the type of cutting edge or point.

SENSE OF ROTATION

Cutters can also subdivided according to the sense of rotation. They can be made to turn clockwise or to turn counter clockwise. They can have forward and backward cutting arms (figure 13)

IV. CUTTER DRIVE

TWO KINDS

Two kinds of cutter drive are generally applied:

- Electric drive.
- Hydraulic drive.

It is extremely difficult to compare technically the two kinds of drive at equal lever of power.

ELECTRIC

Electric motors can carry instantaneous overload up to 150 %. They are extremely useful in cutter drives because of the variable character of the load on the motor in the cutting process.

HYDRAULIC

The torque of a hydraulic motor is determined by the stroke of the motor and the oil pressure in the motor. The maximum value of the pressure is limited by the setting of a safety valve. Loads requiring a torque value higher than the maximum value of the torque of a certain hydraulic motor results in stopping of the motor. As the cutting process implies a variable torque, the setting of the safety valve is such that the motor operates steadily at 60 % of the maximum value of the pressure. The torque is dependent on the pressure and is available at the end of the shaft at both a low and a high speed.

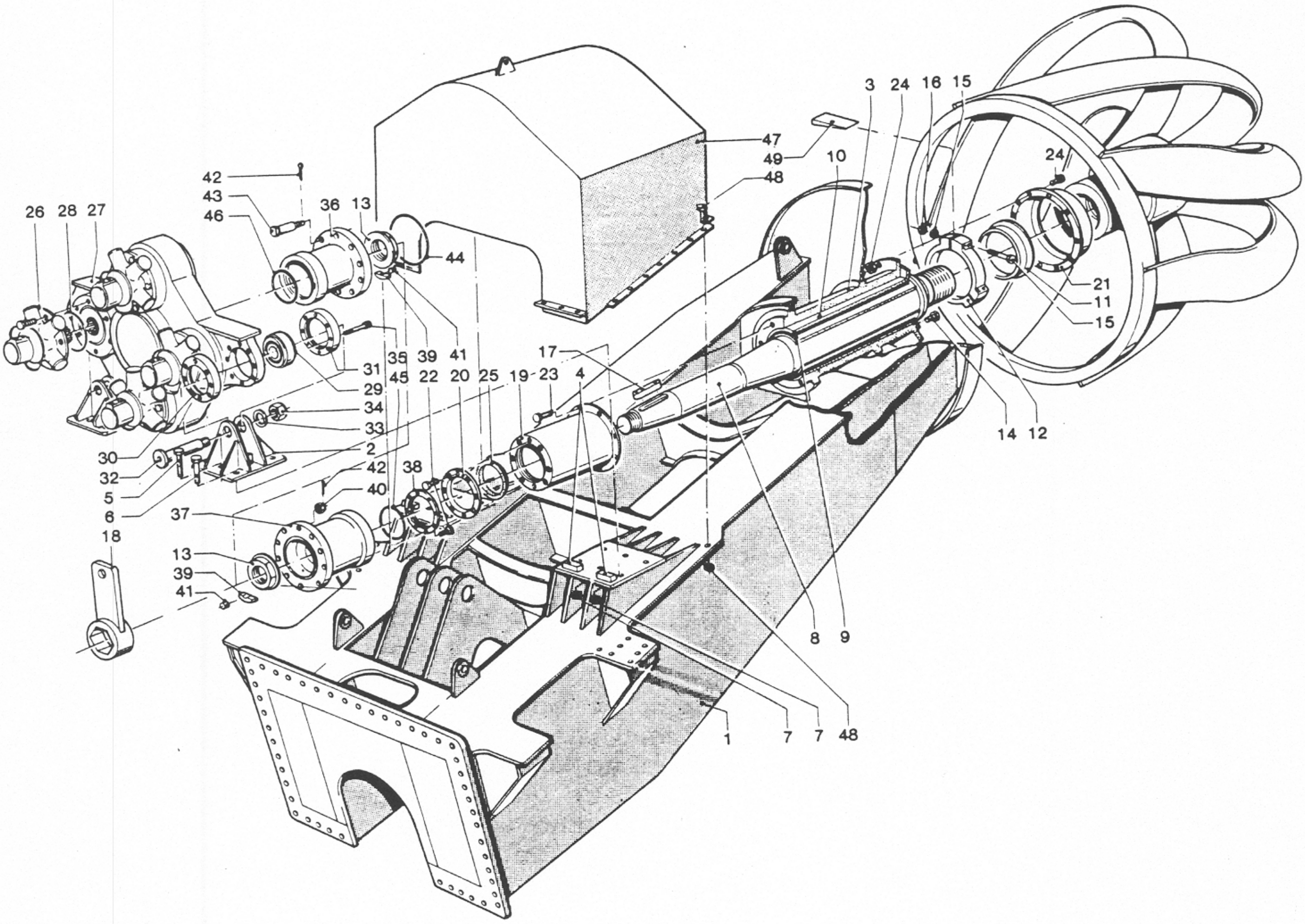


Figure 14   Cutter drive

WEIGHT

Taking the weight of the hydromotor into consideration, it is clear that hydromotors are capable of driving the cutter fairly directly. Generally several hydromotors (usually three to six) are placed on the shaft to co-operate with one gear.

SPEED REGULATION

Speed regulation of a hydromotor is effectuated by regulating the quantity of oil delivered to the motor. Such regulation might involve throttling in the delivery ducts or application of a pump with variable yield. The latter solution is expensive but loads the pump drive minimally.

Finally addition to the flow from other hydraulic pumps into the circuit is now a very commonly used method.

V REMOVING A CUTTER

The cutter is threaded onto the cutter shaft. In order to take it off, it has to be turned off. (This is what the turning speed arrangement is for.)

IMPACT

Because of the fact that during its work the cutter is jammed on very tight by impact, a special device has been incorporated in this design in order to enable us to take it off easily. Between the cutter hub and collar on the cutter shaft, a ring consisting of three parts is installed, the so-called tripartite clamp ring. One side of this ring is straight, while the other side is slightly tilted under a slight angle.

TRIPARTITE CLAMP RING

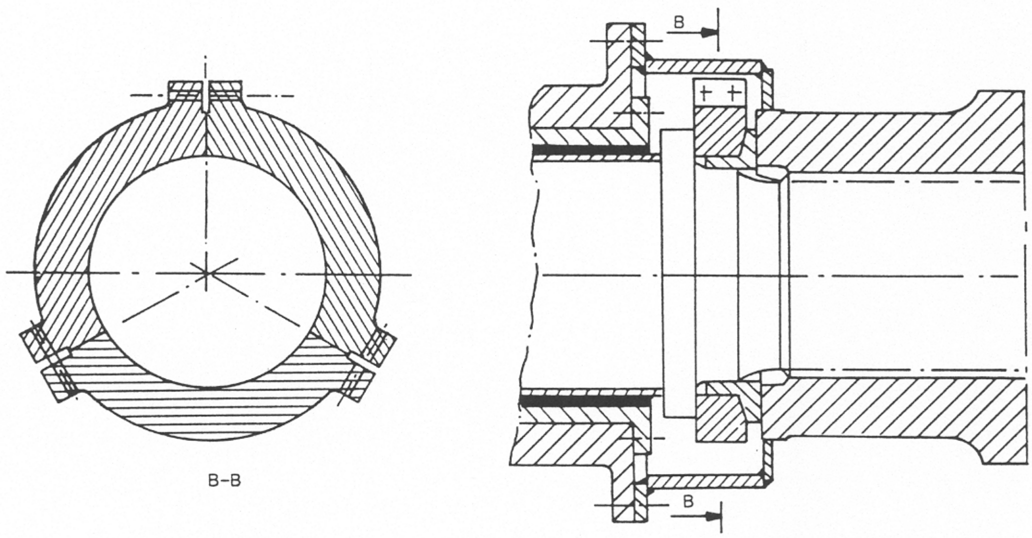


Figure 15 Tripartite clamp ring

By loosening the three parts of this ring from each other and freeing it from its space between hub and collar by means of wrenches, the tension of the tread will be eliminated and the cutter will run off freely.

Suspend the cutter before turning the cutter shaft in reverse rotation.

COVERED

The ring is not directly visible, but covered by a protecting ring, which also covers part of the cutter hub. Remove this protecting ring first.

BOLTS

Before putting the new cutter on, tighten the bolts of the tripartite ring.

VI MAINTENANCE

WEAR

Cutters, the most important devices in cutting, should be kept in optimum condition. Wear caused by friction and/or damage caused by the contact with hard soil should be repaired. Increasing wear reduces the efficiency of the cutting process resulting in a decrease of the production rate with respect to the power consumed.

Graphics can be constructed to determine the optimum time for repairing the wear. It is, however, very difficult, if not impossible, to collect exact data on the cutting process. Repair or exchange of the cutter for the above reason is done on the basis of accumulated experience.

STORAGE

When the cutter is stored on board or in a storehouse or when it is in operation for a long time, protection of the cutter form rust imperative. The conical key or the thread, depending on the mode of securing the cutter, requires special attention. When welding the cutter, the above two places should be protected from stain.

When the cutter is removed from the shaft it is advisable to grease the key or the thread directly and cover the hole in the hub with a wooden plate.

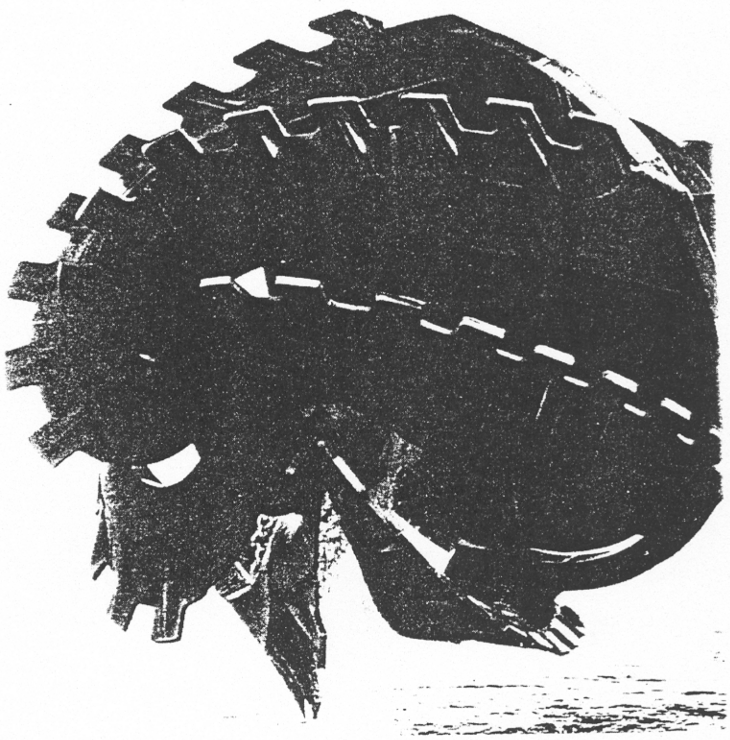


Figure 16 Cutter with serrated cutting edges

VII. REMOVING AND INSTALLING TEETH

CHECK

To check teeth on wear and damages, the cutter ladder should be raised above water at regular intervals. Teeth should never be allowed to wear to the extent that the adapter wears also, as a worn-out adaptor does not support its tooth as required, leading to the loss of its tooth.

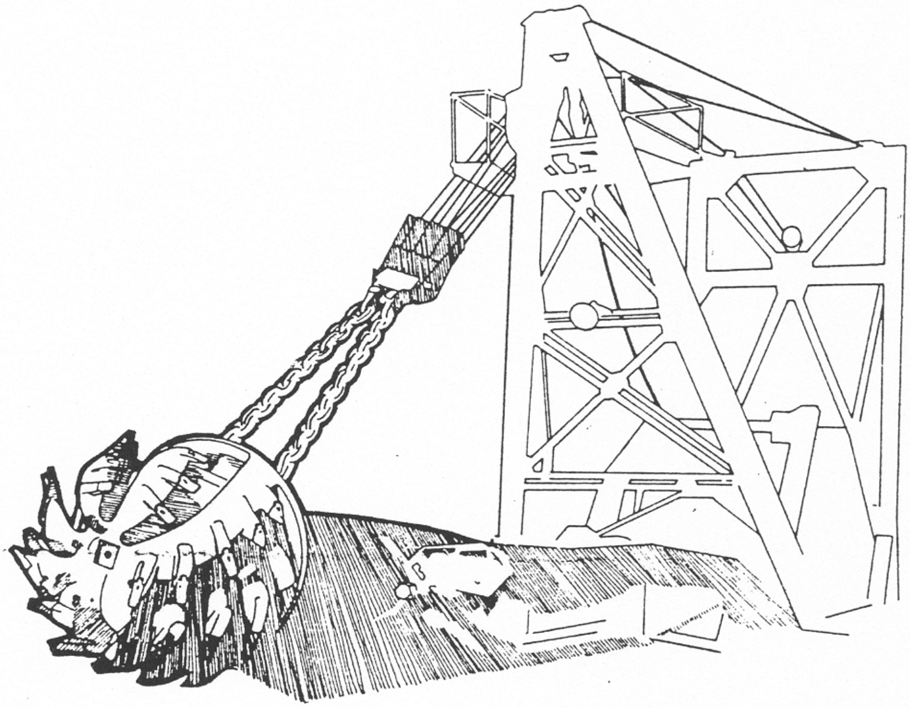


Figure 17 Raising the cutter ladder

FORWARD END

The teeth in the forward end of the cutter will wear out faster than the teeth in the other parts of the cutter. It is possible to change the teeth among themselves to lengthen the lifespan.

RECOMMENDED TOOLS

Changing a tooth should be done according to the specification of the manufacturer with the recommended tools. Usually a hammer and a pin removal tool are sufficient.

CLEAN

When replacing a tooth always clean the end of the adaptor with a wire brush and/or a putty knife and examine it for wear. Since a loose tooth wears the end of the adaptor, some manufacturers recommend to replace, other manufacturers say every time a tooth is replaced, other manufactures say every third time will do. Follow the manufacturer's instructions, but under no circumstances use a worn or damaged pin or rubber keeper again.

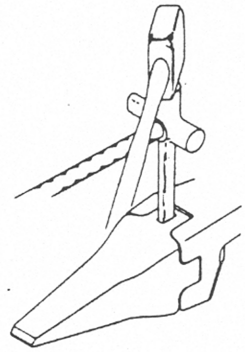


Figure 18 Hammer and pin removal tool

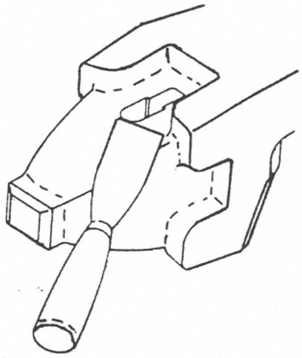


Figure 19 Clean the adaptor

RUBBER KEEPER

Before mounting a tooth, press the rubber keeper in the slot of the adapter, so that the ends not protrude.

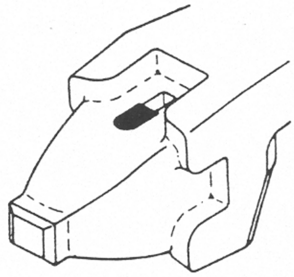


Figure 20 Rubber keeper in the slot of the adaptor

LOCKING PIN

Place the tooth on the adaptor, lining up the slots. Insert the metal locking pin, make sure this is done in the right way. Then drive the pin with the hammer into the slot. With some systems the pin snaps down into position whereby both ends of the locking pin protrude the tooth. With other systems the locking pin needs to be driven in until the pin is flush with the tooth. Check the manufacturer's instruction if you are not sure about the system used.

VIII REPLACING ADAPTORS

In this paragraph we will follow the instruction of Florida Machine and Foundry.

To ensure that the pitch of the teeth and the tooth point positions are accurately maintained when replacing adaptors, some field fabricated tools are necessary. These consist of an adapter locating fixture and an angle bracket.

HUB PLATES

An adaptor locating fixture consists of a central axis, a profile plane and a profile plane support. In order to establish a central axis about which the profile plane rotates, two hub plates are required. These plates are machined to fit the hub counterbores and held in place by tie bolts. The aligned centre holes form the centre line for the 5 cm centre pipe axis.

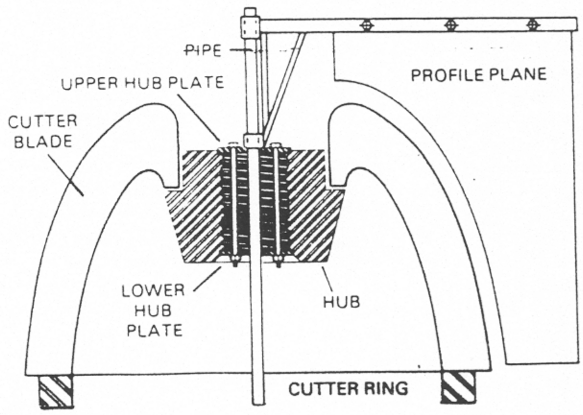


Figure 21 The adaptor locating fixture

PIPE

The pipe when installed is supported on the ground and protrudes through the top plate about 65 cm. The profile plane support is constructed as shown in figure 22 and slips over the 5 cm pipe axis and is free to rotate about it.

PROFILE PLANE

The profile plane is shaped so that when turned it just clears the end of the adaptors with the teeth removed.

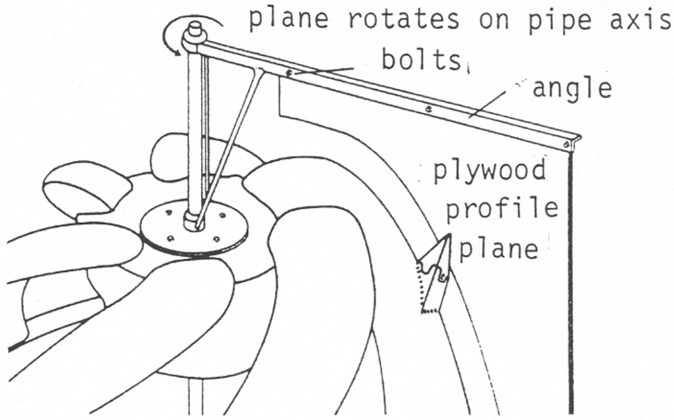


Figure 22 Profile plane support

PLATE

To fabricate an angle bracket, a flat steel working surface is required. First scribe a reference centre line on this working surface. Cut a plate with dimensions ± 1.6 mm x 175 mm x 225 mm. Scribe a centre line perpendicular to the 225 mm dimension. Align the centre line of the work surface and the place and tack weld. Using a replacement tooth scribe a centre line on the ends of the slotted ears for alignment with centre line on working surface.

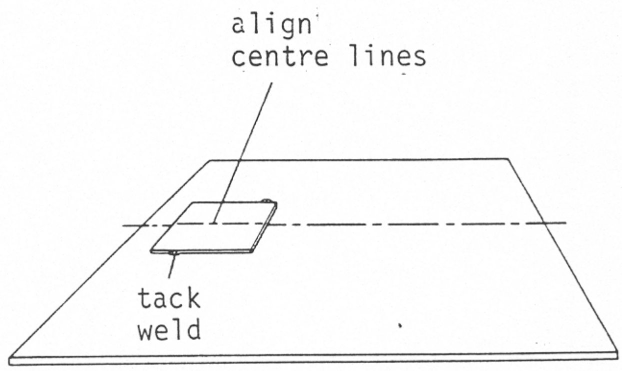


Figure 23 Working surface and plate

GUSSET

Cut a 1.6 mm plate steel triangular gusset, approximately 10 cm long as shown in figure 24. The angle of the gusset plus half of the included angle of the tooth point should equal 45° (or any other desired angle). Tack weld this gusset on the centre line of the plate. Place the tooth point at the gusset plate intersection and tack. Using a carpenter's square, align the centre lines of the slotted ears with the centre line of the working surface.

ALIGNING

It is important that the centre lines of the slotted ears, the plate and the working surface are aligned.

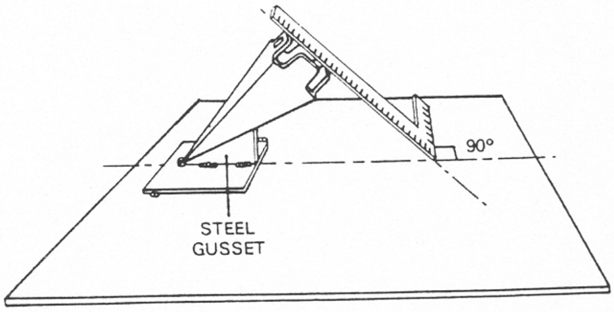


Figure 24 Alignment

ADJUST

Should it be necessary to adjust the tooth to align the centre lines, retaking the tooth point will soften the weld and allow the tooth to be adjusted to the square by hand. Then tack weld components securely for handling and detach from working surface.

Replacing weld-on adaptors

BEST RESULTS

To obtain the best results with a locating fixture, the cutter should be placed on a relative flat surface with approximately 1 meter of clearance around. All teeth should be removed from the cutter and all adaptors inspected for wear and cracks.

REFERENCE LINE

All broken or damaged adaptors should be burned off of the cutter. This is done only after measuring to the burning line from a known reference line on the cutter blade (figure 25).

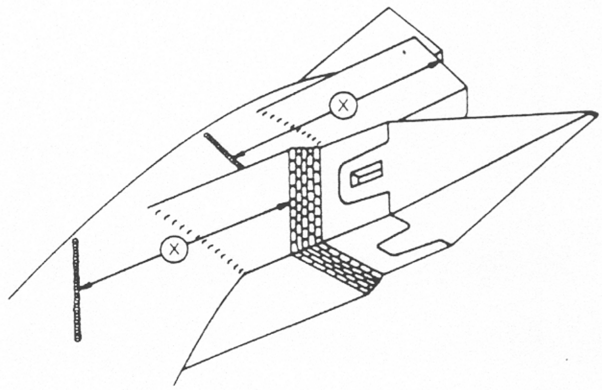


Figure 25 Reference line

With a wire brush or grinding wheel the adaptor landing portion of the blade is cleaned to remove all of the burning slag. Now the adaptor locating fixture with the vertical profile plane is put on the cutter hub. The location of the missing adaptor is determined by placing the angle bracket on one of the two remaining adaptors in the same circular row and bringing the profile plane against the angle bracket so that this position can be marked on the profile plane. Now the angle bracket is removed from the existing adaptor and clamped to the profile plane in the marked position. This method will ensure that the replaced adaptor when installed with its tooth will strike the same target area of ± 18 mm diameter as the other two points in that row. Now all dirt, paint and storage rust is cleaned from the base of the adaptor. The adaptor is now placed in the angle bracket and the assembly is swung against the landing of the blade.

PROFILE PLANE

ADAPTOR

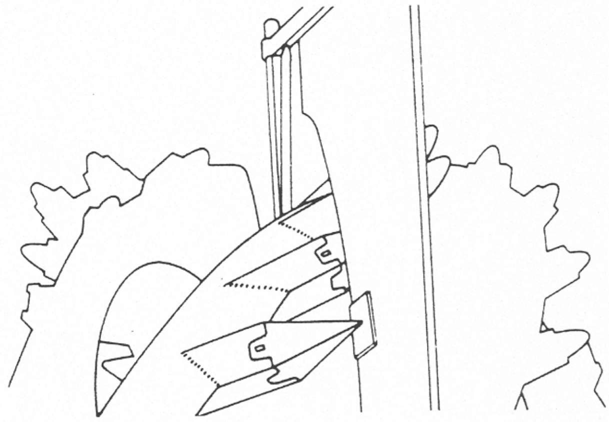


Figure 26 Angle bracket on one of the remaining adaptors

The adaptor is now tack welded to the landing from the inside of the cutter at the mid-width of the adaptor welding base. The angle bracket is now released from the profile plane. With the angle bracket still in place on the adaptor the profile plane is swung back to meet the angle bracket. If the angle bracket lays flat against the profile plane, the pitch of the adaptor is correct. If there is a gap where the two planes should meet, the tack is heated by striking an arc at the tack point, enabling the bracket lays flush against the profile plane. By observing this relationship during welding, the tooth point position can be controlled very accurately.

CORRECT PITCH

Now the adaptor is heated to 180 - 200 °C. With a small rod a root pass is run on one side of the adaptor. Then from the opposite side the "stand off" portion of the adaptor base is removed. This will ensure that a full penetration weld can be made from the opposite to the original root pass.

With a small rod a root pass is run on the opposition side of the first weld. 6 to 8 welds on each side are alternated until the adaptor is stabilized in position. With the angle bracket and the profile plane the tooth position is checked to be sure it has not changed.

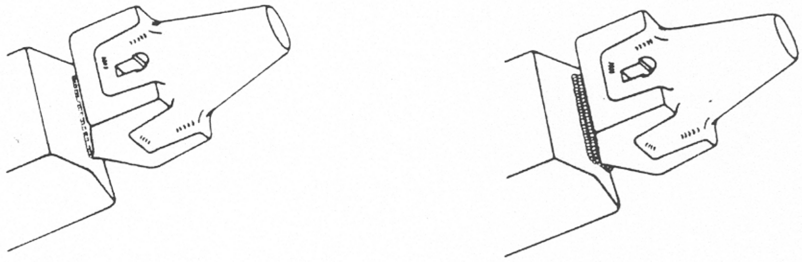


Figure 27 The welding

Now with bead width not exceeding two times the depth of penetration, half of the remaining filled weld on one side is completed. Then the opposite half of the filled weld is completed. Then the first side and the opposite sides are finished. The surface is cleaned and the tooth point position is checked again.

STRESS RELIEVE

It is recommended to get localized stress relieve if possible by heating the weld to approximately 425 °C and allowing it to cool slowly.

The replacing of other types of adaptors is done more or less the same way.

Figure 28 The welding