National Conference on Recent Advances in Design Engineering (RADE 2007)
Department of Mechanical &Manufacturing Engineering
Manipal Institute of Technology, Manipal – 576104
February 22 – 24, 2007; MDS – 02

DEVELOPMENT OF A DOOR STEERING MECHANISM FOR A LARGE AUTOCLAVE

Ramaswamy[1], Dayananda[2], Subba Rao[3]

[1]*Scientist, Advanced Composites Division, ramaswamy@css.nal.res.in*
[2]*Scientist, Advanced Composites Division, dayanand@css.nal.res.in*
[3] *Head, Advanced Composites Division, maddela@css.nal.res.in*
National Aero-Space Laboratories
Bangalore- 17

ABSTRACT

Davit arms are usually employed to handle doors of large size autoclaves. These arms require a guiding mechanism to guide the door in a desired path and locate in the desired position. In this work, various options of door handling / steering mechanisms were examined and finally a four bar mechanism is chosen for detailed design. A Geometric model was developed to understand the path traced by the door for various link angles and lengths. Solid modeling of the door was carried out using Solidworks R and simulation of the path of the door for various angles and lengths of the links of the 4 bar mechanism was also done. The prototype model of the autoclave door was fabricated with a 4 bar mechanism mounted on the davit arm of the door. Number of trials were made by changing link lengths and angles to determine the path of the door, using the CAD geometric model. These results are in agreement with the experimental results obtained using fabricated model.

Key Words: Autoclave, Door steering, Four bar mechanism, Geometric modeling, prototype model

INTRODUCTION

Autoclave moulding techniques are increasingly used in advanced composites manufacturing for aero-space structures. As consequence large and larger structural parts are being built, this requires very large autoclaves. Recently Boeing has established the world's largest autoclave. Its working envelope is 9.2m diameter, 23m length and a volume of about 2,322m^3. This type of autoclaves require special door handling systems [3].

The Autoclave shell is a pressure vessel that provides the means to retain pressure inside the workspace. The autoclave door is usually torispherical in shape. Spherically dished covers are also used to reduce the height of the dish. This will reduce the longitudinal and transverse moments during opening and closing of the door, which will have a bearing on the design of door handling mechanism. The Autoclave doors have to be quickly closed and locked to reduce the loading time. Accordingly suitable door handling mechanism needs to be designed. It is mandatory to design and fabricate the pressure vessels to ASME/BS/IS requirements. One of the critical design features of large autoclaves, is the design of reliable and efficient door handling mechanism.

a: Door Handling Systems

Generally full opening equivalent to the shell diameter is provided for the autoclave to load the components for curing. The doors are employed to close these openings. The door has to be quickly closed and locked to reduce the door operation time. Since the autoclave is a pressure vessel, the weight of the door increases steeply as the diameter of the shell increases. Correspondingly, the door handling systems weight also increases. For large autoclaves, the design of the door handling systems is a challenge to the designer. The requirements of the Door Handling systems of autoclave are as follows

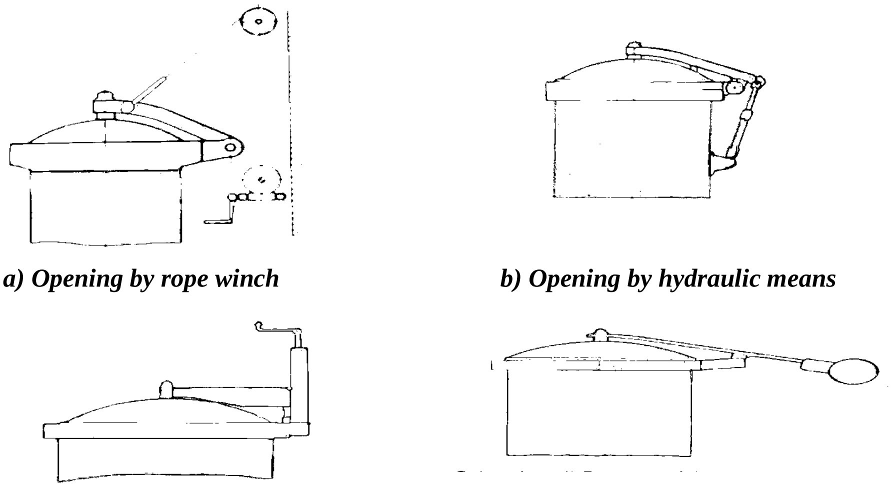
- It should occupy less space for the door path and for the parking of the door
- It should not hamper the loading and unloading of the parts in to the autoclave

- The complete door closing and locking operation should be as quick as possible
- It should have less number of components and be easy to assemble and disassemble
- It should have the provision to adjust the door alignment with the shell. It is important for large autoclaves
- It should not compromise the safety aspects of the pressure vessel and the design should meet the pressure vessel code requirements

Depending on the requirement, size, available space, various methods are being used to handle the doors. The autoclaves are either vertical or horizontal type. Vertical autoclaves are generally used for curing components such as solar panels of the satellite/ aircraft control surfaces whose one dimension is far less than the other two dimensions.

Fig.1 shows types of door handling systems for vertical autoclaves. Fig.1a shows the opening of the door by rope winch, which is generally used for small autoclaves. This occupies more space. Fig.1b shows the opening of the door by hydraulic means. This occupies less space and handles heavy doors. . Fig. 1c shows the door operation by swivel arm with spindle operation. This system lifts the door for upright operation without tilting it. Fig. 1d shows the door with hinge and balance weight. This reduces the effort required to operate the door but takes more space and is heavier for a given size.

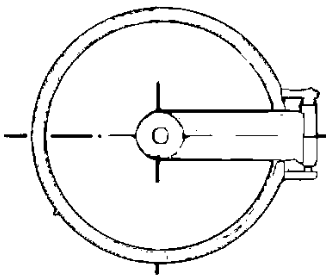
The horizontal autoclave doors are either hinged type or suspended by Davit arm .The Fig 2a shows the hinged door. Manufacture of the hinged mechanism for the door is fairly simple. The hinged door, offers the advantage of easy fabrication and assembly. However, it suffers from the disadvantage that it occupies the precious shop floor space and hampers the free movement of personnel in the vicinity of the door. Also, for large size shell, the hinged door is uneconomical. The required over hang radius of the hinged door is more than half of the diameter of the door, which is very high when compared with the overhang radius of the davit arm which is generally about 1/3 rd of the door diameter. This substantially reduces the weight of the door handling system components, particularly for large autoclaves, as the davit arm door components have to resist the less moment. The davit arm mechanism is shown in Fig. 2b. It is slightly more involved in both the design and manufacturing and its notable advantage is that it enables the door to be tucked to the side, thereby making the shop floor space in front of the autoclave available for the free movement of men and material. It is also economical and elegant, particularly for large size shells. [1]



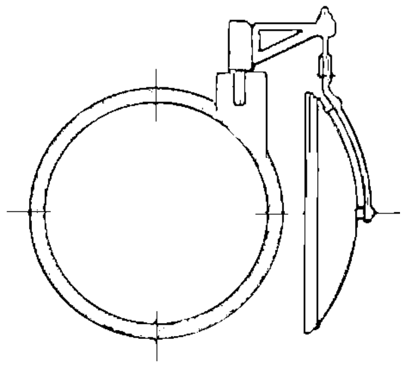
a) Opening by rope winch ***b) Opening by hydraulic means***

c) Swivel arm with spindle ***d) Hinge with balance weight***

Fi***g1. Door handling system for Vertical Autoclaves***



a. Hinged Door



b. Davit arm type door

Fig2. Door handling system for Horizontal Autoclaves

NEED FOR THE DOOR STEERING MECHANISM

As was discussed, the davit arms are generally employed for handling large autoclave doors. The davit arm provides the means for supporting the door and it takes the total weight of the door. The davit arm is rotated to move the door. It requires a guiding mechanism to guide the door in a pre-determined path and locate it in the desired position. The door should open at the beginning, along the longitudinal axis of the shell in order to avoid the interference with the lock ring of the autoclave shell. The door should not collide with the shell during its motion. Generally the door should travel the least distance and occupy less space for door movement and should be parked as close as possible to the shell to avoid large radius of davit arm.

The conventional guiding system of davit arm is shown in Fig.3a and Fig 3b. In this system, the radius of the path of the door has to be changed continuously during movement in order to get the required path. The door is mounted on the carriage to change the radius of the door. The carriage has to handle the weight of the door. The guiding mechanism of the carriage consists of a guide, side guide rollers, guide lever etc. The path of the guide has to be accurately designed and built. This complicates the design & fabrication of the entire door handling system apart from increasing the weight of the door handling components. In this system, there is no provision to adjust the door path after installation. In case, the required path of the door is not achieved, the entire guiding system has to be changed. The guiding system has to be designed accurately for smooth motion of the door without jerks and shocks, as there is no provision for altering the path after installation.

This has motivated us to look for a mechanism which will reduce the number of components (particularly the carriage) is easy to build and have provision for altering the door path and make minor adjustments by simple means even after installation of the door.

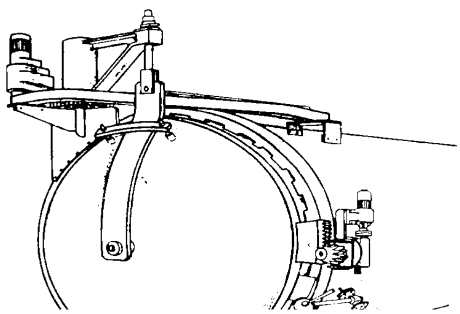


Fig3a. The Davit arm with conventional guiding mechanism

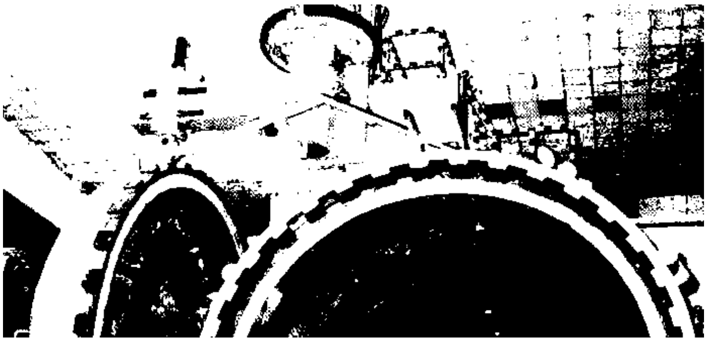


Fig3b. The Davit arm with conventional guiding mechanism

DOOR-STEERING MECHANISM

The various options of the door handling/steering mechanisms were examined and finally a four bar mechanism was chosen for detailed design.

a: Four bar linkage design

In engineering practice, most of the problems of four-bar linkage design fall into two classes.

(i) Co-ordination of input and output angles.

Double lever, crank lever and double crank mechanisms are used to coordinate input and output crank angles. In other words, when the input link sweeps through a specified angle, the out put link must pass through another specified angle.

(ii) Co-ordination of input and output linear displacement.

Slider crank mechanism is used to coordinate angles with linear displacements. In other words, when the input crank sweeps through a specified angle, the output slider must pass through a specified position on a straight line, & vice versa.

b: Design Approach

There are two approaches to the design problems of four bar linkages; the analytical and the graphical (geometric). The geometric approach is generally preferred by the designers because of its simplicity, clarity, accuracy and ease of application for engineering purposes. Designers can also visualize how the linkage would move and how it would fit the available space [2].

Initially Ackermann steering mechanism of an automobile was considered. In this mechanism, the angles of rotation of the two links are limited and cannot be rotated. Hence this mechanism could not be considered. Since the davit arm needs to be revolved by about 180°, to park the door side ways, we have to look for a mechanism, whose links (at least two) can make a complete rotation. There should not be dead centre position during a complete cycle of operation. The double crank mechanism, which meets the above requirement, was chosen. Fig 4 shows the line diagram of double crank mechanism. While designing the four bar linkage, the transmission angle of the linkage also has to considered. The transmission angle (μ) is of the same importance in the linkage design as the *pressure angle* is in cam design. The transmission angle is the angle between the coupling rod and output link. Generally the force transmission from the coupling rod to the output crank is effective for higher transmission angles. In this problem, we have chosen the geometrical approach to analyze the mechanism.

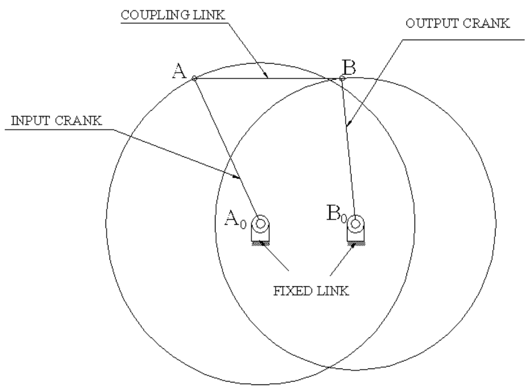


Fig4. Line Diagram of Double Crank Mechanism

IMPLEMENTATION OF FOUR BAR MECHANISM TO THE DAVIT ARM

The davit arm, which is rotated for door movement, was chosen as input crank. For the mechanism to work, it should have at least one fixed link. The link between davit mast & second crank is chosen as fixed link.

The output crank is designed as adjustable link, whose link length is adjustable. The coupler link is connected between the door and the output link. To adjust the link angles, key less hubs are used. Fig. 5 shows the arrangement of the four bar steering mechanism on the davit arm.

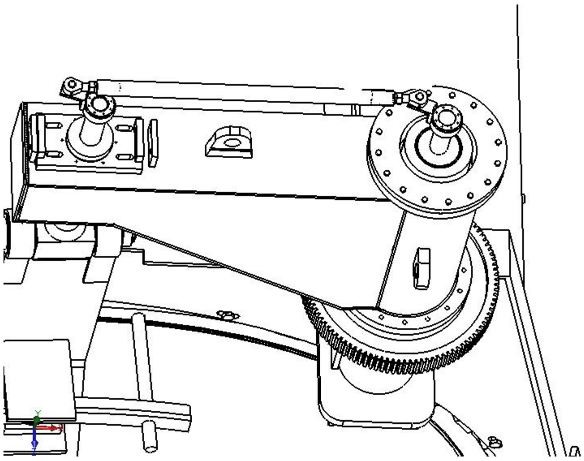


Fig5. The arrangement of steering mechanism on the davit arm

GEOMETRIC MODELING

To analyze the co-ordination of input &output angles of the linkages of the four bar mechanism and to predict the path traced by the door, a concept was chosen and a geometric model was developed using Auto Cad for that concept.

Fig 6 indicates the geometric model of the mechanism indicating various positions of door for a given link length &link angle. This geometric model has enabled us to try various door paths for various permutations & combinations of link lengths and link angles and finally arrive at an optimized link length and angle.

Solid model of the door arrangement and simulation of the path of the door was carried out using Solidworks^R software for a given configuration. This simulation of the door has enabled us to understand the path of the door for a given geometry and to arrive at the optimized door movement and davit arm radius that will take least space & least radius. The door movement/path obtained by geometrical model and path obtained in solid model were in agreement

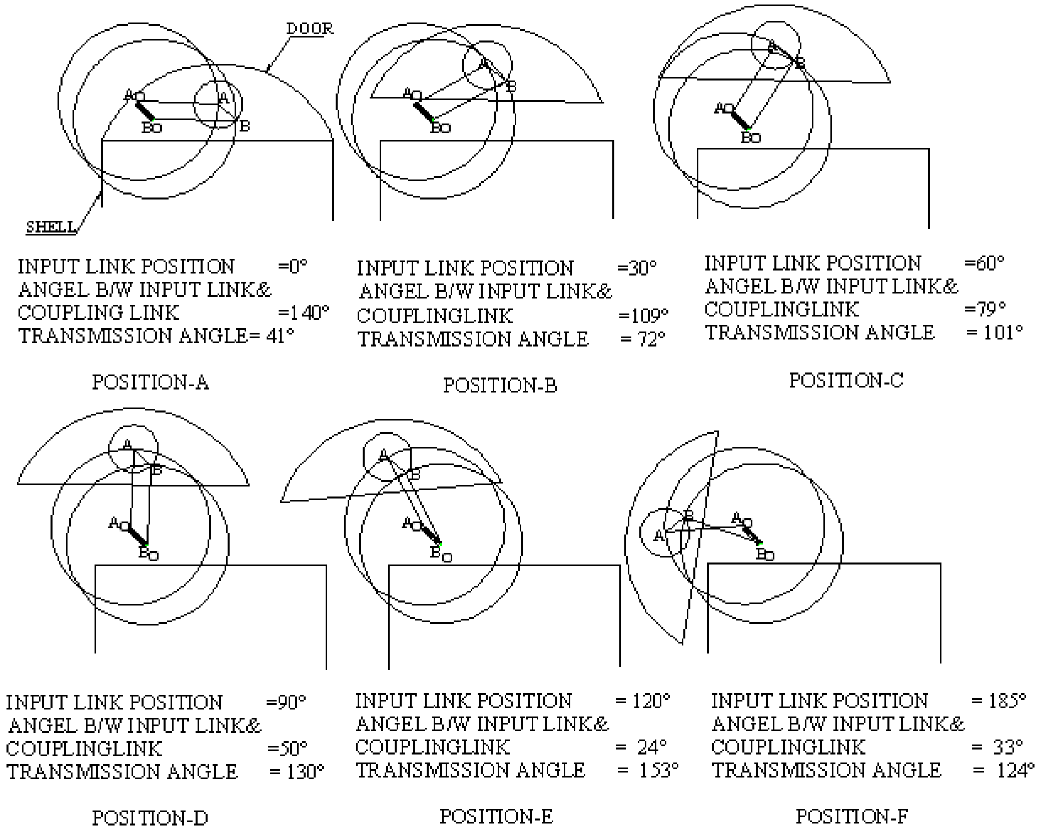


Fig6. Geometric model of the mechanism with various door positions

FABRICATION OF PROTOTYPE MODEL

A prototype autoclave model (Diameter of the shell is about 500mm) with davit arm door & door steering mechanism mounted on the door was fabricated. Fig 7 shows the photograph of the fabricated model. Fig. 8 shows the line diagram of four-bar mechanism with the link dimensions and angles. The configuration of the linkage was arrived after several trials made using the geometric model and simulation in Solidworks. The measured angle between davit arm & coupling link of the model was compared with the geometrical model readings. Table 1 shows these values. These values are in agreement with the experimental values.

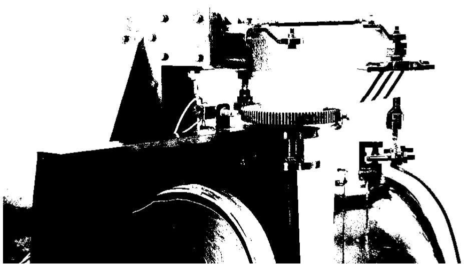


Fig7. Prototype model with steering mechanism mounted on the davit arm

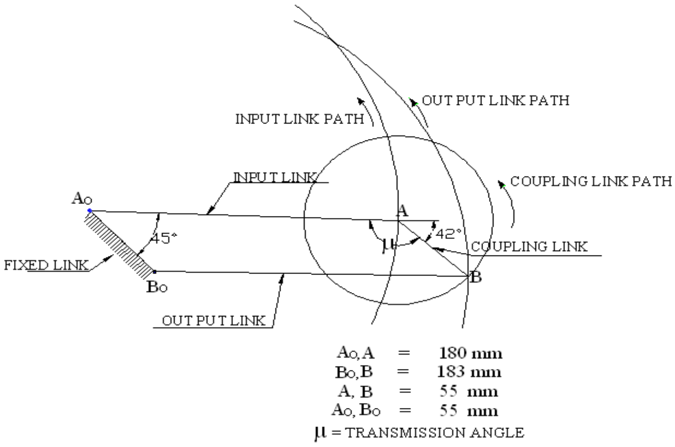


Fig8. Line diagram of a steering mechanism used for prototype

Table 1. Table showing the readings obtained from geometric model and prototype model

Input link Rotation (Davit arm rotation)	Angle between input link & coupling link	
	Geometric model Readings	Prototype Model readings
0°	140°	140 °
10°	129°	130°
20°	119°	119°
30°	109°	108°
40°	99°	99°
50°	89°	89°
60°	79°	79°
70°	69°	69°
80°	59°	59°
90°	50°	49°
100°	40°	40°
110°	32°	32°
120°	22°	24°
130°	18°	18°
140°	16°	16°
150°	17°	17°
160°	22°	20°
170°	26°	24°
180°	31°	29°
185°	34°	33°

CONCLUSION:

The door steering mechanism using for four-bar mechanism was successfully developed. Geometric model was developed to understand the path traced by the door for various configuration of the mechanism. The geometric model enabled us to optimize the davit arm radius and the door path. The prototype model was fabricated to validate the results obtained by geometric model. The results of geometric model & fabricated model were compared and found in agreement. This successful development of door steering mechanism has motivated us to implement it in the 5meter diameter autoclave (that is being built by NAL) in place of conventional mechanism.

ACKNOWLEDGEMENTS

The Authors wish to gratefully acknowledge the contributions of the following persons. Dr. A.R. Upadhya, Director for the encouragement, Mr. G.M. Kamalakannan for providing necessary electrical support, Mr. B. Partiban, Mr. K. Prakash, Mr. B.K. Bhaskar for fabricating the prototype model, Mr. V. Harish, Mr. L. Murugan, Mr.K Arun kumar, Mr. J.Christopher Daniel for providing CAD support.

REFERENCES

1. Dayananda .G.N, Subba Rao.M and Somashekar B.R, 1994, Indigenous Development of Auto-Clave Technology, proceedings of National symposium on development in Advanced Composites & Structures.

2. D.C. Tao, 1967, Fundamentals of applied kinematics, Addison-Wesley publishing company, Massachusetts

3. High performance composites Magazine, Sep ‘2006 Edition.

4. Jeremy Hirsch horn, 1976, Kinematics and dynamics of plane mechanism, McGraw-Hill Book Company, New York.

6. Todol Taricco, Auto clave cure system, ASM hand book of composites,Vol.1, 645- 648.