FADELPO
Groundwater and Wells

Sonic Pulses as a Methodology for Well Stimulation and Development

LINO DEL CAMPO CASTAÑEDA

SUMMARY

The current state of well stimulation, whether for extraction or water injection, is based on a combination of physical and chemical principles, such as brushing, piston action, jetting, airlift, and/or the addition of chemical agents. These techniques often exhibit varying efficiencies and require extended execution times, as well as incurring costly measures to mitigate their environmental impact. In this context, the use of sonic pulse generators for well stimulation, combined with airlift pumping and the use of a double packer system, when necessary, demonstrates the potential to overcome these limitations.

The generation of sonic pulses is achieved by the sudden release of pressurized gas inside the well, combined with a simultaneous airlift pumping. This combination of devices allows the simultaneous application of three physical principles. The pulse generator produces a focused high-power compressive wave, followed by a regressive wave due to the collapse of the air bubble inside the well and the instant evacuation of particles extracted from the capture to the surface through airlift. This process results in thorough agitation of the filtering zones, facilitating the removal of particles that reduce the porosity of the gravel bed and, consequently, the extraction efficiency.

INTRODUCTION

In recent years, progress in the development and improvement of techniques for stimulating newly drilled or operational wells has been limited. This is partly due to a lack of awareness among users regarding the importance of thorough stimulation after drilling and a lack of understanding of how well efficiency decreases over time, leading to higher operating costs.

Furthermore, a change in mindset among users has not contributed to this shift, as corrective maintenance is more common than preventive maintenance. A cause of this could potentially be that the latter often involves substantial costs and frequently offers limited economic returns compared to traditional methods of maintenance for well structures.

Well users and the market, in general, tend to believe that efficiency and potential savings are mainly achieved through improvements in the pump system and electrical equipment. However, according to Fadelpo's experience, these benefits are often much smaller than those achieved through proper maintenance of the well structures.

Currently, well stimulation techniques are based on mechanical or chemical approaches, or a combination of both. Mechanical methods include brushing, high-pressure water injection, compressed air application, piston action, liquid CO2 injection, dry ice, among others. On the other hand, chemical approaches involve acidification and the use of dispersants, among other techniques. Implementing these techniques requires mobilizing multiple equipment and personnel, as well as various actions and materials to mitigate environmental impacts. In the case of acidification methods, there are associated safety risks. These operations often take several days or even weeks, depending on the well's depth and the length of the filter section. This extended duration not only makes stimulations costly but also disrupts the water supply from the well. In cases where there is no alternative water supply source, it can sometimes mean the impossibility of using traditional maintenance methods.

In summary, although stimulation techniques for wells, both mechanical and chemical, have been developed, a lack of understanding of their importance and the logistical and environmental challenges associated with them have limited their widespread and effective adoption in the sector.

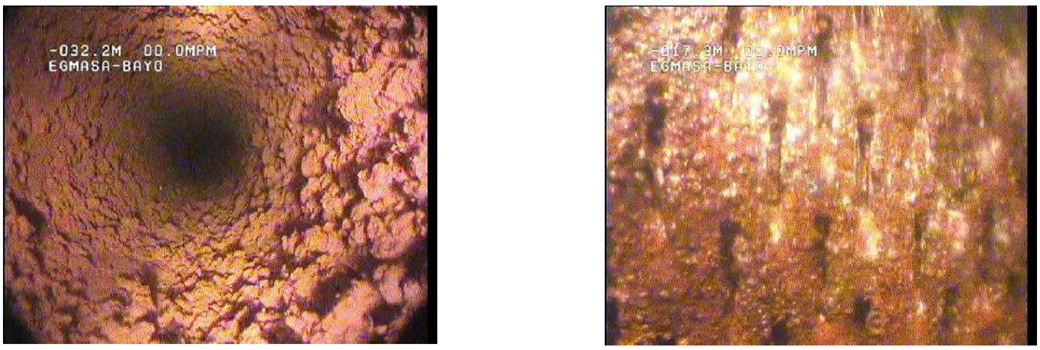

Figure 1: *State of the filtering zones in wellbores.*

OBJETIVES

With the aim of increasing efficiency in well stimulation processes and reducing execution times, FADELPO has developed a specific procedure and equipment for this purpose, known as the Well Rehabilitation Unit (WRU).

Sonic Generator:

The Sonic Generator is a device designed to suddenly release compressed air and in a controlled manner, reaching a working pressure of 350 bars in a span of 0.08 milliseconds. This release of air is directed perpendicular to the filtering sections of the wellbore. The action generates a high-energy expansive wave followed by a regressive wave. The magnitude of released energy is measured in TNT equivalents, ranging from a few grams to half a kilogram per pulse. The impact zone of each pulse covers approximately 35 centimetres of the well's filter section. Fadelpo offers several types of standard pulse generators and has the capacity to manufacture generators tailored to the conditions and needs of each well or project.

Figure 2: *Illustration of the sequence for generating the discharge of compressed air at 150 bars using the pulse generator.*

Stimulation Process:

The energy released in the form of an expansive wave penetrates the slotted pipe and the gravel pack, reaching several meters into the aquifer formation. The high-energy shockwave dislodges any particles adhered to the filters, the gravel pack, and the interface with the aquifer formation. The subsequent regressive wave, generated when the air bubble collapses inside the well, induces a rapid inward flow, allowing the dislodged particles to flow into the wellbore.

This back-and-forth process in the filtering zone causes intense agitation in the gravel bed, facilitating the breakup and mobilization of embedded or precipitated particles that have reduced the original filter permeability. The removal of sludge and fines, which were not eliminated during the initial well cleaning, is also achieved, as well as recompacting the gravel pack.

Airlift and Monitoring System:

The pulse generator is inserted and operated through the airlift pipe. Simultaneously, the material extracted by the sonic pulsing of the filtering zones is removed to the surface through the airlift system, allowing for efficient control of the solid content in the water. The airlift pipe is placed as close as possible to the interval of filters to be stimulated, maximizing the suction of solid particles from the filter interval. After stimulating one filter, the process proceeds to the next interval and repeats. During this procedure, the water reaching the surface reduces its solid load and turbidity as the process progresses. A video camera can be introduced into the airlift pipe to visualize the state of treatment within the interval.

Figure 3: *Insertion of the generator inside the airlift pipe, along with the discharge head, and the extraction of embedded material.*

Specific and Chemical Cases:

In specific situations where it is necessary to isolate an aquifer section or work with chemicals, the end of the airlift pipe is equipped with a double packer system that allows for the creation of a window between the two packers to perform pulses in that area. By isolating this region, if the usage of chemicals is needed, the required amount will be minimal and will only affect the isolated section.

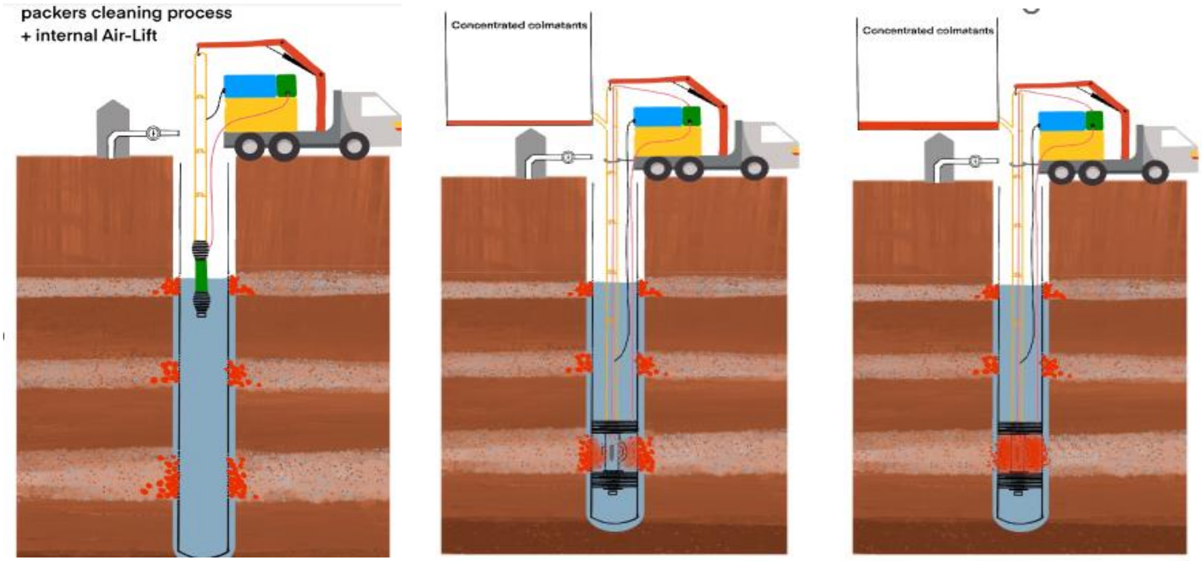

Figure 4: *Sequence of insertion, inflation, and pulsing through the double packer.*

SETS OF EQUIPMENT INVOLVED IN THE PROCESS

The complete process involves the operation of two independent sets of equipment, the WRU and the airlift system, detailed below:

Well Rehabilitation Unit (WRU):

1. ***Winch for Pulse Generator Handling:***
   - Line capacity: 1500 meters.
   - Assisted by a 7.5 kW electric motor with frequency converter.
   - Capability to switch between short and long range.
   - Operating speed from less than 0.5 cm/second to over 3 meters/second.
   - Clutch with tension-adjustable slip.
   - Controlled free fall with hydraulic brake.
   - Locking system via hydraulic brake.
   - Winding control with adjustable pressure roller.
   - Depth controlled using optical encoder, load cell (0-1000 kg) for line tension, motor electrical parameters, and adjustment and control of pneumatic system pressures.

2. ***High-Pressure Pneumatic Control Panel:***
   - Used to modulate the working pressure of the pulse generator within a range of 0 to 350 bars.
3. ***High-Pressure Compressor System and Accumulation Cylinders:***
   - Capacity: 48 m^3/hour at 330 bars.
4. ***Auxiliary Elements:***
   - Includes specific tools, lighting, etc.
5. ***Pulse Generators and Foldable Centring Systems:***
   - Equipped with devices to maintain proper alignment during operation.
6. ***Side/Front Video Camera System:***
   - Capable of visual inspection up to 800 meters.

Figure 5: *Pressure Control Panel (left) and Operations Winch (right).*

Air-Lift System:

1. ***Surface Head with Lifting System:***
   - Used for the assembly and handling of the pipe.
2. ***DN4 Air-Lift Pipe:***
   - Used for pneumatic pumping, API N80, 4" inner diameter, with threaded tips forming quick couplings through a double flexible cord.
3. ***Inflation Valve:***
   - Regulates air injection in the air-lift process.
4. ***Centring Devices:***
   - Maintain the pipe in the proper position.
5. ***Air Injection Hose Reel:***
   - 300 meters of SAE100 R1 hose. Used for injecting air in the air-lift process.
6. ***Surface Rack Feeder for DN4 Pipe:***
   - Organizes and supplies the air-lift pipe. Provides full assistance in pipe assembly and disassembly.
7. ***5" Discharge Hose:***
   - Used to convey the pumped water flow out of the well installation to the final line cyclone.
8. ***Settling Cyclone and V-Notch Sampler:***
   - Used for flow control and sample collection from the process.

9. ***Double Packer System:***
    - Allows isolation of specific well zones for particular tasks, such as chemical injection.

RESULTS

The entire surface equipment, tools, and resources have been configured according to the described procedure. This involved adapting existing tools as well as designing and manufacturing new ones to ensure maximum procedure efficiency. The time required to carry out the process is one to two days, depending on the depth and condition of the filtering system. It is important that this process does not have any impact on the structure and surface installation of the well. The same crane used to uninstall the pump is utilized for the process.

The results obtained by FADELPO using this system have consistently shown a flow rate increase of over 30% in all cases. Additionally, there has been a significant rise in the dynamic level of the well, and in some cases, positive variations in the static level have been observed.

Results Examples:

Before: Flow Rate 12 m^3/h

After: Flow Rate 45.0 m^3/h

Before: Flow Rate 21.0 m^3/h

After: Flow Rate 65.0 m^3/h

Before: Flow Rate 20.0 m^3/h **After**: Flow Rate 33.0 m^3/h

Figure 6: *Results before and after sonic pulse stimulation.*

This technology has proven its effectiveness in both existing well maintenance and newly drilled wells. For example, in a newly drilled well with filters at a depth of 700 meters, after a traditional stimulation of 7 consecutive days, a flow rate of 77 m^3/h was achieved. Following this stage, the sonic pulse process was applied for 7 hours along the length of the filters, resulting in a flow rate of 108 m^3/h.

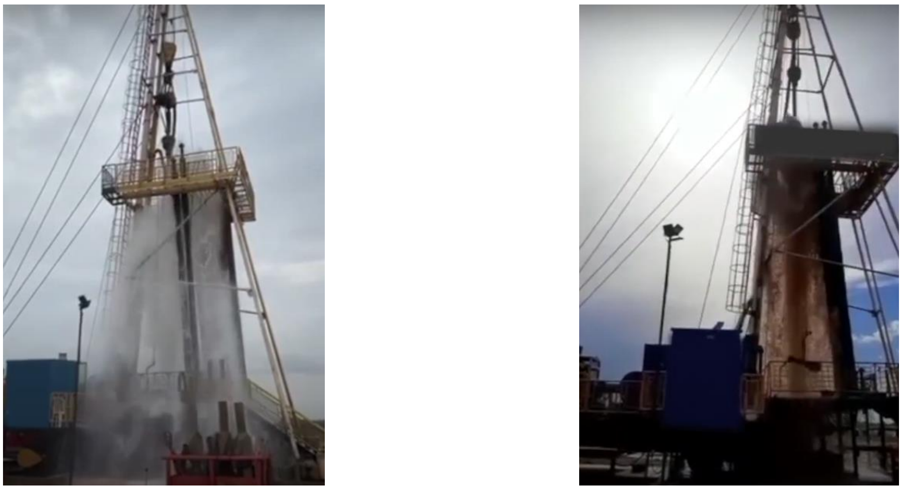

Figure 7: *Sonic pulse stimulation (right) expels a large number of particles that traditional stimulation (left) could not.*

It has been verified that this technology provides approximately four times greater cleaning durability compared to traditional systems. This is primarily due to the deep cleaning that affects the screen, gravel pack, the formation interface with the drill, and the formation itself within a variable radius of influence, depending on the hydraulic characteristics of the lithological formation.

The effectiveness of this system has been demonstrated even in cases of heavily fouled pipes, as illustrated in Figure 8.


Figure 8: *Before and after the application of sonic pulses on a 600mm pipe with 9cm thick calcium carbonate deposits.*

This approach has also been successfully applied to sub-vertical drainage wells, achieving flow rate increases of over 200%, as shown in Figure 9.


Figure 9: *Effect of pulse application on sub-vertical drains inside a tunnel.*

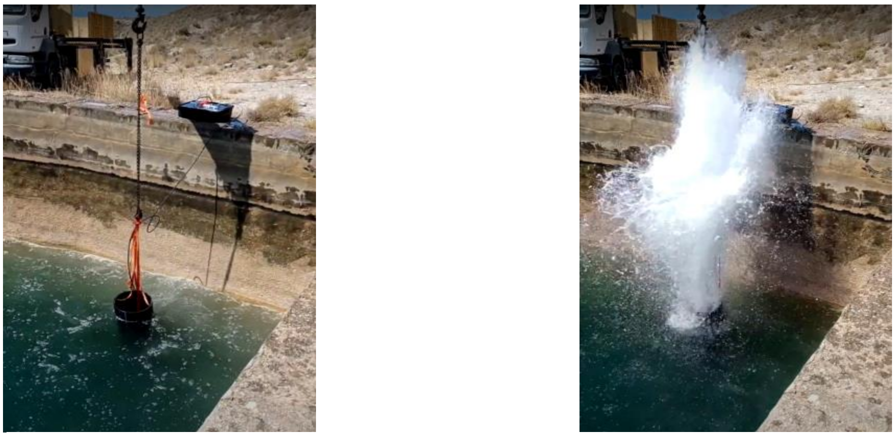

Figure 10: *Demonstration of pulsing on an open pipe.*

CONCLUSIONS

This pulse system, integrated with the airlift technique, has demonstrated superior efficiency compared to existing methods, with a significant reduction in intervention times, no impact on surface installations, and increased cleaning effects durability. Handling pumped flow with a substantial solid load is simplified, and the need for chemical use is minimized, thereby reducing operational costs.

In summary, this innovative approach has proven to be highly efficient and cost-effective, delivering remarkable results in terms of flow improvement (filtration system efficiency) and increased cleaning durability compared to traditional methods, which are more costly and time-consuming.