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Application of Soap Sticks for Enhanced Stimulation in Geothermal Wells: Case Study of Lahendong Field, Indonesia

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ABSTRACT

The use of soap sticks for well stimulation in the geothermal industry is limited, yet they demonstrate promising potential for improving well discharge efficiency. Reducing the surface tension of water in the wellbore makes it easier for brine to flash into steam. While this method has been successfully employed in inducing eruptions at geyser manifestation, its application in geothermal well stimulation still needs to be explored. This study explores the application of soap sticks as a surfactant-based stimulation method in three non-self-discharging wells in the Tompaso Prospect, Lahendong Geothermal Field, Indonesia. Field trials in wells TPS-1, TPS-2, and TPS-3 demonstrated that combining soap sticks with air compression significantly enhanced discharge potential. TPS-1, with a bottom-hole temperature of 298°C and a feed zone at 2,100 meters, failed to discharge despite multiple air compression attempts up to 95 barg. Notably, TPS-2 and TPS-3 achieved sustained flow at a reduced air compression pressure, lowering the required pressure by up to 25% (22.5 barg lower) compared to targeted stimulation pressure from the Sta Ana method (Af/Ac). These findings validate the effectiveness of soap-assisted stimulation in geothermal wells, particularly in liquid-dominated reservoirs with deep feed zones where conventional high-pressure stimulation methods fall short. Further empirical research is essential to validate the broader applicability of soap sticks and explore additional innovative approaches for effective geothermal well stimulation across varying conditions and fields.

1. INTRODUCTION

Geothermal wells are categorized as either vapor-dominated or liquid-dominated systems. Some liquid-dominated wells, despite having high permeability and temperature, may not be able to self-discharge due to having a high-water column. Non-self-discharge wells require stimulation before they can effectively produce two-phase fluids. Unlike artesian wells, which naturally flow due to sufficient reservoir pressure, non-self-discharge wells lack the pressure needed to lift geothermal fluids to the surface. Several stimulation methods can be used to start the discharge process. These include pressurizing the well, gas lift, steam or two-phase injection, and workover (Grant & Bixley, 2011; Mubarok & Zarrouk, 2017).

An alternative technique for stimulating non-self-discharge geothermal wells includes the application of soap or surfactants. The utilization of soap sticks in geothermal settings is not a new concept. According to Zarrouk & McLean, 2019, soap stick stimulation can be done in geothermal wells that are <100 meters from the casing head flange (CHF). Additionally, soap has been used to trigger eruptions in geothermal manifestations such as The Geysers in California, Yellowstone National Park in the United States (Hague, 1889; Hurwitz & Manga, 2015), and the Lady Knox Geyser in Waiotapu, New Zealand. The surface tension of water drops when surfactants are added (Mata et al., 2022; Zarrouk & McLean, 2019). This makes it easier for steam bubbles to form and grow, which improves fluid discharge. This method gives tourists accurate eruption times and shows how surfactants might be used to stimulate geothermal wells by lowering surface tension and increasing fluid discharge.

The Af/Ac method used to determine whether a geothermal well requires stimulation by predicting whether it will self-discharge (see Table 1). This method helps to assess the pressure needed to increase the chance of discharging the well effectively. StaAna (1985) developed the Af/Ac method, an empirical technique that compares Af (Area of Flashing) with Ac (Area of Condensation). Before attempting stimulation, one must measure the static downhole pressure and temperature to apply this method. Based on Mubarok and Zarrouk (2017) the Af/Ac method matches how wells behave during discharge testing, making it an effective way to predict when to stimulate a well**.**

Table 1 The range of Af/Ac ratio criteria (StaAna, 1985).

Af/Ac Ratio	Discharge Prediction
< 0.70	Little or no chance for successful self-discharge
0.70 – 0.85	Uncertain discharge
> 0.85	Excellent chance for successful self-discharge

The Lahendong geothermal working area, located in North Sulawesi, Indonesia, comprises two main prospects: the Lahendong Prospect and the Tompaso Prospect (see Figure 1), and it is believed that these systems are separate geothermal systems (Prabowo et al., 2021). The Tompaso Prospect currently operates with an installed capacity of 40 MW, with plans underway to increase this by an additional 50 MW in the coming years. The Tompaso Prospect is characterized by a liquid-dominated reservoir with temperatures ranging from 250°C to 330°C. Production wells in the area typically exhibit reservoir temperatures of 260°C to 280°C. Most wells in the Tompaso Prospect are directional wells and require stimulation to initiate flow, whether for electricity generation or production testing. This study includes the stimulation of one monitoring well and two newly drilled exploration wells using the combination of soap stick and air-cap methods.

Figure 1: Maps of Lahendong geothermal working area, consisting of Lahendong prospect and Tompaso prospect.

2. FIELD DATA

The application of soap sticks in geothermal well stimulation has demonstrated effectiveness in improving well discharge, like the conventional technique of soaping the geyser to trigger eruptions. Soap sticks triggers fluid flow in wells with discharge difficulties by reducing surface tension resulting in changes in phase. In the Tompaso geothermal field, we applied this method across several wells, combining soap stick usage with air compression to boost their initial capability. Each well possessed distinct conditions, requiring unique stimulation strategies. The following parts include an overview of the field data from TPS-1, TPS-2, and TPS-3, explaining their responses to this method and the knowledge acquired from this process.

2.1 Well Stimulation in TPS-1

TPS-1 is a monitoring well that was drilled in 2011. Numerous attempts to stimulate the well through air compression proved not successful, leading to its future use for reservoir monitoring in the Tompaso prospect. While drilling, the well encountered total loss of circulation (TLC) at around 2,100 meters measured depth (1,800 mTVD), with a bottom-hole temperature of 298°C. The deep-feed zone had no output due to its depth and the cooler temperatures present above it. The well had a wellhead pressure of 0 barg when idle, with the water level at a depth of 200 meters.

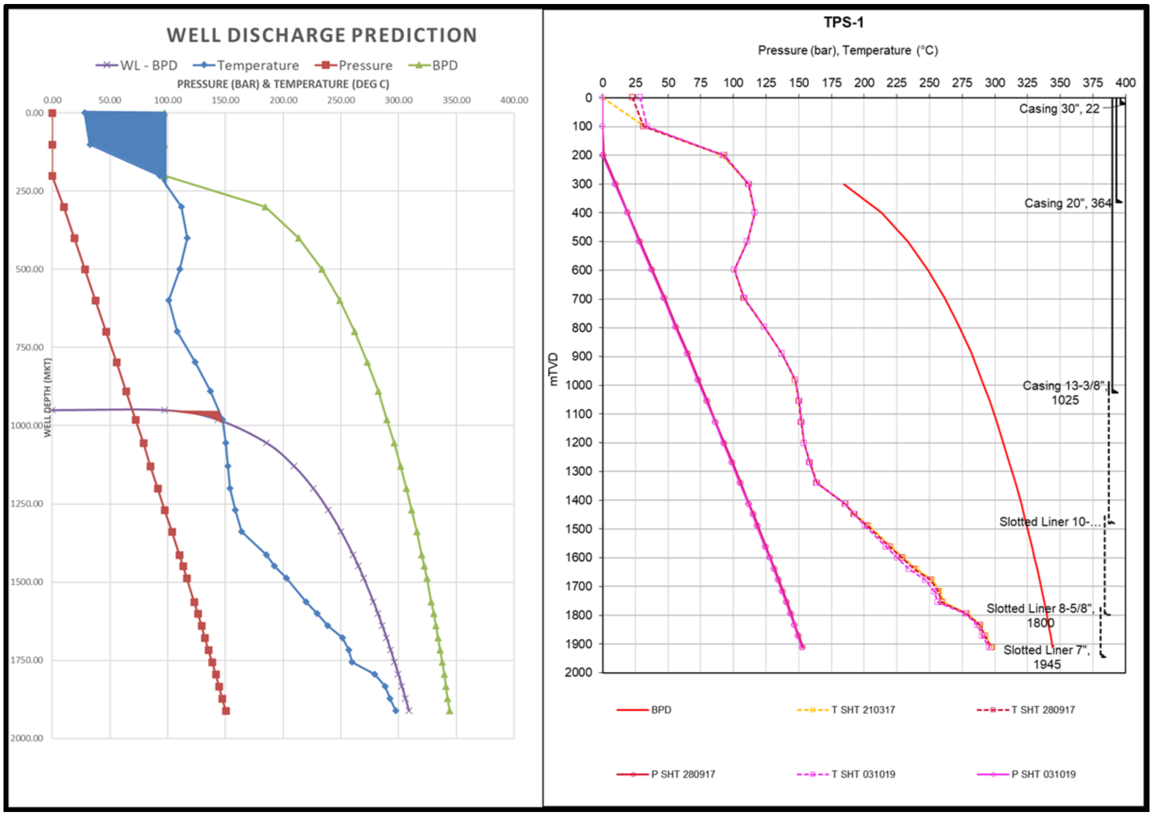

Figure 2 Profile of Af/Ac method in TPS-1 with 95 barg of compression (left), and original pressure temperature profile of TPS-1 (right).

The Af/Ac method categorized the well as non-self-discharging. Despite air compression reaching 95 barg, the Af/Ac ratio stuck at 0.072, indicating low probability of successful discharge based on Sta. Ana (1985). Figure 2 illustrates the pressure and temperature profile of TPS-1 when combined with its Af/Ac ratio. It was determined that air compression up to 95 barg was not sufficient for well stimulation using air compression, leading further compression trials with different holding times, as detailed in Table 2.

Table 2 Air compression pressure, holding time, and result of well stimulation in TPS-1

No.	Air Compression Pressure (barg)*	Holding Time (days)	Af/Ac Ratio	Soap Stick	Result
1	93	3	9.3 * 10-5	No	No discharge
2	91	5	9.3 * 10-5	No	No discharge
3	95	17	0.072	No	No discharge
4	93	1	9.3 * 10-5	Yes	Discharge

*Air compression pressure at first compress is 95 barg, at the table are the pressure just before opening the valve

A slight pressure drop was observed during air compression attributed to condensation. The well was periodically repressurized every three days to maintain pressure, ensuring it reached >90 barg before to each discharge test. A stimulation attempt was conducted using soap stick addition along with air compression at 95 barg for a holding period of one day. Approximately 4,400 grams of soap stick were introduced into TPS-1, resulting in the successful stimulation of continuous flow. The trial indicated that the application of soap sticks improved stimulation, promoting sustained flow.

Through the manipulation of parameters including holding time and air compression pressure in the first three attempts, it was established that the critical factor distinct unsuccessful from successful discharge was the addition of a soap stick. The surfactant decreased the surface tension of the water, thereby promoting flashing. Soap sticks were selected instead of liquid surfactants because of the well's deviation, which facilitates a deeper penetration into the reservoir. To assess the effectiveness of surfactant-based stimulation, identical methods were used for TPS-2 and TPS-3.

2.2 Well Stimulation in TPS-2

TPS-2 is an exploration well drilled in 2023, which later underwent production testing following the reaching of its static temperature. Under static conditions, the well demonstrated wellhead pressure of 0 barg. Total loss circulation (TLC) occurred during drilling shortly after reaching the casing point. The reservoir feed zone depth in TPS-2 is different to that in TPS-1.

The Af/Ac method categorized TPS-2 as a non-self-discharging well. However, the well demonstrated the potential to achieve an Af/Ac ratio of 0.85, indicating a high likelihood of discharge, with a minimum air compression pressure of 87.5 barg.

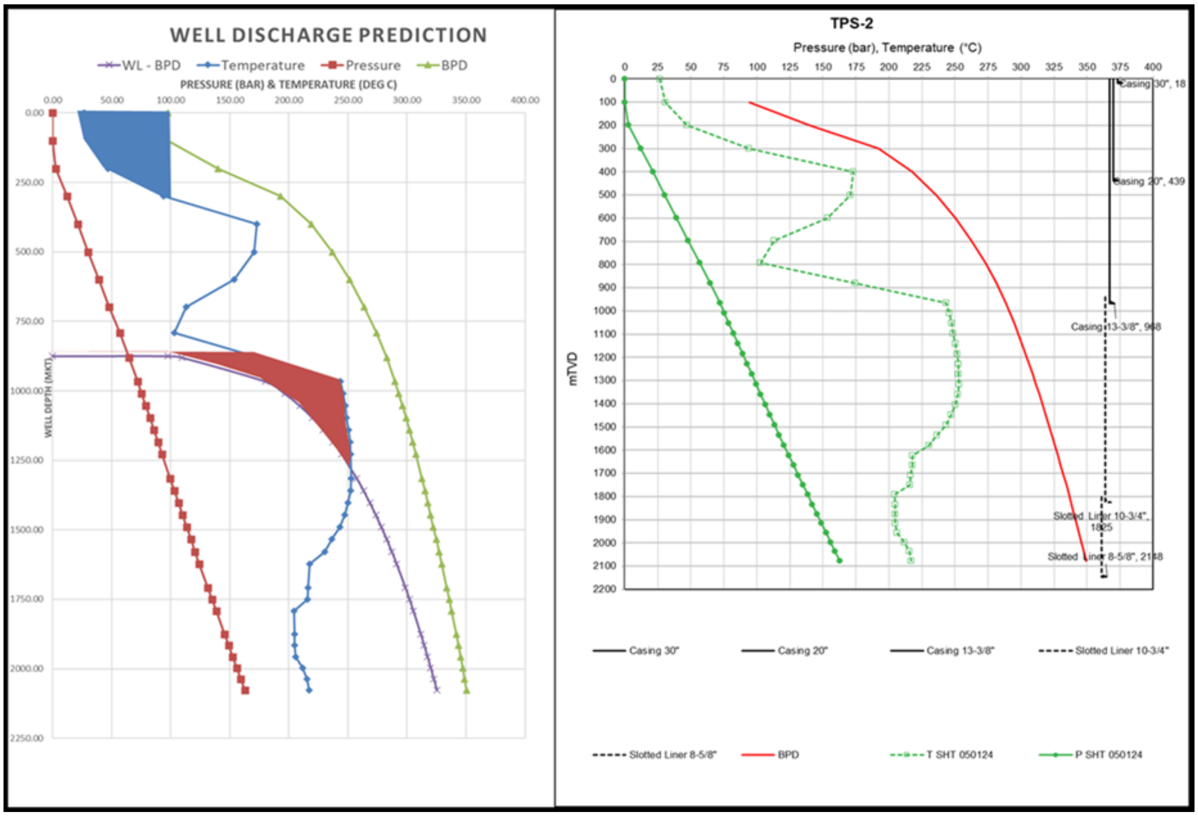

Figure 3 Profile of Af/Ac method in TPS-2 with 87.5 barg of compression with Af/ac ratio >0.85 (left), and original pressure temperature profile of TPS-2 (right).

Figure 3 shows that TPS-2 has a reservoir temperature of 250°C, with the water level at a depth of 200 meters. TPS-2 was stimulated using a combination of soap stick and air compression, applying the same soap stick concentration per water column volume as in TPS-1. Stimulation was conducted at 65 barg, compared to the typical 87.5 barg required to achieve a high probability of self-discharge. Under these conditions, the Af/Ac ratio was 6.17×10^{-5}, indicating a minimal likelihood of discharge as classified by Sta. Ana (1985). With the addition of soap sticks, TPS-2 successfully discharged at an air compression pressure of just 65 barg, reducing the required pressure by 22.5 barg (25.7%) for successful well discharge. The well had stimulation done on two occasions under identical conditions, resulting in successful discharge each time.

2.3 Well Stimulation in TPS-3

TPS-3, an exploration well, was drilled in 2023, reaching a total measured depth of 2,930 meters. The well initially experienced total loss circulation (TLC) at a recorded depth of 1,135 meters (mMD). The static temperature reaches a maximum of 275°C at true vertical depths ranging from 1,300 to 2,000 meters (mTVD), with the water level at a depth of 200 meters. Like TPS-2, TPS-3 observed an inverse temperature gradient beneath 2,000 mTVD. The Af/Ac approach categorized TPS-3 as a non-self-discharging well, required a minimum stimulation pressure of 88.5 barg to achieve an Af/Ac ratio over 0.85 (see Figure 4), indicating a high probability of discharge.

To stimulate TPS-3, the identical soap stick concentration utilized in TPS-1 and TPS-2 (20 grams/m³ of water column) was employed. In the initial experiment, following the addition of the soap stick and the application of air compression at 65 barg, the well effectively discharged and proceeded to production testing. According to Sta. Ana (1985), air compression at 65 barg yields an Af/Ac ratio of 7.54×10^{-5}, indicating a small chance of discharge. Nevertheless, the introduction of surfactant (soap stick) enabled TPS-3 to discharge at a reduced compression pressure, illustrating the surfactant's efficacy in augmenting well stimulation.

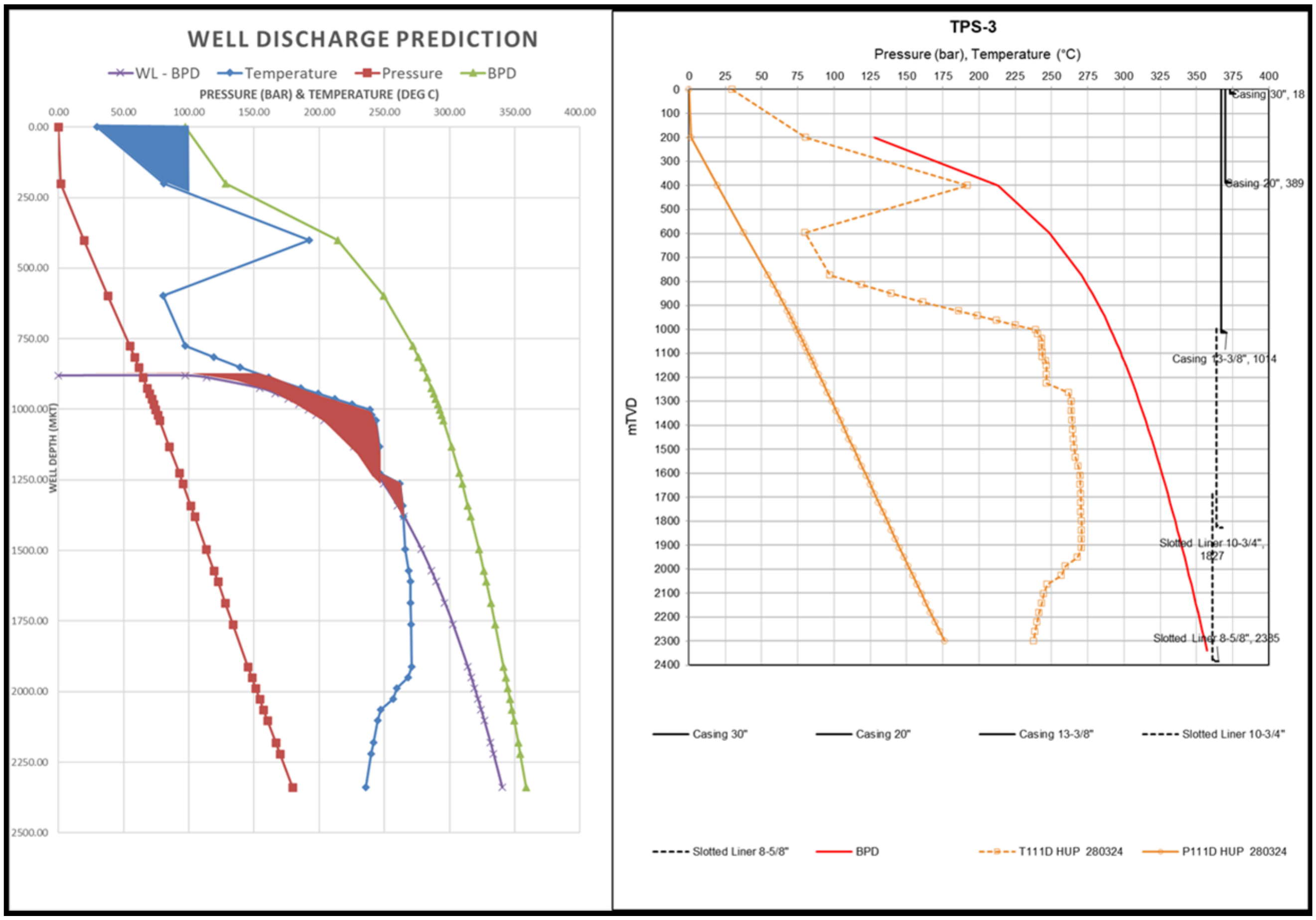

Figure 4 Profile of Af/Ac method in TPS-3 with 88.5 barg of compression with Af/ac >0.85 (left), and original pressure temperature profile of TPS-2 (right).

3. DISCUSSION

Air compression is a common method for stimulating geothermal wells, as it operates independently from any other well, in contrast to well-to-well stimulation. This makes it particularly ideal for exploration wells that are frequently drilled in secluded locations. However, the depth of the production casing typically limits the effectiveness of air compression. Below this threshold, the injected air is susceptible to leaking into surrounding feed zones.

Zarrouk & McLean (2019) previously examined the application of soap sticks for stimulating geothermal wells with water levels less than 100 meters. Our field trials indicate that the integration of soap sticks with air compression effectively stimulates wells with water levels reaching depths of 200 meters.

All three tested wells successfully discharged following surfactant stimulation via air compression. TPS-2 and TPS-3, having the same well characteristics, necessitated identical pressure to commence flow. Both wells adhered to the Sta. Ana (1985) ratio requirement of Af/ac > 0.85, and stimulation was accomplished with only 65 barg of air compression. The other case, TPS-1, which includes a deep reservoir feed zone, which overlaid by a cooler reservoir. This condition prevented efficient stimulation through air compression alone.

The outcomes show that surfactant-assisted stimulation works well in geothermal wells, especially those with deep, high-temperature reservoirs where reservoir pressure is insufficient to overcome the static water column. From Efficiency perspective, the application of surfactants reduced the necessary air compression pressure to meet the Af/ac > 0.85 criteria, further demonstrating the Sta. Ana (1985) approach in practical applications.

4. CONCLUSION AND FUTURE WORK

Despite their historical application in stimulating natural geysers like The Geysers in Yellowstone, U.S., and Lady Knox in Waiotapu, New Zealand, the utilization of soap sticks and surfactants remains uncommon in the geothermal industry. Authors conducted a study on three non-natural discharge wells in the Tompaso prospect within the Lahendong working region, yielding promising results. The integration of soap sticks with air compression proved effective as an additional stimulation method, effectively discharging wells that had previously been unsuccessful with air compression alone. Additionally, adding surfactants lowered the required air compression pressure for stimulation by as much as 25%, meeting the Sta. Ana (1985) criteria of Af/Ac > 0.85.

Initial results show that surfactants could be useful in geothermal well stimulation. However, more research is needed to be sure that they work in all types of fields and reservoir conditions. Later research on wells with different rock types and fluid types will figure out the best amount of surfactant to use and how it works to lower the surface tension of the water, and the pressure needed to compress the air. By using surfactants in more geothermal conditions, we can learn more about how they improve stimulation and improve the overall efficiency of geothermal business.

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