

## FUNCTIONAL OPTIMIZATION OF THE EXPERIMENTAL RESEARCH STAND IN ORDER TO OBTAIN REACTIVE MIXTURES

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**Abstract.** The objective of this paper is to functionally optimize the experimental research stand in order to obtain reactive mixtures by changing the shape of the stirred tank reactor. The initial stand had a parallelepiped recipient which had the disadvantage of producing residual currents in the four corners of the reactor, having a negative influence over the intensity of the mixing process. In this paper there has been designed another reactor body, of cylindrical shape and bottom with section shape as a "basket handle", which beside the fact that eliminates the above-mentioned inconvenient, it allows an increased efficiency of the mixing process, by eliminating the „dead” spaces and by optimally passing between the tank’s bottom and the lateral cylindrical part.

**Keywords:** reactive mixture, reactor tank, spiral

### 1. INTRODUCTION

The mixing represents the hydrodynamic operation which has the aim of homogenization (reducing concentration or temperature gradients) within the volume under mixing until reaching a mutual optimal distribution of the constituent materials of temperature uniformity.

The reactor station is a static process equipment fitted with a stirring device in order to obtain solutions, emulsions and dispersions, production or activation of chemical reactions and physic-chemical operations, increased heat exchange.

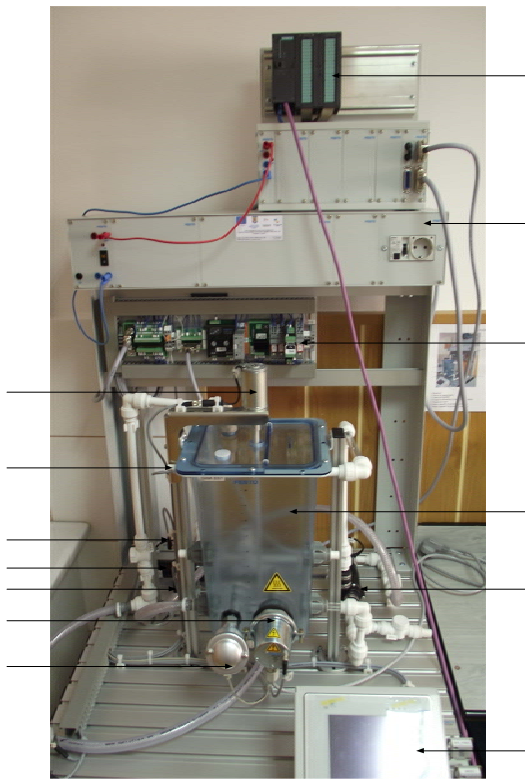


Figure 1. Reactor station with parallelepiped body

The reactor station (Figure 1) consists of a system controlled by digital and analogue sensors and actuators. The control system of the temperature is operated via a PLC controller (Programmable Logic Controller) and Closed Loop (Closed Loop Control). The process runs according to three selectable recipes and consists of the heating and stirring of a liquid. Depending on the recipe selected, the liquid is cooled by a cooling circuit. The ready mixture can be fed towards a downstream station by means of a pump. This consists of the following components:

1. Temperature sensor – measures the temperature. This includes a platinum resistance thermometer and touch interchangeable element.
2. Heating unit – heats the fluid from the tank.
3. Lower capacitive proximity sensor and 5. Upper capacitive proximity sensor – senses the fluid in the tank by changing the capacity of a capacitor integrated in the proximity sensor.
4. Pump of downstream – used to empty the tank.
6. Float switch – serves as overflow protection.
7. Stirring module (drive section + stirring rod) – mixes the fluid in the container by means of the stirrer using an unregulated 24 V DC motor. The stirrer accelerates the chemical reactions, the homogenization of the mixtures, dissolution, in physical processes and also for the improvement of the heat transfer.
8. Touch panel – is an output device for visual and auditory information and in the same time it is a display for receiving orders.
9. Feeding and recirculation pump for cooling – feeds the station and returns the hot liquid in the tank for cooling.
10. Tank – the tank in which takes place the mixing of fluids and solids. Has a capacity of 10 liters. The admitted operating temperature is +65 °C max.

11. Data acquisition and board connection – acquires data from the electromechanical elements, covers them and sends them to the PLC.

12. Power supply 24V – assures the electrical energy necessary for the operation of the reactor station.

13. PLC (Programmable Logic Controller) – is the control unit of the reactor station.

Festo’s didactic learning system for process automation is a compact didactic stand and is oriented towards different training necessities. It facilitates a training industry oriented and a better knowledge of the hardware content of the industrial components. Moreover, this station enables teamwork and develops organizations and cooperation skills. The actual project phases can be taught in training projects which include: planning, assembly, programming, commissioning operation, maintenance, fault finding.

The work station combines four closed loops, each one with digital and analogue sensors and actuators. With the help of a PLC controller it is possible to use these loops individually or cascaded loops:

- Automate control of the level;
- Automate control of the flow;
- Automate control of the temperature;
- Automate control of the pressure.

The touch panel is mounted at the right-hand front of the profile plate. The touch panel FED 120 COL operates with a resolution of 320 x 240 Pixel. The 24 V power supply is established via the 4 mm jack plug.

First connect all the components to the system. The main menu is displayed on the touch panel if all the components are functioning properly (Figure 2).

- the language is selected via the four flag symbols.

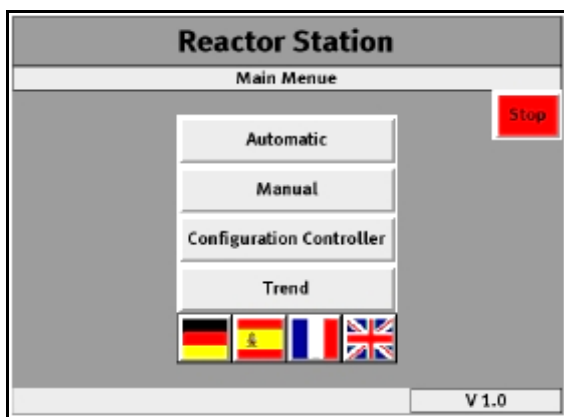


Figure 2. Main menu for the touch panel display

- select one of the four modes of operation, automatic mode, manual mode, configuration controller or display of trend. [1]

In accordance with different recipes, a liquid in the reactor tank is to be heated by means of the heating unit and stirred using a stirring module. The temperature of the liquid is to be increased by means of the heating unit and, depending on the sequence of the recipe either be simultaneously or subsequently stirred.

The system temperature is to be recorded as an actual value by means of a temperature sensor and is to remain constant even after malfunction or setpoint step-changes.

All actuators can be switched on in the manual menu on the touch panel (touch-screen switch). All analogue values and sensor signal statuses are displayed. In manual mode, the station must be signaled as busy to ensure that no liquid is pumped into the container from an upstream station. The STOP function is active at all times and switches-off all actuators.

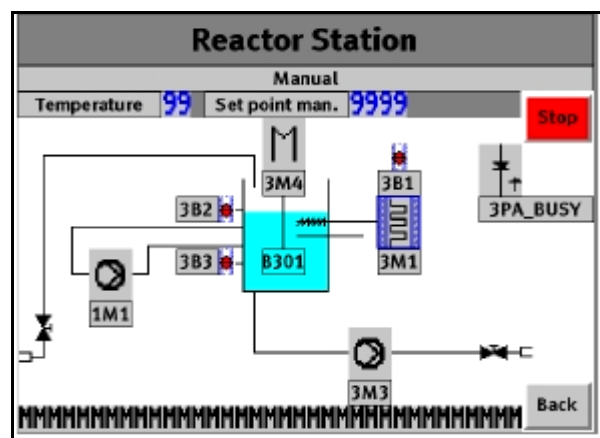


Figure 3. Manual mode flow diagram on the touch panel

## 2. DESCRIPTION OF THE REACTOR BODY WITH CYLINDRICAL SHAPE

The stirring operation plays an important role in the industrial processes from the food and chemical industry representing a vast research topic.

An industrial process brought on a small scale through the Festo stand is ideal for understanding the elements that compose a large-scale process. The stand provides all the specific elements of a real process, from data acquisition sensors and specialized software to the ability to act on the process through actuators.

The level adjustment involves the use of specific elements: sensors, actuators, PLC and a monitoring device.

The stirred reactors have many applications in the chemical processes where mixing is important for the overall performance of the process.

The stirred tank is an essential part of the machinery involved in the processes of food, chemical, pharmaceutical, with a broad scope of application, such as making the dispersion of suspended solids or gas phase by effect of turbulence in Newtonian or non-

Newtonian fluids. Therefore, for the agitation is important to make a motion under conditions of turbulence. [2]

During stirring, at greater agitator's speed a vortex appears. The vortex formation leads the fluid to climb on the tank's wall, the relative motion between particles is reduced, so the mixture is no longer carried with the same intensity.

The tank which is currently used has the disadvantage of producing residual currents in the four corners of the reactor, having a negative influence over the intensity of the mixing process.

In order to optimize the mixing process there has been designed the cylindrical reactor tank with the section shaped as a "basket handle".

The shape of the reactor's bottom can have a significant effect on the hydrodynamic conditions inside it and hence the ability to achieve a homogeneous suspension. At a lower intensity of the process of mixing solid particles (crystals) tends to settle in the bottom of the tank in the region where the flow pattern is one of stagnation. This phenomenon is more common in flat-bottomed tanks; in this case is preferably to use a cylindrical one. Agitators also must be chosen according to the mixing operation that will be done and the nature of the substances to be mixed in the reactor tank.

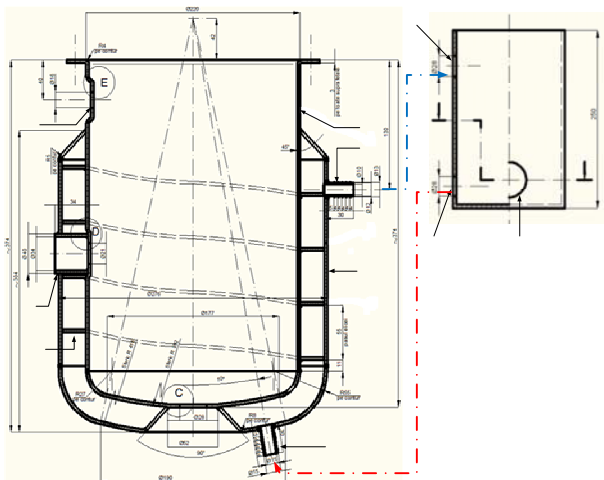


Figure 4. New optimized stand scheme

1 – float switch; 2 – temperature sensor; 3 – uniformity spiral; 4 – connecting pipe for heat agent supply; 5 – reactor's heat mantle; 6 – connecting pipe for heat agent evacuation; 7 – inside reactor tank; 8 – heating unit; 9 – outlet for the heated agent; 10 – inlet for the recovery of the heat agent with low temperature.

Mixing in cylindrical tanks, symmetrical is complete and optimal, the tanks are easier to clean, require less wash fluid than the rectangular ones [3] and most important, it allows an increased efficiency of the mixing process, by eliminating the „dead” spaces and by optimally passing

between the tank's bottom and the lateral cylindrical part.

The material of the inside reactor body (Figure 4 - item 7) and the heating mantle (Figure 4 - item 5) will be transparent and resistant to temperature min. -10°C and max. 80°C. The pitch of the uniformity spiral will not be bigger than 52 mm. The heating mantle thickness is determined by the relation [4]:

$$s_{pm} = [(p_m \cdot D_m) / (2f_a \cdot z \cdot p_m)] + c_1 + c_{r1} \text{ [mm]} \quad (1)$$

in which  $p_m$  and  $D_m$  represents the pressure from the mantle and respectively, the internal diameter of the mantle;

$f_a$  - permissible voltage at the computation, MPa;

$z$  - coefficient of resistance of the welded joint;

$p_c = p_i$  - computation pressure, MPa;

$c_{r1}$  - added rounding up to the nominal thickness of the tank material, which takes into account the negative deviation of the material, mm;

$c_1$  - added for the exploiting conditions.

The switch float (Figure 5) monitors the rising liquid in the tank and will be placed on the reactor tank surface at a distance of 40mm from its superior side (Figure 6). The float switch is directed from the inside through the upper lateral opening in the tank. Prior to attachment, the float switch is aligned so that the "float" is positioned horizontally above the reed contact. If during filling of the tank the maximum liquid level is exceeded the float switch interrupts the signal and float must turn upwards. The check and position setting of the sensor is done by repeated filling and emptying. [5]



Figure 5. Float switch

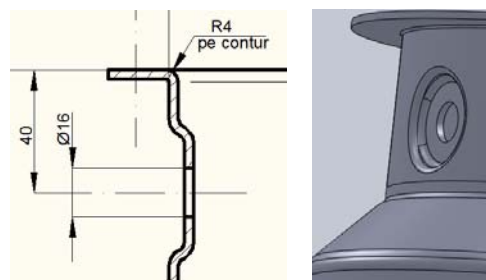
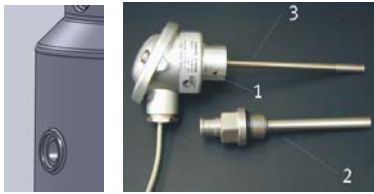


Figure 6. Placement of the float switch

The temperature sensor (Figure 7) is placed on the mantle's surface at a distance of 195mm from the reactor's top. The temperature is sensed using a temperature sensor. The resistor signal of the temperature sensor is converted into a standard signal for voltage (0 - 10 V) by means of a measuring transducer and can thus be read via an analogue PLC input. The

sensor has a measurement range between  $-50^{\circ}\text{C}$  and  $+150^{\circ}\text{C}$ .



**Figure 7. Placement of the temperature sensors; components of the temperature sensor**

1 – set of screws (2x); 2 – protection collar; 3 – thermal element.

The outlet for evacuating the mixture is placed in the center of the reactor's bottom in shape of a "basket handle" (the element that closes ends of a cylindrical or conical form mantle forms a recipient [6]).

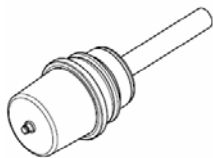
The stress concentration produced by the holes does not overlap in the profiles crossing the equator bulges, where the request is stronger.

The bottom "basket handle" is obtained from a spherical cap of radius 392 mm connected to a toroidal portion of radius 24 mm connected to the cylinder head portion.

The supply and discharge connections are located on the surface of the heating mantle to 374 mm and 130 mm from the top of the reactor body.

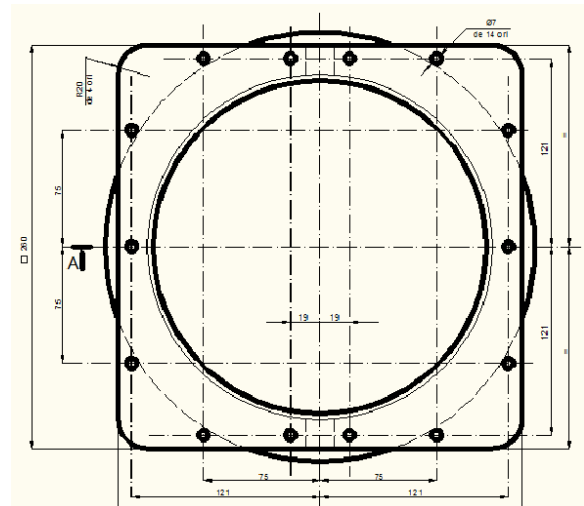
To achieve optimum mixing process without disturbing elements in the body of the reactor, an auxiliary heating system will be connected consisting of a parallelepiped vessel with 250 mm height, which will be wall-mounted heating unit (Figure 4 – item 8) screw and isolated by a threaded sleeve. The unit (Figure 8) can be operated at 230 V AC and is put into operation only when the heating element is completely submerged in liquid. The tank has two holes with a diameter of 25 mm on the left to the body for joints connecting reactor.

This system is designed to supply auxiliary the portion between the mantle and reactor body with heating agent for cooling or heating the mixtures.



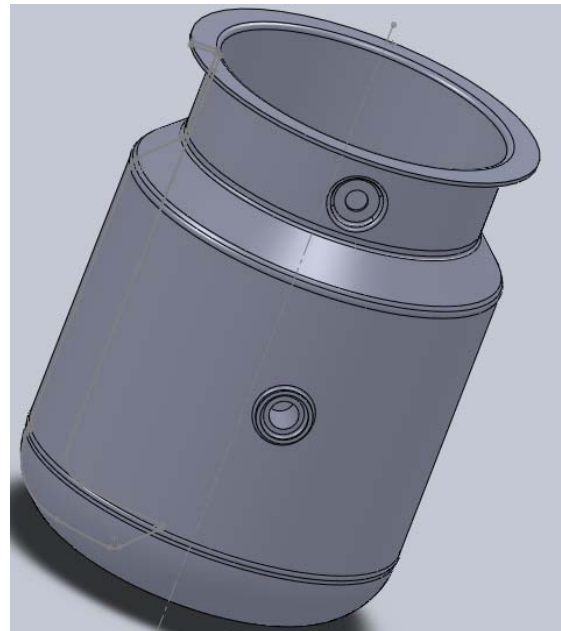
**Figure 8. Heating unit**

The cap (Figure 9) which covers the body of the reactor and on which the stirring module will be mounted is of rectangular in shape, is removable and is designed with holes for verification; for this, the container is provided with a flange assembly.



**Figure 9. Cap of the reactor tank**

In Figure 10 there the 3D view of the reactor body, made in SolidWorks. The layout of holes for the float switch location and the temperature sensor can be seen.



**Figure 10. 3D view of the reactor body**

### 3. CONCLUSIONS

Round-bottomed containers lead to increased mass of particles in suspension by eliminating areas that are "dead" at the intersection of the tank wall. "Dead" areas or regions of segregation are found at the intersection of walls, especially in flat-bottomed tanks.

The main advantages of using cylindrical containers include a higher volumetric loading and more efficient use of storage space.

The heating room of the reactor tank is connected to an auxiliary system (positioned in the right side of the reactor body (Figure 4)), which supplies heat agent that is forced by a centrifugal pump to enter the heating area



via the connection pipe item 4, to follow the prescribed path by the mounted helical item 3 and out through the connection pipe item 6 and going back into the auxiliary heating system.

The helical item 3 has an important role as it facilitates the uniform temperature throughout the heating room. If it had not been mounted then the heat agent provided by auxiliary heating system would go a direct route from junction 4 to junction 6 and thus the heat transfer efficiency between the heating agent and fluids to be mixed in a reactor vessel would decrease greatly.

The route followed by heating the heating chamber can be improved by studying the optimum pitch of the helical so that the heat agent gets back to a lower temperature in the auxiliary system. The path must be tailored to ensure that the heated fluid circulating in it will have the optimal duration of the path crossing in order to avoid the standing of the heat agent in the heating room. But its length should not be reduced

anymore because this leads to a lower heat transfer to the core of the reactor tank.

#### 4. REFERENCES

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