

Design of Fixture for Evaporator Rotor Assembly

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ABSTRACT: To fabricate the wipers for an Evaporator rotor, conventional methods can result in alignment errors and dimensional tolerances may not be achieved as per the required design which thereby may lead to run-out of rotor during operation. Fixtures are generally used during machining but they may also be used for fabrication and assembling purposes to achieve better quality. Hence, designing a fixture for assembling the Evaporator rotor may fasten the welding process and required tolerances can be achieved with higher accuracy and precision. Adopting a Computer Aided Fixture Design approach provides flexibility in modelling and analysis and can lead to a stable design.

KEYWORDS: Wiper, rotor, base stand, end plates, CAD model, analysis.

I. INTRODUCTION

Evaporator is crucial equipment in the field of some chemical processing industries. Its major components are shell, rotor, condenser, entrainment separators and power drives. In Evaporator, separation of the volatile materials and useful products take place between the rotor and shell by means of creation of a thin film. Any kind of errors produced during rotation of rotor may affect the process badly. The smallest error may result in larger effects when the rotor is subjected to rotation up to 300 rotations per minute. Operating accuracy depends upon manufacturing process adopted for the rotor as well as accuracy of that process.

In the present conventional method of assembling rotor (as shown in the fig. 1), one of the end rings is placed on rotary flat surface e.g. table of vertical turret lathe, etc. and is clamped rigidly. Thereafter, three to four wipers are vertically placed and their perpendicularity is verified. Second end ring is placed on those perpendicular wipers and then using a spirit level and other levelling techniques, the parallelism of the end rings as well as perpendicularity of the top end ring is ensured followed by welding process. A consequence of the existing method is that there arise problems of misalignment when centres of both the end rings are not co-incident. As on lathe, the best method of holding the cylindrical components is by centring. In the same way, cylindrical rotor can be held between two centres. Allowable axial run-out during operation is 3mm. Since there is no possibility of holding the rotor from centres, instead of centring, two end plates with extruded projections can be used. These projections will be helpful for holding the ring from the inner diameter of the end ring.

The fundamental condition to be fulfilled by the fixtures is that part should be in contact with all locators before application of any clamp. Also, if multiple clamps are applied to one part face, they should be applied simultaneously. Verification checks must be done so that fixtures do not interfere with machine tool and fixture elements do not collide with each other. It must be ensured that no collision of the fixture occurs with the work-piece [1].

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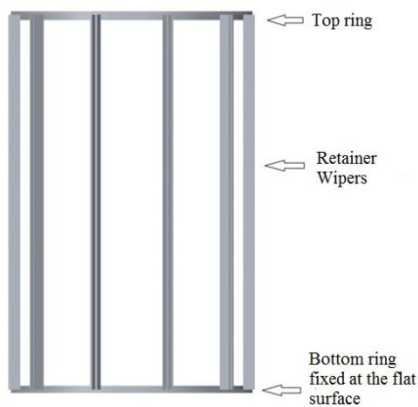


Fig.1. CAD model of arrangement of rotor in conventional system

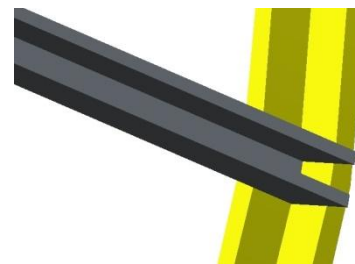
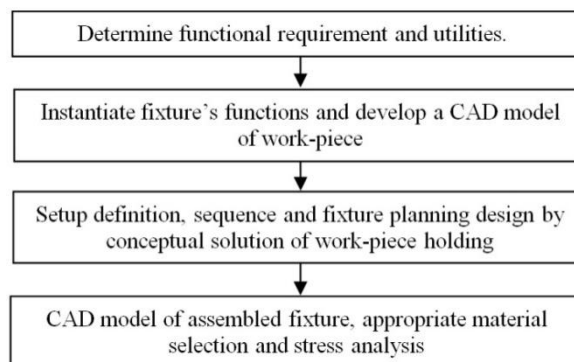


Fig.2. CAD model of location of welding location of wiper

The solution is to verify its static interference by modern computer aided design and analysis systems which give a clear idea about collision detection using geometric constraint in modelling to ensure that fixture elements do not collide with each other. A welding fixture is designed considering welding parameters affecting distortions and residual stresses, such as reverse distortion as well as welding speed. Also, the weld sequence influences work-piece distortions [2]. Basically, the fixture is to be used for Gas Tungsten Arc Welding and assembling purpose. Hence, enough clearances must be provided for the thermal contraction of the rotor length. Since the weld area is lesser, the distortions are produced in lesser amount.

II. METHODOLOGY

In industry, manual prototyping and testing cannot be avoided during the development of new fixturing solutions for complex processes and components in order to estimate the effective working of a new fixture design in meeting manufacturing requirements. This inevitably leads to longer lead-times and higher costs, especially when inexpedient fixture designs have to be iteratively improved and re-tested by prototyping. On the other hand, trying to reduce the risk of developing ineffective fixturing solutions by sacrificing work-piece accessibility would often cause unexploited commercial savings. A simulation methodology that will allow fixture designers to model, simulate and evaluate the performance of new fixture designs without the need for costly prototypes. This can lead to reduction of the costs and lead times which are commonly associated with new fixture development [3]. The steps to be followed for fixture design are as follows:



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III. ROTOR

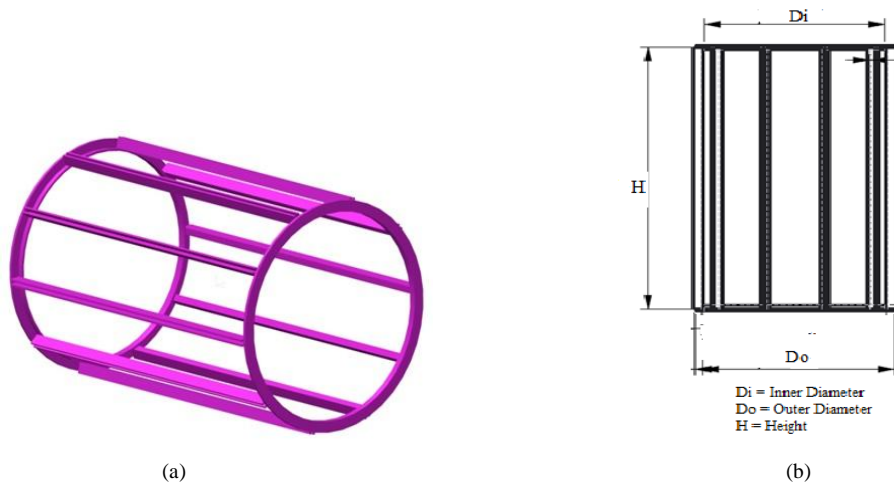


Fig. 4 (a) CAD Model of rotor with wipers (b) Evaporator Rotor

In rotor, there are wipers welded at the two ends of the end rings at an equal interval of 36° by Gas Tungsten Arc Welding using Argon as inert gas and then welding chevrons between each pair of wipers. Whole welding process is manual welding as it contains complicated geometries. The CAD model of rotor and its schematic diagram are shown below in the fig. 4 (a) and (b) respectively. The total mass of the rotor is 1150kg.

IV. COMPONENTS OF FIXTURE

A. Base stand

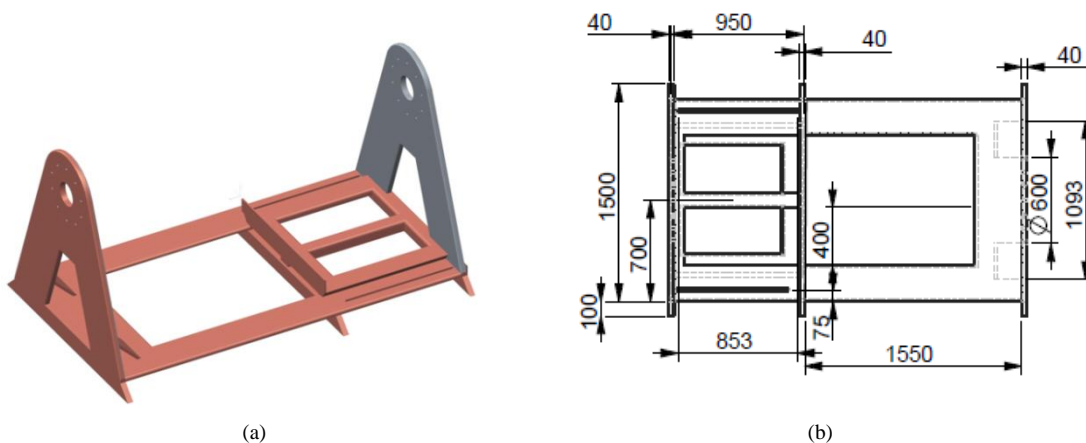


Fig.5 (a) CAD Model of Base Stand of the fixture (b) Drawing of base stand in top view

Base plate is supported on three columns. Two vertical columns are mounted at the ends above the base plate of the stand. One of the ends is welded to the base plate while the other is movable for the adjustable length of 850mm. A slot is provided for clamping the movable column on both ways (at the right end of the CAD model in fig.5 (a)) and the fixed end is welded with a plate at 45° to the horizontal plate.

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Columns contain cylindrical holes of $\text{Ø}170$ for accommodating the bearings within it. 10 smaller holes are drilled at an angle of 36° each at an offset distance of 100mm from the centre of bearings centre line. The reason behind providing these drilled holes is locking the rotational movement of the rotor by inserting a dowel pin. Half part of dowel pin would be within vertical column and remaining half in end plates.

Measured crack growth angles in dovetail specimen.

Specimen contact angle α ($^\circ$)	Crack growth paths (different from angle φ in the study) ($^\circ$)
35	12–17
45	13–18
55	6–14

Fig.6. Effect of dovetail angle on failure [4].

It is possible to adjust length by means of close type dovetail path provided on the base plate and replica of the same has been produced on the movable vertical column. A dovetailed structure is used because it locks the transverse movement of the job and linear movement with accuracy is available. Also the crucial factor in dovetail structure is its angle. Using the results shown in fig.6, the angle of the dovetail in the fixture has been provided 55° to opt for the safest design.

B. End plate

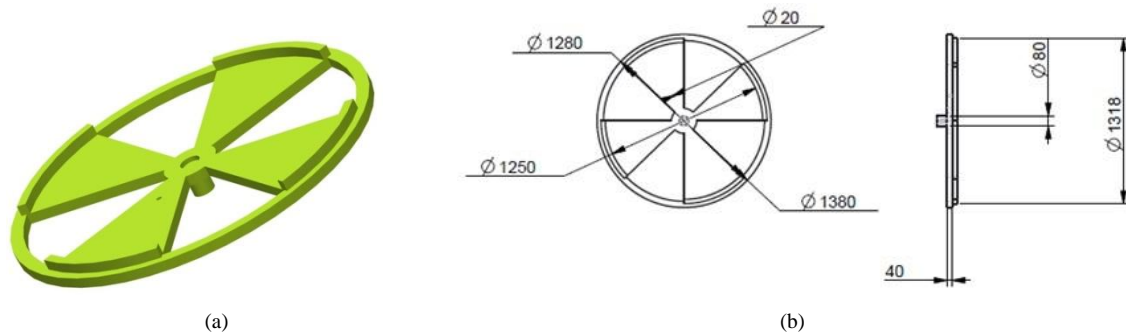


Fig.7. (a) CAD Model of End Plate (b) Drawing of End Plate

End plates contain four circumferential projections of 40mm height. The outer diameter of the projected plates is equal to the inner diameter of the rotor on which two end rings would rest in such a way that the axis of end plates as well as rings would be horizontal. In the central part, cylindrical threaded hole is provided to mate with the central rod. This plate would be held by the bearings fixed within the vertical columns of the base stand.

Also, one drilled hole is provided in the flange (as shown in fig.7 (a)) so as to fit the dowel pin with the base column and thereby restrict the rotational motion of the rotor. The dimensional details are mentioned in fig.7 (b).

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C. End lock

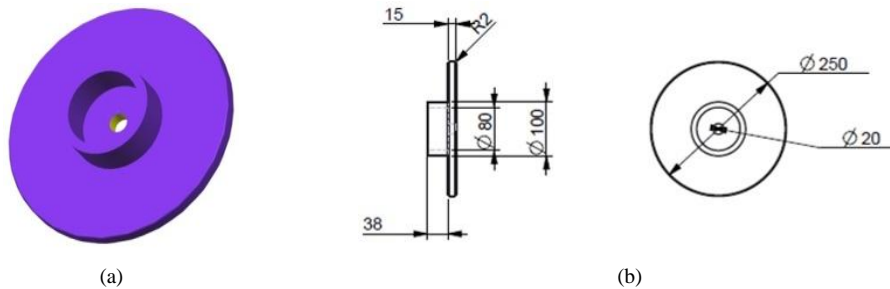


Fig.8. (a) CAD Model of End Lock (b) Drawing of End Plate

End locks are designed to lock the inward movement of the end plates due to its self weight or any other external forces. It is provided on both sides of the fixture. The projected cylindrical portion of the end plate would fit in the hollow cylindrical portion of end lock and it is then bolted tightly. The dimensional details are mentioned in fig.8 (b).

D. Central rod

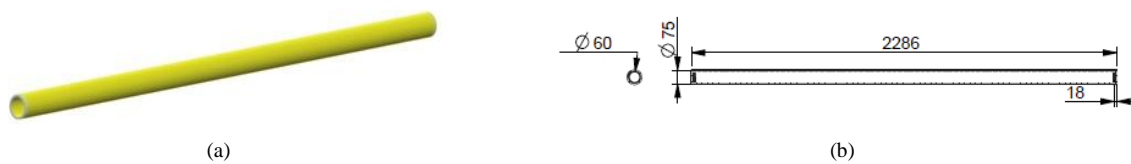


Fig.9. (a) CAD Model of Central Rod (b) Drawing of Central Rod

This rod is basically a hollow shaft. It is externally threaded at the two ends to fit in the slots provided at the end plates. It restricts the inward motion of the end plates thereby providing a planar constraint. At both the ends, threaded length is 18mm. This rod is only useful for only one kind of rotor. For rotor of different models of evaporator, the length of the rod can be varied. The dimensional details for one of the cases are mentioned in fig.8 (b).

E. Ball bearing

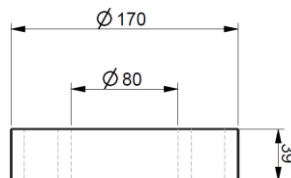


Fig.10. Drawing of ball bearing

Inner diameter of the bearing would match cylindrical projected portion of end plates. Bearing would be fitted in the vertical column of base plate. As per the standard table, the specifications of bearing are as follows:

- Dynamic Load Bearing Capacity: 123 kN
- Static Load Bearing Capacity: 86.5 kN
- Mass: 3.59 kg
- Material: Corrosion Resistant Bearing Steel

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V. ROTOR ASSEMBLY

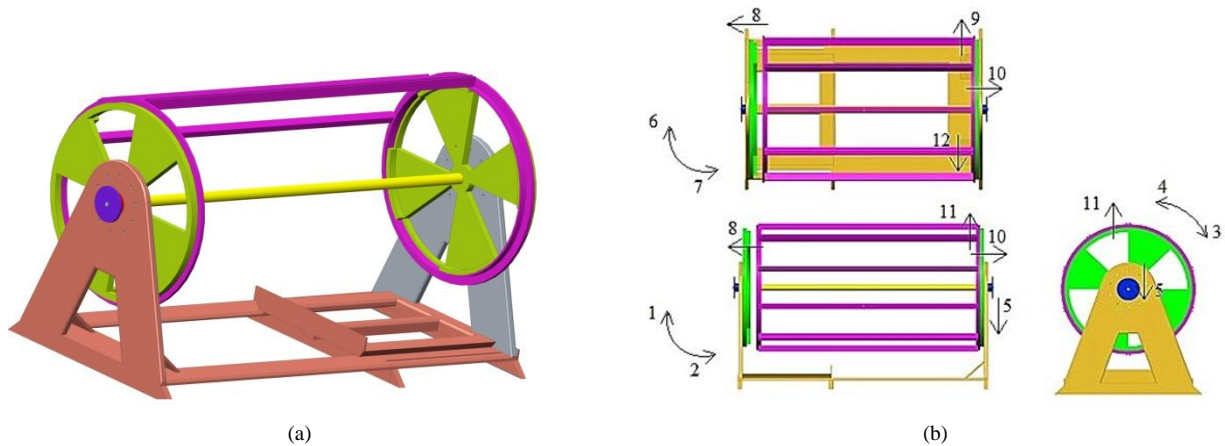


Fig.11. (a) Rotor Assembly (b) Restricted movements of final assembly

Fig.11 (a) shows evaporator rotor attached on fixture with welded wipers. Some clearance is kept between two end plates for easy removal of the welded rotor. After welding, one of the columns which is movable can be removed manually and rotor can be removed sideways. End rings may be bolted to end plate projections for better tightening. The restricted motions of the assembled fixture are shown in the fig. 11 (b).

VI. MATERIAL SELECTION

Generally, the most preferable material for fixture is mild steel but for larger fixtures, Structural Steel proves better. IS: 2062 plates shall have following mechanical properties:

- Yield Strength : 250 MPa (min)
- Tensile Strength : 410 MPa(min)
- Elongation: 23% min.
- Bend Test: 3T (min).[5]

Mass of the fixture components calculated by considering the density of Structural steel (IS: 2062) as 7850 kg/m³ are shown in Table 1 as follows:

Table 1
Mass of fixture components

Component	Volume (mm ³)	Surface Area (mm ²)	Mass (kg)	Total Mass(kg)
Stand	176535610	10533583	1385.80	1385.80
Bearings(2)	457327	76969	3.59	7.18
Plates(2)	37786066	2396346	296.62	593.24
End Lock(2)	823560	127579	0.65	1.30
Central Rod	3634188	976081	2.85	2.85
Total Mass of Fixture				1990.37

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VII. ANALYSIS

A. Analysis without central rod under full loading conditions



Fig.12. Stress Analysis without central rod

Assembly has loading conditions at the base due to self weight of components and due to weight of rotor during welding. Final assembled rotor produces high stresses on the columns resulting in displacement of top region of the column by 1.58 mm (as shown in the fig.12). This situation will only arise when the central rod is not assembled to the fixture. To eliminate such situation, central rod is essential. Also, it creates a planar constraint on the end plates on both sides.

B. Analysis with central rod under full loading conditions

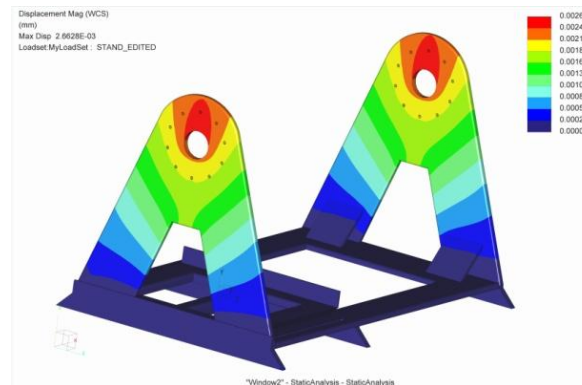


Fig.13. Stress Analysis with central rod

When central rod is attached to end plates, movement of both the columns is locked and then forces act. Maximum deflection in vertically downward direction is 2.6 μm which is also indicated by the critical stress region in red (as shown in fig.13).

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C. Deflection of central rod

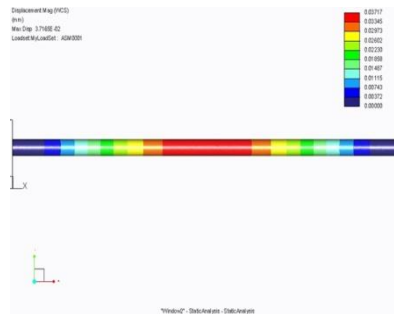


Fig.14. Analysis of central rod

Maximum Deflection of the rod at the central region obtained will be 37 μm (as shown in fig. 14) under the full load conditions, which is negligible. After full loading, the rotor would be removed and this deflection is for short time duration. Hence, it will not create major distortions.

VIII. CONCLUSIONS

Following points can be concluded from the above designed fixture:

- Designed fixture proves rigid under the 1.1 times loading conditions than the actual case. Central rod provision may reduce the angular distortion and provides planar constraints. Hence, one of the columns must be definitely kept movable and later fixing it using available clamping devices.
- The fixture would help in eliminating the axial dislocations. Hence, a dynamically balanced rotor would be obtained. Also, the levelling time for comparing parallelism of the end rings will be reduced to zero. The set up time is greatly reduced. Allowances provided for thermal distortions would not affect the geometry of rotor and run out problems during operation would be minimized.

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