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Development Of Working Model of 3-D Mixer

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***Abstract*—** Mixing machine based on Paul Schatz mechanism is a very interesting machine that uses only few simple components without cams or gears etc. However full cycle mobility of this machine is only possible when, link lengths are in appropriate proportion. This paper describes a practical approach for developing such wonderful 3D mixer by exploring the overconstrained mechanism & achieving its full cycle mobility.

Keywords-*3D Mixer, working model, Paul Schatz, six link mechanism, overconstrained mechanism*

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I. INTRODUCTION

Usually in all conventional mixing machines the movement of the mixing container or the agitator is two dimensional (i. e. movement can be viewed fully while looking from one direction). The limits of generally used 2 D mixing systems such as barrel mixers or shakers are quickly reached when mixing compounds with different densities or sizes are used. Three dimensional cyclic movements can be useful to resolve such issues to a great extent. The extraordinary spatial movement of the mixing container can create sensation in mixing technology. A three dimensional mixer can impart such spatial movement to the mixing container. Although the mechanism of such machine is not new, its development has not been reached to the required level. Recently, one or two foreign manufacturers have started developing such machines, but in India, still this type of machine is not known.

In 1939 Paul Schatz, a Swiss anthroposophist and geometrician has invented a mechanism which with few links generates spatial motions [1]. Mixing machine based on this Schatz mechanism uses a highly ordered form of three dimensional motion that brings centrifugal and centripetal forces to dynamic balance. This results in ideal mixing environment. However these types of mixers are still not known to Indian industry. While exploring this mechanism, it was then clear that this mechanism is a six link spatial mechanism which does not satisfy the Kutzbach criterion of full cycle mobility [2]. However, Dr. Constantinos Mavroidis, in his study "Analysis and Synthesis of Overconstrained Mechanisms" mentions that such kinds of mechanisms are over-constraint mechanisms and their full cycle mobility is due to special geometric reasons [3]. He also suggests that the construction of a real model is necessary to prove the mobility of the linkages in full cycle. Inspired with Dr. Mavroidis' suggestion it was decided to make systematic attempts to make similar mechanism practically. Hence the work of making metal strip model, polypropylene model and actual working model was carried out in this research work. This work was helpful for developing confidence in work.

II. PRINCIPLE OF OPERATION OF 3-D MIXER

Mixing barrel is suspended on the ends of driving, and driven axles through two "Y" type universal joints, which are crossing and vertical to each other in the space. When driving axle is driven to rotate, universal joint makes the barrel perform composite motions, including horizontal moving, rotation and turning in the space. By which, materials also performs 3-dimensional motion inside the barrel. Several kinds of materials inside the barrel flow, diffuse, penetrate each other and finally form uniform status.

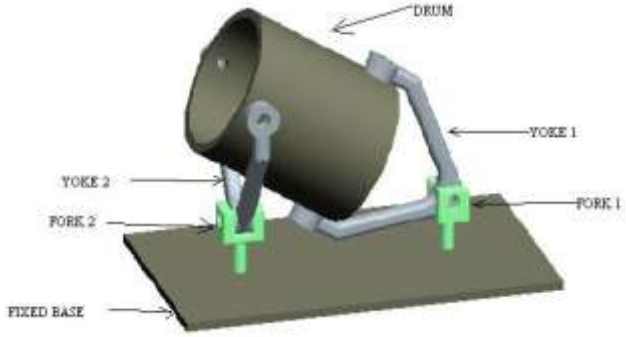

Figure 1. Assembly of 3D Mixer

3-D mixer is based on the same operation principle as a gravity mixer, in which the mixing vessel circulates around one axis to achieve a mix that is often referred to as "free-falling." 3-D mixer is also designed primarily for free-flowing formulations, gravity mixers use the force of gravity, rather than an external mechanism, to pull and blend the mix.

This mixer improves on this design by using three axes rather than two to accomplish the mixing process. Due to the intrinsic design of the three-dimensional motion, the homogeneity of the mix does not depend on the size or shape of the vessel; instead, the energy input is distributed proportionally throughout the entire volume of the vessel, ensuring a gentle, constant and reproducible mixing process at all times (see Figure 1). The addition of the third axis tremendously increases the effectiveness of the mix, both in speed and uniformity [4].

The extraordinary efficiency of the 3-D Mixer is based on the introduction of a well established type of kinematics' principle. In addition to the traditional principal motions of rotation and translation, a third fundamental motion of inversion-based on the Schatz inversion geometry-is present in 3-D Mixer machines [5].

In conventional mixers, the centrifugal force of the motion of rotation tends to favor segregation rather than mixing. The turbulence created (by baffles, inclined surfaces, etc.) is an afterthought and not intrinsic to the design of the blender.

III. THE ACTION ON MATERIAL INSIDE 3- D MIXER

In the 3-D Mixer a third fundamental motion of inversion subjects the contents of the mixing container to two alternating, rhythmic pulsating motions which have the effect of continuously compressing and thinning out the container.

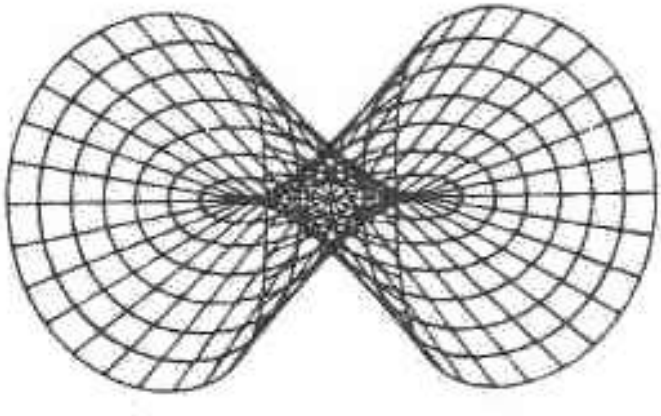

Figure 2. Path of motion travelled by axis of mixing chamber

The alternative acceleration and retardation of particles along changing paths can be seen from the path of motion traveled by the axis of the mixing chamber (see Figure 2). The surges in the material constantly change energy gradients resulting in superior blends; it is an ordered motion for distribution rather than the random motion of conventional mixers.

The pulsating inversion movement of the 3-D Mixer fluidizes mixing material and gently forces it into constant motion. Due to friction the material attaches to the vessel walls and is lifted with the wall, when it rotates. At the highest point gravity pulls the material down, where it is displaced by the rhythmically pulsating vessel wall.

Without any sharp reversal of movement the mixing material undergoes alternating compression and decompression. Due to this very special motion even compounds with highly varying physical properties do not segregate. The quality of the mixture or of the emulsion does not decrease.

Due to this unconventional motion, the 3-D Mixer is a highly efficient but gentle high-performance mixer

IV. DEVELOPMENT OF WORKING MODEL 3D MIXER

As discussed earlier, the mechanism of 3D mixer looks very simple, as it doesn't involve any complicated components like gears, cams, etc. However the issue of developing such mechanism is not that simple. If the link lengths of the mechanism are selected arbitrarily, it may result in locked or immobile mechanism. The related issue was discussed with two entrepreneurs, who have earlier tried to make this mechanism but could not succeed.

Based on the feedback received from the entrepreneurs, the main parts of the 3D Mixer are identified as follows:

1. Fixed Base
2. Fork 1
3. Yoke 1
4. Cylinder
5. Yoke 2 and
6. Fork 2

Each of this part represents the links of the basic mechanism. Hence our machine is Six Link Spatial Mechanism. The joining of cylinder with the Yokes resembles the Universal Joints with joining axis at both ends are mutually perpendicular.

V. DEVELOPMENT STAGES

Metal Strip Model

Initially, the shapes of the above parts i. e. Yokes and Forks were formed with the thin aluminum strips. A small plastic bottle was used to represent the cylinder. The joints between the parts were made with light pins. The whole assembly was mounted on wooden board. For this model, torque was applied manually on one of the Fork. The applied torque on Fork 1should be able to turn Yoke 1; Yoke 1 to Cylinder, Cylinder to Yoke 2 and finally Yoke 2 to Fork2. If it becomes possible to turn Fork 1 full cycle (360°), then it will result in spatial movement of the cylinder. However, the initial attempt to turn the mechanism for full cycle was failed. But in next step attempt was made to vary the linear distance between Fork 1 and Fork 2. Every time after varying the distance attempt was made to rotate the fork 1 full cycle manually to result in full cycle movement of the mechanism.

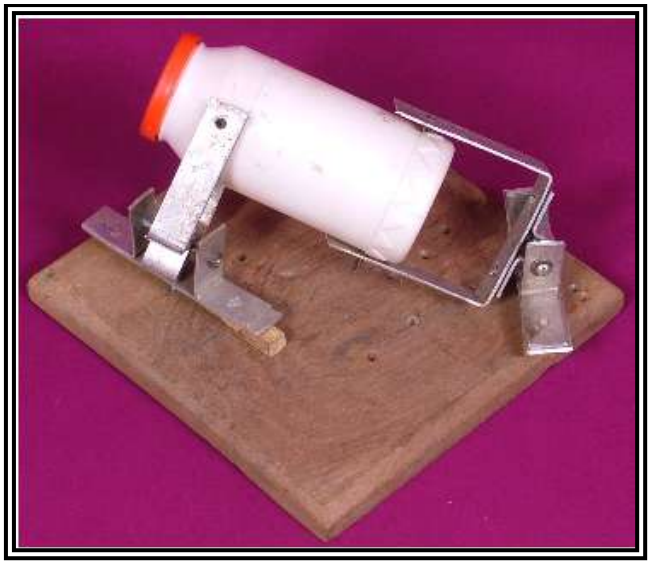

Figure 3. Metal Strip Model of 3-D Mixer

It was observed that within some specific range of distance between Forks, the whole mechanism has mobility. As the torque to the Fork was applied manually, it was difficult to judge the exact critical distance between the two Forks which makes the mechanism to move smoothly over whole cycle.

The above trial was the first essential step to explore the mechanism. Though the method applied in trial was crude, it was able to generate an essential initial judgment that for the given length of the links, there must be some specific distance between the Forks which imparts full cycle mobility to the mechanism.

However, still there are many more questions to be addressed, like:

- Is there only one critical link length which affects the mechanism mobility?
- Is the measure of distance between the Forks, which makes the mechanism mobile, is the unique measure or are there any more alternative measures of distance between the Forks which also imparts full cycle mobility of mechanism?
- What about the other link lengths and their respective mutual proportions? Do they affect to mechanism mobility?

Making the model with Polypropylene parts

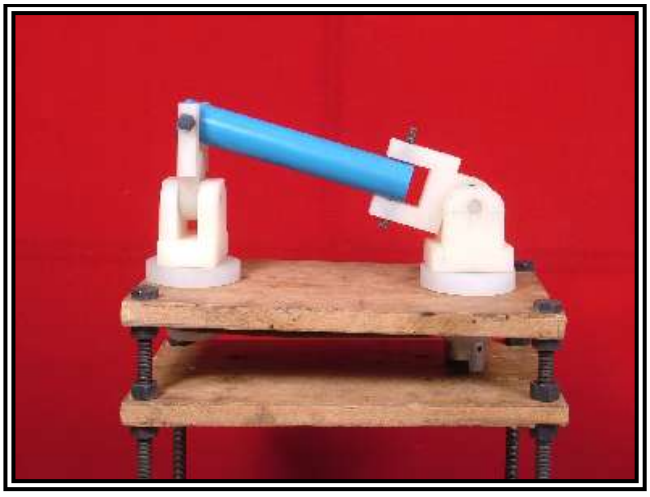

Figure 4. Polypropylene Model of 3-D Mixer

The strip model has generated some useful clues and hence it was felt necessary that instead of applying torque manually at the Fork 1, an electric motor is to be used to turn the Fork 1 and thereby whole mechanism. Hence it was necessary to make the parts properly and to connect the assembly to motorized drive. As the requirement was just to make a model which should resemble to actual machine, it was essential that the material of the parts should be light weight, at the same sturdy enough to withstand the loads. Polypropylene was the obvious selection, which is cheap, can be easily machinable and shaped, light in weight compared to metal and tough enough to absorb shocks and loadings.

The parts are fabricated and assembled. For mounting this assembly a two tier wooden platform is made. Simple ball bearings are used at the joints of Yoke & Fork and Fork & Base. Bearing housing at the joint of Fork 1& Base was fixed with base. For mounting the Fork 2 bearing housing, an oblong hole is made on wooden board, so that distance between the two Forks can be varied within some range as required. Fork 1 is driven through stepper motor and pulleys. Every time after varying the distance between the Forks, motor is driven and the mobility of the mechanism is verified.

The above trial was successful to some extent. At some specific position of Fork, mechanism has given full cycle mobility. But here the problem of mutual interference of parts was observed. The width of the Yoke was bit larger with respect to its length and hence there was interference either at Yoke & Wooden Board (Fixed Base) or at Yoke & Fork. This hindered the full cycle mobility of the mechanism.

With this trial important conclusion could be drawn that if the interference between the parts is avoided by reducing the width of parts in transverse direction and if two Forks are positioned properly at some specific distance, the full cycle mobility of mechanism can be achieved.

VI. WORKING MODEL OF 3-D MIXER

Model with Sheet Metal Rolled Cylinder:

After learning from the above two trials, it was decided to make a full fledged working model of 3D Mixer using Mild Steel sections, Cast Iron and Sheet Metal as chief raw materials.

Initially the CAD model of the 3D Mixer was made in Pro/E and its interference and mobility is verified with Mechanism mode. With some trials & errors dimensions of the parts were finalized.

Yokes required for the model were to be made from C. I., so its wooden pattern was made and given for casting. Forks and other parts were machined from M. S. bars. For the base, metal sheet was formed to provide the sturdy base. While assembling, the distance between the Forks was fixed by trial & error method to achieve full cycle mobility of the machine. To drive the Fork 1, 0.25 HP 3 Phase motor is used and to reduce its RPM a 50:1 gear box is employed.

When the motor is switched on, cyclic spatial movement of the cylinder is started.

It was observed here that, at some instants of the cycle, the movement of cylinder is jerky at driven end. This is mostly due to the pin joint between Yoke & Cylinder. It was also observed that after switching off the motor, mechanism stops with locked position, from where it becomes difficult to restart the machine.

Pin joint has only one degree of freedom and if we can change this joint (joint between Yoke & Cylinder) to ball joint, three degree restricted movement may be achieved. This will perhaps, solve the above mentioned problem and smooth movement of Cylinder may be achieved.

Model with Spherical Bearings:

To implement the idea of ball joint, suitable size of spherical bearing was selected to use it at Yoke-Cylinder joint. Since mounting of these bearings requires modification of Yoke, it was decided to make new pair of Yokes.

New pair of Yokes was cast and required machining was done to accommodate the spherical bearings. The bushes required for this joint was also designed and made.

Machine is reassembled with this modified Yokes. Motor drive is switched on and movement of cylinder is observed. Earlier jerky movement of cylinder seems reduced now. Machine is stopped and restarted frequently to verify the locked position of the links at any instant. It was observed that machine can be restarted from any stopped position and thus locked position is now avoided.

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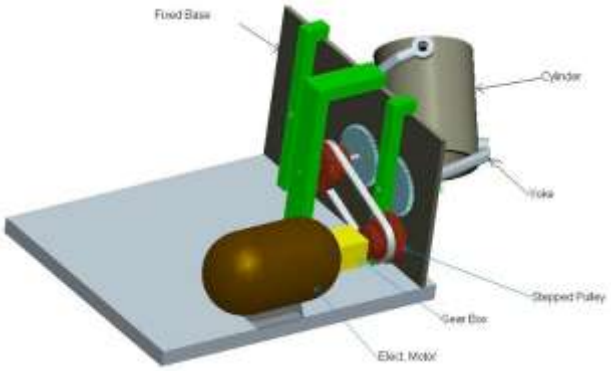

Figure 5. 3D Mixer Assembly (View 1)

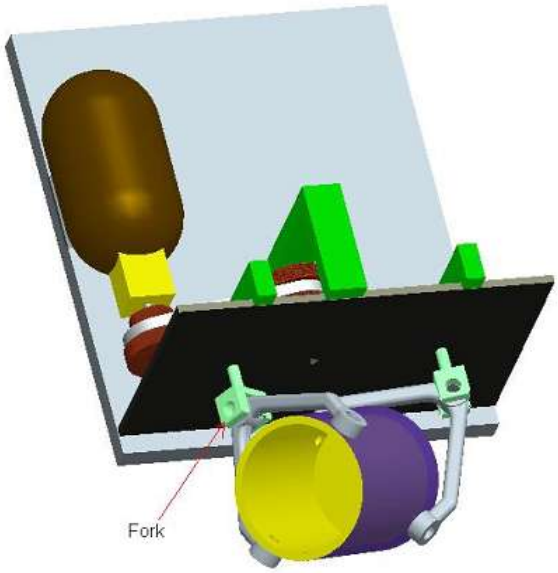

Figure 6. 3D Mixer Assembly (View 2)

Figure 7. Yoke

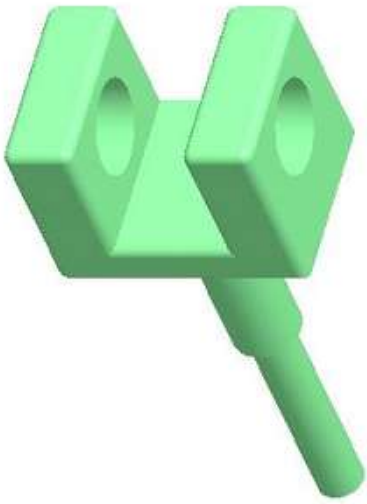

Figure 8. Fork

The function of Cylinder is to hold the contents mixture. Presently the Cylinder used is made of rolled sheet metal, which is too heavy (4.50 Kg.). Hence it was decided to make wire frame form Cylinder which can hold the removable container.

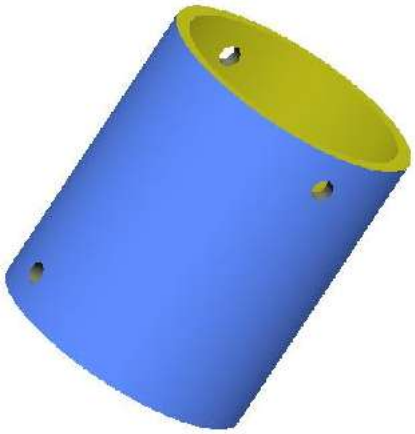

Figure 9. Cylinder

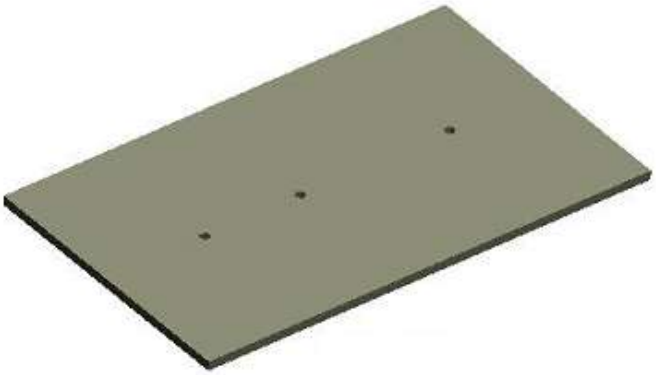

Figure 10. Fixed Base

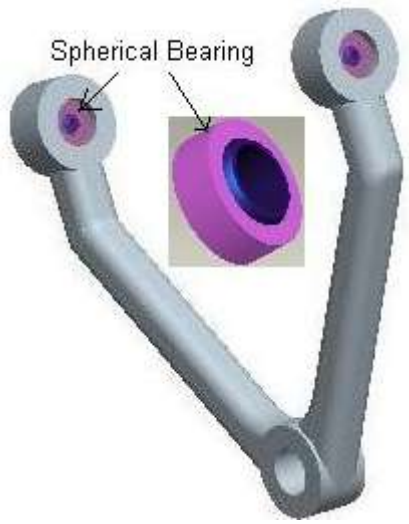

Figure 11. Yoke with Spherical bearing

Model with Wire Frame form of Cylinder

To make wire frame form Cylinder, M. S. Flat 20 X 3 mm is used. Two pieces of flats are formed to ring shaped with diameter of ring equal to the diameter of our earlier cylinder. Both these rings are joined with four numbers of straight pieces of flat to make wire frame cylinder. Necessary arrangement is made for holding the plastic bottle / Jar. Also rubber cushions are provided inside this cylinder to avoid wear of container surface. The arrangement could reduce the weight of Cylinder considerably and also loading and unloading of container has become easy.

With this reduced weight cylinder, its movement further smoothened and jerks were avoided totally. Locked position instant was also disappeared totally.

Figure 12. Wire Frame Form of Cylinder

VII. CONCLUSION

A mixing machine described here employs a very interesting mechanism. Attempt is made here to develop the working model of this mixer. The mechanism of this 3D mixer contains six links including the fixed base. If the lengths of these links are selected arbitrarily then the mechanism may either result in locked position or there may be mutual interference of part surfaces. This paper describes the practical approach of developing the actual working model of such mechanism. Mobility of the mechanism is proved by making actual working model of 3D mixer.

Cost effective development of working model of 3-Dimensional Mixing machine is the achievement of this work. The whole assembly of this machine involves only few simple parts. The process of fabrication of these parts is not only common and simple but it is very economical also. With the few parts, assembly of this machine gives brilliant movement to the Drum and hence this type of mixing machine has several advantages over the conventionally used machine. With simplicity in design, maintenance and running cost of the machine can be lowered. Benefits like time saving, cost saving and achieving homogeneity of the mixture regardless of variation in size, shape or densities of the ingredients of the mixture can impart a sharp cutting edge over other mixing machine

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