ISSN 2395-1621

Design, Development and Analysis of Schatz Mechanism with 3-D Motion Mixer

#1K.L.Bhoite , #2G.M.Kakandikar

1klbhoite@gmail.com

2kakandikar@gmail.com

#12Dnyanganga College of Engineering & Research, Savitribai Phule Pune University, Narhe, Pune-41, India

ABSTRACT

Mixing of two or more materials (i.e. heavy density metal powder in the fluid) is very difficult. In conventional method of mixing the metal powder and fluid mixing is carried out on unidirectional stirring machine. This paper investigates the limitations of the conventional mixer. The stirrer of conventional mixer rotates in one direction only which create a particular flow pattern in the fluid hence particles tend to stick to the wall of container due to centrifugal force. Most of the materials are settle down below the container due to high density. In conventional mixer, the other main issue is the vibrations, thrust and bending forces that create noise and high maintenance of machine. The research work is based on the Schatz geometry shaker mixer which is used for a homogeneous mixing of powdery substances with differing specific weights and particle sizes. The product is mixed in its own closed container. The mixing container is set into a three dimensional movement that use of rotation, translation and inversion according to the Schatz geometric theory. It is design, development, and analysis of driving system of Schatz mechanism with 3D-motion mixer to produce desired motion pattern, increase mixing rate and quality.

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

Keywords- **conventional mixer, inversion, Schatz mechanism.**

I. INTRODUCTION

In many industries mixing of powder is a common operation and for this different mixing devices such as V-shaped drum mixer, Turbula mixer and static mixer will be used. Static mixers can be used for mixing powders of different density and Turbula mixing devices used in pharmaceutical industry for very fine powders.[1] A mixture can be told as homogenous if every sample of the mixture has the same composition and properties as any other. In conventional method of mixing the metal powder and fluid mixing is carried out on unidirectional stirring machine. The stirrer of conventional machine rotates in one direction only which creates a particular flow pattern in the fluids hence the particles tend to stick to the wall of container due to the centrifugal force; ultimately results into poor quality mixture will be formed. Most of the materials having high density are settle down as compare to low density materials. [2] In conventional mixer, the other main issue is the vibrations, thrust and bending forces that create noise and high maintenance of machine.[3] So, There is the need of producing the apparatus having the combination of rotating, tumbling and shaking movements of a material in a container which has a closed and constrained invertible kinematic link-work of which at least one link serves as receptacle for the container, and motive power for driving the link work can be provided by imparting thrusting power, rather than the rotating power. [4] For each mixing method a characteristic mechanism determines the rate and the attainable degree of mixing. The mixing quality, i.e. the degree of homogeneity is especially important when a relatively small amount of an active ingredient is to be distributed in a large quantity of bulk solids or powders.[5] The proportions of materials to be mixed play a very important role in powder mixing. It is easy to mix the powders if they are available in equal quantities but it is difficult to mix small quantities of powders with large quantities of other ingredients or diluents. Material density, particle size, particle shape, particle attraction these physical properties of powdery material also affect the mixing. [6] A three-dimensional movement of a cylindrical container can be achieved in the Turbula mixer. The Turbula mixer is a laboratory scale mixer, which is widely used in industry for the development or testing of new granular products. It comprises simple vessel geometry that moves with a complex 3D motion. The container motion consists of two rotations of the container around its longitudinal axis and a horizontal translation. [7]

A. *Construction and Working of Schatz Mechanism*

The Schatz linkage discovered and patented by Schatz was derived from a special trihedral Bricard linkage. Schatz linkage is also known by the name Turbula. It is used for mixing fluids and powders. [8] Elements in the following description are identified by like reference designations. Turning to Fig.1This shows a base 1 from which vertically mounted shafts 3 and 4, which are suitably placed in the enclosure 2 of base 1. The drive system contained in base 1 is identified by reference designations M1 and M2. The torque imparted to shafts 3 and 4 is respectively transmitted to clevises 6 and 7 and then to yokes 8 and 9 which, in turn, are linked to the receptacle identified by reference designation R. The yokes hinges at (10, 11) and (12, 13) in right angles to each other in different planes, and the two yokes 8 and 9 are hinged at their respective mid- points two the clevises 6 and 7. Yokes 8 and 9 are always in different planes, and the clevises 6 and 7 being extensions of the two parallel shafts 3 and 4, which are mounted in the base 1. Fig.1 and 2 taken together with Fig.3indicate the operation of inversion linkage mechanism with torque being applied to vertically disposed drive shaft 3 and 4. In every 360˚ rotation of a respective shaft (3 and 4) there are only two phases, indicated by segments of arc, during which lifting of the center link 14 takes place. With respect to the vertically disposed shafts (3 and 4) lifting in specification refers to the facts that the yokes 8 and 9 are positioned perpendicularly with respect to one another and the right hand end 14a of the center link 14, has been raised from the mid-way position in the lifting motion of the inversion linkage mechanism.

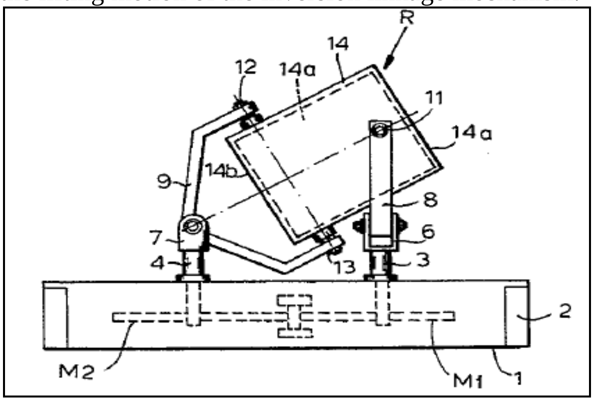

Fig.1 Schatz linkage in which receptive link at its highest position.[9]

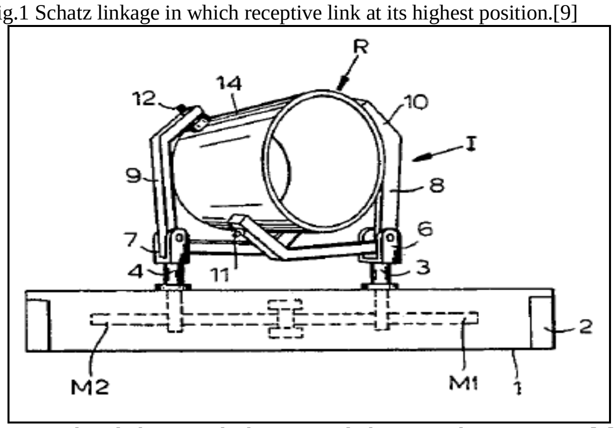

Fig.2 Schatz linkage in which receptive link at its mid-point position[9]

The mid way position is indicated in Fig.2 and the yokes 8 and 9 are now positioned parallel with respect one another the mid-way points are on lines X-X in Fig.3, and the highest position of lifting motion, as is indicated in Fig.1, are on lines Y-Y in Fig.3.

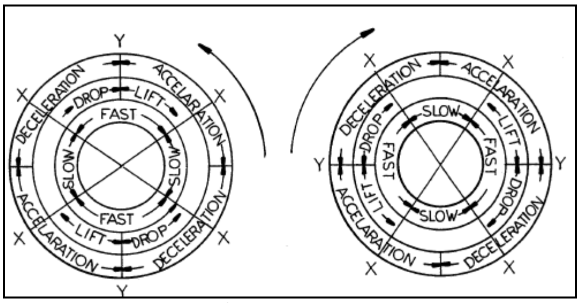

Fig.3 Operation of inversion linkage mechanism[9]

(14a) and (14b) is lifted twice during each 360˚ rotation of each drive shaft (3 and 4). Because of pivot axes of the clevises 6 and 7 at which are connected the centers of the yokes 8 and 9, are disposed at 90˚ angle to each other. A total of four lifting phases must occur in each 360˚ rotation of the center link 14. [10]

II. DESIGN OF DRIVING SYSTEM OF SCHATZ MECHANISM

Estimation of the torque, stresses and power requirements of Schatz geometry shaker mixer for mixing of specified viscous fluids for 1.5 litre volume of mixture.

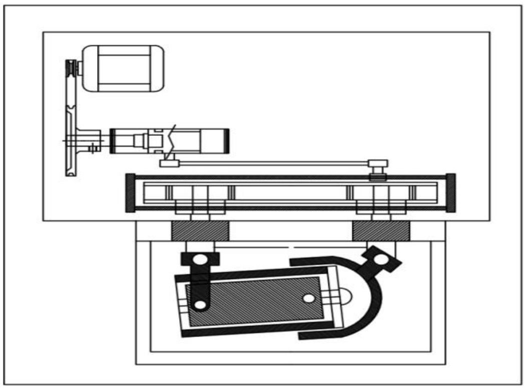

Fig.4 Line diagram of Schatz geometry 3-d motion mixer

A. *Motor Selection*

The selecting a motor of the following specifications
Single phase AC motor
Commutator motor
TEFC construction
Power = 50 watt
Speed= 0-14500 rpm (variable)

B. *Design of Worm and Worm Wheel*

The pair of worm and worm wheel used in the machine is designated as

1/80/10/1.5

The worm is made of case hardened steel 14C6 and the worm wheel is made of Cast iron.
No. of starts on Worm = Z_1 = 1
No. of Teeth on Worm Wheel = Z_2 = 80
Diametral Quotient = q= 10
Module = m = 1.5 mm.

Speed Ratio = i = $\frac{Z_2}{Z_1}$ = 80 mm.

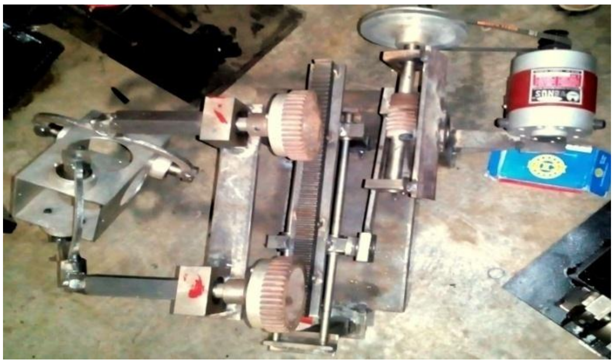

Fig.5 Photograph of test rig

Worm Input Shaft Speed = N_1 = 1550 rpm
Worm Wheel Output Shaft Speed = N_2 = 1550/80 = 20 rpm
Dimensions of Worm
Pitch circle Diameter = d_1=qm = 15 mm
Outside diameter of the worm = $d'_{a1} = m(q+2) = 18$ mm
Lead angle = $\tan\gamma = \frac{Z_1}{q}$ = 5.71°
Root diameter = $d_{f1} = m(q+2-4.4\cos\gamma) =$ mm
Circular pitch of the worm=$Px = \pi m$=4.71 mm
Dimensions Worm Wheel
Pitch circle Diameter = d_2 = m x Z_2= 1.5 x 80 = 120 mm
Throat Diameter $=d_{a2} = m(Z_2 + 4\cos\gamma - 2) = 122.97$ mm
Root diameter = $d'_{f2} = m(Z_2 - 2 - 0.4\cos\gamma) = 116.40$ mm
Face Width = $F = 2m\sqrt{(q+1)}$ = 9.94 mm
Clearance = C = 0.2mcosγ = 0.3mm
$L_r = \{d_{a1} + 2C\}\sin^{-1}\{\frac{F}{d_{a1}+2C}\}$ = 632mm
For case hardened steel,
Bending Stress Factor= S_{b1} = 28.2
For CI,
Bending Stress Factor = S_{b2} = 6.2
Speed factor for worm= X_{b1} = 0.25
Speed factor for worm wheel= X_{b2} = 0.48
Permissible torque on the worm wheel
$M_{t1} = 17.65 X_{b1} S_{b1} m L_r d_2 \cos U$ = 4.694 x 10^6 N-mm
$M_{t2} = 17.65 X_{b2} S_{b2} m L_r d_2 \cos U$ = 1.98 x 10^6 N-mm
The lower value of torque is on the wheel = 1.98 x 10^6 N-mm
Power transmitting capacity = $P = \frac{2\pi N_2 M_t}{60\times10^6}$ = 7.46 KW
As the drive is capable of transmitting 7.46 KW and we intend to transmit 0.05 KW the drive is safe.
Design of Worm Wheel Shaft
The power is known by

$$P = \frac{2\pi NT}{60}$$

Motor is 50 watt power, run at 6000 rpm, connected to worm shaft by belt pulley arrangement with reduction ratio 1:5
Hence input to worm gear box = 1550 rpm
The worm gear box is the reduction gear box with 1:80 ratio
Hence input speed at the input shaft = N_1 = 1550/80 =20 rpm

$$T = \frac{60 \times P}{2\pi N_1}$$

= 23.87 N-m
T_{design} = 24 N-m

Design stress of wormwheel=σ_c= 540/(z/q)√((z/q)+1/a)^{3Mt}
=3.497 ×10^6

C. Check for Torsional Shear Failure of Shaft:
Assuming minimum section diameter of worm shaft = d_1 = 15 mm

$$f_{s\,act} = \frac{T_d x16}{\pi x d^3}$$

$$= \frac{16 \times 24 \times 10^3}{\pi x 15^3}$$

$$= 36.22 N/mm^2$$

As $f_{s\,act} < f_{s\,all}$
Input shaft is safe under torsional load.

III.KINEMATIC ANALYSYS OF THE SCHATZ LINKAGE

Schatz linkage is an over constrained single-loop linkage proposed by Schatz [1], which is one of a best mechanisms that have been applied to industry. The Turbula shaker-mixer is used for the homogeneous mixing of powdery substances with differing specific weights and particle sizes. The product is mixed in its own closed container. It is also possible to mix wet and dry components or different wet components. The production process is hygienic and dust-free, making the Turbulaeasy to clean. The mixing container is set into three-dimensional movement that exposes the product to always changing, rhythmically pulsing motion. The results fulfill the highest requirements and areachieved in a minimum of time.
Schatz linkage is a 6R loop, and its joint axes are distributed with special conditions expressed as $a_{12} = a_{56} = 0$, $a_{23} = a_{34} = a_{45} = a$, $a_{61} = \sqrt{3}a$,
$\alpha_{12} = \alpha_{23} = \alpha_{34} = \alpha_{45} = \alpha_{56} = \alpha_{61} = \pi/2$,
$R_i = 0$ (i = 2,...,5), $R_1 = -R_6 = R$

It is well known that the structure analysis for a classic single loop is very difficult due to the special geometric distribution of the joint axes. A ruled surface defined by the change of the constraint wrench when the linkage drive angle y1 changes from 5° to 85° is shown in Fig. 6, in which the lengths of the lines segments represent the magnitudes of wrenches. This also denotes all possible resultant wrenches of constraint existing in a linkage.

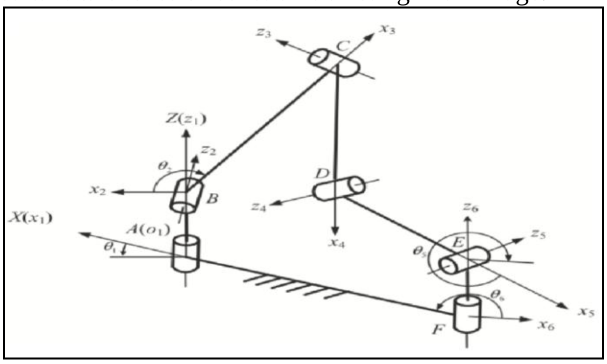

Fig.6 Sketch of Schatz mechanism

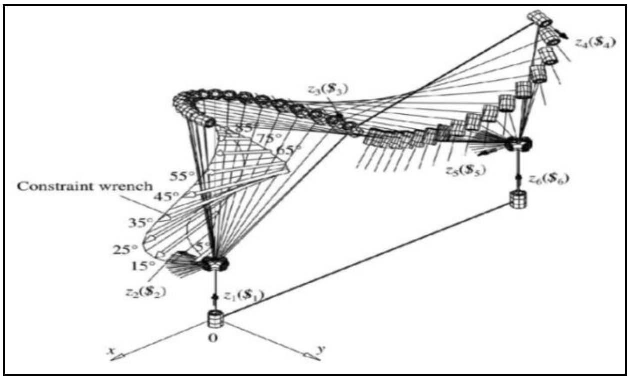

Fig.7 Change of the position of the yokes when linkage operates.

IV.DESIGN VALIDATION USING FEA

The structural model to be analyzed is divided into many small pieces of simple shapes called elements. Finite Element Analysis (FEA) program writes the equations governing the behaviour of each element taking into consideration its connectivity to other elements through nodes. These equations relate the unknowns, for example displacements in stress analysis, to known material properties, restraints and loads. The program assembles the equations into a large set of simultaneous algebraicequations - thousands or even millions. These equations are then solved by the program to obtain the stress distribution for the entire model. In recent years, with the initiation of advanced software's, the FEA based software ANSYS, COSMOL, DIANA, ABACUS and NASTRAN have been very useful for stress analysis. These software's are preferred by users according to the type of stress analysis, the type of elements to be analysed and the depth of accuracy required.

A static structural analysis of the worm, worm wheel and worm wheel shaft are conducted by using ANSYS 14.5. For the safe design, compare the values of stresses in ANSYS and analytical method.

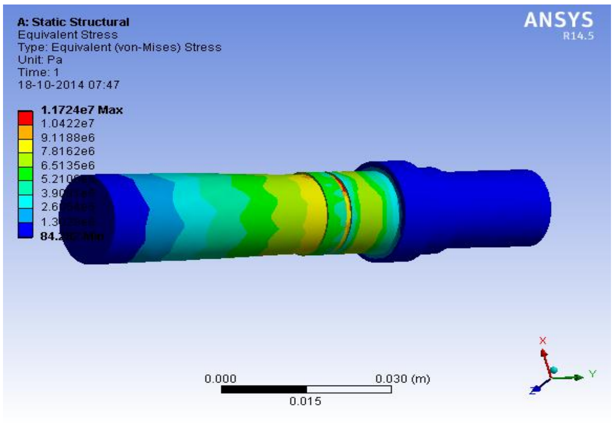

Fig.8Stress contour of the worm wheel shaft

A worm wheel shaft having clockwise moment will be act in the y-axis direction which magnitude is 4 N.m. Its moment components are (0, 4, 0). Fig.8 shows the maximum equivalent (von-mises) stress of the worm wheel shaft is 10.724 $\mathrm{N/mn}$ and the stress by analytical method is 36.22 $\mathrm{N/mn}$.

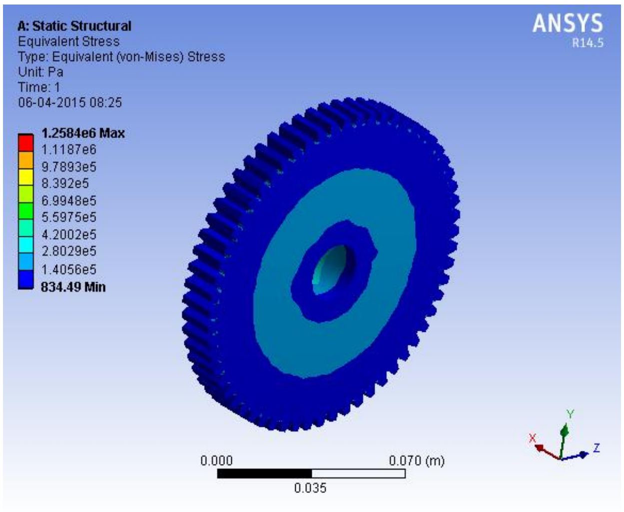

Fig.9Stress contour of the worm

A worm wheel having anticlockwise moment will be act in the x-axis direction which magnitude is 16 N.m. Its moment components are (-16, 0, 0). Fig.9 shows the maximum von-mises stress having magnitude is $1.25\mathrm{N/mm^2}$ and which is act at its inner core. A worm having clockwise moment will be act in the y-axis direction which magnitude is 16 N.m. Its moment components are (0, 16, 0). Fig.10 shows the maximum von-mises stress having magnitude is $1.25\mathrm{N/mm^2}$ and which is act at threads.

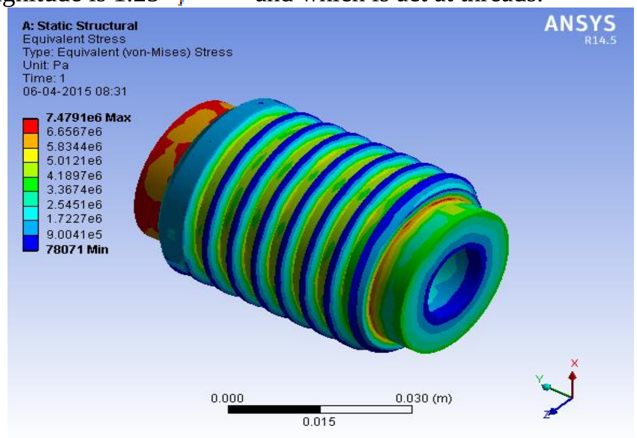

Fig.10Stress contour of the worm

V.CONCLUSION

The Schatz geometry shaker mixer is used for a homogeneous mixing of powdery substances with different specific weights and particle sizes. The features of this mixer are- they mix extremely heavy powders with light ones, minute quantities with huge volumes, fragile granules without crumbling, particles of different diameter, dust-free processing, easy cleaning, minimum shear force, no product separation and minimum machine maintenance. The designed drive system having low cost, good performance and easily drive Schatz linkage. Mechanical design of critical components validated using the FEA analysis by ANSYS.

ACKNOWLEDGMENT

The satisfaction and exhilaration that accompany the successful completion of any task would be incomplete without the mention of the people whose constant guidance and encouragement aided in its completion. The authors would like to express the voice of gratitude and respect to all who had directly or indirectly supported for carrying out this study and special thanks to Moraya garage and DCOER, Pune.

REFERENCES

[1] Ingrid Bauman, Du Ska, Curi C and MatijaBoban, “Mixing of Solids in Different Mixing Devices”, Sadhana, Vol. 33, Part 6, December 2008, pp. 721–731.

[2] [2] C-C Lee and J S Dai, “Configuration Analysis of the Schatz Linkage”, Journal of Mechanical Engineering Science, Vol. 217, Part C, 2003, pp.779-786.

[3] Donald I. Cruse, “Apparatus with Inversion Linkage Mechanism”, Patent No- 5360265, United States, Date of Application-Dec.15, 1992.

[4] P. S. Kulat, Prof. R. B. Chadge,”3d Motion Mixer for Material”, International Journal of Pure andApplied Research in Engineering and Technology, Vol. 2 (9), 2014, pp.97-102.

[5] Yong KweonSuh and Sangmo Kang, “A Review on Mixing in Microfluidics”, Micromachines, Vol.1, 2010, pp.82-111.

[6] Benjamin Ivorra, Juana L. Redondo, Juan G. Santiago, Pilar M. Ortigosa and Angel M. Ramos, “2D and 3D modelling and optimization for the design of a fast hydrodynamic focusing micro fluidic mixer”, Stanford University, April-2012, pp.1-28.

[7] Douglas Bohl, Naratip Santitissadeekorn, Akshey Mehta, and Erik Bollt, “Characterization of Mixing in a Simple Paddle Mixer Using Experimentally Derived Velocity Fields”, Clarkson University, pp.1-24.

[8] Jiten Patel, G.K. Ananthasuresh, “A Kinematic Theory for Radially Foldable Planar Linkages”, International Journal of Solids and Structures, Vol. 44, 2007, pp .6279–6298

[9] Yan Chen, “Design of Structural Mechanisms”, Dissertation Submitted for the Degree of Doctor of Philosophy in Department of Engineering Science at the University of Oxford Trinity Term 2003.

[10] P.S.Jadhav, Prof. B.R.Jadhav, “A Study on Mixing of Composite Solids in the Three Dimensional Turbula Mixer”, International Journal of Advanced Engineering Research and Studies, Vol. II, April-June, 2013, pp.138-141.

[11] Richard S. Hartenberg, and Jacques Denavit, “Kinematic Synthesis of Linkages”, Mcgraw-Hill Series in Mechanical Engineering, 1994, pp.343-366.

