Design of a small press for extracting essential oil according VDI 2221

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Abstract. The paper presents a constructive solution to the original construction of a small mobile press for the extraction of essential oils of plant origin. The press is hand-operated, intended for field treatment of plants harvested in mountainous areas. The construction of the press is made according to the special requirements of the client who plans the mass production of the press, so the price limit is a priority. The research was done using the principles of methodical design according to the standard VDI 2221.

1. Introduction

The extraction of plant oil extracts (essential oils) is an interesting small business. Essential oils, also called volatile odoriferous oil, are aromatic oily liquids extracted from different parts of plants, for example, leaves, peels, barks, flowers, buds, seeds, and so on.

There are several ways to extract oil from plants and trees. For example, there is distillation and solvent extraction in which the plant is infused in other substances to extract the aromatic particles. But when extracting oil from the seed, cold pressing is preferred. This process is used for most carrier oils and many essential oils. This process ensures that the resulting oil is 100% pure and retains all the properties of the plant. The cold pressing process does not need an external substance as with other methods. The seeds are crushed and pressed in order to force the oil out.

The term cold pressed theoretically means that the oil is expeller-pressed at low temperatures and pressure. Cold pressed method is one of the best methods to extract essential oils. This process is used

![Figure 1. Cold pressing method.](image)

![Figure 2. The draft-drawing of the initial idea from the costumer.](image)
for most carrier oils and many essential oils. This process ensures that the resulting oil is 100% pure and retains all the properties of the plant (Figure 1). It is a method of mechanical extraction where heat is reduced and minimized throughout the batching of the raw material. The cold pressed method is also known as scarification method. Cold pressed method is mainly used for extracting essential oils from plants, flower, seeds, lemon, tangerine oils [1] (Arnould et al., 1981). In this process, the outer layer of the plants containing the oil are removed by scrubbing. Then, the whole plant is pressed to squeeze the material from the pulp and to release the essential oil from the pouches. The essential oil rises to the surface of the material and is separated from the material by centrifugation.

2. Material and method

The picture on Figure 2 is a draft-drawing from the client through which the idea of what should be the final product is communicated. In the picture, one can see what is expected and through more detailed calculations afterwards, it is easy to determine whether such a design can meet all the requirements and reach production phase. Of course, there is no limitation to only this design - but there is an open space for bidding on better solutions in order to meet the requirements and provide optimum design.

One can conclude that the client wants a very simple solution and his idea is to use only one gear, rack and lever. The latter is a topic of discussion and requires calculations to be done in order to determine if this mechanism can be implemented and will the gear, rack and lever have rational size and at last, can the desired pressure be easily achieved. A piece of paper is placed between the two plates for this special purpose. The herb out of which the oil should be extruded is then placed on that paper, and, assuming that the press is already heated, the plant and the paper are pressed between the plates at the desired pressure of 100 psi, held around ten seconds after the separation, the oil has already been absorbed into the paper. After that, the oil is separated from the paper through a separate procedure and packed for sale.

One can notice that the client does not take into account some components such as rolling bearings, brake to prevent the lever from falling down from the weight, etc. It is also noticeable that the frame of the press is a body that seems to look very simply and at the same time aesthetically appealing - it is hardly feasible for many reasons. If the frame is one body with all the irregular shapes offered by the client - although it would be easy to be modelled in any CAD software - its production could be a problem because it is a frame of a press that needs to reach a pressure of 0.69 MPa on a relatively large surface of 203mm - so the body is likely to reach maximum height of 457 mm. In order to produce this frame as such, very expensive large modes are required and that opposes the requirement to cut cost on mechanical works.

Digital temperature control is feasible - in fact, it is easy to actually design a system that will digitally manage temperature and at the same time measure and display the value of the pressure between the plates.

In order to establish a systematic design procedure, the discursive design method according to directive VDI 2221 was selected (VDI 2221, 1993). The directive divides the engineering process into seven fundamental working steps. Depending on the problem for each of these steps, several specific methods are recommended. The steps and the referring results are shown in Figure 3 [2]. For step one, the “searching matrix” method proposed by Roth (Roth, 1994) was used, resulting in several detailed requirement lists. For step two, directive VDI 2222 was selected (VDI 2222, 1997). For step three the method of VDI-engineering morphology was used (VDI 2222, 1997). Referring to Pahl/Beitz (Pahl et. al., 2005) an own pre-evaluation method was developed. Applying the pre-evaluation method, the principle solutions were combined to two promising general concepts. These were constructed in step four and five. Then these two competing preliminary embodiment designs were evaluated by using technical and economic aspects according to Kesselring and VDI – directive “Technisch-wirtschaftliches Konstruieren” (VDI 2225, 1998; VDI 2223, 2004; VDI 2222, 1982). The best design was selected and finalized in step six.
Certainly, the idea has to be modified from what we received as a client’s request - the base, the body and the mechanism itself are fully developed, all parts are solidified in Solid Works and an assembly is made to consider the final result of the work. The battened lath and gasket are selected with ANSI standard module 8 because the client will sell the press on the US market. Module 8 is selected because it is a mechanism where the moment of transmission and its forces are more important than the shifts and gears.

3. Results and Discussion

3.1. Requirements and main function of the small press for extracting the essential oils

Following the client’s request, it is necessary to design a prefabricated press that can be easily used on any table as a base - this press will serve for extrusion of essential oils from plants and primary requirements are:

- the price to be less than 300 euro;
- the press is manually operated and the plates are locked for at least 10 seconds;
- the maximum height of the press is 18 in or 457 mm;
- to have circular plates as working surfaces with an interference distance of 120 mm;
- the diameter of the circular plates is about 8 in or 203 mm;
- the boards should be made of stainless steel;
- the plates or the work surface should be heated;
- thermostat or digital temperature control must be added;
- the temperature should be adjustable from 100ºC to 200ºC;
- switch for connecting and disconnection of heating elements to be used;
- the working voltage is 110V, with a frequency of 60Hz;
- pressure of 100 psi or 0.69 MPa between the plates must be easily reached;
- the drive unit must be made of polished aluminium;
- the body is made of iron and painted in black;
- to save money on mechanical components;
- to invest more in electronics and heating elements;
- to use as many components already available on the market;
- custom – made parts to be only those that give uniqueness to the press, such as the body of the press;
- workshop drawings of the parts to be provided;
- the design should be delivered in 3D format (.STEP) ready for production;

If the constructive solution satisfies all these requirements, together with other requirements such as the cost price and the maximum size of the machine - then the solution is rejected as inadequate. Certainly, if we manage to achieve the desired pressure with smaller driving force - that would be positive.

Figure 4. Main function and partial functions of the design process of a small manual press for extracting the essential oil according to VDI 2221.

3.2. Concept Design and Concept Pre-Evaluation
The most important problem that needs to be solved is the mechanism that transmits the movement - in this case, the torque is of interest to us in the kinematics, so we will consider several solutions of the mechanism in order to achieve the desired pressure with a lower driving torque – that is by applying less power to achieve the desired pressure, which would make the machine itself easier to use. The other components will be considered in detail only in the solution that will be finally chosen.

Heating of the plates, heating elements, cable thickness, thermostat, and to a certain extent, the base of the press will remain unchanged, regardless of the mechanism used for transfer. It does not make sense to mention these components in each possible solution, but they will be thoroughly detailed only in the chosen solution.
SOLUTION A – Gear, rack and lever. The first solution is the client’s proposal. It features a simple construction, easy to manufacture, assembly, mobility. The gear and rack are selected with ANSI standard module 8 because the costumer intents to sell the press on the American market. The calculations show that with the maximum permissible force of 400 N, a pressure of only 69460 Pa can be achieved and that is around 10 times less than the required pressure. On the other hand, in order to obtain the desired pressure with this mechanism, a force of 3973.5 N is needed - which is a very high value, so this solution for the mechanism is expelled as inadequate since it does not satisfy the basic requirement – to achieve pressure of 100 psi or 0.69 MPa without much effort of the press operator.

SOLUTION B – Manual hydraulic press. The great advantage of this solution is that the pressure can be achieved very easily. In our case we need a pressure of 0.69 MPa and to achieve this pressure on the surface of the plates with diameter of 203 mm - it has been estimated that a force of around 22 kN is required. This is approximately 2 tonnes of force that is relatively low power if hydraulics is used. Another advantage of this solution is the simplicity of the body as welded construction that does not occupy a large space and also contributes to the simplicity and compactness of the solution. The high cost price is it main disadvantage - it is necessary to invest in high-quality hydraulic components - cylinder and manual hydraulic pump with adequate capacity. Similar hydraulic presses cost over 1,000 euros - while the orderer of this press wants to make it operational with the price of under 300 euros per piece.

SOLUTION C – Power screws. The third solution is the simplest solution and includes only one threaded spindle, well dimensioned to bear the forces that will emerge in it. The biggest advantage of this solution is simplicity and cost - it would be very simple at the base, almost the whole construction could be welded - with a single movable part - screwed itself and nothing else. Calculations show the
need for the longitudinal force with a value of 22 kN. It takes a lot of effort to achieve this pressure on such a surface. Also, turning of the threaded spindle and moving downwards while holding a driving torque is a disadvantage. Constructive resolution by inserting additional components leads to losing of this’ solution biggest advantages - simplicity and cost, while on the other hand a solution is obtained where again a great effort is needed to achieve the desired pressure.

**SOLUTION D - Two-steps power screws.** The fourth solution is the modification of the first one by introducing structural components that make it more complicated and more expensive. As a result, we obtain a press that has several advantages over the initial idea of the customer considered in the solution A and very important – implementation of all technical requirements. This solution uses a two-stage transmission - the first movement is transmitted through a snail-drive transmission with a reduction degree of 40 - then through another gear it is transmitted in a linear motion of the pointed plane - vertically upward and downward. Calculations show that the desired pressure will be achieved very easily. The biggest advantage is that now it is not necessary to install a brake so that the plates stand merged for about 10 seconds - unlike the first solution, the movement has a very large resistance in the opposite direction meaning that the weight of the top plate will not be able to move down the rack without applying drive moment on the wheel. A visual representation of this solution can be seen in Figure 8. The advantage is the implementation of mechanical components that can be found at a low price and the housing is relatively simple, the plates are cylindrical instead of conical in order to save on processing and to also save space between the plates, because when they are conical, the tip of the cone remains virtually unused space. The disadvantage is that it has more components than other solutions and will cost slightly more than the first solution, but if we take into consideration the fact that we have eliminated the need for a brake and that now we have a solution that actually works - the price will offset and a small increase does not play a major role - we can still consider this solution to satisfy the price requirement.

3.3. **Technical and Economical Evaluation to Estimate the Best Concept**

After consultations with the client, four groups were identified to evaluate the proposed construction variants:

- The pressure generated on the plates
- Other technical requirements (transmission, heating, power transformation)
- Simplicity of construction and mobility
- The cost of the press

For a comparison of the four engineered solutions with state-of-the-art solutions, the VDI technical-economical evaluation method was applied as shown in Figure 9. The technical average grade of option A is $x_A=0.36$, option B has $x_B=0.76$, option C has $x_C=0.86$ and $x_D=0.82$ for option D. The referring economical values are $y_A=0.85$, $y_B=0.37$, $y_C=0.8$ and $y_D=0.75$, respectively. The computed VDI “product strength” $s_i$ of the alternatives are $s_A=0.8$ and $s_B=0.7$. Other State-of-the-art mixing devices were also technically evaluated (Company I-III). Their technical grade referring to the requirements lists is drawn in Figure 9. All new solutions A, B, C and D are characterized by a significantly higher product strength compared to the existing systems. Due to the lower production costs, option D was selected for the production and testing of a prototype. Following step six of the VDI design procedure, the first prototype of the small press for extracting oil from the plants was manufactured and tested as shown in Figure 13. Some parts of the final solution are shown on Figures

Table 1. Optimal solutions according to four criteria groups.

| Variant of the solution: | Solution A | Solution B | Solution C | Solution D |
|--------------------------|------------|------------|------------|------------|
| Pressure on the plates (x1) | Not satisfying | Satisfying | Satisfying | Satisfying |
| Group of the technical requirements (x2) | Satisfying | Satisfying | Not satisfying | Satisfying |
| Simplicity (x3) | Satisfying | Satisfying | Satisfying | Satisfying |
| Cost (y) | Satisfying | Not satisfying | Satisfying | Satisfying |
10, 11 and 12. We will make a calculation to check that the selected components satisfy the request of the customer - i.e. whether the desired pressure of 100 psi can be achieved with a driving force of less than 400 N. We got a score of 331.2N - which means using the selected components we can achieve the desired pressure with a 30 kg force - which meets the requirement to achieve pressure with a force less than 400 N.

**Figure 9.** Strength chart of the competing technical solutions compared to state-of-the-art solutions.

**Figure 10.** Visual display of the mechanism together with the shaft and other component.

**Figure 11.** Heating wires - represented in red colour.

**Figure 12.** Visual display of the base and both plates.

**Figure 13.** Full construction of the press.
Because in this case more important was the transmission of forces and moments - in contrast to the accuracy of the movement, speeds and acceleration - gears with an 8-inch module were selected - meaning that they have larger teeth that can convey great forces and moments without any defect on the machine. Also, an angle of 20 degrees is selected - which means that there will be a larger contact area between the teeth - again in order to withstand high stresses that in this case can occur because the machine is not driven by an engine - which means that we do not have a precisely determined maximum torque.

Four roller bearings, four fuses and two pins are used - that is, two bearings, two fuses and one wedge for each shaft. We can conclude the design of the mechanism and continue to the other components of the machine (Figure 10).

The housing should be very simple and cost less because it does not have any particular functional role, except that it gives a support to the whole mechanism. Top plate has been selected as a moving plate for a simple reason. If the lower plate was chosen as movable, the strain on the screws holding the press in place and on the whole construction in general would have been much greater. In order to keep the cost as low as possible - we will go with as many welded joints as possible and we will reduce the number of developmental joints to a minimum, that is, just as much as it is necessary for the machine to be folded and disassembled easily.

Firstly - the base will be composed of two welded parts on which a top plate will be added with a developing joint of eight screws, the plate is added separately for two reasons - first, it is made of stainless steel as opposed to the body that will be made by some type of iron, and second, it can be easily separated if in the future it is necessary to make a replacement of the heating elements located therein (Figure 12).

For heating elements, two heaters with a spiral shape and an appropriate dimension are selected so that they can be placed in the upper and lower plates, with low price and thermal power of 2600 W for fast heating of the plates. The simplest type of thermostat is selected, allowing the regulation of the desired temperature in the range of 200 to 400 degrees Fahrenheit, at the lowest price (Figure 11).

4. Conclusion

The aim of the paper is to present a problem-solving approach according to the norms of VDI 2221 when there are unconditional requests by the machine's orderer (client) not to be changed. In such immutable requirements, it is necessary to find the executors of the partial functions that mostly satisfy this requirements that are probably not the best technical solutions. In this case, these requirements were the price to be up to 300 euros, the maximum pressure to be applied to be 0.69 MPa, a set of technical preconditions (easy portability, manual operation, light construction, etc.), as well as overall construction simplicity. If any of these conditions could be changed, another final decision would be made. Thus, using VDI 2221 procedures, an optimal solution is found that meets the customer's main requirements and, most importantly, meets his design and other conceivable conditions.

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