Abstract - Ferrule bite fitting is used as sealing in connection of high pressure tubes. Therefore, it is designed & manufactured with very high degree of precision. The fitting design is generally carried out as per the standard specification. But we have observed that small changes in bite ferrule configuration can affect its performance. So the performance of the ferrule can be studied over wide range of configuration. This study is being carried out by deciding the bite ferrule configuration & other fitting component dimension from standard tube specimen of 22 mm outer diameter with wall thickness of 2mm. The fitting Assembly is modelled using SOLIDWORKS 2014 & FEM analysis, swaging is performed using ANSYS 14.5. The DOE is in process for finding the performance of various configuration of bite ferrule. The DOE will also be carried out using Ansys Workbench 14.5, & the experimental validation is being carried out on the basis leak test & Burst test which are the performance basis of ferrule fitting.

Keywords: Ferrule, bite fitting, FEM, DOE

I. INTRODUCTION

The Ferrule bite fitting is popular due to the simple assembly which basically just requires two wrenches. All threads, hexagons, bores and other dimensions are purely metric. These fittings are recognized for the high pressure performance from a compact body. These are available in the three series for low, medium and high pressures (L, L, and S-Series). This allows cost savings and space minimized solutions for each specific application. The bite type fitting has worldwide acceptance. Most European, Asian, African and South American industry standards are purely metric. But also in Australia and Northern America bite type fittings are gaining acceptance due to the metrification and end user specifications. Many machine operators prefer fittings that can be assembled without any additional equipment[1]. The bite fitting is formed by multifunctional nut, ferrule & body. The ferrule is generally surface hardened which ensures smooth biting & strong gripping on the tube. A slight bowing up of the ferrule is desirable while swaging or biting, which is necessary for providing permanent compensation for flexural vibration and setting effects in the thread of the fitting nuts. In the Surface hardening process the core material properties remains intact ensuring the bowing of ferrule. The sealing of the tube connection is mainly depends on the gripping of the ferrule on tube.

A. Ferrule functionality

The ferrule is particularly useful when employed in a tube coupling or connector body generally it is being employed on a pipe or tube end. The tube coupling comprises connecting nipple or connector body, a sealing ring or ferrule and a pressure applying nut. The connector has a threaded end which has a conical inner surface which has an included angle of approximately 24°. The inner surface extends into a cylindrical surface which is a diameter larger than the outer surface of the tube end. The cylindrical surface is terminated by a shoulder which interconnects the surface with an inner cylindrical surface which has an inner diameter substantially equal to the diameter of the inner surface to the tube. When the tube is inserted in the connector, the end surface of the tube abuts against the shoulder to limit the depth of the insertion. The pressure applying nut has an internally threaded counter bore at one end to be received on a threaded end of the connector. When threaded together, the nipple and the pressure applying nut form a cavity which receive the sealing ring. As illustrated, the pressure applying nut is provided with a conical surface at the base of the threaded counter bore. The pressure applying nut and connector are standard items which are commercially available and when threaded together, apply a force on the ring or sleeve to deform and contract it onto the outer surface of the tube or pipe.

II. LITERATURE

Many inventors has carried out research for developing the cutting ring seal. The ingenious invention of the cutting ring fitting was made by the founder of Parker Ermeto. Nowadays fittings are recognised for the high pressure performance from a compact body[1]
Changxiang Xu, WenZhou researched a tube fitting with either single or double ferrule swage design common in one system[2].

Rolf Castrup, Versmold-Oesterweg invented a fitting with a ferrule for use in connecting tubes which includes the advantages of the known ferrules with more than one cutting edge but without having their disadvantages. The further object of the invention to provide a tube joint or a tube fitting with a ferrule requiring little energy during assembly and which indicates to the assembler a distinct and steep increase of resistance when the connection is completely finished[6].

Leonard J. Kowal, Albert J. Schwarz comprehends an improved flareless tube fitting which eliminates the disadvantages of the prior art structures in a novel and simple manner. More specifically, it has been found that a single biting nose is adequate even in relatively high pressure fittings to provide the necessary seal and retention of the tube end in the fitting. The invention comprehends the provision of means at the outer end of the sleeve for providing an annular support of the tube end axially outwardly of the biting nose to provide the desire vibration force locking action[5].

Hans Kreidel, sr. and Hans Kreidel invented sealing sleeve for use in a tube connection in which the sleeve is inserted between a connecting nipple and a pressure applying nut. The object of the invention is to provide a sealing ring in which the leading cutting edge is of a size so that the leading end portion is not susceptible to breaking during assembly of the ring on a tube[3].

III. THEORY & APPROACH

A. Design consideration

i. Application

According to the application i.e pressure the tubing has to be selected, on the basis of the tube size (O.D) & its wall thickness the ferrule is selected. Also as per the application the thread size is selected as per the standard which will help to reduce the torque requirement for the swaging operation. The following table gives the selection of tube as per its pressure application & its torque ranges. Finite element analysis (FEA) was used in order to avoid the cost and limitations of compiling a database of real world parts. FEA permits arbitrary combinations of input parameters including design parameters and process conditions to be investigated with limited expense.

<table>
<thead>
<tr>
<th>Tube O.D. (mm)</th>
<th>Wall Thickness (mm)</th>
<th>Design Pressure (bar)</th>
<th>Torque (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>1.5</td>
<td>200</td>
<td>190</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>267</td>
<td></td>
</tr>
</tbody>
</table>

ii. Material

Material selection is generally based on the working environment & application. As the fitting can come across various types of fluid & Pressure conditions, the fitting material must sustain high pressure & resistant to corrosion. SS-316, Inconel, Monel, brass are some of the material used in fitting, among these SS-316 is the most common material used for fitting. As per the ISO 8434-1 for the satisfactory performance usually same material must be used for both fitting & tube.

iii. Standards:

The fitting selection/designing is done according to ISO 8434-1 & the material is selected on the basis of ASTM A276

B. Simulation Approach

The fitting consist of three parts body, ferrule & Nut, these components are modeled according to specification given by ISO8434-1, but not all dimensions are standardize. Therefore the non-standardize dimension can be taken according to the designers instinct. According to these dimensions the performance of the fitting can be varied.

i. Fitting model

Modelling 22 mm O.D tube & wall thickness of 2 mm, length of ferrule 10.76 mm

![Fig 2 (a) Exploded view ferrule Fitting](image)

![Fig 2 (b) Assembly model of ferrule fitting](image)
Modelling & Performance Analysis of Single Ferrule Bite Fitting

iii. Boundary conditions

As in real swaging action the connector buckhead is fixed to rest the fitting. Therefore fixed support is considered at the connector buckhead & the torque as mentioned above is applied to nut to perform the swaging action. Defining the contacts is the most crucial part of the simulation. Because these contacts will determine the required torque & amount of penetration of ferrule on the tube.

a. Contacts

b. Loads

For the purpose of simplicity of solution the threads are not provided on the body & nut. So to perform the Swaging action the nut has to apply force on the ferrule. this will achieve by providing the displacement to the nut & Fixed Support is provided at bucklehead of the body.

\[
\text{Displacement } = \text{pitch } \times \text{ no. of rotations} = p \times n
\]

\[
\text{Displacement (D)} = 1.5 \times 1.5 = 2.25\text{mm}
\]

C. Result & discussion

For the proper swaging of the tube the bite or the penetration should be 50\% of the tube thickness. The bite of the current configuration of the ferrule is 1mm which is half of the tube thickness. The ferrule configuration is satisfying the criteria of the bite. It should also satisfy the Performance criteria which are burst test & leak test. These can check by further analysing the fitting assembly.
IV. PROPOSED FUTURE PATH

The factors that affect the performance of bite ferrule can be categorized as:

(a) Geometrical parameters (e.g., length, no of cutting edges, camming angle),
(b) Material parameters (material groups such as steel and brass; Strain hardening exponent (n) values, Strength coefficient (K))
(c) Process parameters (pressure, torque & friction coefficient).

It is crucial to understand all the effects and interactions of all these parameters at the time of swaging operation in order to obtain better performance. Low cost response surface method (LCRSM) permits these Interactions to be investigated with minimum experimental cost.

The four major steps in the application of LCRSM are:

1. Setting up and testing which includes the selection of the factors and the FEA experimentation based on pre-specified, computer generated experimental designs, (2) fitting a list of polynomial regression models and selecting the best based on least squares regression,
2. Diagnosing whether the model is sufficiently accurate using the LCRSM diagnostic procedure
3. Performing additional testing, if necessary, using the pre-tabulated follow-up runs.[9]

The optimum configuration of ferrule will be validated experimentally by

a. Burst test b. Leak test

REFERENCES:

[1] Parker Industrial Tube Fittings Europe Catalogue 4100-7/UK
[7] Parker ‘EO and EO-2 Metric Bite Type Fittings’ Catalogue 4300