Willard Says……

The Full-Length Chain Ladder

Sand and gravel dredge miners often complain that one or more of the following problems interfere with satisfactory operation:

1. Cannot penetrate “hardpan.”
2. Pump plugs frequently.
3. Too much oversize rock.
4. Clay gums things up.
5. Lousy production.
6. High production cost.

Such complaints are very common where conditions are less than ideal. Ideal means little oversize, no clay, no cemented layers and a solids bank that slides down to the suction in a continuous stream as it is undercut. “Rare” is another attribute that applies to the concept of an ideal mining pit.

Other W*illard Says* papers address the virtues and shortcomings of various mechanical diggers. Here we explore the classic full-length chain ladder.

In 1936 an Iowa sand and gravel producer was granted a patent for a chain-type digging device for use on the suction inlet of a hydraulic dredge—a work of genius that is still in use. Likely he was experiencing one or more of the typical problems listed above and set out to conquer them.

In light of his difficulties, the Iowa guy probably sat back, took stock of his problems and decided that a new tool was needed—a chain digger.

The Ladder Frame

The classic chain ladder consists of a structural steel framework long enough to extend from the hinge pin/sprocket shaft located above water at the front of the dredge hull down to the maximum desired mining depth. A rule of thumb says that the maximum angle of incline should be about 60 degrees, which means that a 100-foot-long chain ladder can dig to a depth of about 85 feet. Another way to look at this rule of thumb would be to say that a chain ladder could dig to a depth equal to 85% of its length.

The frame has chain tracks built into its top and bottom structure and a 180-degree return track at the end. The radius of the return bend can be as small as 18 inches or as large as 48 inches. The suction pipe in fitted into the framework between the tracks.

The pathway along which the chain travels is usually fitted with replaceable wear strips. Replaceable manganese cast arc segments usually protect the pathway around the nose section.

The Chain

The digger chain resembles a humongous bicycle chain—large enough to have four to eight inch square openings through the links and weighing up to 140 pounds per foot. Rollers are mounted on the ends of each link pin so that the chain rolls along its track instead of being dragged. At regular intervals, perhaps every fourth link, the regular links are replaced by ones that have a projection that functions as a digger tooth. A crossbar can be fitted through the digger teeth to increase the digging action of the chain.

The digger chain drive sprocket is mounted on a heavy shaft located above water at the front of the dredge hull. The sprocket shaft also functions as the ladder hinge pin. Historically the drive mechanism consisted of open reduction gears mounted on shafts running in babbitt bearings powered by an electric motor or a hydraulic motor through a V-belt drive.

The chain runs in a track formed by angle irons that also function as top and bottom chords of the ladder structure. The suction end of the ladder, the “nose” is a semicircular section of track that forms a pathway to guide the chain from the lower track to the upper track. Normally the chain travels from the sprocket toward the nose in the lower track, upward over the nose onto the upper track and back to the sprocket. Travel speed is usually about 20 feet per minute; however, it can be as slow as 10 or as fast as 40 feet per minute.

The suction pipe is incorporated into the ladder frame and ends at a “nozzle” or expanded section that is fitted into the bottom inside section of the “nose.” The nozzle opens to include about 90 degrees of the 180-degree nose track. This arrangement assures that all solids entering the dredge system will be “screened” by the chain traveling across the nozzle opening. Rocks too large to pass through the chain links cannot enter the dredge system.

While the chain can travel either direction—assuming the drive is reversible—digging action is much more effective when it moves upward over the nose. Moving in this direction enables the chain to penetrate the solids bank, lift the solids forward and up past the nozzle. Particles small enough to pass through the chain links are pulled into the nozzle where they enter the suction pipe and flow to the pump inlet. Oversize pieces are conveyed upward and away from the suction area.

There used to be several foundries making digger chain. Each had a different concept of what was required to make a chain for this service. There were chains with small rollers, narrow rollers, multiple-part links, over-wide links, undersize pins, wimpy digger teeth and too often, really bad metallurgy. All these shortcomings—limited digging capability, relatively short service life, frequent breakage, high cost—made it easy to view the chain ladder as a money pit.

The Slack Adjuster

Classic full-length chain ladders featured a slack adjuster, a contraption provided to keep some tension on the chain. Gravity working on counter-weighted arms provided the force needed to take up slack in the chain while the ladder was up, horizontal and out of service. As the ladder was lowered and put in operation the gravity force acting on the counter weighted arms diminished to zero which meant that the slack adjuster ceased to function just when it was most needed—while the chain was operating.

Operation

The chain ladder is a slot cutter. Digging action takes place in a vertical arc about the ladder hinge pin. It is not designed to dig continuously while crowding sideways like a rotary cutter.

The dredge is anchored to remain stationary when the operating chain ladder is lowered into the solids bank. The vacuum will increase as solids enter the suction inlet and flow up to the dredge pump. The operator's job then becomes one of raising or lowering the ladder as required to maintain the desired vacuum (rate of production). When the bottom of the deposit is reached, the operator raises the ladder 6 to 8 feet, swings the dredge sideways 5 or 6 feet, lowers the ladder and repeats the digging cycle.

Positioning

The 3-wire positioning system is the most effective way to moor and maneuver a chain ladder dredge. It provides flexibility of movement and the ability to advance the dredge on the digging arc whenever necessary.

Some operators utilize a stiff discharge pipe as a radius arm about which to swing the dredge. The shortcomings (dumbness) of this scheme is thoroughly explored in the *Willard Says* paper, "Stiff-Pipeline Positioning."

The use of spuds to position a chain ladder dredge is likewise a bad idea and not recommended.

Hoist Winch

The chain ladder dredge operator's task is to raise or lower the ladder to maintain production. The required movements are frequent and small.

Older dredges often had (and have) mechanically controlled friction winches, which are physically demanding to use. Those who operated dredges with these winches soon developed the habit of waiting for the vacuum (production) to taper off to a considerable extent before gathering enough energy to operate the mechanical controls and lower the ladder to restore a satisfactory rate of production.

A more modern control system for friction winches was to add air/over controls. These are physically easy to operate, however, the operator gets absolutely no feedback that would

enable him to “feather” the winch or otherwise have any indication the amount of cable that is being take in or let out.

The chain is likely to stall if lowered too far. A stalled chain requires that the ladder be raised to restore digging action. Failure to utilize the proper hoist winch results in lost production and further tarnishes the reputation of the chain ladder.

The Chain Drive

Historically, there seemed to be a rule or design requirement that called for the chain drive motor, be it hydraulic, electric, gas or a diesel engine, to connect to the chain drive reduction gearing through a V-belt drive. Size or model, factory manufactured or home made, it had to have a V-belt drive.

Chain ladders are relatively powerful devices, which frequently encounter objects that are reluctant to move. Each time this occurs there are three possible outcomes:

1. The object’s reluctance is overcome.
2. The chain stalls.
3. Something breaks.

The first outcome is always the most preferred.
The second outcome is preferable to the third.
The third option must be prevented.

This is where the V-belt drive problem comes into play. Whether dumb design, ignorance or intent makes no difference—the V-belt drive became a sort of slip-clutch safety device in the drive train.

Astute operators prevented criticism for breaking something and avoided the trauma of having to shut down for repairs by adjusting the V-belt tension so it would slip well before anything broke. The result was a chain that stalled often, lacked aggressive digging capability, produced poorly and did not break.

Using the V-belt drive as a very imprecise slip clutch, adjustable to suit the whim of the operator, exposed to heat, cold and rain, did much to detract from the chain ladder’s reputation.

Fixed speed is another classic chain drive feature. A new chain has a finite number of miles that it can travel before it wears out and breaks. Per ton chain operating cost increases if each of those miles is not used to obtain maximum production. Digging conditions should dictate how fast the chain needs to run to satisfy production requirements. A fixed speed chain is usually too fast or too slow so it either wears out prematurely (too fast) or fails to support a capacity rate of production (too slow).

Advantages

The classic chain ladder offers many advantages over plain suction and several over a rotary cutter:

1. Effectively loosens solids and makes them available at the suction pipe inlet.
2. Concentrates the digging force in a small area.
3. Screens out oversize and eliminates interruptions caused by pump plugging.
4. Self-cleaning feature increases the ability to cope with clay.
5. Reduces the amount of clay delivered to the process plant.
6. Moves oversize away from the suction so it can not interfere with digging action.
7. Enables production to greater depths than is possible with any other digger.
8. Low power requirement.
9. Enables production in deposits that cannot be mined using a rotary cutter.

Hog Wash

The full-length chain ladder is usually credited for another feature that is in fact a figment of some folk's imagination. Supposedly, "they" say, the chain deals with oversize by conveying it up to the surface where it is dumped back into the water as the chain passes over the drive sprocket. This supposed ability (and consequent key to its success) to move the oversize away from the digging area by conveying and stockpiling it at a point well behind the suction does not hold up very well to even a superficial analysis.

Consider the chain ladder to be a conveyor. The dimmest of conveyor klutzes would have to agree that it is narrow, steeply inclined and moves very s-l-o-w-l-y. How many of these attributes would you specify in the next conveyor you buy? None? I agree. Case closed.

The fact is that particles too large to pass through the chain and enter the dredge system are conveyed upward over the nose of the ladder where the majority fall off to one side or the other. The accumulated oversize remains above the descending suction inlet where it cannot interfere with continuing digging action. A few oversized particles may ride the chain up to the sprocket, however, they are a very, very small percentage of the total available and waiting to teeter their way up this so-called "conveyor."

Disadvantages

When I came upon the dredging scene many users viewed the chain ladder as a necessary evil. Stress the evil part. They ignored the advantages and concentrated on complaining about maintenance costs and the high cost of a new chain. Classic chain ladders did not, and to some extent still do not have a "good name."

The ignorant focused on chain operating and maintenance costs while losing sight of the fact that their goal is to mine sand and gravel at a profitable rate. If they replaced the chain (and some did) with a rotary cutter they would diminish or eliminate the profit goal all together (and some did).

Some sand and gravel dredge owners belong to that band of inept businessmen who blunder along toward bankruptcy by failing to keep records. They measure success by the size of their bank account. The fastest way to do this is to not spend money on maintenance. It is these folks who are really steamed when faced with prospect of spending thousands of dollars on a new chain. Typically they react by making the operator fix the old chain "to get the life out of it."

It is easy to spot these owners because the decks of their dredges are strewn with a large collection of worn and broken chain parts. I watched many an operator stop and replace a broken chain part ever time one came to the surface to pass over the sprocket. This quarter-to-half-hour stoppage often occurred several times a day.

Does the old adage, "A chain is no stronger than its weakest link" fit in here somewhere?

I have yet to see a dredge producing when it is broke down.

Good record keeping enables owner to determine the *per ton* cost of operating their dredge as a whole as well as wear costs of specific items such as the pump and chain. Only very severe conditions will cause the per ton cost of chain operation to exceed 10 cents. A rotary cutter would fail utterly in conditions considered to be "very severe" for a chain. How much does it cost to operate a dredge that is producing poorly while mining only the top half of the deposit?

In general, the advantages of the classic chain ladder far outweigh the disadvantages.

One practical disadvantage is the difficulty of mounting a ladder pump on a full-length chain ladder. A customer insisted that we show him how to mount a ladder pump, bought used and cheap, onto his existing homemade full-length chain ladder. We did and he did and the marriage worked fairly well ugly as it was. The dredge pump was a problem. It had a Jack Daniels drive that caused no end of downtime just as it had for its previous owner. Jack Daniels drive? That would be one designed and built in Tennessee.

Comment, question, criticism, information on products mentioned?
Contact willard@willardsays.com