DimCuve : An Automatic Tool for the Optimisation of the Design and Realization of a Raw Palm oil Storage Tank

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***Abstract*—This paper concerns the study of the design and realization of a storage tank for raw palm oil. The main objective is to solve the problems of supply shortages of raw palm oil to stock-out to small and Medium Size Enterprises in Cameroon. We first of all look at the state-of-the-art of the design and realization of storage tanks, and then, and in the case of raw palm oil storage, we design an open cylindrical vertical tank with a conical roof supported by a framework. We then proceed with the sizing of all the structural elements based on specially chosen mechanical criteria. We put in place software, DimCuve, to be used for the automatic sizing of storage tanks. The interest of this work is conclusive for enterprises of this sector.**

Keywords-- Design, Sizing, Realization, Tank, Mechanical Criteria.

List of symbols

RPO	*Raw palm oil*
$P_{v(i)}$	*Pressure on the ferrule i.*
e	*thickness of roof sheet*
α	*Angle of the roof sheet.*
σ_{ep}	*Elastic working stress in MPa*
σ	*Stress in the material*
m	*Mass in Kg*
F	*Force in N*
ρ	*Density in kg / m^3*
n_x	*Quantity of the element x*
q	*Load distribution in $N.m^{-1}$*
l	*Length in m*
f	*Deflection in mm*

I. INTRODUCTION

The production of palm oil is abundant during the harvest period. In an economic context where palm oil becomes more and more scarce, since part is used as biofuel, it is imperative for enterprises to store this raw material to respond to future market demand. This work concerns the design and realization of raw palm oil storage tanks. At first sight, these reservoirs seem to be of a simple design and construction within safe working conditions? This is not the case, given the many registered accidents in the past years. This work is aimed at anticipating the shortage of raw material in the manufacturing industries. Our work articulate around the following points : The situation of palm oil cultivation in Cameroon, presentation of the state – of the – art and review of the problem background, presentation of the different design approaches, choice of a particular type of tank, sizing and presentations of results.

II. PROBLEM STATEMENT

Most Cameroonian enterprises using palm oil as raw material have storage tanks of low capacity (about 500 tons). These storage capacities become very insufficient given its abundant use by soap and oil industries. In periods of plenty (usually from February to June of each year), although the Cameroonian palm oil plantation sees a decrease in production relative to the international market, its production assures a good supply to these industries. But managing the shortage period (July to November each year) is based on the renting of RPO storage tanks, with a significant cost (approximately 45.2 CFA francs per Kg and per week), giving a total of several hundred million CFA francs per year. Moreover, the usage capacity being generally of about 100 tons /day at the oil mill and 70 to 80 tons/day at the soap factory, this generates functioning situation with tense flux resulting sometimes to the stopping of the production chain cumulated to a month per year, all due to a lack of raw material (RPO). The main objective of this work is thus to design and realize a high capacity storage tank for RPO and the putting into place of a software for the design and sizing of storage tanks with supported roof work. The results obtained will permit enterprises to guarantee full time functioning, eliminate RPO storage cost, to avoid tensed flux functioning due to logistic variabilities and to profit from low provision prices during harvest period.

III. General concepts on storage tanks

Storage tanks are used to store liquids, solids or gases material. They possess particular specificities related to their working conditions (temperature, pressure), form (cylindrical, spherical), volume, and constitutive material (steel ...) e.g. [1] [6].

There are different types of storage tanks. We have ambient temperature storage tanks used to store liquids (crude oil, gasoil, aerofuel, white spirit, kerosene, benzene, toluene, raw palm oil ...), temperature controlled storage tanks for liquefied gases (propane, propylene, ammoniac, chlorine, carbon dioxide, ethane, ethylene, etc..) and silos for storage of pulversed and dry products (grains, cereals, food products ...) [10].

a) Design methods for reservoirs

The complexity in the design does not only relate in their variety but also and particularly in the working conditions. A storage tank type will depend on the material concerned (solid, liquid, gas). Storage conditions are related to pressure and temperature. Tanks can be at ambient atmospheric pressure, sealed at low or high pressures. Concerning temperature, it can be with or without a heat source.

It should be noted that the study and construction of tanks are governed by codes or construction standards in one hand and methods from the engineering science on the other hand. These methods take into account rules concerning design, calculation, choice of material, construction, welding and control and resistance tests.

Frequently used codes include: CODRES (in France) prepared by the National Syndicate for Welding, the API 650 (USA) developed by the American Petroleum Institute, the BS 2654 Code (United Kingdom) written by the British Standards Institution (BSI), and DIN 4119 (Germany) edited by the Deutsches Institut für Normung (DIN) (in [7] [8] [9]).

The design of tanks is particularly based on the following characteristics:

- The shape (cylindrical with vertical or horizontal axis, plane base conical, semi conical, hemispheric, elliptical meridian or basket-shaped, spherical or parallelepipedic).
- The constitutive material (steel, reinforced plastic with glass fibers…)
- The reinforcement elements

Besides, we also take into consideration aspects related to the installation site and the safety specifications. For a complete design, it is essential to have a global view of the subject. It is thus necessary to organize the set information related to storage tanks. At first, a thorough study will permit us to recuperate certain number of specific characteristics for each storage type and then extract the pertinent elements. These elements include: storage type, storage site, geometry, dimensions, structural composition, capacity, product nature, storage instrumentation and safety specifications. All these elements permit us to identify, describe and choose the type of reservoir relative to the project charter.

b) Design specifications

Three criteria are taken into account during the design:

- Variable constraints relative to elements of the structure which change characteristics depending on the real weight of the structure, the adopted technology and the quantity of stored oil.
- Standards constraints relative to ergonomic and environmental exigencies.
- Realization and manufacture action constraints related to the finish: control of welding joints, external surface treatment.

Hence, haven defined the work, it is now possible to begin the design phase.

IV. Design and implementation of software for the sizing of a storage tank for raw palm oil

The palm oil sector being in expansion in Cameroon, to participate in this policy, we put into place a tool for the sizing of vertical cylindrical reservoirs entitled DimCuve.

a) The raw material to be stored: palm oil

Palm oil is extracted from the palm fruit pulp by pressurized heating. 100 Kg of fruit give about 22 Kg of oil. Palm oil is an essential ingredient in the kitchen and is widely used in industrial products and cosmetics due to its low production cost. Palm is cultivated in all tropical regions at high efficiencies: up to 7 tons of oil per hectare per year. Recent research shows that the carbon balance sheet is positive.

The demand of palm oil in food processing industries and cosmetics is in a rapid rise. The exploitation of palm oil, very profitable, pushes cultivators in forest regions to replace natural forest by palm plantations. This causes destruction of tropical forests, with the consequence of worsening the release of green house gases (e. g. [5]).

b) Design approach

The elements of the project charter for the design of this tank include: Volume V = 2413 m³, diameter Ø = 16 m, height H = 12 m. The different steps to be followed are: The choice of material, the technology, the sizing method, and the manufacturing downscale of the constitutive parts.

1) Choice of the material and the technology

Palm oil does not possess corrosive and aggressive properties; we can use steel S235 as the construction material. This material is considered homogeneous, isotropic, and used in the sub domain of linear elastic behavior. We choose a vertical cylindrical tank with conical roof fixed on a support. Some modifications on wind protection are considered.

2) Sizing of elements of the tank

The support constitutes a load for the covering, that is why we begin the sizing from this aspect, followed by the covering and then end with the base.

- *Modeling and calculation of the framework*

Adopting the simple modeling seen above, we determine the load applied on the rafters.

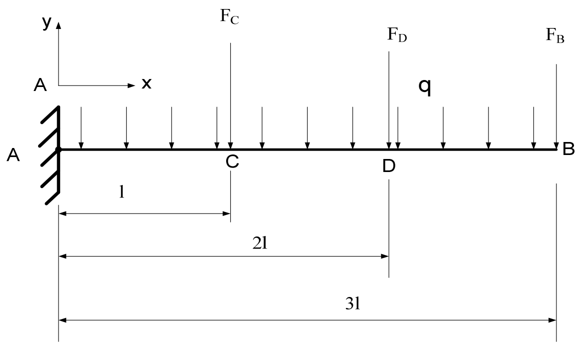

Fig. 1. Modelling the framework

The load distribution is a combination of the weight of the sheets, the real weights of the rafters and that of the exploitation assembly. The load at B is the resultant of the weight of the manhole on the rafter. Weight C and D are respectively combinations of weight struts and wind protections. We use the rigidity criteria to size rafters: $|f|_{max} \leq f_{limit}$

Hence, we retain for the two beams belonging to the plane of symmetry of the structure, 2 IPE270 and for the others 32 IPE 240. For the stresses, we note that:

$$\sigma_{max} = 22{,}17MP_a < \sigma_{ep} = 235MP_a$$

- *Modeling and sizing of the roof sheet rim:*

For reservoirs, the minimal characteristics of the beams are function of the diameter.

TABLE 1
BEAM DIMENSIONS AS A FUNCTION OF DIAMETER

Diameter D of reservoir	Beam dimensions
$D \leq 15m$	$50 \times 50 \times 5$
$15 < D \leq 36m$	$60 \times 60 \times 6$
$36 < D \leq 48m$	$70 \times 70 \times 7$
$48 < D \leq 60m$	$80 \times 80 \times 8$
$D > 60m$	$100 \times 100 \times 8$

Hence we can retain UPN140 (of length $=2\pi(R + e_1)$ ie length $= 50{,}3m$) for the rim. The assembly of the roof will be done by cutting and welding.

- *Modeling and Calculation of the covering*

In order to take into account the forces due to the roof and the weights of the supporting rings, we size the supporting rings from up to down, assuming that the supporting ring is built-in.

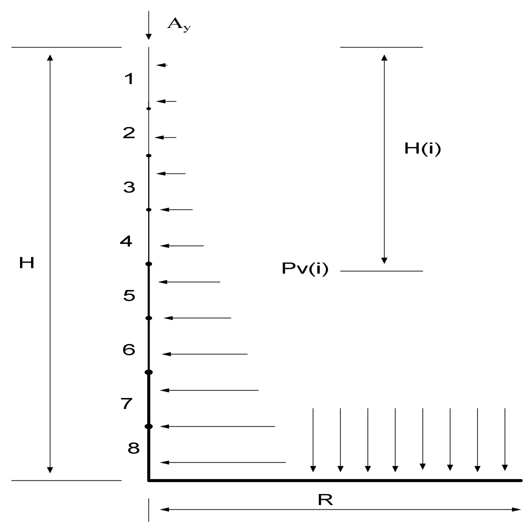

Fig. 2. Axisymmetric mode of the tank

The hydrostatic pressure on the supporting ring is

$$P_{v(i)} = \rho g(H(i) - 0{,}3) \;\; where \; H(i) = ih\,;$$

$$1 \leq i \leq 8\,; h = H/8$$

From the radial and the circumferential stresses, the Tresca mechanical criterion gives the following condition on the thickness of the supporting ring: $e_i \geq \frac{P_{v(i)}R}{\sigma_{ep}-P_{v(i)}}$

- *Modeling and sizing the base*

Beyond the containers of average dimensions, we preview two thicknesses:

For the marginal sheets of the base: The thickness is at least equal to that of the base, in this case, 8 mm.

For the interior sheets of the base: The thickness is equal to the average thickness of the supporting ring, here 6 mm.

3) *Structural analysis*

The objective is to compute the structure with help of finite element method, in other to eventually to complete the optimization loop [2] [3] [4].

- *Verification of the covering and the base*

The covering and the base can be considered as a variable thickness cylindrical tank where the first four supporting rings are of 4 mm, and others: 5, 6, 7 and 8 mm.
We characterize the used material by the density, Young's modulus and elastic limit.

- *Boundary conditions*

Here, we take into consideration the relation between the studied system (covering and base) and the external medium; however we neglect the action of the roof on the covering.

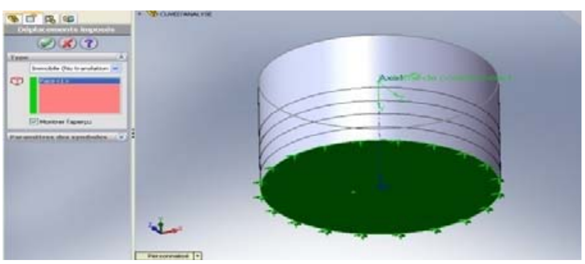

Fig. 3. Boundary conditions

- *External reactions*

This variable pressure corresponds to the hydrostatic load arising from the stored palm oil in the tank. The structure being entirely under actions, we proceed with meshing, and then with the calculation.

- *Calculation of the assembled structure*

From the obtained meshing, we use the finite element method.

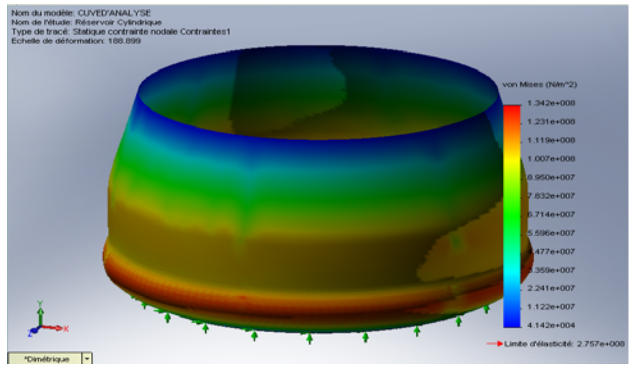

Fig. 4. State of the stresses

The results obtained shows that the state of stresses are satisfactory as the maximum internal stress of the structure is: $134\ MP_a < \boldsymbol{\sigma}_{ep} = 235 MP_a$.

- *Verification of roof*

All the beams are subjected to deflection. The beam is built in free with three forces acting at equal distance from each other. We get: $\mathrm{f_B} = 10{,}78\ \mathrm{mm} < \mathrm{f_{limit}} = 15{,}42\ \mathrm{mm}$.
For the state of the stresses, we have:

$$\sigma_{\max} = 22{,}17\mathrm{MP_a} < \sigma_{\mathrm{ep}} = 235\mathrm{MP_a}.$$

Hence for our structure we obtain: 2 IPE 270 and 32 IPE 240

4) *Presentation of the software "DimCuve"*

To participate in the development politics for palm oil production by making available raw palm oil in storage tanks during the periods of abundance, it is important to put into place a tool for the automatic design and sizing reservoirs. Useful data include: height H of the storage tank, its diameter, D. The software developed is able to determine the parameters of the different elements.

For the roof, an algorithm permits us to obtain the thickness e_t of the roof sheets, their lengths, that of the framework $l_1, l_2\ et\ l_g$ and the angle α of the roof sheet. For the covering, we obtain the number of supporting rings, n_0. For the base, we determine the number of roof sheets n_t.

Then for the roof we calculate: P_t roof weight, F_B, F_C, F_D applied forces on the framework, q_{roof}, q_{exp}, q: load distribution on the roof and minimum moment of inertia of the transverse vars of the framework. We can hence size the steps and the flotter.

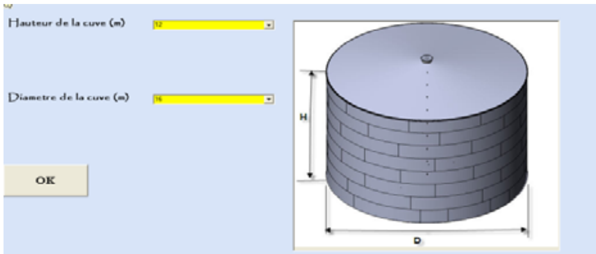

Fig. 5. Data input

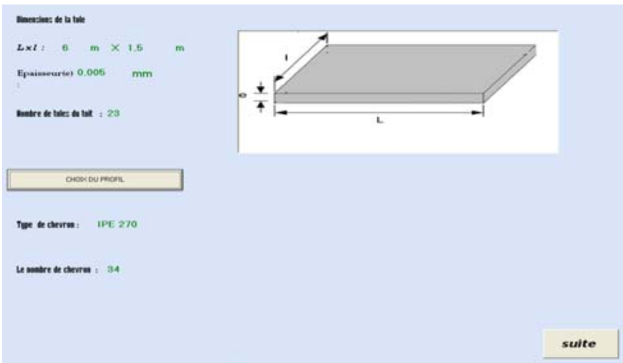

Fig. 6. Results for the framework

TABLE 2
MANUFACTURING RUNDOWN OF SOME PARTS OF THE STRUCTURE

N°	*Designation*	*Profile*	*Quantity*	*Manufacturing operations*
1	Base	TPN of 8 mm TPN of 6 mm	18 5	Oxygen cutting, Grinding, and Welding.
2	ferrule	TPN of 8 mm TPN of 7 mm TPN of 6 mm TPN of 5 mm TPN de 4 mm	9 9 9 9 34	Oxygen cutting, Grinding, and Welding.
3	Roof sheet	TPN of 5mm	23	Oxygen cutting, Grinding, and Welding.
4	Roof's rafters	IPE 270x 8000 IPE 240 x 8000	2 32	Oxygen cutting, Grinding, and Welding.
5	Serpentine	TRN black iron DN50 DN50 T	58 58 1	Sawing, Grinding and Welding

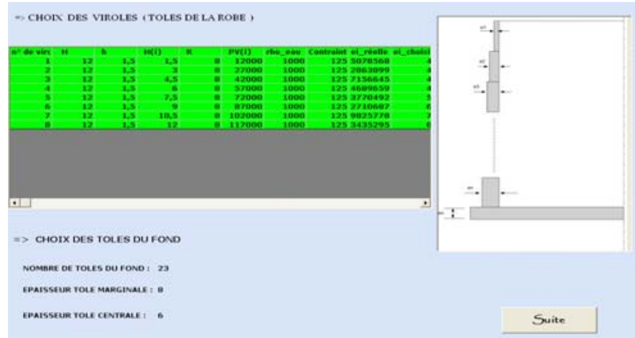

Fig. 7. Results for the covering and base

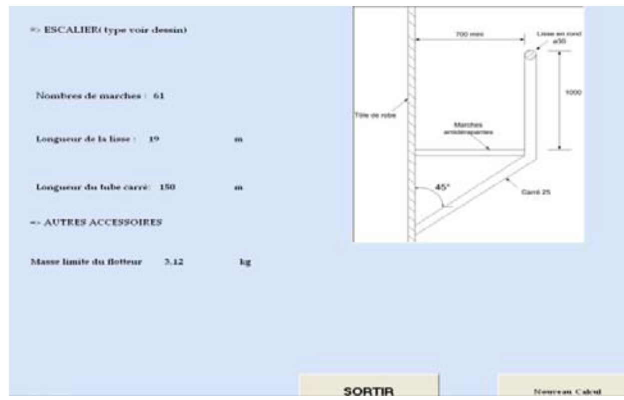

Fig. 8. Results for the accessories

The manufacturing downscale is actually established at the methods department. The elaboration permits the respect of engineering principles. This approach allows the teams to reduce construction time, measure quality, reduce cost and better integrate customer exigencies.

V- CONCLUSION AND PERSPECTIVES

This paper is about the optimization of the design and realization of a storage tank for row palm oil. It was expected to define the technology, the applied reaction forces on the working tank, to size the tank by giving constitutive elements of the structure and their dimensions that will drive to the realization of the tank. We presented the different types of storage by specifying the technology and restrictions relative to each type. We were interested with cylindrical reservoirs with fixed and auto supported roof. The sizing of the tank accompanied with some recommendations arising from the code and construction standards of storage tanks was realized.

Finally, from the economic and financial analysis, the investment for a cylindrical storage tank involves many areas of expenditure: cost of equipments, studies, installation. We then realize that with a discount rate of 10%, and a linear amortization, the realization of the storage tanks becomes profitable at the end of two years. It arises that the tool DimCuve is very useful.

The work contributes to solve the crises surrounding raw palm oil production in Cameroon to prevent companies using raw material to reduce their production scale or even proceed with redundancy action on the staff. Finally, this work permits the restarting of the palm oil sector.

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