# COST REDUCTION IN AIRCRAFT HYDRAULIC ACTUATORS THROUGH VAVE TECHNIQUES

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## Abstract

*In today's global Aircraft business scenario companies are facing more competition in the market for survival. Manufacturing high quality products with low cost will facilitate in achieving competitive edge to the organization. Companies need to continuously improve quality of their products and services in addition to cost reduction. To achieve this Value Analysis and Value Engineering tools are widely used globally.*

*In the present study, Aircraft Hydraulic Actuator was considered for reduction of cost and possibility of introducing common components through standardisation to reduce the number of variants. The primary goal was to arrive at an actuator design that can be used for business jet aircraft primary flight controls, with lower recurring and non-recurring costs than the current generation of flight control actuators manufactured by Moog. Value Engineering and tools were used for achieving the above objective. Construction and functions of each subcomponent was studied in detail and "Actuator Housing" part was chosen for reengineering. It was found that the actuator housing alone was contributing 43% weight compared to other parts of the actuator. This housing part accommodates all the functional components and electrical connectors.*

*Alternative materials were compared to reduce the weight of the actuator housing using function cost worth analysis. It was found that existing material Al 7050 T74511 was appropriate. Further, the actuator assembly was studied for possible elimination of redundant parts without compromising the basic function. The standardization of housing resulted in reduction of assembly time by 60 min, moreover 4 different stall loads and working strokes were achieved through use of replaceable sleeves and glands in same housing. The proposed alternative design enabled the cost benefit of 34.18%. The new design was validated through FEA for operating conditions. Prototype was assembled and tested as per Moog standard procedure.*

**Keywords: VAVE, Cost Reduction, Weight Reduction, Aircraft Hydraulic Actuator, FEA**

**Abbreviations**

| | |
|---|---|
| AFT | After |
| BOI | Bought out items |
| DFC | Design for change |
| DFMA | Design for manufacture and assembly |
| EHSV | Electro hydraulic servo valve |
| FMEA | Failure mode effect analysis |
| FMECA | Failure modes, effects and critically analysis |
| FWD | Forward |
| LVDT | Linear variable differential transducer |
| MITC | Moog India Technology Center |
| MOS | Margin of safety |
| PO | Purchase order |
| QS | Quality standard |
| ROA | Region of analysis |
| RPN | Risk priority number |

## 1. INTRODUCTION

The primary group of flight control surfaces includes ailerons, elevators, and rudders. The ailerons attach to the trailing edge of the wings. They control the rolling motion of the aircraft. This action is known as longitudinal control.

The Elevators are attached to the horizontl stabilizer and control the climb or descent (pitching motion) of the aircraft. The Rudder is attached to the vertical stabilizer. It determines the horizontal flight (turning or yawing motion) of the aircraft. The Ailerons and Elevators are operated from the cockpit by a control stick on single engine aircraft. A yoke and wheel assembly operates the ailerons and elevators on multiengine aircraft [1].

Value engineering being used for cost reduction since 1947. It is a form of cost / benefit analysis where function are viewed as the beneficial set apart of the product. Every unnecessary component, every unwanted operation has to be eliminated for economizing. Materials may have to be changed; tolerances in manufacturing may be relaxed because value can be created in terms of reduced volume, reduced weight of product without affecting the basic functionality [2].

The product chosen to work on is aircraft hydraulic actuators used in aircraft actuation system. Each actuator drives the control surface by being operated by supply of pressure oil from aircraft central hydraulic power source. It is beneficial to reduce weight and size of the actuators. In addition, standardisation of actuator subsystems would reduce the part count and number of variants leading to better management of inventory [3].

In the present study, an attempt has been made to redesign a selected hydraulic actuator to reduce the cost and weight using VAVE approach.

## 2. BACKGROUND THEORY

Value analysis and Value engineering originated in a search for alternatives for short supply of materials, was soon established as the ideal technique for achieving 'Cost Reduction'. The importance was on providing the required function reliability at the lowest overall cost. However in recent years of the problem solving methodology of value engineering, i.e. Cross functional team approach, problem identification and in depth analysis, generating ideas to overcome the root causes through creative techniques, evaluation and development of optimum solutions etc., has been proved to be most effective and appropriate in meeting the challenges of competition.

### 2.1 Value Engineering:

A number of case studies and success stories studied during the literature review shows the application of value engineering for reducing costs, improving quality and value to the customers, reducing the response and delivery times, and thus demonstrating that value engineering is the most useful management tool to achieve competitive advantage in both the domestic and global markets. Value engineering has been prescribed as a must under QS-9000 international supplier quality system requirements [4]. Figure 1 shows the systematic process flow map of value engineering different phases.

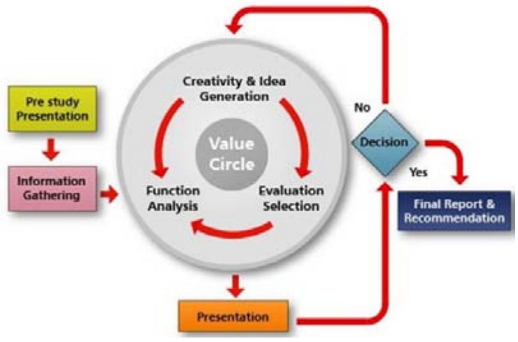



**Fig. 1 Value Engineering Process Map [5]**

### 2.2 FMEA Concept of Value

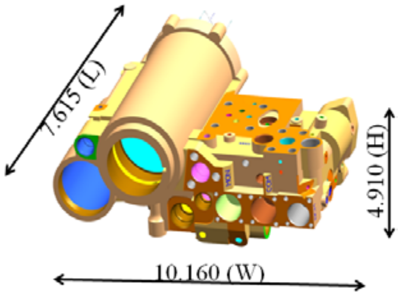
Also called potential failure modes and effects analysis; failure modes, effects and criticality analysis (FMECA). Failure modes and effects analysis (FMEA) is a step-by-step approach for identifying all possible failures in a design, a manufacturing or assembly process, or a product or service.

"Effects analysis" refers to studying the consequences of those failures. Failures are prioritized according to how serious their consequences are, how frequently they occur and how easily they can be detected. The purpose of the FMEA is to take actions to eliminate or reduce failures, starting with the highest-priority ones [6].

## 3. PROBLEM STATEMENT

There was a scope to reduce housing size using VAVE techniques. Figure 2 shows the actuator housing.

The aim of the study was to reduce cost of Aircraft Hydraulic Actuator by 30% and standardization of the Actuators to reduce the number of variants by applying VAVE Techniques. Details of the systematic approach followed with analysis and validation is presented in the following sections.




Note: All dimensions are in inches.

**Fig. 2 Actuator Housing**

## 4 DATA COLLECTION AND ANALYSIS

### 4.1 Data Collection – Information Phase

Data for understanding present status of product and selecting of proper solution for the problem will be achieved by proper information. The data enables user to understand the requirement of the product and its needs based on application. Improvement process relies on the data collected for finalizing target and analyze for problem solution. Data collection improves decision-making by focusing on objective information and process details.

The main objective of the Information Phase was to acquire knowledge of the design to be studied. This phase is intended to provide a thorough understanding of the product, operation, or item under study by an in-depth review of all of the applicable accurate data. Complete information is essential to provide the foundation upon which the entire Value Engineering study is based.

To start with all the required information has been collected and they are shown in Table 1.

**Table 1. Information collected about the chosen product**

| INFORMATION PHASE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Subject:** Cost Reduction in Aircraft Hydraulic Actuators through VAVE Techniques | | | | | | | Cost/Unit ($) =292 | |
| | | | | | | | Annual Qty: 500 no | |
| **BILL OF MATERIALS** | | | | | | | | |
| Sl. No. | Component | Qty/ Assy. | Bought or made | Raw material (RM) Bar stock | RM Weight lb (**kg**) | RM Cost/lb in $ (**Rs.**) | Cost/ Piece in $ (**Rs.**) | Cost/ Assembly in $ (**Rs.**) |
| 1 | Housing | 1 | Machined | Aluminium 7050 7.75"x10.25"x5.0" (L x W x H) | 39.72 (**18 kg**) | 7.35 **Rs.456/-** | 292 **Rs.18104/-** | 292 **Rs.18104/-** |

**Note:** Currency conversion $1 = Rs.62/-

Collected relevant information about components in actuator assembly like, length, width and height and raw material. Weight distribution was plotted to indicate the % contribution from each main part. This helps in identifying which part is to be prioritised. Weight breakup is shown in Figure 3.

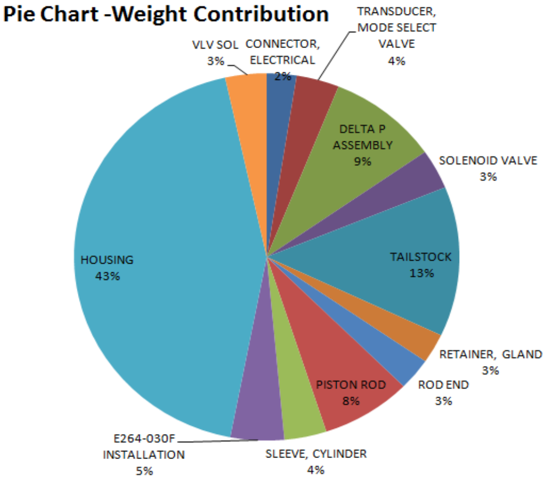



**Fig. 3 Pie Chart-Weight Breakup**

Housing was contributing more weight when compared to other parts' weight and envelope.

**Action:** Re-design the housing in order to reduce the cost, weight and envelope size.

### 4.2 Function Analysis Phase

Once all the relevant and required data and information have been collected, the next plan was to carry out function analysis. In this phase the following activity done.

- Functions of the actuator housing were analysed.
- Defined functions are classified as basic (essential) or secondary (desirable or unnecessary) for actuator assembly as well as for each part.
- The present cost of providing the function (i.e. what it costs at present) and the worth of the function (what it should cost) were established.
- The value gap (difference between function-cost and function-worth) or the value index (the ratio of function-worth to function-cost) was determined.
- Thus, low zero value functions (i.e. components and features which are in excess and do not add any value) were identified in order to eliminate them, and those having maximum potential for cost reduction and improvements were mentioned.

### 4.3 Function -Cost-Worth Analysis Phase:

Functional cost worth analysis is a value engineering method that aims to increase the difference between the cost and the value of a product. The cost is the amount that is incurred in the production and delivery of the product. This expense can include the price of parts, labour, overhead (e.g., building, power), packaging, shipping, and advertising, among others. What the product is worth in the eyes of the customer is considered the value. When completing a functional cost analysis, remembering this definition of value is extremely important. The design team may not perceive a certain product feature to be valuable, however if it is important to the customer, then that feature must be regarded as valuable. Table 2 shows the FCWA.

**Table 2. Function Cost worth Analysis**

| FUNCTION - COST - WORTH ANALYSIS | | | | | |
|---|---|---|---|---|---|
| Sl. No. | Item | Basic/essential function | Function Cost in $ (**Rs.**) | Function Worth in $ (**Rs.**) | Value Gap in $ (**Rs.**) |
| 1 | Housing | The Housing consists the centerline components and Electrical connector. It establishes flow connection from Electro hydraulic servovalve (EHSV) to Pressure chambers. | 292 (**Rs.18104/-**) | 204* (**Rs.12648/-**) | 88 (**Rs.5456/-**) |

**Note:** Currency conversion $1 = Rs.62/-

Housing Size reduction per figure 3 as been considered as bench mark for function worth Analysis and it is expected a cost benefit of 30% approximately.

## 5.0 PROBLEM SOLVING

Creativity techniques have been used to generate a large number of ideas for solving the problem, followed by systematic evaluation and investigations, leading to optimal acceptable solution.

### 5.1 Creative Phase

After thoroughly analysing and understanding the functional requirements we look for other ways of fulfilling these requirements. In this effort, by applying creativity techniques the team members were able to generate a large number of ideas.

### 5.2 Brainstorming

The creativity technique most widely adopted for value engineering, and which is also the simplest and easy to use is brainstorming. It is a team effort which has a multiplier effect on the creativity of an individual, where ideas were formed, tossed about combined, refined and modified to give rise to many more ideas. The net result is the generation of large number of ideas, which would never be possible for any individual to achieve in the normal course.

Table 3 shows the ideas generated through brainstorming and their feasibility check report.

**Table 3. Creative Phase**

| CREATIVE PHASE | | |
|---|---|---|
| SL No. | Ideas generated | Proposal |
| 1 | Redesign Housing with 4340 (AMS 6415) Steel Material. | NO |
| 2 | Redesign Housing with Ti6Al4V (AMS 4979) Titanium Material. | NO |
| 3 | Redesign Housing with existing Material 7050 T74511 Aluminium with keeping in mind to reduce the envelop. | YES |

### 5.3 Evaluation Phase:

The next step was the evaluation phase which is also referred as development phase. In this, the generated ideas are evaluated, screened and short listed, and further refined, combined and developed into an acceptable alternate solution. By choosing appropriate attributes for selection, giving the weightage, and making use of the evaluation technique, these ideas were then ranked in the order of preference as shown in Table 4.

**Table 4. Product Attribute Weightage**

| EVALUATION PHASE | | | |
|---|---|---|---|
| CRITERIA | | WEIGHTAGE | |
| Code | Attributes | Score points | Weightage |
| A | Least Cost | 8 | 8 |
| B | Weight | 8 | 8 |
| C | Envelop | 6 | 6 |
| D | Fatigue life | 9 | 9 |
| E | Manufacturability | 5 | 5 |
| | **Note:** Scale is from 1-10<br>1= worst, 10=Best | | |

When faced with a number of seemingly equally good alternative solutions, all satisfying the minimum functional requirements, but each one better in some aspects and not so good in others, it becomes an extremely difficult mental task to rank them in the order of acceptability and select the most optimum solution for implementation. This technique helps in overcoming this difficulty in making right choice.

After selecting the attributes to be considered and deciding upon their weightage, the next step was to compare the various alternative solutions with respect to each attribute. For this purpose, the ranking of the attributes of each alternative was considered and points given as below:

- Excellent: 03points
- Good: 02points
- Fair: 01point

Similarly the evaluation of each of the attributes was done and the points scored by each alternative are noted in the relevant column as shown in Table 5. These were then added and the sum entered in the last column as shown in Table 5.

By looking at the results, Model 'Z' has scored the maximum number of 85 points and therefore ranked excellent (most appropriate solution for implementation).

### 5.4 Recommendation Phase

1. The Material should be kept same i.e., Aluminum 7050 T74511 [7,8].
2. The Basic function and load requirement of the Actuator shall not change.
3. Exclude Relief Valves, Solenoid valve and check valve in proposed design since these are considered as redundancy items based on current functionality is shown in Figure 4 [9,10].
4. If customer requires the redundancy items, there is a provision to assemble them in the Aircraft hydraulic circuit.
5. Moog learning experience from the past programmes with Aluminium 7050- T74511 material and based on the data collection found Higher Strength 7050- T74511 Extrusion Exhibits Excellent Fatigue Life.
6. The existing design and proposed design of housing model is shown in Figure 5.

**Table 5. Comparison of Attributes of different Models and Rankings**

EVALUATION PHASE

COMPARISON OF ATTRIBUTES OF DIFFERENT MATERIALS

**WEIGHTAGE POINTS:**
Excellent - 03 points
Good - 02 points
Fair - 01 point

| Models \ Attribute wtg. | Least Cost (A) =8 | Weight (B) =8 | Envelop (C) =6 | Fatigue Life (D)= 9 | Manufacturability (E) =5 | Total |
|---|---|---|---|---|---|---|
| Titanium 'X' | 1 / 8 | 2 / 16 | 3 / 18 | 3 / 27 | 1 / 5 | 74 |
| Steel 'Y' | 3 / 24 | 1 / 8 | 2 / 12 | 2 / 18 | 2 / 10 | 72 |
| Aluminium 'Z' | 2 / 16 | 3 / 24 | 2 / 12 | 2 / 18 | 3 / 15 | **85** |

**Final ranking of Models:**
Model 'X' – Good, Model 'Y' – Fair, Model 'Z' – Excellent

NOTE: Aluminium has scored highest marks hence selected Al 7050 T74511

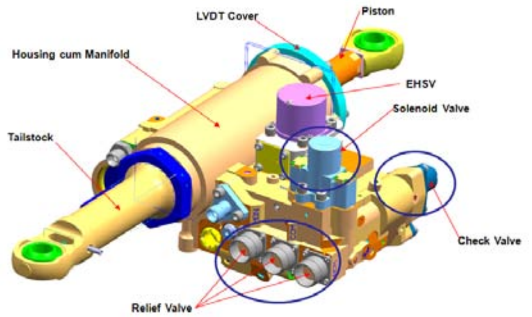



**Fig. 4 Existing Actuator Assembly**

**Note:** Highlighted parts are redundant considering the present functionality. This has been endorsed by the customers.

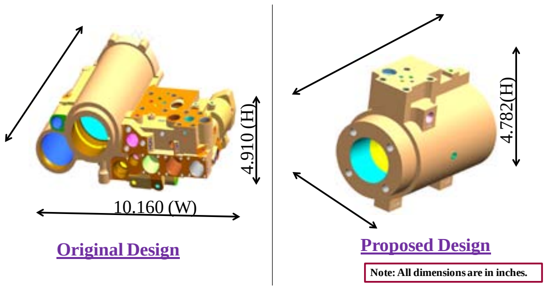



**Fig. 5 Comparison of existing and proposed housing model**

### 5.5 Recommendation Phase

#### 5.5.1 Envelop comparison

The comparison of envelop between existing and proposed housing is shown in Figure 6.

The bar chart signifies that there is average envelop reduction from the current design to proposed design is 13.01%.

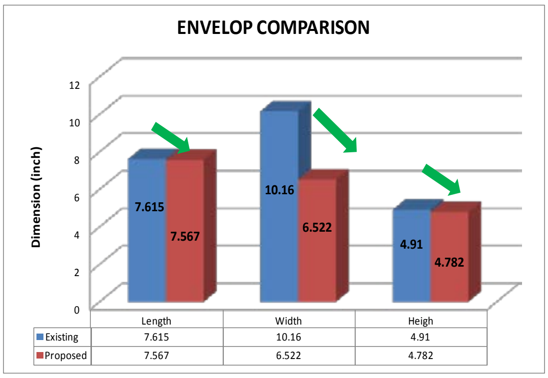



Fig. 6 Bar chart-Envelop comparison

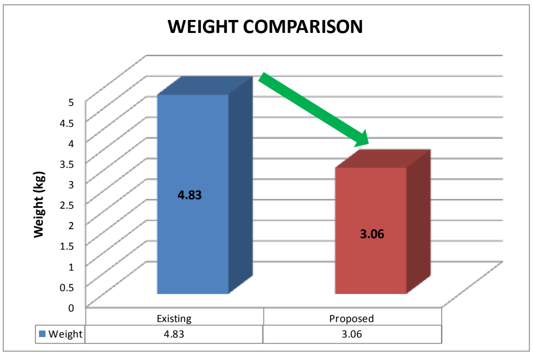



Fig. 7 Bar chart- Finished housing weight comparison

The bar chart signifies that there is weight reduction from the current design to proposed design is 36.75%.

### 5.5.3 Raw material cost comparison

The comparison of finished housing weight between existing and proposed housing is shown in Figure 8.

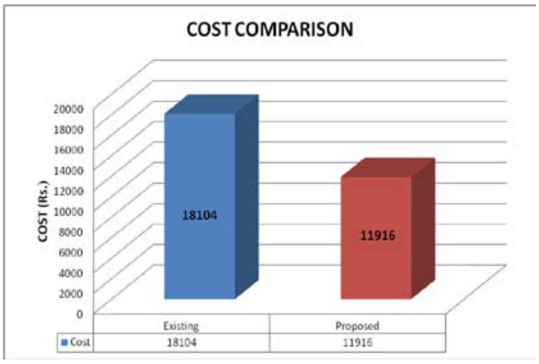



Fig. 8 Bar chart- Raw material cost comparison

The bar chart signifies that there is a raw material cost reduction from the current design to proposed design is 34.18%.

## 6. CRITICAL DESIGN REVIEW PHASE

In Critical design review phase the following activity were carried out: Modeling & Analysis, Detailed Drawings, Design Documents, Assembly & Test Procedures, Configuration Management and Physical Mock-up.

### 6.1 Standardization of actuators

Table 6 shows the actuator with different stall load and working stroke achieved by standardising the housing.

**Table 6. Actuator dash number indicating 4 variants**

| Description | Unit | Actuator dash No. | | | |
|---|---|---|---|---|---|
| | | -001 | -002 | -003 | -004 |
| Working Stroke | in | ±1.2 | ±0.9 | ±1.2 | ±0.9 |
| Electrical Stroke | in | ±1.3 | ±1.0 | ±1.3 | ±1.0 |
| Mechanical Stroke | in | ±1.4 | ±1.1 | ±1.4 | ±1.1 |
| Min. Stall Load required | lbf | 4752 | 4752 | 3802 | 3802 |
| No Load Rate | in/s | 8.85 | 11.04 | 8.85 | 11.04 |
| Dry Weight | lb | 16.56 | 17.97 | 16.64 | 16.90 |
| Wet Weight | lb | 16.80 | 18.17 | 16.84 | 17.07 |

### 6.2 Sleeves for different loads type 1 & 2

To achieve the various stall loads required, an interchangeable sleeve concept was adopted as shown in Figure 9. Type-2 sleeve ID is more compared to Type-1. By this the annular area gets increased. Hence higher the stall load can be achieved.

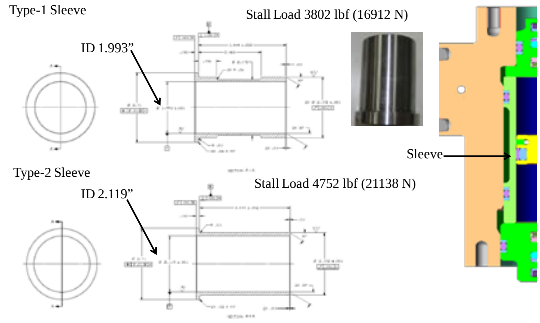



Fig. 9 Interchangeable sleeves for different stall loads

### 6.3 Glands for piston stroke type 1

To achieve the various actuator piston stroke length required, an interchangeable gland concept was adopted as shown in Figure 10.

### 6.4 Glands for piston stroke type 2

To achieve the various actuator piston stroke length required, an interchangeable gland concept was adopted as shown in Figure 11.

Type-1 Glands Length is less by 0.3" compared to Type-2. Hence the working stroke of Type-1 is more.

### 6.5 Design of Housing

Actuator housing design is shown in Figure 12.

### 6.6 Stress Analysis

Stress analysis was required to approve the modified design. The analysis was done for the same boundary conditions as earlier. FEA was carried out for two extreme positions of the actuator namely, piston extended and retracted condition.

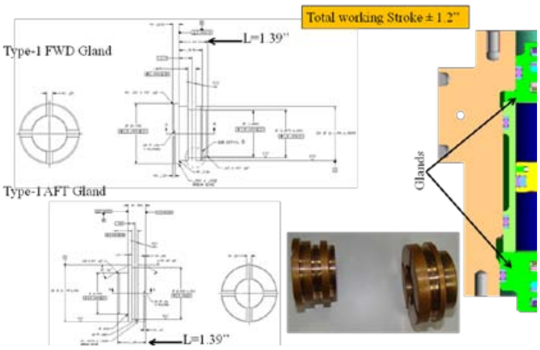



**Fig. 10 Interchangeable glands for different stroke length**

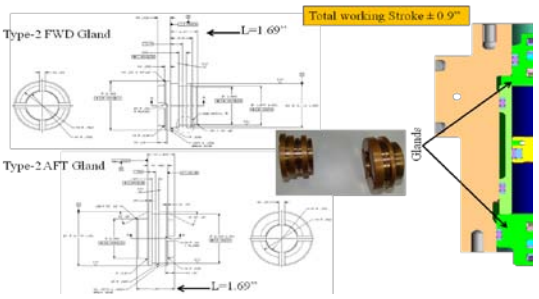



**Fig. 11 Interchangeable glands for different stroke length**

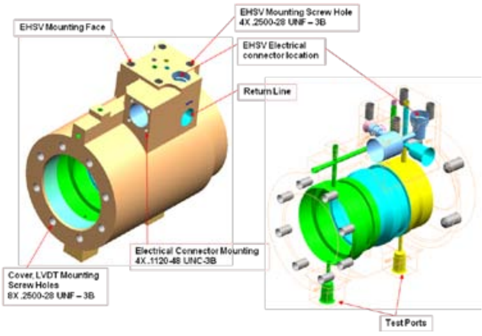
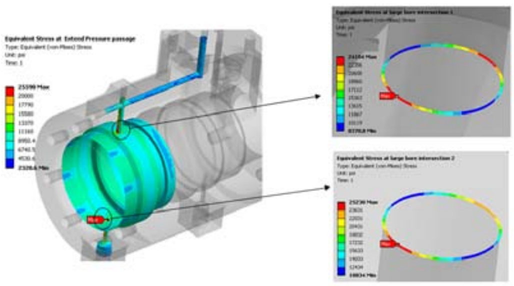



**Fig. 12 Housing design**

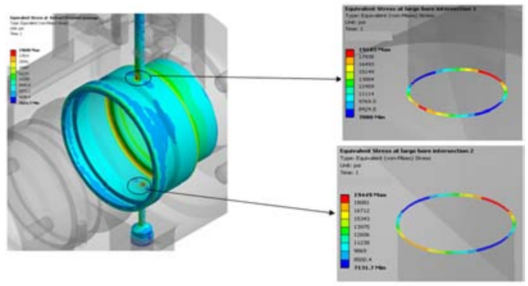
**Note:** Rest all other parent component design has been carried out by similar way.

Stress analyses was carried out for piston extended and retract case and found margin of safety (MOS) is positive and damage is less than one as shown in Figure 13 and Figure 14.



| No | Load Case | ROA | Peak FEA Stress | MOS | Damage for Impulse pressure |
|---|---|---|---|---|---|
| 1 | Fatigue Retract | P1 | 24.104 Ksi | NA | 0.168 |
| | Fatigue Retract | P2 | 25.230 Ksi | 0.29 | 0.267 |

**Fig. 13 Housing Stress ROA's conditions-Piston extended**



| No | Load Case | ROA | Peak FEA Stress | MOS | Damage for Impulse pressure |
|---|---|---|---|---|---|
| 1 | Fatigue Retract | P1 | 19.449 Ksi | NA | 0.004 |
| | Fatigue Retract | P2 | 19.183 Ksi | 0.697 | 0.003 |

**Fig. 14 Housing Stress ROA's conditions-Piston extended**

**Note:** Similarly the stress analysis has been carried out on other elements and found margin of safety (MOS) is positive and damage is less than one.

## 7. FAILURE MODE EFFECTS ANALYSIS

Failure modes and effects analysis (FMEA) is a step-by-step approach for identifying all possible failures in a design, a manufacturing or assembly process, or a product or service [11].

### 7.1 FMEA steps

- ➢ After the product design was done, FMEA was performed involving all cross-functional team members.
- ➢ Identified the scope of the FMEA.
- ➢ Functions often included are design, manufacturing, quality, testing, reliability, maintenance, purchasing and customer service.
- ➢ The ways in which failure could happen was identified for each function.
- ➢ For each failure mode consequences were identified.
- ➢ Determined how serious each effect is. This is the severity rating rated on a scale from 1 to 10, where 1 is insignificant and 10 is catastrophic.
- ➢ For each failure mode, determined all the potential root causes.
- ➢ For each cause, determined the occurrence rating.
- ➢ Based on brainstorming session with the core team the cut-off RPN has been identified as 80.
- ➢ Failure modes with RPN with greater than 80 were required to take further action to reduce the RPN.
- ➢ **Note:** The FMEA result was found the RPN was not crossed 80 and hence there is no further action required.

## 8. QUALIFICATION HARDWARE - REALIZATION PHASE

The Qualification hardware realization phase involves the following steps:

- ➢ Components Manufacturing

- BOI's Procurement
- Assembly

### 8.1 Assembly

Assembly of actuator was carried out as per standard assembly work instruction of moog internal document. The actuator assembly is shown in figure 16.

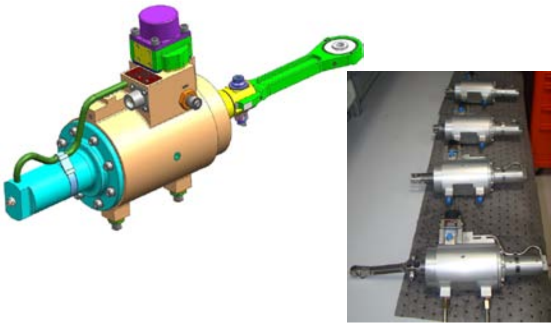


**Fig. 16 Actuator Assembly**

### 8.2 Assembly time reduction:

There is a reduction in assembly time by standardizing the Actuator housing is shown in Table 7.

**Table 7. Assembly time for respective activity**

| Sl. No. | Component | Activity | Assembly time for 1st Actuator (Min) | Assembly time for next Actuator (Min) |
|---|---|---|---|---|
| 1 | Ultrasonic Cleaning | Assembly of Helicoil Insert, Expansion Plug, and Lee Plug | 10 | 10 |
| 2 | Housing (Standard) | Assembly of O-rings, Back-up rings, Primary & Secondary Seals | 30 | 0* |
| 3 | Gland Fwd | Assembly of O-rings, Back-up rings | 17 | 17 |
| 4 | Housing Seals Assembly | Assembly of Seals in to main Housing | 8 | 8 |
| 5 | Sleeve Assembly | Assembly of O-rings, Back-up rings, Helicoil Insert, Bush Collar, Piston rings, Glide rings | 7 | 7 |
| 6 | Piston Rod Assembly | Assembly of O-rings, Back-up rings, Primary & Secondary Seals | 15 | 15 |
| 7 | Gland AFT Assembly | Assembly of O-rings, LVDT Cover, Self locking Nut, LVDT & Strap Bonding | 19 | 19 |
| 8 | LVDT Cover Assembly | Assembly of Crimp LVDT Lead wires, Screws, Wire lock the screws etc., | 18 | 18 |
| 9 | 10 Pin Connector Assembly | Assembly of O-ring, connector plug, screws & washers, wire locking the screws etc., | 15 | 0* |
| 10 | EHSV Assembly | Assembly of spherical bearing, Roller bearing, Dog bone Link, Nut and washer etc., | 15 | 0* |
| 11 | Dog Bone Assembly | Assembly of union, flareless tube – inlet along with O-rings. | 20 | 20 |
| 12 | Inlet & Outlet Assembly | All machined parts need to be ultrasonic cleaned except seals and O-ring | 6 | 6 |
| | | **Total Time Taken for assembly of 1 Actuator** | **180** | **120** |

* Housing was pre-assembled with Helicoil inserts, expansion plugs and Lee plugs were kept ready on shelf since it is standardized irrespective of load and stroke requirement. EHSV assembly and 10 pin connectors were no need to remove during reassembly of actuator

By standardizing the housing there was a reduction in assembly time by 60 min with 4 different features achieved with combination of different stall load and actuator working stroke. Hence by this method reduced the number of variants.

## 9. QUALIFICATION TESTING PHASE

The Qualification Testing Phase involves testing of actuator assembly details as per MITC test standards. The following tests were performed and the actuator:-

- Acceptance test
- Temperature Test
- Impulse Test
- Vibration Test and Endurance Test

**Note:** All inputs to the actuator met the requirements per standard test procedure and all applicable specifications. The actuator did not incur any visible structural damages or deformation throughout the test.

## 10. RESULTS AND CONCLUSION

- Outcome of information phase: It has been found that the Actuator Housing alone was contributing 43% weight compared to other parts of the Actuator.
- Outcome of re-designing of Housing: It is found that there was a reduction of raw material envelop size by 13.01%, finished housing weight by 36.75% and cost by 34.18%.
- Outcome of Stress analysis Phase: Post Analysis results found Actuator Housing and other major parts of the actuator margin of safety is positive and damage factor is less than one.
- Outcome of Fabrication and assembly phase: By standardizing the Housing there was a reduction of Assembly time by 60min with 4 different features achieved with combination of different stall load and Actuator working stroke.
- Outcome of Qualification Testing Phase: The Actuator did not incur any visible structural damages, deformation or cracks throughout the test that can be determined by an external visual inspection.
- Outcome of Post Test D & I Phase: At the conclusion of Qualification test Actuator was subjected to full DNI and no test article structural damages, fracture, deformation or cracks were discovered. However during inspection found evidence of wear/scoring marks on Piston OD which is acceptable as per Standard norms.
- <u>Benefits:</u> There was a cost benefit of 34.18% and also by standardization of Housing reduces the assembly time by 60 min (33.33%) and able to offer 4 Variants of Actuator to customer.

## 11. RECOMMENDATION FOR FUTURE WORK

There are recommendations for further research in the area of conceptual design. These recommendations are relate as follows:

- The VAVE analysis is proposed to extend study on remaining parts of the Actuator like study on Piston Glands, Sleeves, piston rod etc for the possibility of benefits.

- The VAVE analysis is also proposed to other families of hydraulic actuators in business jets and private jets Aircrafts.

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