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# STRUCTURAL ANALYSIS OF SYNCHRONIZER GEAR ASSEMBLY

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**Abstract-** Design of the synchronizer plays a vital role in determining the shifting force and gear box performance in manual transmission. In this paper a synchronizer assembly of the 4th gear of a Volkswagen Golf is modeled using Creo 2.2 and structural analysis is carried out using Ansys 15. The simulation is carried out in two mating positions;the "Just meshed" and the "Completely meshed" condition. Also, the paper observes the variation of the behavior due to the change in synchronizer material. Steel, Aluminum alloy and Brass are the three materials ofsynchronizer ring for which the analysis is carried out. The analysis is conducted at varying loads from 400 N to 1600N. The parameters to determine the behaviour for the above mentioned conditions are the Ring and Sleeve Deformation, Equivalent Von Mises stresses and Maximum Principle Stresses. In conclusion, suggestions are made regarding the optimum materials for the synchronizer ring and sleeve

**Keywords-** synchronizer ring, sliding sleeve, ansys15, creo2.2, shift force, material.

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## I. INTRODUCTION

The transmission system influences the power, fuel economy and behavior of a vehicle. The performance of transmission system depends upon gear efficiency, gear shift comfort during gear changes and on gear noise. Hence for better performance of engine it is necessary to optimize various transmission parameters. The transmission system efficiency of an automobile depends upon the type of transmission i.e., manual or automatic transmission and type of gear box used. Manual transmission system, due to its higher transmission efficiency is the most commonly used in automobile industry in India. Manual transmission system comprises of sliding mesh, constant mesh and synchromesh gear box. With constant mesh gear box it is difficult to obtain smooth engagement of gears during gear changes which causes noise and vibrations in the gear box. Also double declutching is required with constant mesh gear box. On the contrary with the use of synchromesh gearbox we can have easy gear shifts with smooth engagement and disengagement of gears. Synchronizer mechanism determines the working performance in synchromesh gear box. Hence the design of synchronizer plays a vital role in synchromesh gear box.

The synchronizer consists of different components like synchronizer ring, hub, sleeve, cone, plunger and spring. The working of synchronizer consists of different processes of which synchronization and meshing meshing are discussed in this paper. The performance of synchronizer system depends upon the materials of synchronizer components, shift force, cone angle, blocker angle, coefficient of friction between synchronizer ring and meshing gear cone.

To understand the behavior of synchronizer many researchers have done experiments and analysis on synchronizing process. Xi Li [1] presented a single cone synchronizer model using dynamic implicit algorithm. With simulation in Abacus software the effect of variation of stresses and contact forces in relation to time was determine. It helped to improve shift quality and life span of synchronizer. JinningLi [2] determined the parameters of synchronizer which affects the gear shift performance. Virtual parametric models were developed in Addams and were used for analysis purpose.The shift time and the shift force are mainly predicted from the research work. SayyedRazzacki [3] has developed a mathematical algorithm and tolerencing and dimension scheme. To determine the relation between sleeve and blocker ring pointing angle with cone torque

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coefficient of friction and synchronizer size a mathematical algorithm is proposed. T.M. ManozKumar [4] developed a transfer function to determine the effect of design parameters on the performance of synchronizer. The mean radius, cone friction coefficient and cone angle of synchronizer ring were considered as a design parameters. The paper predicted various performance parameters such as synchronization efficiency, shift quality and synchronizer life on the basis of specific power dissipation and hoops stresses, shift force and clash ratio respectively.

In this paper the influence of change in materials of synchronizer ring and sleeve and the effect of shift force is observed. For the analysis the synchronizer of fourth gear of Volkswagen Golf car is selected. The effect of change in shift force in materials of above components is presented in the form of stresses and displacements. For synchronizer ring the commonly used materials are brass, steel, molybdenum and for sleeve the materials used are stainless steel, brass, Aluminum alloys etc. Therefore Aluminum alloy, Steel, Copper Alloy(Brass)materials are selected for synchronizer ring and sleeve for analysis purpose.While the shift force for each material is varied from 400 to 1600 N.

## II. METHODOLOGY

**The following are the important stages by which the work is completed:**

1. Selection of car model and obtaining the dimensions for synchronizer ring and sleeve for the same.
2. Modeling of synchronizer components based on previously acquired dimensions using Creo 2.2.
3. Assembly of modeled components based on the two required conditions; “Just meshed” and “Completely meshed” condition.
4. Analysis of “Just meshed” assembly in Ansys Workbench 15 at the range of loads to obtain the deformation and stresses as required.
5. Analysis of “Completely meshed” assembly in Ansys Workbench 15at the range of loads to obtain deformation using Steel as the material.
6. Repeating steps 4 and 5as described above to determine the behavioral changes caused by the material changes.
7. Providing suggestions regarding the optimum materials and shift forces based on which the synchronizer must be designed

## III. MODELING OF SYNCHRONIZER GEOMETRY

There are two major components of the synchronizer system; the synchronizer ring-gear assembly and the sliding sleeve. The dimensions of both these components were obtained for the 4th gear configuration of the synchromesh gearbox as shown below. Modeling of thecomponents and the assembly of the same is done using Creo 2.2 modeling software.

For the “Just meshed” condition, the gear teeth of the synchronizer ring and the sliding sleeve are not in a meshing or mating position but touching face to face, resulting in a stressed and axially loaded position. For the “Completely meshed” condition, the meshing of the gear teeth is assumed to have taken place, and the only deformation existing is the one caused due to the movement of the teeth against one another.

**Table I:**.Dimensions of synchronizer components

| Sr. No. | Parameter | Dimension (mm) |
|---|---|---|
| 1 | Outer hub dia. | 47 |
| 2 | Synchronizer ring Outer dia. | 64 |

| | | |
|---|---|---|
| 3 | Sleeve outer dia. | 89 |
| 4 | No of teeth on synchronizer ring | 30 |
| 5 | Blocker angle | $120^{O}$ |
| 6 | Cone angle | $0^{O}$ |
| 7 | Width of Synchronizer ring | 7.5 |
| 8 | Width of Sleeve | 22 |
| 9 | Width of gear | 11 |

## IV. STRUCTURAL ANALYSIS OF SYNCHRONIZER RING

Static structural analysis is conducted for the synchronizer ring and sleeve assembly at the “Just meshed” and “Fully meshed” conditions for three different materials. For the “Just meshed” condition, the deformation of the ring and sleeve are to be obtained, alongwith the equivalent Von Mises stresses and maximum principal stresses acting on them. The analysis is carried out in Ansys 15 WorkbenchStatic Structural Module. The pressures obtained from the load ranges as shown below are used as the pressure inputs for the movement of the sleeve while defining the synchronizer ring as the fixed support. The results of this analysis show the structural changes undergone by the gear teeth and gear body of the ring and sleeve.

**Table II.**Pressure acting on the sleeve

| **Sr. No.** | **Load (N)** | **Pressure (MPa)** |
|---|---|---|
| 1 | 400 | 0.713 |
| 2 | 800 | 1.426 |
| 3 | 1200 | 2.139 |
| 4 | 1600 | 2.85 |

## V. RESULTS OF STRUCTURAL ANALYSIS

### A. Just meshed condition: Deformation of the ring

**Table III.** Deformation (Ring)

| **Load (N)** | **Steel ($x10^{-3}$ mm)** | **Aluminium alloy ($x\ 10^{-3}$ mm)** | **Copper alloy ($x\ 10^{-3}$ mm)** |
|---|---|---|---|
| 400 | 159.62 | 63.645 | 39.261 |
| 800 | 162.8 | 77.142 | 160.94 |
| 1200 | 103.28 | 63.726 | 65.84 |
| 1600 | 162.3 | 54.428 | 161.05 |

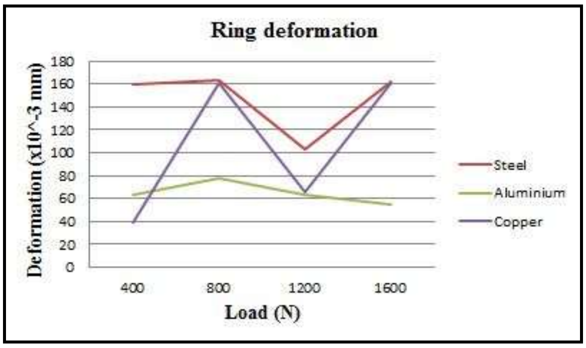


**Fig. 1:** Deformation of ring

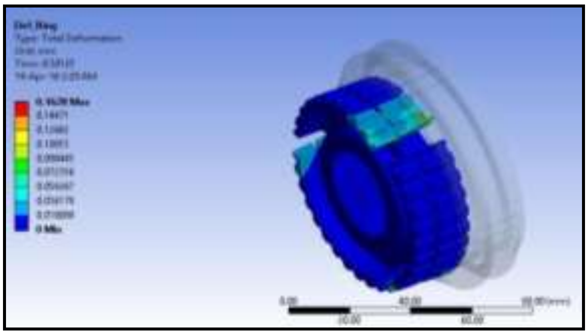


**Fig. 2:** Deformation of ring for Steel (800 N load)

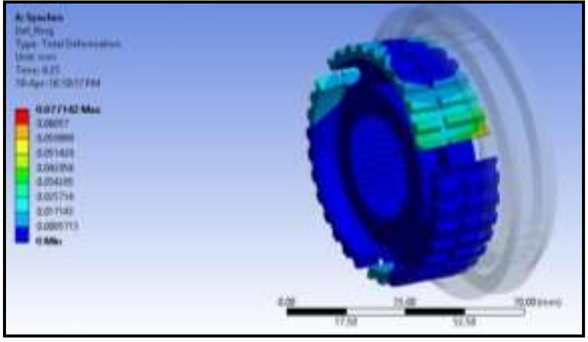


**Fig. 3:** Deformation of ring for Aluminum (800 N Load)

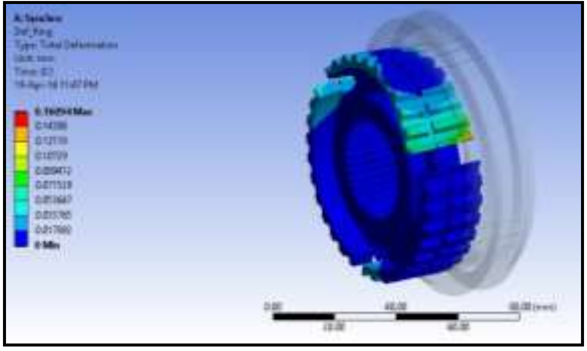


**Fig. 4:** Deformation of ring for Copper (800 N Load)

### B. Just meshed condition: Deformation of the sleeve

**Table IV.** Deformation (Sleeve)

| **Load (N)** | **Steel ($x10^{-3}$ mm)** | **Aluminium alloy ($x\ 10^{-3}$ mm)** | **Copper alloy ($x\ 10^{-3}$ mm)** |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 400 | 152.4 | 65.516 | 80.828 |
| 800 | 155.64 | 78.319 | 160.03 |
| 1200 | 101.66 | 65.668 | 67.198 |
| 1600 | 156.01 | 56.285 | 160.17 |

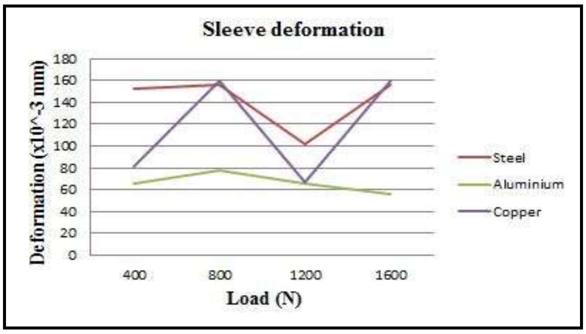


**Fig. 5:** Deformation of sleeve

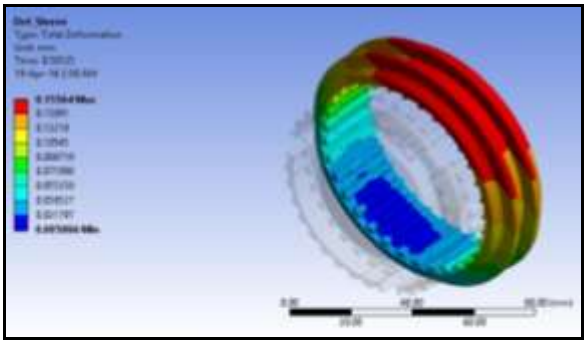


**Fig. 6:** Deformation of sleeve for Steel (800 N Load)

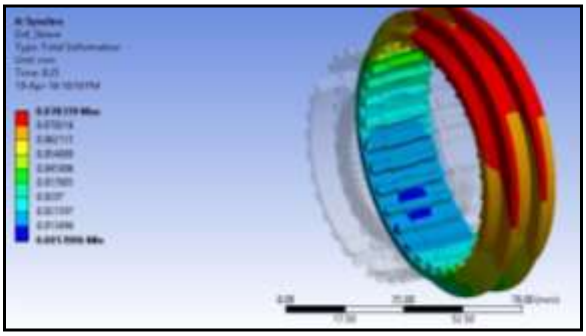


**Fig. 7:** Deformation of sleeve for Aluminum (800 N Load)

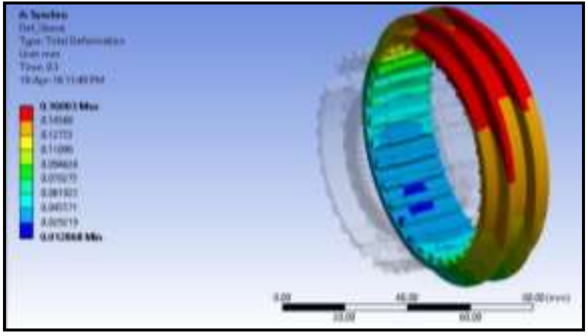


**Fig. 8:** Deformation of sleeve for Copper (800 N Load)

### C. Just meshed condition: Equivalent Von Mises stresses acting on the ring

**Table. V:** Von Mises stresses (Ring)

| Load (N) | Steel (MPa) | Aluminium alloy (MPa) | Copper alloy (MPa) |
|---|---|---|---|
| 400 | 447.36 | 249.7 | 217.67 |
| 800 | 447.42 | 249.63 | 323.31 |
| 1200 | 443.81 | 249.68 | 194.39 |
| 1600 | 447.66 | 249.67 | 324.67 |

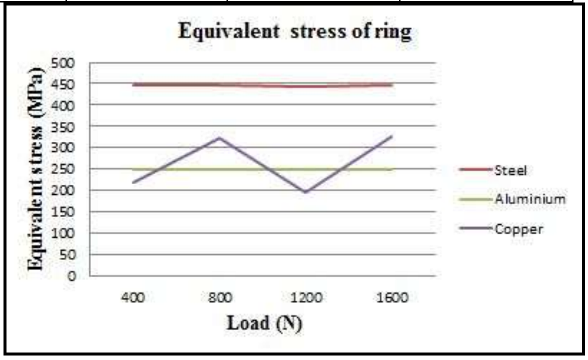


**Fig. 9:** Equivalent Von Mises stresses acting on ring

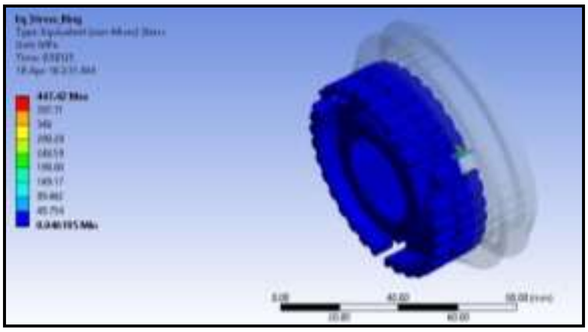


**Fig. 10:** Equivalent Von Mises stresses acting on ring for Steel (800 N Load)

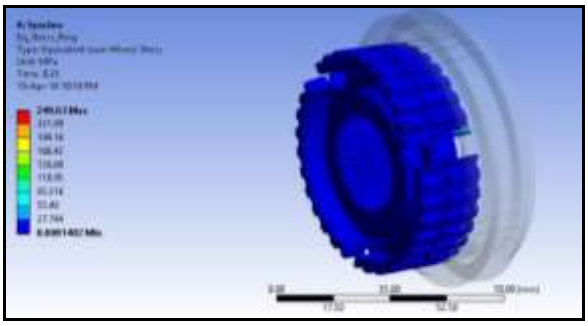


**Fig. 11:** Equivalent Von Mises stresses acting on ring for Aluminium (800 N Load)

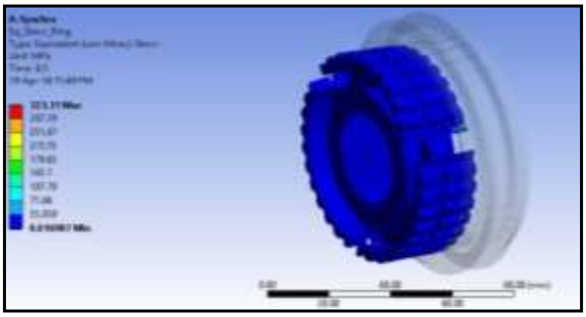


**Fig. 12:** Equivalent Von Mises stresses acting on ring for Copper (800 N Load)

### D. Just meshed condition: Equivalent Von Mises stresses acting on the sleeve

**Table. VI:** Von Mises stresses (Sleeve)

| **Load (N)** | **Steel (MPa)** | **Aluminium alloy (MPa)** | **Copper alloy (MPa)** |
|---|---|---|---|
| 400 | 323.35 | 211.51 | 155.36 |
| 800 | 320.11 | 223.44 | 234.76 |
| 1200 | 343.99 | 211.15 | 134.2 |
| 1600 | 331.81 | 194.2 | 235.6 |

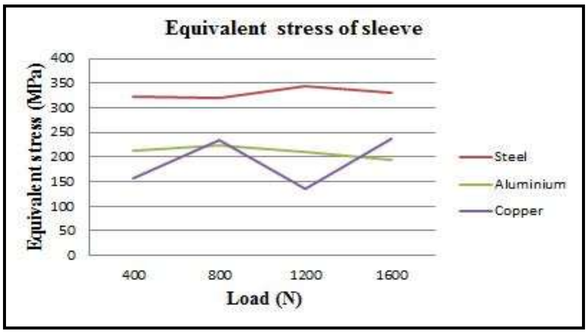
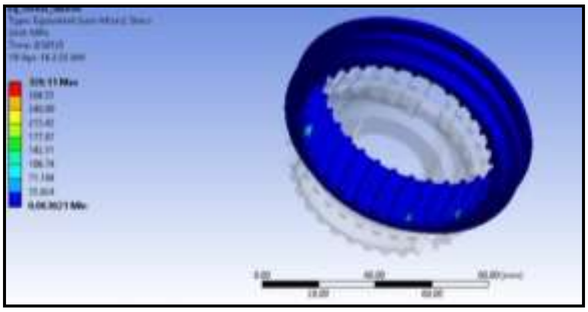


**Fig. 13:** Equivalent Von Mises stresses acting on sleeve



**ig. 14:** Equivalent Von Mises stresses acting on thesleeve for Steel (800 N Load)

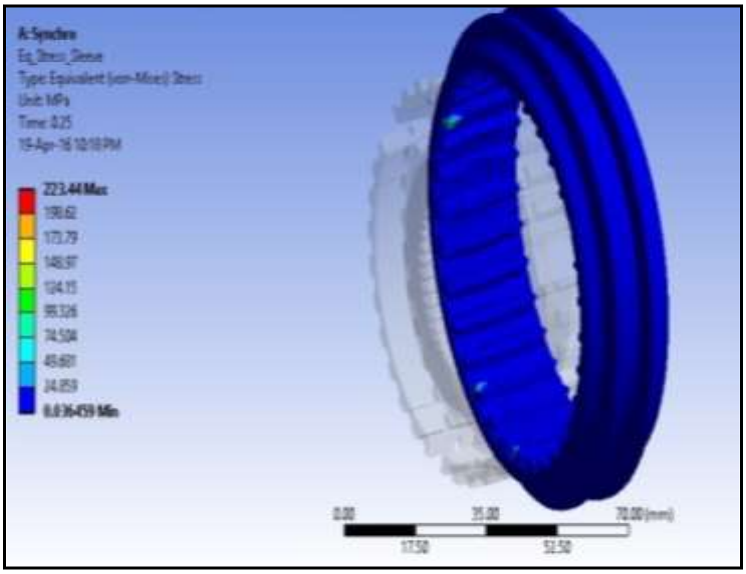


**Fig. 15:** Equivalent Von Mises stresses acting on the sleeve for Aluminium (800 N Load)

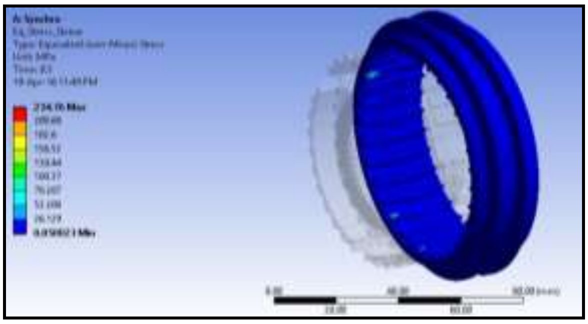


**Fig. 16:** Equivalent Von Mises stressesacting on sleeve for Copper (800 N Load)

### E. Just meshed condition: Maximum principal stress acting on ring

**Table. VII:** Principal stresses (Ring)

| Load (N) | Steel (MPa) | Aluminium alloy (MPa) | Copper alloy (MPa) |
|---|---|---|---|
| 400 | 127.78 | 39.034 | 30.163 |
| 800 | 128.05 | 61.25 | 60.955 |
| 1200 | 111.58 | 39.277 | 25.738 |
| 1600 | 127.96 | 33.947 | 60.389 |

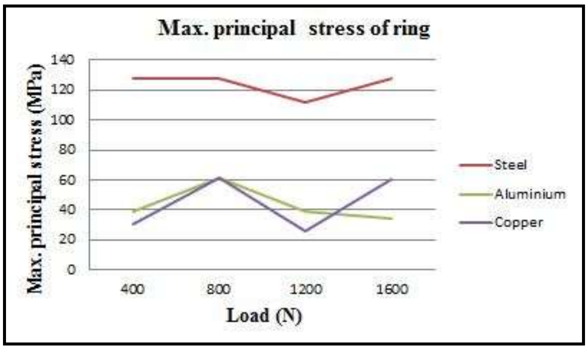


**Fig. 17:** Maximum principal stresses acting on ring

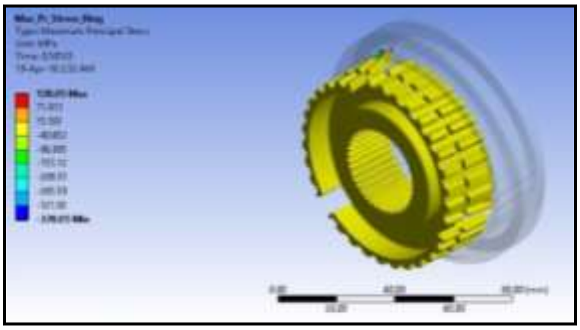


**Fig. 18:** Maximum principal stresses acting on ring for Steel (800 N Load)

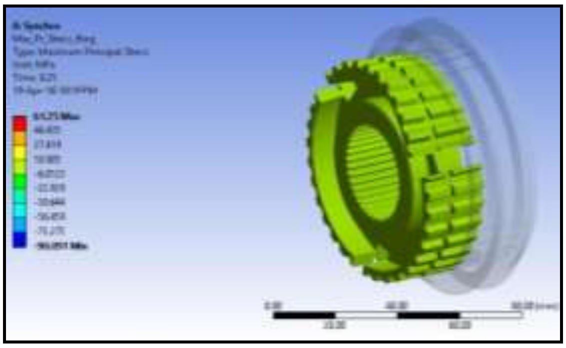


**Fig. 19:** Maximum principal stresses acting on ring for Aluminium (800 N Load)

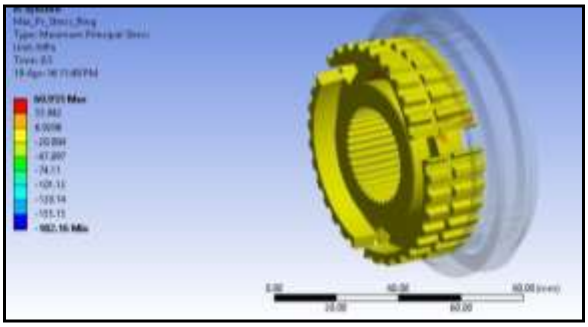


**Fig. 20:** Maximum principal stresses acting on ring for Copper (800 N Load)

### F. Just meshed condition: Maximum principal stress acting on sleeve

**Table. VIII:** Principal stresses (Sleeve)

| Load (N) | Steel (MPa) | Aluminium alloy (MPa) | Copper alloy (MPa) |
|---|---|---|---|
| 400 | 34.233 | 16.566 | 13.072 |
| 800 | 34.383 | 17.932 | 21.825 |
| 1200 | 31.916 | 16.649 | 11.562 |
| 1600 | 34.281 | 15.264 | 21.547 |

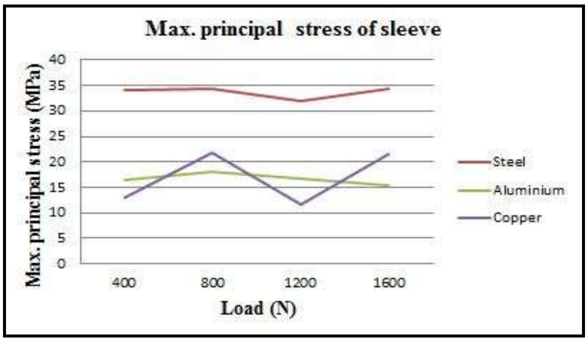


**Fig. 21:** Maximum principal stresses acting on sleeve

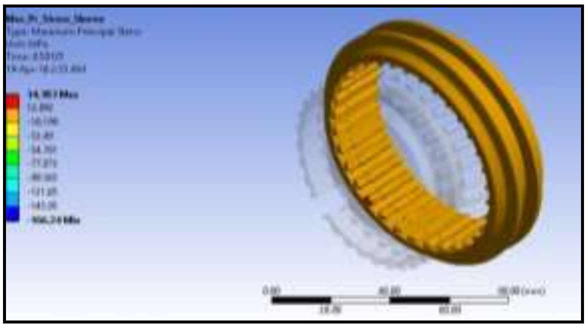


**Fig. 22:** Maximum principal stresses acting on sleeve for Steel (800 N Load)

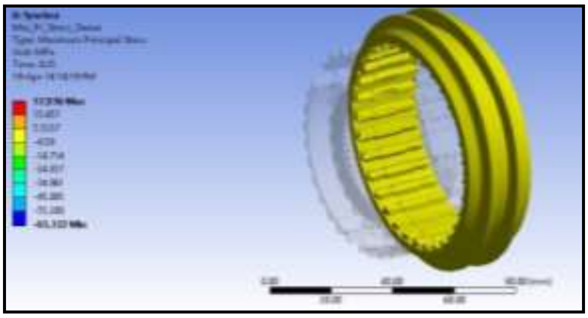


**Fig. 23:** Maximum principal stresses acting on sleeve for Aluminium (800 N Load)

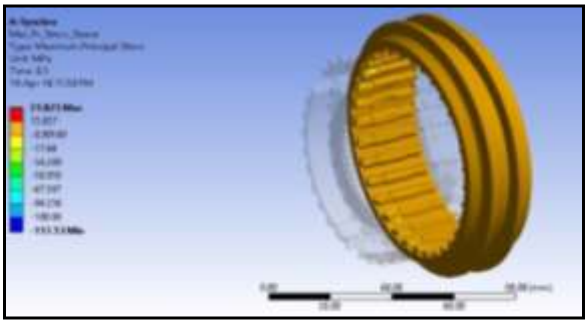


**Fig. 24:** Maximum principal stresses acting on sleeve for Copper (800 N Load)

### G. Deformation of ring for just meshed and completely meshed condition for Steel

**Table. IX:** Deformation of ring for just meshed and completely meshed condition (Steel)

| Load (N) | Just meshed condition | Completely meshed condition |
|---|---|---|
| 400 | 159.62 | 1.4819 |
| 800 | 162.8 | 2.9639 |
| 1200 | 103.28 | 4.4458 |
| 1600 | 162.3 | 5.9238 |

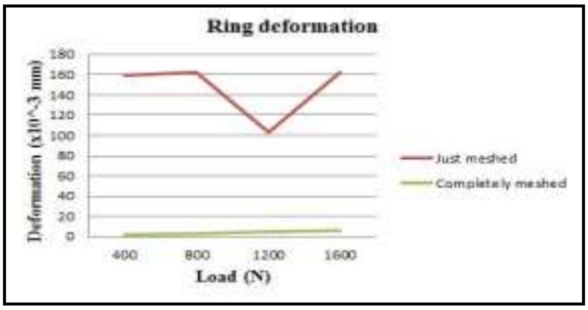


**Fig. 25:** Ring deformation: Just meshed condition v/s completely meshed condition (Steel)

### H. Deformation of sleeve for just meshed and completely meshed condition for Steel

**Table. X:** Deformation of sleeve for just meshed and completely meshed condition (Steel)

| **Load (N)** | **Just meshed condition** | **Completely meshed condition** |
|---|---|---|
| 400 | 152.4 | 2.0819 |
| 800 | 155.64 | 4.1639 |
| 1200 | 101.66 | 6.2458 |
| 1600 | 156.01 | 8.3219 |

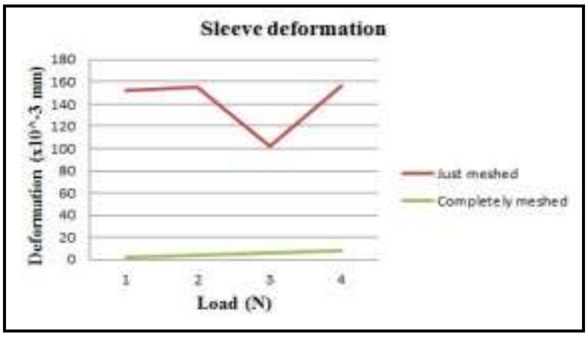


**Fig. 26:** Deformation of sleeve: Just meshed condition v/s completely meshed condition (Steel)

## VI. CONCLUSION

Structural analysis was conducted on the synchronizer ring assembly consisting of synchronizer ring and sliding sleeve to determine the optimum shifting force and optimum ring and sleeve material. The results for the structural analysis are summarized as given below:

- Based on the deformation criteria, Aluminium is the most optimum material for both ring and sliding sleeve, as the results show minimum deformation values in both bodies(0.054428 mm for 1600 N load for Ring, 0.056285 mm for 1600 N load for Sleeve)
- Based on the equivalent Von Mises stress criteria,Copper is the most optimum material for both ring and sliding sleeve, as the results show minimum equivalent stress induced values in both bodies (194.39 MPa for 1200 N load for Ring, 134.2 MPa for 1200 N load for Sleeve)
- Based on the maximum principal stress criteria, Copper is the most optimum material for both ring and sliding sleeve, as the results show minimum principal stress induced values in both bodies (25.738 MPa for 1200 N load for Ring, 11.562 MPa for 1200 N load for Sleeve).

Also observed, the deformation undergone by both the synchronizer ring and the sliding sleeve is relatively much higher in the case of just meshed condition as compared to the completely meshed condition.

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