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Influence of interpolation of the method of mixing the liquid in the container on the mixing efficiency

KEYWORDS

Anthropomorfic robot; manipulator; sustainable approach; efficiency mixing; interpolation

ABSTRACT

An anthropomorphic robot, i.e. a robot that can reproduce the movements of the human arm, is equipped with various types of interpolation. The robot can be used to mix two liquids enclosed in a shaker mixer. The problem that has to be solved is the selection of the optimal types of interpolation, as well as the sequence of these robot movements that is able to provide better results higher mixing efficiency, in other words a more sustainable approach to the mixing process, using an anthropomorphic robot. The shaker-type container used the shape of a truncated cone has a positive effect on the efficiency of the liquid mixing process. The difference in density between the two liquids contributes to a sustainable approach to the mixing process. It is preferable to use different shaker position with respect to the gravitational acceleration vector and to use different linear and arc interpolation. The use of variable position in relations to gravitational acceleration vector, due to the shape of the truncated cone of the mixer, will cause chaotic movement of particles inside the shaker, which is a desirable phenomenon, because then both mixed liquids mix quickly.

1. Introduction

The mixing proces is used in industry to mix different substances (two or more). We can mix liquids, bulk materials, gases, or all a tonce and with each other. Mixers with agitators are used in the industry for the mixing proces. Another way to mix is, for example, mixing by vibrations on vibrating mixers. In the category of mixing liquids, we can also notice the process performer by an industrial robot – an anthropomorfic robot, which is supposed to resemble a human arm in the way it works. An anthropomorfic robot is usually equipped with several drives providing 6 degrees of freedom, which gives a large range of control possibilities.

The mixing process happens, according to [1, 5, 6], when macroscopic flow occurs. In some cases, turbulent flow is not appropriate due to the potential damage to the mixed materials [7]. The macroscopic flow in the mixer is created by the centrifugal force and the liquid climbing under the influence of this force on the wall of the liquid container. The mixing process is also influenced by the disproportion between the mixed substances and the remaining space in the container (free space occupied by, for example, air). According to [2], the mixing of liquids with different densities, with the simultaneous presence of an air gap in the mixer, is tested using the SPH method, which is an abbreviation of the name "Smoothed Particle Hydrodynamics". The SPH method is used to determine the efficiency effect of changes in density differences between mixed fluids. As it is written in [2], providing this air gap favorably favors the mixing process it is more effective (it enables cycles of rising and falling of mixed substances, which results in the formation of a convexity in the free space). In the reference [3], the formula for the cut-off frequency of mixing was derived, which causes macroscopic flow of the fluid, but the formula applies to the mixing of fluids in test tubes. In the case of the mixer - shaker, the issue is more clearly described in [4].

The dimensions of the designed shaker can theoretically be arbitrary (within a reasonable range). The only thing that needs to be taken into account is the influence of the mixer diameter on the required mixing frequency. Narrow but tall containers will mix liquids differently than wide and low containers. As [1] wrote for mixers with geometric dimensions a tall shaker and a small surface area of the shaker base, a large centrifugal force is needed to create a macroscopic flow.

2. Solution

Starting to design the geometric model of the mixer shaker, a question had to be asked: what to a point of view do we design the container? The point of view – mixing efficiency, a mixer shaker with a complicated geometry should be designed in order to obtain a chaotic movement of particles, i.e. a macroscopic flow. An effective and costly solution to produce (complex shape). In this case, we have a manipulator that can create complex and effective interpolations. We can create a simpler model, consisting of the construction of a mixer in the shape of a truncated cone.

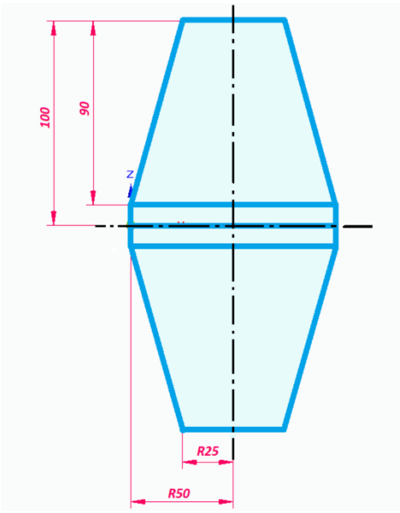

Fig. 1. Visualization of the mixer shaker, taking into account only the geometric parameters of the internal walls

When designing such and no other dimensions of the internal walls, the main aspect of the design is the use of a three dimensional object that is not an ordinary cuboid, cylinder or cube. The shape of a truncated cone on both sides causes that the liquid climbing the walls of the shaker, under the influence of the centrifugal force, meets the curvature of the surface. The curvature of the surface causes a change in the behavior of the mixed liquids, such that the movement becomes more chaotic than in a simple cylindrical mixer. It increases the probability that by setting the mixer in motion, we will obtain macroscopic flow, which is desirable.

The next thing after proposing a mixer is to develop an exemplary control algorithm. Control algorithm understood as a sequence of interpolations performed by an anthropomorphic robot. Examples of interpolations taking into account the position of the shaker relative to the Earth are shown in Fig. 2.

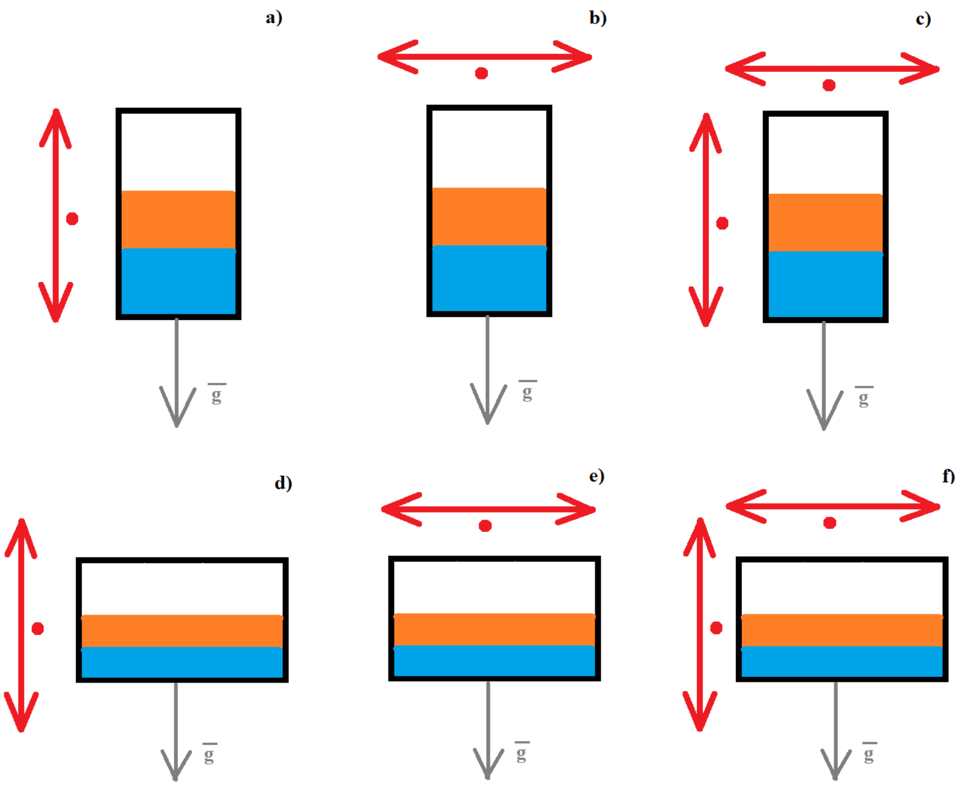

Fig. 2. Type of interpolation that robot has equipped
(a and d – vertical move, b and c – horizontal move, c and f – mix od interpolation)

Interpolations can be supported by tilting the container with mixed liquids by various angles, theoretically any angle that can be realized by the robot's frame at the same time. From the point of view of increasing the chaotic movement of mixed particles, set the mixer at an angle of 45 degrees to the horizontal and then perform dynamic interpolations in accordance with Fig. 2. It is better not to use arcing movements, because their gentle movement around the bends reduces the chaotic movement of particles. Using point or linear interpolation will be a better solution. The container setting itself is shown in Fig. 3. Fig. 4 shows the attachment of the container to the robot and the linear interpolations used.

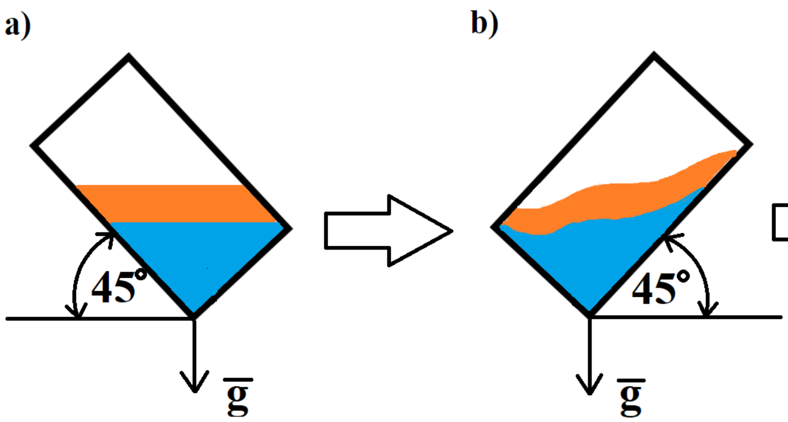

Fig. 3. Settings container and interpolations used

According to Fig. 3a, manipulations of the container set at an angle of 45 degrees and making cyclic movements each time changing the position of the container relative to its original position causes disturbances (Fig. 3b). The result is a chaotic movement of the molecules of both liquids, which begin to gradually mix together, as shown in Fig. 3c. The number of cycles until potentially maximum mixing is often between 200 and 600 cycles. In this case, the density difference of the two mixed liquids plays an important role. In the case of a container mounted to the robot, in addition to the use of cyclic tilting of the container, the manipulator movements should be added: vertical and horizontal, as shown in Fig. 4. Additional trajectories of movements improve the final effect.

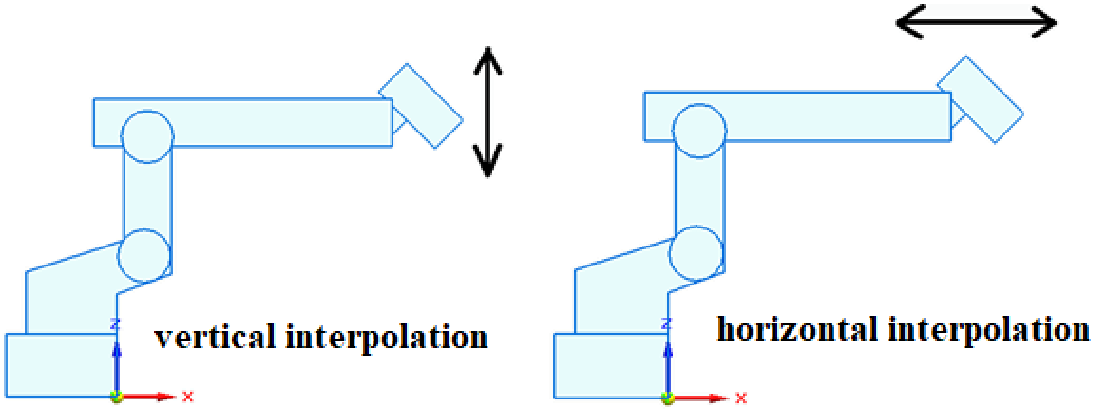

Fig. 4. Robot with a mounted container and interpolations used

3. Conclusions

When designing the shape of the mixer, we must be aware that the shape of the shaker affects the mixing process and the efficiency of the entire process. If we are mixing two liquids with a fairly similar density, it will be advantageous to use a shaker-type mixer with the shape of a truncated cone on both sides from the economic point of view.

The anthropomorphic robot we intend to use for mixing should have enough work space around it. Otherwise, collisions may occur along the route between key positions in space.

If we have installed a container for mixed liquids as a gripper in the robot used, we must properly calibrate the reference point, i.e. the gripper calibration, preferably using the TCP method.

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