Purification of harvested tree stumps by means of pulse swirling hydraulic jets

I A Polyanin¹, K N Nikonorov¹, A V Egorov¹, M N Voldaev¹, A V Lysyannikov², Yu F Kaizer² and K S Stepanova¹

¹Volga State University of Technology, 424000, Yoshkar–Ola, 3, Lenin Square, Russia
²Siberian Federal University, 660041, Krasnoyarsk, 82/6, Svobodny Avenu, Russia

E–mail: kaiser171074@mail.ru

Abstract. The article deals with the separation of soil, bark and rot from the surface of the tree stump before its further use in the production of turpentine and rosin. Developed and manufactured installation for experimental studies of the operating parameters of pulse swirling jets of liquid under the influence of the treated tree stump. In general, the dependence between the parameters of the pulse swirling liquid jet and its impact on a stationary object is revealed. In general, the dependence of the influence of the initial parameters of the pulse swirling hydraulic jets on the width of the treated surface of the harvested stump when removing soil, bark and rot is established. The convergence of theoretical and experimental data for determining the width of the treated surface of the harvested stump by pulsed swirling jets of liquid is estimated, the maximum divergence of 3.0 % in determining the width of the treated surface when removing rot.

1. Introduction
The present level of development of methods of processing of materials are characterized to be wide enough using pulsed hydraulic processing. A significant number of works by modern researchers are devoted to solving the problems of scientific and technical justification of pulsed hydraulic materials processing [1-9].

One of the possible directions of application of pulsed hydraulic processing is its use in logging enterprises in solving the problems of useful use of stumps remaining in the cutting area after the completion of operations of cutting trees.

The most valuable part of the harvested stump is pneumatic osmol, as it is a raw material for turpentine and rosin production.

After uprooting the tree stump, it contains a large amount of soil (about 40-50 % of the total weight), bark and a small root system. In the complexity of obtaining pneumatic osmol, the specific weight of cutting and cleaning is from 35 to 50 %.

The aim and the main task to be solved is the development and scientific justification of the operating parameters of the process of cleaning harvested tree stumps by pulsed swirling hydraulic jets.

The essence of hydraulic treatment of harvested stumps is the impact on the harvested tree stump hydraulic jet fed under high pressure on the surface to be treated. As shown by the results of preliminary studies, the use of pulsed hydraulic jets in the treatment of the surface of the stump has low efficiency and high cost.
To improve the efficiency of processing the surface of a prepared stump is possible using pulsed twisted hydraulic jets.

2. The development and scientific substantiation of parameters of the cleaning process of harvested stumps impulse twisted hydraulic jets

To solve the problem of increase of efficiency of processing of harvested stumps hydraulic jets to Volga state University of technology has developed an installation hydraulic pulse cleaning stumps from the soil, bark and rot, which ensures compliance with the technical requirements of raw materials supplied to the enterprise for the production of turpentine and rosin [10].

The schematic diagram of the experimental setup is shown in Figure 1. The installation works as follows, the high-pressure pump 7 from the feed tank with water 8 delivers the working fluid through the pressure nozzle 10 to the pulse swirling fluid jet shaper 11. Shaper pulse of swirling fluid jets 11, takes the pulse of a swirling jet of liquid at the surface of the tree stump 23. Using the horizontal platform 12 moves the shaper pulse of swirling jets of liquid 11 to a vertical post 16 by the actuator 14 and chain transmission 15, at the same time there is an effective cleaning of the processed tree stump from soil, bark, rot and small root system. Simultaneously with the vertical movement of the shaper pulse of swirling jets of liquid 11, the rotation of the workpiece 23 stump on the platform 6 from the actuator 17 through a gearbox 18.

![Figure 1](image-url)

**Figure 1.** The scheme of experimental installation: 1 - tank 2 filtration tank; 3 - drain hole of the tank; 4 - oblique cap; 5 - cross, 6 - platform 7 - high pressure pump, 8 - a nutrient tank with water, 9 - suction nozzle, 10 - pressure tube, 11 - shaper pulse of swirling fluid jets, 12 - horizontal platform 13 is a vertical platform 14 - a drive 15 - chain transmission, 16 - vertical stand, 17 - drive, 18 - reducer, 19 - sieve, 20 - casing, 21 - fastening the stump, 22 - motor 23 - process tree stump.

Removed from the surface of the stump soil, bark and rot with liquid fall on a sieve 19. The small fraction of ballast passes through the sieve 19 and the inclined lids 4 falls on the filter mesh, where it is clear of the water.
3. Mathematical modeling of pulsed hydraulic swirling jet

The main element of the developed installation is the generator of pulse swirling jets of liquid 11, so the determination of the parameters of its useful effect is the most important component of this work.

Consider some aspects of hydrodynamics, in relation to the generator of pulsed swirling jets of liquid.

The momentum of the swirling jet of liquid is directed to a solid flat surface, which for the purpose of simplification is assumed to be cylindrical and is considered in a rectangular XY coordinate system (Figure 2).

![Elementary jet in the coordinate system.](image)

The total number of motion pulse elementary swirling jet is expressed from the sum of a pulse component and rotational.

\[
M_{total}^1 = M_{impuls}^1 + M_{rotat}^2
\]

(1)

where \(M_{impuls}^1\) - impulse component of the amount of motion; \(M_{rotat}^2\) - rotational component of the amount of motion.

\[
M_{total}^1 = M_{impuls}^1 + M_{rotat}^2 = \int_{S_1} \rho \nu_{impuls}^2 (H, t) dS_1 dt + \int_{S_1} \rho \nu_{rotat}^2 (H, t) dS_1 dt = \rho dt \left( \nu_{impuls}^2(t) + \nu_{rotat}^2(t) \right) (H, t) dS
\]

(2)

where \(S_1\) - pulse component of the amount of jet motion; \(S_1\) - rotational component of the amount of motion of the jet; \(\rho\) - liquid density; \(\nu_{impuls}^1(H, t)\) - the velocity of the impulsed component of the medium; \(\nu_{rotat}^1(H, t)\) - the speed of the rotating component of the medium; \(dS_1\) - the cross-sectional area of the pulse-swirling jet; \(dt\) - time increment of the pulse-swirling jet.

System of equations for determining the rise and fall of variable pressure with time change \(t\).

\[
\begin{align*}
    p_1(H, t) &= p_{min} + k_1 p_{min} t, & \text{at } t_{min} \leq t \leq t_{max} \\
    p_2(H, t) &= p_{max} - k_2 p_{max} t, & \text{at } t_{max} \leq t \leq t_p,
\end{align*}
\]

(3)

where \(p_1(H, t)\) - the force of the impact of the pulse component of the jet on the barrier; \(p_2(H, t)\) - the force of the rotational component of the jet on the barrier.
Hence, the impact force of the pulse swirling jet of liquid is defined as

\[
P(H,t) = \rho S_0 (\phi^2 + \gamma^2 + 4(p_{\text{max}} - p_{\text{min}})S_0) + \omega^2 \left(4(p_{\text{max}} - p_{\text{min}})S_0/\rho \omega^2\right)
\]

provided \( t_{\text{min}} \leq t \leq t_{\text{max}} \) and \( t_{\text{max}} \leq t \leq t_{\text{p}} \).

The maximum force of the impact of the pulse swirling liquid jet on the barrier:

\[
P_{\text{max}}(H,t) = 2S_0 \phi^2 p_{\text{min}} (1 + k t_{\text{max}}) + \frac{4 P_{\text{min}} - 4 S_0 P_{\text{max}}}{\rho},
\]

where \( P_{\text{max}}(H,t) \) - the impact of the pulsed swirling flow over an barrier; \( S_0 \) - area of outlet nozzle; \( P_{\text{min}} \) - minimum pressure in the hydraulic pulsator; \( P_{\text{max}} \) - maximum pressure in the hydraulic pulsator; \( \phi \) - speed coefficient depending on the profile of the nozzle of the hydraulic pulsator; \( k \) - coefficient of pressure drop in the hydraulic pulsator; \( t_{\text{max}} \) - the time of the maximum value of the force of impact of the jet on the barrier.

4. Experimental technique and methods of processing the results

Experimental studies on the removal of soil, bark and rot were carried out on full-scale samples of tree stumps. As varied factors selected distance from the outlet nozzle of the shaper pulse of swirling jets of liquid to the work surface \( l = 0.08 \pm 0.4 \) m; the diameter of the outlet of the shaper pulse of swirling jets of the liquid \( d_0 \), the magnitude of pressure before the injector driver impulse of swirling jets of liquid \( p_0 \), pulse repetition frequency \( f = 16 \pm 32 \) Hz, the angular frequency of rotation of the jet \( \omega_c = 30 - 60 \) s\(^{-1}\). The experiments were carried out at a constant feed rate of the working body equal to 1 m/s. As a result of experimental studies, regression equations of the influence of independent initial parameters of pulse swirling hydraulic jets on the width of the treated surface of the stump were determined in General form when removing soil, bark and rot.

Taking into account the coefficients found regression equations of mutual influence of independent parameters on the width of the treated surface have the form

\[
B_{\text{soil}} = (0.0095 + 2.0093 f^{0.5326})0.6366 p_{\text{u}}^{0.1184} (0.1421 - 0.0091 f^{0.2545})0.6352 \omega^{0.189},
\]

\[
B_{\text{bark}} = (-4.7553 l^2 + 2.3072 l + 0.2212)0.0983 p_{\text{u}}^{0.5435} (0.1944 - 0.0049 f^{0.2761})0.00965 \omega^{0.7},
\]

\[
B_{\text{rot}} = (0.0223 + 1.5464 l^{0.8062})0.1872 p_{\text{u}}^{0.6596} (0.1632 - 0.0059 f^{0.3524})0.1885 \omega^{0.55}.
\]

Comparison of experimental results with numerical values calculated according to the above-obtained dependences showed that the average relative error did not exceed values of 0.7% for regularities characterizing the removal of soil; and 1.7% on characterizing the removal of bark; 3.0% - for dependencies, characterizing the removal of decay.

5. Conclusion

- The scientific and technical justification of the impact of a pulse swirling jet on the surface of the treated tree stump has been developed.
The obtained functional dependences of the width of the treated surface of the tree stump on the influence of the initial parameters of the pulse swirling hydraulic jets.

The estimation of the convergence of theoretical and experimental data determine the width of treated surface of a tree stump pulse spun by jets of liquid, the maximum difference of 3.0% in the determination of the width of the machined surface when removing rot.

References
[1] Wendler B, Kozariszczuk M and Bange S 2016 Increased productivity of a steel wire pickling line with integrated high-pressure water jet treatment Stahl und Eisen 136 55–60
[2] Careddu N 2010 Surface treatment of ornamental stones by high-pressure, water-jet technology Mining Engineering 62 44–50
[3] Stafslien S J, Bahr J A, Daniels J W, Wal L V, Nevins J, Smith J, Schiele K and Chisholm B 2007 Combinatorial materials research applied to the development of new surface coatings VI: An automated spinning water jet apparatus for the high-throughput characterization of fouling-release marine coatings Review of Scientific Instruments 78 (DOI: 10.1063/1.2755965)
[4] Tuovinen O, Pitarilla V and Pietinen P 2003 New active water jet stone conditioning control for stable groundwood pit pulp quality at MAXIMIZED grinder motor loads International Mechanical Pulping Conference pp 141–7
[5] Ota S, Ishimura T and Tamura T 1997 Improvement of fatigue strength of fillet-welded joints by water jet treatment of weld toe region Welding International 11 528–37
[6] Klemm L, Meyer A, Ehrler P and Hottner M 1996 Use of water jet technology in finishing International Textile Bulletin Dyeing/Printing/Finishing 42 39–40
[7] Başyiǧit M and Özçelik Y 2013 Geostatistical investigation on water jet surface treatment Rock Characterisation, Modelling and Engineering Design Methods - Proceedings of the 3rd ISRM SINOROCK pp 267–71
[8] Borkowski P 2004 Properties of high-pressure hybrid jet used for surface treatment 17th International Conference on Water Jetting: Advances and Future Needs pp 161–9
[9] Borkowski P 2003 Basis of high-pressure water-ice jet creation and application for surface treatment Computational and Experimental Methods 7 85–95
[10] Polyanin I A and Nikonorov K N 2014 Hydroinsulator RF patent № 2531286 4 p