ME 3263

Design For Manufacture and Assembly

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Semester I

Term Paper

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Table of Contents

Introduction

When an engineer or designer faces a problem, he will usually go straight to his product design, neglecting the fabrication and assembly methods. Thus this leads to increased cost and lead-time when he wishes to actually produce this part or product. This becomes especially true when it comes to automated or mass production because of the lack of human intervenes to correct real time problems. Design for Manufacturing and Assembly (DFMA) was the solution. DFMA aims to assist the designer in solving many fabrication, machining and assembly problems.

DFMA is a design philosophy used by designers when a reduction in part counts, a reduction in assembly time, or a simplification of subassemblies is desired. It is a combination of two complementary review processes involving step-by-step assessment of manufacturability issues. DFMA is able achieve reduced assembly procedures, material wastes, time and therefore cost as compared to producing parts without DFMA. By reducing the amount of components required, work quality will also be improved.

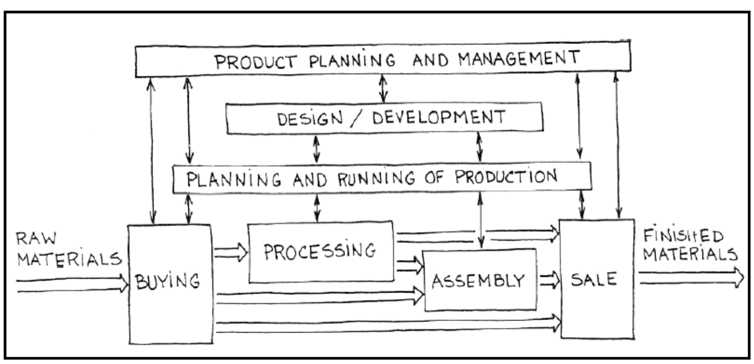


Fig. 1
An integrated approach must be adopted so as to achieve the intentions of DFMA.

In this paper, we apply Design for Manufacturing and Assembly to a radio controlled (R/C) model race car shock absorber. We will analyze its design efficiency by looking at the manual assembly time and respective assembly costs. Thereafter, we shall look at possible modifications to be done on this assembly so as to achieve lower assembly times, costs and overall product cost.

Selected Product

Being activity involved in R/C car model racing for the past 8 years, I have come to realize the high costs involved in this sport/hobby. Many performance oriented parts are required for motor sports and this increases the costs dramatically.

The featured item is the **Tamiya Racing Factory (TRF) Low Friction Damper** found on the TA04-R 1/10th scale electric powered touring car. A set of 4 dampers costs about S$90.00.

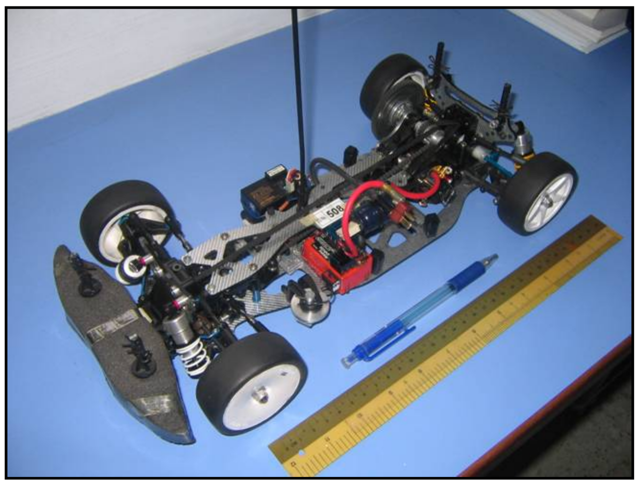


Fig. 2.1
A snap shot of the Tamiya TA04-R R/C Touring Car Chassis

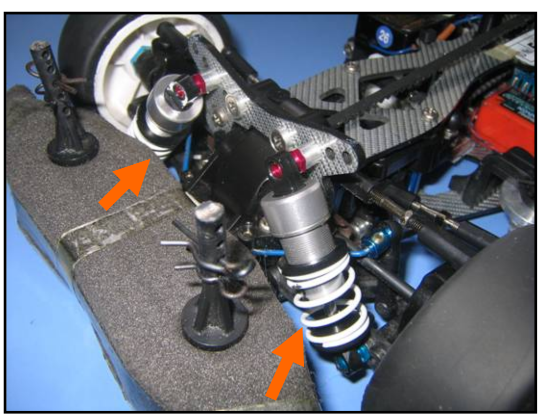


Fig. 2.2
A pair of TRF Dampers support the front end of the car.

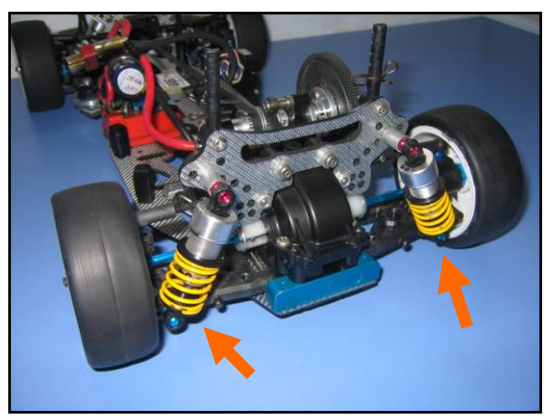


Fig. 2.3
A total of 4 damper units are installed on the car.

Details of the TRF Damper unit

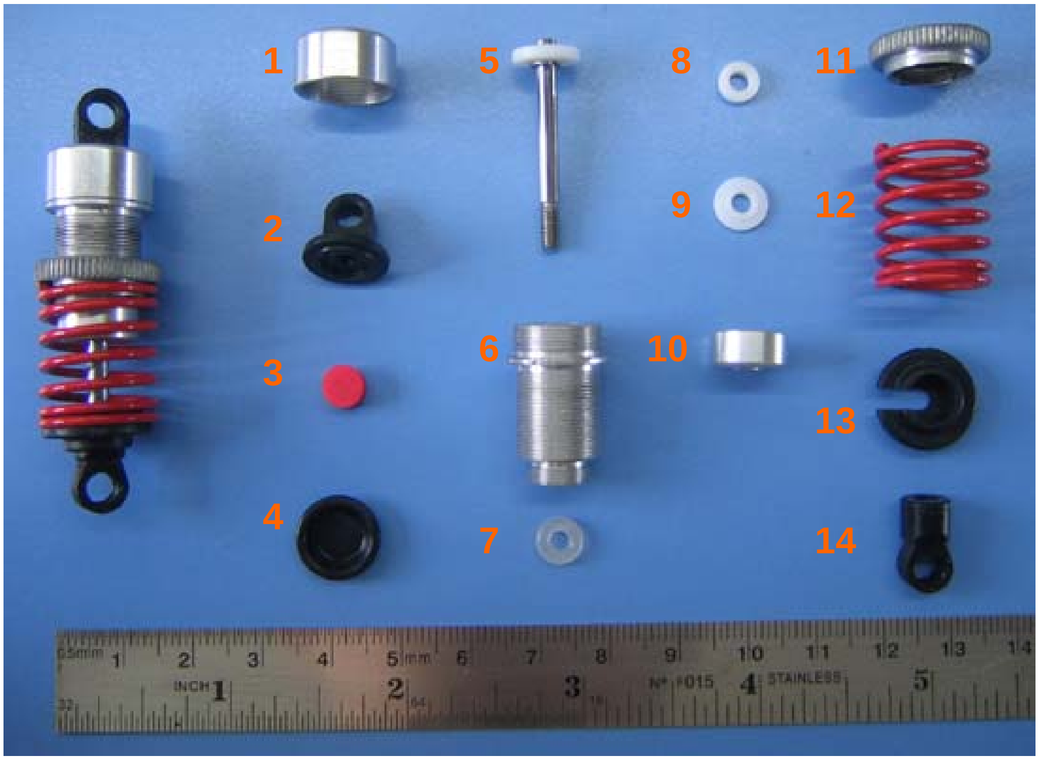


Fig. 3 Main parts of the TRF Dampers (Assigned part numbers in orange)

Item No.	Description	Function	Material
1.	Shock Cap	Caps bladder seal	6061-T6 Alum.
2.	Cap Socket Joint	Attaches damper	Molded Nylon
3.	Volume Compensator	Compensate for piston displacement	Foam
4.	Bladder	Seals damper fluid	Silicone
5.	Piston Assembly (Piston held by 2 E-Clips)	Gives required damping	Teflon Piston/ Stainless Steel shaft
6.	Shock Body	Stores shock fluid	6061-T6 Alum.
7.	O-Ring	Seals damper fluid	Silicone
8.	Spacer	Compresses O-Ring	Teflon
9.	O-Ring Seat	Compresses O-Ring	Teflon
10.	Shock End Cap	Caps O-Ring seal	6061-T6 Alum.
11.	Preload Adjuster	Adjusts ride height of car	6061-T6 Alum.
12.	Spring	Provides Suspension	Spring Steel
13.	Spring Retainer	Holds spring in place	Molded Nylon
14.	End Socket Joint	Attaches damper	Molded Nylon

Bill Of Material

Item No.	Description of Item	No. of Item	Material of Item	Thickness of Item (mm)	Size of Item (mm)
1.	Shock Cap	1	6061-T6 Alum.	7.5	14.6
2.	Cap Socket Joint	1	Molded Nylon	12.2	11.3
3.	Volume Compensator	1	Foam	3	6
4.	Bladder	1	Silicone	3	12
5.	Piston Assembly (Piston held to shaft by 2 E-Clips)	1	Teflon Piston/ Stainless Steel shaft	10	30.5
6.	Shock Body	1	6061-T6 Alum.	14.6	22.5
7.	O-Ring	1	Silicone	2	7
8.	Spacer	1	Teflon	2	6.8
9.	O-Ring Seat	1	Teflon	1.5	8
10.	Shock End Cap	1	6061-T6 Alum.	5	10.9
11.	Preload Adjuster	1	6061-T6 Alum.	5	17
12.	Spring	1	Spring Steel	16.3	20.5
13.	Spring Retainer	1	Molded Nylon	6	15
14.	End Socket Joint	1	Molded Nylon	7	13.9

Piston sub-assembly: 4 parts (Piston + 2x E-clips + Shaft)

Number of parts in main assembly: 14 parts

Assembly Procedure of TRF Damper

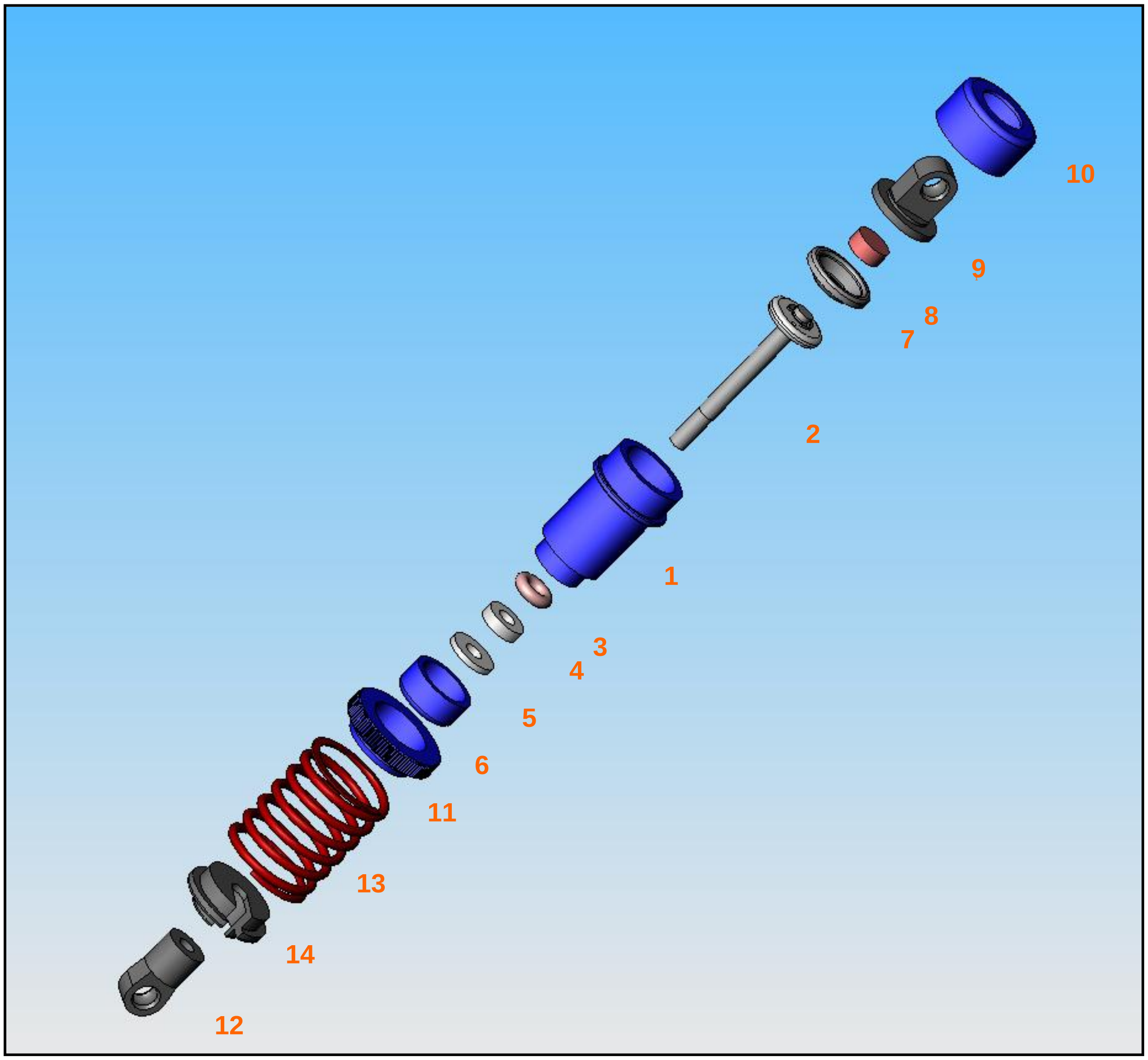


Fig. 4.1 **Assembly procedure of the TRF Damper**
Refer to next page for detailed descriptions

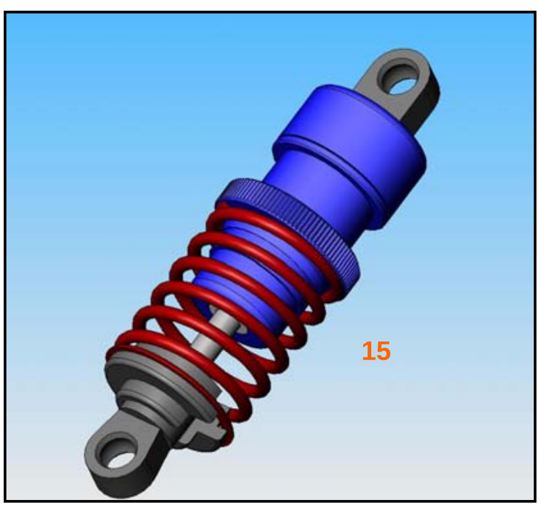


Fig. 4.2
Completed TRF Damper unit

Description of Procedures

1. *Shock body* is held in place horizontally in a fixture
2. *Piston* sub-assembly is inserted into the *shock body*
3. *O-Ring* is lubricated with silicone grease before insertion to *shock shaft* to prevent tearing the *o-ring*
4. *Spacer* inserted into the *shock body* from below the *o-ring*
5. *O-ring* seat is then inserted into the *shock shaft*
6. *End cap* is screwed onto the *shock body* compressing the *o-ring* slightly giving an air tight assembly
7. *Shock body* is placed vertical and is filled silicone shock fluid before the *bladder* seals the top end of the damper
8. *Volume compensator* is placed centered on the *bladder*
9. *Cap socket joint* is placed onto the *volume compensator* and *bladder*
10. *Shock cap* is screwed onto the *shock body*. Shock fluid is sealed
11. Spring *preload adjuster* is then screwed onto the *shock body* from the bottom end
12. *End socket joint* is screwed onto the *shock shaf*t, alignment of the 2 socket ends can be adjusted after assembly is completed
13. *Spring* is inserted into the *shock body*
14. *Spring retainer* is inserted onto the *shock shaft* through the slot and seats the spring coaxially in the assembly
15. TRF Damper assembly is completed

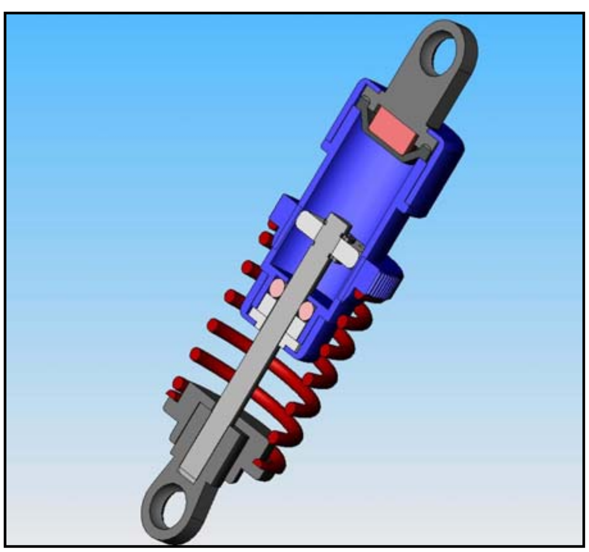


Fig. 4.3
Cutaway view of
Completed TRF Damper unit

Operational Worksheet

Manual Bench assembly	No. of Items	Alpha Angle	Beta Angle	Manual Handling Code	Handling Time Per Item (s)	Manual Insertion Code	Insertion Time Per Item(s)	Total Operation Time RPx(TH+Ti)	Total Operation Cost Cents (TAxOP)	Figures for Min. Parts	Operator Rate (OP): $40.00/hr
Item Name/ Assembly Operation	**RP**	**(deg)**	**(deg)**	**MC**	**TH**	**IC**	**Ti**	**TA**	**CA**	**NM**	Description
1. Shock Body	1	360	0	11	1.8	00	1.5	3.30	0.037	1	Place in fixture
2. Piston Assembly (Piston held to shaft by 2 E-Clips)	1	360	0	11	1.8	06	5.5	7.30	0.081	1	Add & hold down
3. O-Ring	1	180	0	03	1.69	06	5.5	7.19	0.080	1	Add & hold down
4. Spacer	1	180	0	04	2.18	06	5.5	7.68	0.085	0	Add & hold down
5. O-Ring Seat	1	360	0	11	1.8	06	5.5	7.30	0.081	0	Add & hold down
6. Shock End Cap	1	360	NA	11	1.8	38	6	7.80	0.087	1	Add & fasten
7. End Cap Fastening	1	-	-	-	-	92	5	5.00	0.056	-	Standard Operation
8. Silicone fluid filling	1	-	-	-	-	99	12	12.00	0.133	-	Special Operation
9. Bladder	1	360	0	11	1.8	00	1.5	3.30	0.037	1	Add
10. Volume Compensator	1	180	0	11	1.8	00	1.5	3.30	0.037	1	Add
11. Cap Socket Joint	1	360	0	11	1.8	00	1.5	3.30	0.037	0	Add
12. Shock Cap	1	360	NA	11	1.8	38	6	7.80	0.087	1	Add & fasten
13. Cap Fastening	1	-	-	-	-	92	5	5.00	0.056	-	Standard Operation
14. Preload Adjuster	1	360	NA	10	1.5	38	6	7.50	0.083	1	Add & fasten
15. Adjuster Fastening	1	-	-	-	-	92	5	5.00	0.056	-	Standard Operation
16. End Socket Joint	1	360	NA	11	1.8	48	8.5	10.30	0.114	1	Add & fasten
17. Socket Joint Fastening	1	-	-	-	-	92	5	5.00	0.056	-	Standard Operation
18. Spring	1	180	0	00	1.13	06	5.5	6.63	0.074	1	Add & hold down
19. Spring Retainer	1	360	360	30	1.95	41	7.5	9.00	0.100	1	Add & snap fit
Total	**-**	**-**	**-**	**-**	**22.85**	**-**	**98**	**120.40**	**1.338**	**11**	**-**

Calculations

Total Assembly Cost = Total Time x operator Cost

$$= \frac{120.40}{3600} \times \$40.00$$

= **$1.338 (3 decimal place)**

T Avg =

$$\frac{TA/2}{(\text{Total Operations} - \text{Additional Operations})}$$

$$= \frac{120.40/2}{19 - 5}$$

= **4.3**

Efficiency % =

$$\frac{N\ Min \times T\ Avg}{TA}$$

$$= \frac{11 \times 4.3}{120.40}$$

= **39.28%**

Suggested Redesign and Modifications of the TRF Damper unit

After analysis, it is suggested that the following parts be modified.

1. **Shock Body** 
2. **Shock cap** 
3. **Shock End cap** 
4. **Preload Adjuster** 

The reason for modification is due to the fact that these parts are CNC machined from solid aluminum billets. Machining such hollow and threaded items give rise to material waste and machining time which both adds to the total cost of the damper unit.

Modifications as follows:

1. All Aluminum CNC parts to be replaced by molded Delrin. Delrin is stronger and stiffer than nylon. Threads can also be molded reducing machining time,
2. Shock Cap and End Cap will be molded as a 1-Piece part with other adjacent parts. This results in reduced parts count and therefore reduced assembly time.

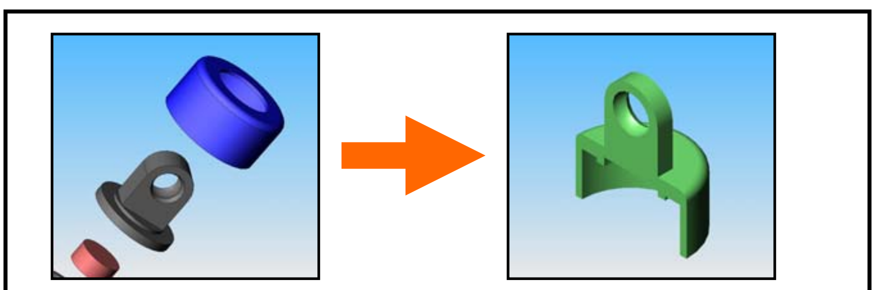


Fig. 5.1
Modified Shock Cap
2 pieces molded as 1

Part count reduction = 1

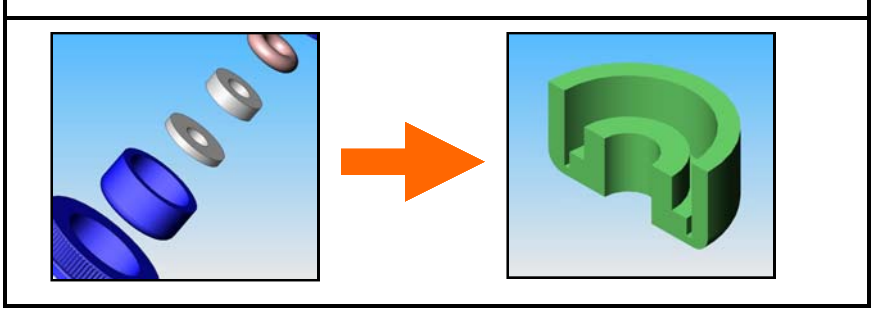


Fig. 5.2
Modified End Cap
3 pieces molded as 1

Part count reduction = 2

Modified Bill Of Material

Item No.	Description of Item	No. of Item	Material of Item	Thickness of Item (mm)	Size of Item (mm)
1.	Shock Cap	1	6061-T6 Alum.	7.5	14.6
2.	Volume Compensator	1	Foam	3	6
3.	Bladder	1	Silicone	3	12
4.	Piston Assembly (Piston held to shaft by 2 E-Clips)	1	Teflon Piston/ Stainless Steel shaft	10	30.5
5.	Shock Body	1	6061-T6 Alum.	14.6	22.5
6.	O-Ring	1	Silicone	2	7
7.	Shock End Cap	1	6061-T6 Alum.	5	10.9
8.	Preload Adjuster	1	6061-T6 Alum.	5	17
9.	Spring	1	Spring Steel	16.3	20.5
10.	Spring Retainer	1	Molded Nylon	6	15
11.	End Socket Joint	1	Molded Nylon	7	13.9

Piston sub-assembly: 4 parts (Piston + 2x E-clips + Shaft)

Number of parts in main assembly: 11 parts

Modified Assembly Procedure of TRF Damper

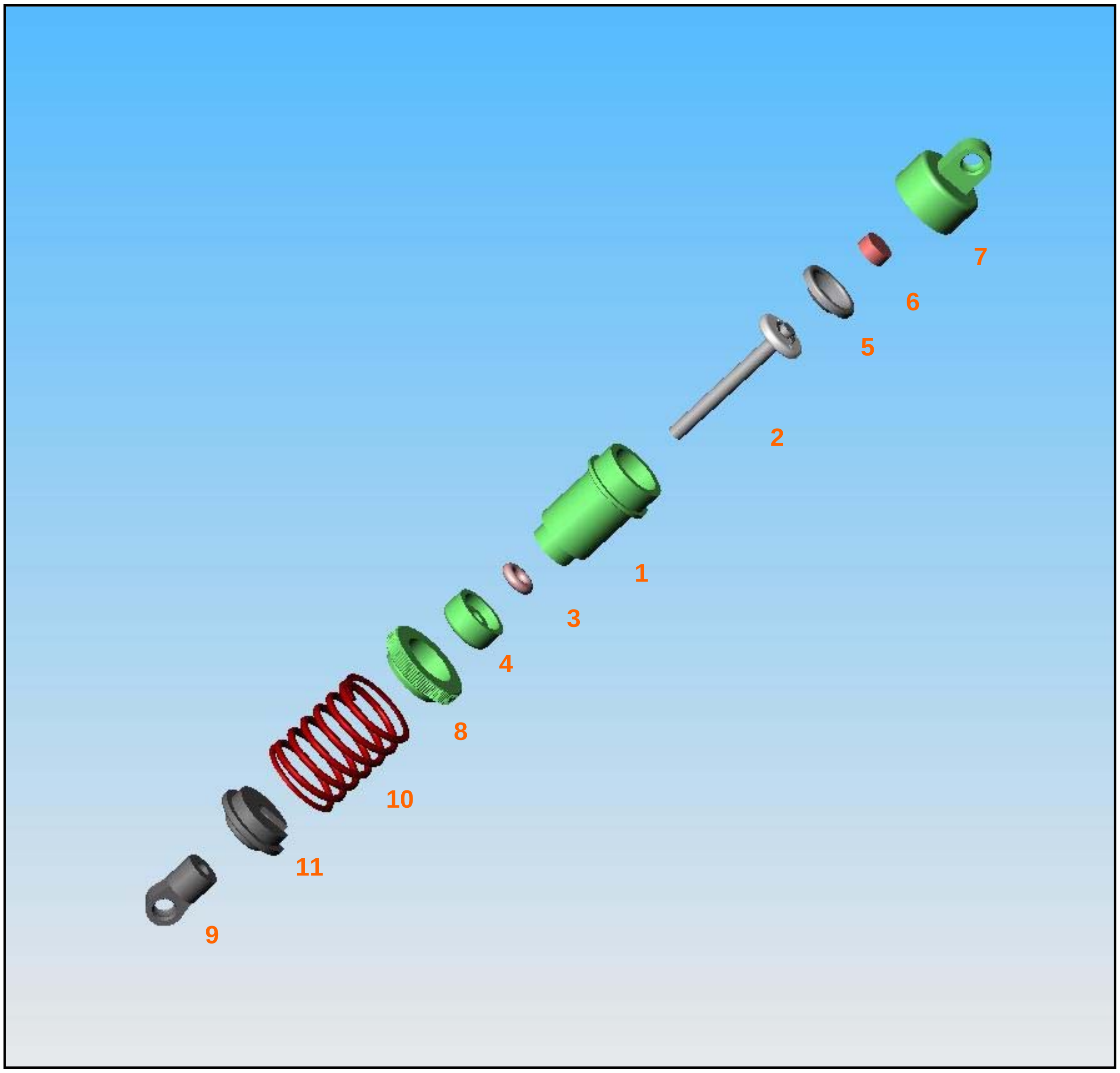


Fig. 5.3 **Assembly procedure of the MODIFIED TRF Damper**
Refer to next page for detailed descriptions

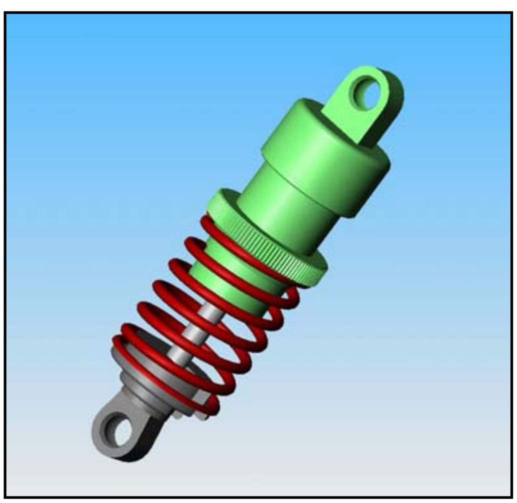


Fig. 5.4
Completed Assembly of the Modified TRF Damper unit

Description of Modified Procedures

1. *Shock body* is held in place horizontally in a fixture
2. *Piston* sub-assembly is inserted into the *shock body*
3. *O-Ring* is lubricated with silicone grease before insertion to *shock shaft* to prevent tearing the *o-ring*
4. *Modified End cap* is screwed onto the *shock body* compressing the *o-ring* slightly giving an air tight assembly
5. *Shock body* is placed vertical and is filled silicone shock fluid before the *bladder* seals the top end of the damper
6. *Volume compensator* is placed centered on the *bladder*
7. *Modified Shock cap* is screwed onto the *shock body*. Shock fluid is sealed
8. Spring *preload adjuster* is then screwed onto the *shock body* from the bottom end
9. *End socket joint* is screwed onto the *shock shaf*t, alignment of the 2 socket ends can be adjusted after assembly is completed
10. *Spring* is inserted into the *shock body*
11. *Spring retainer* is inserted onto the *shock shaft* through the slot and seats the spring coaxially in the assembly
12. *Modified* TRF Damper assembly is completed

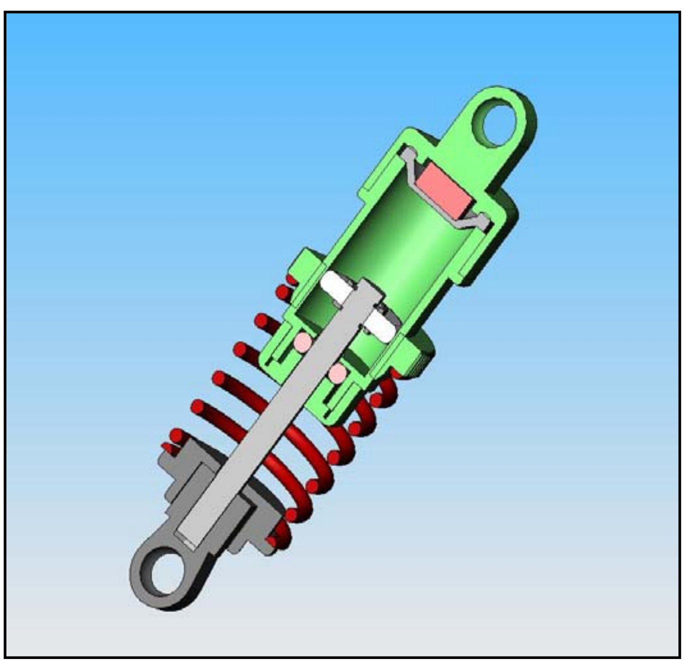


Fig. 5.5
Cutaway view of MODIFIED TRF Damper unit shows clearly the less cluttered assembly due to reduced part count

Modified Operational Worksheet

Manual Bench assembly	No. of Items	Alpha Angle	Beta Angle	Manual Handling Code	Handling Time Per Item (s)	Manual Insertion Code	Insertion Time Per Item(s)	Total Operation Time RPx(TH+Ti)	Total Operation Cost Cents (TAxOP)	Figures for Min. Parts	Operator Rate (OP): $40.00/hr
Item Name/ Assembly Operation	**RP**	**(deg)**	**(deg)**	**MC**	**TH**	**IC**	**Ti**	**TA**	**CA**	**NM**	Description
1. Shock Body	1	360	0	11	1.8	00	1.5	3.30	0.037	1	Place in fixture
2. Piston Assembly (Piston held to shaft by 2 E-Clips)	1	360	0	11	1.8	06	5.5	7.30	0.081	1	Add & hold down
3. O-Ring	1	180	0	03	1.69	06	5.5	7.19	0.080	1	Add & hold down
4. Shock End Cap	1	360	NA	11	1.8	38	6	7.80	0.087	1	Add & fasten
5. End Cap Fastening	1	-	-	-	-	92	5	5.00	0.056	-	Standard Operation
6. Silicone fluid filling	1	-	-	-	-	99	12	12.00	0.133	-	Special Operation
7. Bladder	1	360	0	11	1.8	00	1.5	3.30	0.037	1	Add
8. Volume Compensator	1	180	0	11	1.8	00	1.5	3.30	0.037	1	Add
9. Shock Cap	1	360	NA	11	1.8	38	6	7.80	0.087	1	Add & fasten
10. Cap Fastening	1	-	-	-	-	92	5	5.00	0.056	-	Standard Operation
11. Preload Adjuster	1	360	NA	10	1.5	38	6	7.50	0.083	1	Add & fasten
12. Adjuster Fastening	1	-	-	-	-	92	5	5.00	0.056	-	Standard Operation
13. End Socket Joint	1	360	NA	11	1.8	48	8.5	10.30	0.114	1	Add & fasten
14. Socket Joint Fastening	1	-	-	-	-	92	5	5.00	0.056	-	Standard Operation
15. Spring	1	180	0	00	1.13	06	5.5	6.63	0.074	1	Add & hold down
16. Spring Retainer	1	360	360	30	1.95	41	7.5	9.45	0.105	1	Add & snap fit
Total	**-**	**-**	**-**	**-**	**17.07**	**-**	**85.5**	102.57	1.140	**11**	**-**

Modified Calculations

Total Assembly Cost = Total Time x operator Cost

$$= \frac{102.57}{3600} \times \$40.00$$

= **$1.140 (3 decimal place)**

Cost Reduction = ***1.338 – 1.140***

= ***$0.198***

%Improvment = *(1.338 – 1.140)/1.338 x 100%*

= ***14.8%***

T Avg $= \dfrac{TA/2}{\text{(Total Operations – Additional Operations)}}$

$$= \frac{102.57/2}{16 - 5}$$

= **4.66**

Efficiency % $= \dfrac{\text{N Min x T Avg}}{\text{TA}}$

$$= \frac{11 \times 4.66}{102.57}$$

= **50.00%**

%Improvment = *50 – 39.28*

= ***10.72%***

Conclusion

From the application of DFMA we achieved savings by:

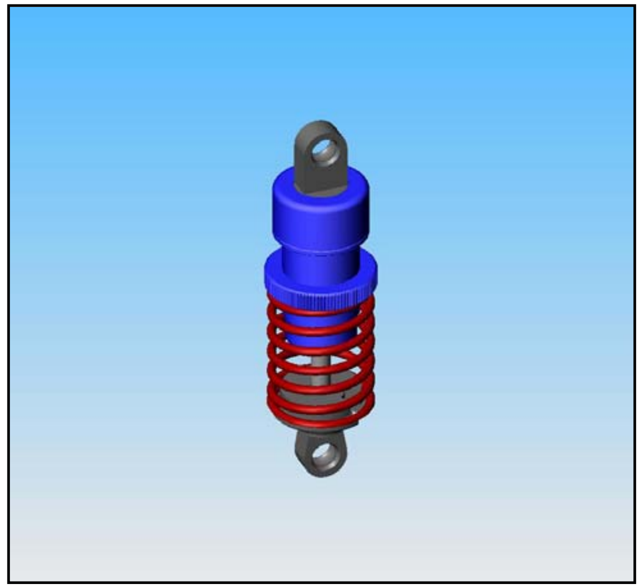
- ✓ **Reduction in material cost**
    - o By selecting molded Delrin as a replacement for 6061 aluminum, we were able to maintain the low-friction characteristics of the original damper and also still maintain structural rigidity required for good damper performance under racing conditions.
    - o Reduced product weight is a bonus as Delrin has a density of 1.42g/cc as compared to aluminum with a density of 2.7 g/cc.
- ✓ **Reduction in machining cost**
    - o The threaded features on the original damper unit were expensive and time consuming to produce by machining.
- ✓ **Reduction in part count**
    - o By molding, we are able to integrate several parts into a 1 piece molded part, thus reducing part count.
- ✓ **Reduction in assembly time**
    - o Reduction in part count directly reduced assembly time and costs.

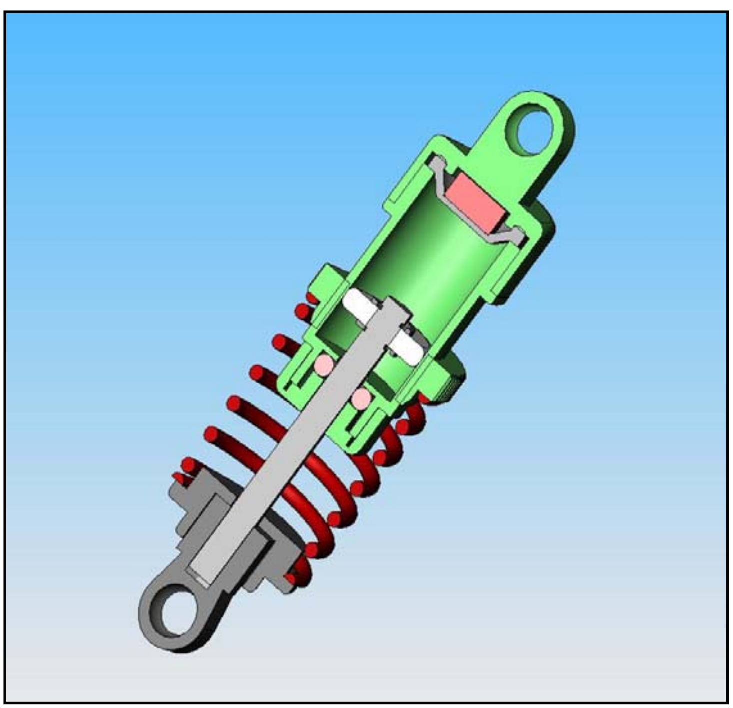
From the case study and discussion, we can see the significance of assembly cost in production. Product design for assembly is essential. We can see that there is three very significant benefits if ease for assembly is take into consideration when designing a product.

Reduction in lead-time leads to less labor cost due to shorter production time, higher productivity to meet any customer's demands, thus leads to increase in company's reputation etc.

The production line can produce higher quality products due to decrease in probability of assembly errors. This in turn reduces a need for larger sampling size for inspection. Quality products also reduce material waste.

Proper and well taught out design and production brought about by the Design for Manufacturing and Assembly design philosophy has made production of an expensive product more affordable, faster and easier. Almost all products big or small can adopt DFMA in order to increase production and reduce cost.





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