FEATURE STRAP

HAMMER OUT DIFFERENCES

Diesel piling hammers may have fallen out of favour in some parts of the world but the technology is worth modernising, given its low cost and high efficiency, argues Michael D Justason.

The technology behind the diesel piling hammer has not changed significantly since the machines were first produced by Delmag in 1938 in Germany. The underlying principle is simple: diesel fuel is ignited by the compression of air beneath a falling mass.

This combustion, together with the elastic collision between the falling mass and the pile (and other intermediate bodies), produces the required energy to return the falling mass to a sufficient height such that a self-sustaining, repetitive process is achieved. The purpose of this process is, of course, to drive a pile into the ground.

Although the basic principles have not changed in the past 65 years, there have been advances and there are moreover reasons for pursuing, modernising and perfecting this simple and efficient technology.

The merits of diesel hammers can be compared with hydraulic hammers in a number of ways. The purpose of the comparisons is to rationalise further development and modernisation of diesel hammer technology.

Berminghammer diesel hammers driving timber piles in the 1950s.

Operational criteria

Safety

Hammer manufacturers have addressed the issue of safety since it is a primary concern of all contractors and project owners. It is difficult to give an advantage to either diesel hammers or hydraulic hammers in this respect, as the safety of a pile driving operation depends more on the activities surrounding piling than the driving itself.

Reliability

The simplicity of operation of a diesel hammer gives it an advantage over hydraulic hammers in reliability.

A single acting diesel pile hammer can have as few as five moving parts, most of which can be serviced or replaced in a matter of minutes. As a self-contained, self-powered unit, a diesel hammer requires no

While problems with hydraulic hammers generally necessitate repairs by a qualified service technician or manufacturer representative, problems with diesel hammers can most often be diagnosed and solved by the contractor's own site personnel.

Familiarity

It would be difficult to find a piling contractor without experience with diesel pile hammers. While this may seem trivial, it can be a major factor in their selection of pile driving equipment. US contractors seem particularly loyal to diesel hammers.

Operating weight

The operating weight of a pile hammer can influence the selection of the crane or piling rig. Hammers (diesel and hydraulic) should be evaluated based on their actual impact energy (manufacturer's "rated" energy

a hydraulic hammer at an equivalent or lesser operating weight. A comparison of two of the more competitive hammer manufacturers is shown in **Table 1**.

Table 1 shows the diesel hammer has a higher impact energy by about 25% to 35% at the rated stroke while the operating weight is 15% lower. However, if the hammers are compared while running at the same blow rate (40 blows per minute, for instance), then the hydraulic hammer has a 10% to 15% higher impact energy, exactly offsetting the higher operating weight.

But it should not be forgotten that hydraulic units are generally large, and while they can sometimes be mounted on the back of the rig many times they cannot, creating an added complication to the mobility of the piling operation.

Dedicated hydraulic piling rigs can overcome this problem by incorporating the necessary hydraulic flow to run the hammer into the design of the base-unit itself.

In the area of operating weight diesels have the advantage.

Controllability

One of the main misconceptions about diesel hammers is that they are not controllable.

This is partly due to the fact that unlike hydraulic hammers, diesel hammers are "coupled" to the pile. In other words, the performance (impact energy) of a diesel hammer depends on the soil resistance and the mass and stiffness of the pile being driven. Likewise, the resulting capacity of the pile depends on the performance of the pile-driving hammer.

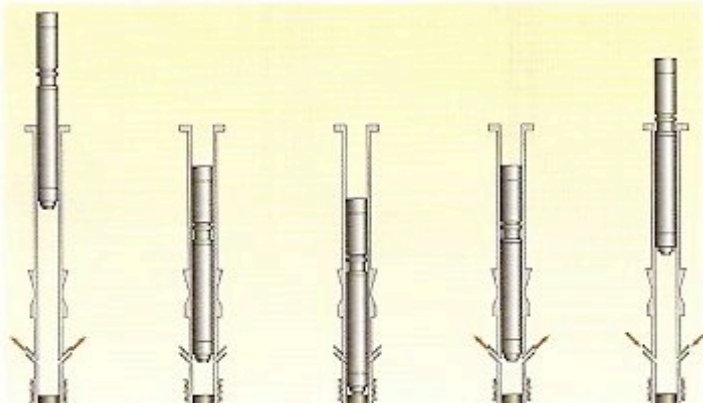


Table 1 – Comparison of operating weights for comparable 'impact energy' diesel and hydraulic pile hammers

	Hydraulic Hammer Junttan HHK3a	Diesel Hammer Berminghammer B21	Hydraulic Hammer Junttan HHK12a	Diesel Hammer Berminghammer B-6505
Rated Energy (kNm)	35	72	143	273
Impact Energy at Rated Stroke (kNm)	35	47	143	176
Impact Energy (kNm) @ 40-BPM	35	31	143	122
Ram mass (kg)	2,994	2,096	11,975	8,001
Operating Weight (kg)	5,897	4,900	21,772	18,597

This is one of the primary reasons why there has been a recent preference for hydraulic hammers, since the impact energy or "stroke" of a hydraulic hammer is relatively independent of pile resistance.

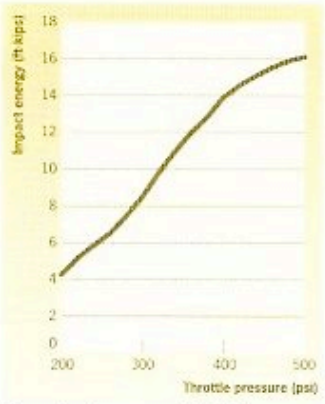
Proponents of diesel hammers tend to view the interdependency of the pile resistance and the hammer performance as an advantage rather than a disadvantage. When driving concrete piles the impact energy of a diesel hammer will be low when the soil resistance is low, thus helping to minimise potentially damaging tension stresses.

Proponents of hydraulic hammers can easily match this feature, as the energy of a hydraulic hammer can be set very low in soft driving and then increased as the pile gains resistance – mimicking the performance of a diesel hammer.

Another concern with diesel hammers is that the impact energy may suddenly increase and over-stress the pile. This can be a concern when driving piles through very soft soil to a hard rock bearing layer. It is also possible to over-stress a pile when using a hydraulic hammer, but perhaps less likely, due to the more controllable impact energy.

Traditional diesel hammers are equipped with discrete "energy settings" (four settings are common on Delmag hammers, for example). These settings control the amount of fuel delivered to the hammer, and thus the resulting stroke and impact energy.

More modern diesel hammers are equipped with an infinitely adjustable fuel delivery or throttle mechanism, which allows the operator better control over the hammer performance, up to the maximum performance "permitted" by the pile resistance.



Berminghammer infinitely adjustable hydraulic throttle pressure vs impact energy.

While these newer developments in throttling have increased the controllability of diesel hammers, the advantage of controllability must still be given to a properly functioning hydraulic hammer, as most governments and consultants are not yet familiar with the more modern diesel hammers.

Verifiability

On modern construction sites there is a new emphasis on quality assurance and quality control. In pile driving, QA and QC typically consist of pile installation records logging the number of blows per unit of penetration and the final tip elevation for each pile.

Very often, however, the performance of the pile hammer is not logged on the pile installation record, or more disturbingly, the pile hammer may appear to be operating at the desired impact energy, when in fact it is not.

This can lead to a potentially dangerous situation where piles are believed to have more capacity than they actually do.

Historically, the most common problem with diesel hammers has been the phenomenon of pre-combustion or pre-ignition. This problem still exists for diesel hammers using a fuel delivery system known as impact-atomisation, where diesel is introduced beneath the falling ram in a liquid state.

The liquid fuel spends a split-second in contact with the bottom of the combustion chamber known as the impact block. The impact of the ram then disperses the fuel and atomises it sufficiently for combustion to occur.

Pre-ignition occurs when the surface of the impact block becomes very hot (after continued hammer operation) and combustion begins before impact of the ram.

Unfortunately, a diesel hammer experiencing pre-combustion may not show any visible signs of a problem. The combustion pressure may still be sufficient to run the hammer with the desired stroke, yet the impact velocity may be reduced because of the increased gas pressure beneath the falling ram before impact.

Most modern diesel hammers that use a pressure-timed fuel injection system do not experience pre-ignition.

In the late 1980s Berminghammer offered proof that its fuel injected hammers did not pre-ignite. The firm equipped all of its Mark V Series hammers with an instrumentation port to allow monitoring of the impact velocity of the ram using magnetic proximity switches. Testing showed the fuel injected hammers did not experience a loss in impact velocity as the hammer temperature increased.

This led to further development of the velocity monitoring system to include other features for greater QA and QC in pile driving.

In 1990, Berminghammer offered a pile driving monitor (PDM) that included a depth logger and blow counter, calculated impact energy, pile number, cut-off elevation, date, time, project name, splice location, and other pertinent information.

The unit also had a small printer for a hard-copy of the electronic pile driving log. Berminghammer still offers an updated version of this monitor, which is seeing increased use in the US market, although the printer has been replaced by internal flash-memory, downloadable to a computer.

Some hydraulic hammers have built-in monitoring systems, usually on the hydraulic power unit, which can provide some impact velocity and/or energy information. But these features are only available on the more sophisticated models.

During the 1980s and 1990s, Pile Dynamics in the US and TNO in the Netherlands also developed the use of high strain dynamic testing of piles, commonly known as PDA (pile driving analysis or pile dynamic analysis).

Using PDA, engineers can affix strain and acceleration transducers to the pile and monitor the pile stress and delivered energy and using computer models can estimate pile capacity.

This has proved extremely useful in assessing the suitability of a pile hammer for a particular job and is best done during a test-pile programme. Many government organisations use PDA testing routinely to assess pile and pile hammer combinations.

In general, the "verifiability" of diesel and hydraulic hammers depends more on the particular model than it does the type of hammer. In other words, some manufacturers of both diesel and hydraulic hammers have addressed the QA and QC issues, while others have not.

Efficiency, effectiveness and cost

Efficiency

Since the introduction of PDA testing, the concept of "energy efficiency" has become popular when discussing pile driving equipment.

Efficiency can be defined as the percentage of a hammer's rated energy that gets delivered to a pile (as measured by a PDA testing system).

It is the nature of diesel hammers that some portion of the hammer's potential energy (ram mass x actual stroke) is used to compress air used for combustion. This results in an impact energy (or kinetic energy) that is less than that of a theoretically perfect falling mass.

Hydraulic hammers, in contrast, operate using a remote power source and do not need to use any of the ram's potential energy for the operation of the hammer, although frictional and other losses still occur.

Unfortunately, the industry rates hammers using the maximum potential energy of the hammer, which is clearly a flawed system when comparing diesel and hydraulic hammers.

More recently, consultants, PDA testing companies, and academics have begun correcting their terminology. What might have been referred to as "efficiency" is now referred to more correctly as the "energy transfer ratio".

This ratio is of interest when performing drivability studies, but should never be used to assess the efficiency of a particular hammer.

This terminology problem reached a critical point when, on several occasions, diesel hammers were actually excluded from project specifications. One actually declared: "Diesel hammers will

Modern diesel hammers have addressed controlability and environmental issues and have high efficiency and low cost.

not be allowed due to their inefficiency."

The incorrect usage of the word "efficiency" has undoubtedly hurt the diesel pile hammer market and there are a large number of contractors, consultants, and government engineers that still have a false impression of the "inefficiency" of diesel hammers.

The true energy efficiency of a pile driving system needs to consider the amount of "work" performed in a given period of time, and the amount of diesel fuel consumed to perform that work.

Although fuel consumption data for diesel hammers and hydraulic power packs to run hydraulic hammers is somewhat sketchy, a very rough approximation suggests a diesel hammer is between five to ten times more energy efficient than an equivalent hydraulic hammer. This fact alone is justification for the further development and pursuit of diesel hammer technology.

Effectiveness

In Table 1 it can be seen that for a given blow rate diesel and hydraulic hammers are very comparable in terms of the amount of energy delivered to the pile, for a given operating weight.

The two examples discussed show the hydraulic hammer delivering about 15% more energy per blow, but at and operation weight of about 15% higher. This suggests that the two technologies are approximately equivalent.

However, the diesel hammer is capable of operating at a 25% higher energy than that shown at the comparison level of 40 blows per minute. This implies that for a lesser operating weight, the diesel hammer can drive a pile to a higher capacity.

The nature of the energy delivered by a diesel hammer and a hydraulic hammer is fundamentally different. A diesel hammer uses a small mass at a high impact velocity to produce impact energy, while the converse is true of most hydraulic hammers.

The higher impact velocity of a diesel hammer is commonly believed to be more suitable for steel piles driven to a high capacity while the lower impact velocity of the hydraulic hammer is traditionally deemed more suitable for concrete piles.

These different characteristics of the two hammer types make them more "effective" for different types of jobs, with different types of piles and different types of soils.

The complications surrounding the whole hammer-pile-soil system makes the evaluation of the effectiveness of a particular hammer very difficult without actually driving a test pile.

And even when test piles are driven, it is rare that different hammer types are evaluated. The overall "effectiveness" of a pile driving hammer is probably best measured by the time required to drive a given pile, keeping in mind the cost.

Cost

Cost is probably the single most important variable in a contractor's evaluation of pile driving hammers.

In this respect, the contractor's loyalty to the diesel hammer is explained. For a given impact energy, efficiency, effectiveness, the cost of a diesel hammer can be estimated at 50% to 75% of a hydraulic hammer. With continued penetration of Chinese diesel hammers into the US, the cost can approach 30% of an equivalent energy hydraulic hammer.

As diesel hammer technology continues to catch up to hydraulic hammers in other areas such as controllability and verifiability, the issue of cost should ensure the continued presence of diesel pile hammers in the world market.

Environmental concerns

Recently, diesel hammers have fallen out of favour in some countries and urban areas due to their environmental impact – mostly, noise, vibrations, and black smoke.

In the UK for instance, it has been nearly 10 years since diesel hammers have been used. While no formal legislation prohibits the use of diesel hammers there, contractors have avoided using them.

Many observers of the global foundation equipment market would classify the diesel pile hammer as nearing the end of its product life cycle. It is estimated that between 150 and 200 new diesel pile hammers are manufactured each year by a handful of manufacturers, with the current trend being towards the manufacture of hammers in China.

Air pollution from diesel pile hammers has been addressed by Berminghammer as evidenced by its line of new "clean" diesel hammers. Other diesel hammer manufacturers are working towards this goal.

Fundamentally, however, the diesel hammer should have an advantage over hydraulic hammers with respect to exhaust emissions given their lower fuel consumption. However, conventional emission controls for diesel engines can be applied to the power units used to run hydraulic hammers.

Lower cost Chinese diesel hammers have not addressed the environmental concerns of air pollution and noise, but they have been successful using bio-fuels, as have the manufacturers of more sophisticated diesel hammers. Hydraulic hammer manufacturers also provide the option to run their hydraulic power units on bio-fuels.

Noise continues to be a challenge for manufacturers of both diesel and hydraulic hammers. Hydraulic hammer manufacturers have been more successful in this area due in part to their lower impact velocity, but also because a hydraulic hammer can be completely shrouded. It is more difficult to shroud a diesel hammer given its demand for clean air and air circulation for cooling.

Environmental concerns are an area of continued development for both diesel and hydraulic hammers.

Optimal pile driving

This is a developing area of pile driving. By combining the data from an on-board hammer energy monitor and the data from a conventional PDA testing system, together with a system for controlling the energy of a hammer (such as the remote throttle), it is theoretically possible to develop a control system to operate a hammer at the most effective energy setting, or perhaps a target energy.

The potential for an "intelligent" pile driving control system is very real, particularly with increased demand for QA and QC. So far the only hindrance has been the general lack of sophistication among hammer manufacturers, combined with a "separation" of manufacturers and design engineers and owners.

Conclusions

Comparisons between diesel and hydraulic hammers show diesel technology is worth pursuing and modernising. The main advantage they have over their hydraulic counterparts is high "efficiency" and low cost.

Diesel hammers also have advantages in operational criteria, efficiency, effectiveness and cost; and modern models (with energy monitoring and variable throttle) can generally be considered equal to hydraulic hammers in terms of controllability and verifiability. Hydraulic hammers are slightly more advanced when considering environmental effects, particularly noise.

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Pile driving analysis has proved very useful in assessing hammer suitability.