DESIGN AND DEVELOPMENT OF GRIT REMOVAL MACHINE FOR SYNCHROMESH RING (GBS 40)

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Abstract - *The grit removal tool is used for knocking out the grit particles trapped between grooves of synchromesh ring GBS 40, which in turn gives smooth operation of the synchromesh ring. Many of the present practices of grit removal are inefficient in terms of quality, consistency and time. Therefore, the design, analysis and development of the grit removal tool could be considered as innovation. The design of this tool in accordance with GBS 40 ring is carried out by solid modelling package. Further, the developed tool geometry was analyzed for stress consideration using FEA software package. The tool is integrated with necessary fixture and pneumatic actuator for its operation. The proposed tool can be used in future for extraction of accurate synchromesh ring thread geometry with greater consistency and better quality*

***Key Words*: Additive Manufacturing, 3D printing, Fused deposition modelling, FDM, Synchromesh ring, Grit particle, Grit removal tool, solid modelling, FEA analysis**

1. INTRODUCTION

1.1 SYNCHRONIZER RING

These rings are most often made from a special bronze or brass alloy such as manganese bronze, aluminum bronze or silicon bronze. The cone surfaces are provided with thread or groove patterns and axial grooves. They distribute or displace the lubricant faster. The faster the oil exits the friction surface, the earlier the frictional torque increases, thus reducing the slip phase. At the same time, the oil must dissipate the heat from the friction connection. Brass/bronze cones have approx. 40 grooves per inch, and lined components have approx. 20 grooves per inch.

The synchronizer ring will clamp prematurely if there are too many grooves. Driving tabs serving a locking safety function transmit the synchronization torques in the rotating direction. This Gear Box includes Synchronizing Unit that slides over the splined shaft for gear changing mechanism. The ring is required for the smooth gear shifting. The ring is engaged gradually first as the Synchronizing Unit approaches the gear. The Synchromesh Rings have a particular thread profile on tapered surface. This facilitates gradual and smooth engagement and disengagement of gears. The thread surface is provided desired roughness by abrasive grit shoot blasting. The roughness thus achieved is very crucial and important as per the application requirement. The Synchromesh Ring (GBS 40) is used in Synchromesh Gear Box of TATA Indica and TATA Indigo.

Fig -3: Synchronizer ring GBS 40

2.1 MANUFACTURING PROCESS OF SYNCHROMESH RING (GBS 40)

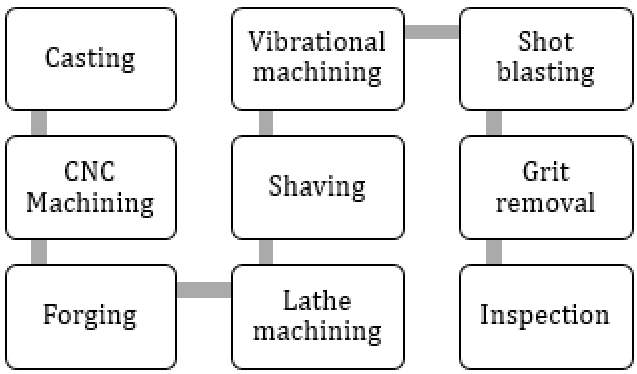

Chart-1 : Manufacturing process layout

3. MANUAL PROCESS

The Synchromesh Ring thread profile achieved by machining does not abide the roughness required as per application. Thus in order to achieve the desirable roughness value, Shot blasting process is applied over the thread surface. In addition, Shot blasting improves the overall strength and load carrying capacity of thread surface. Conversely, due to this process, the grit particles are trapped into space between adjacent threads; which is undesirable. Thus, the shot blasting process has to be essentially followed by some grit removal process. The grit removal process is done manually. The workers use a wire brush to knock out the trapped grit particles. Also, a blade like sharp tool is passed through these ring threads individually to remove the trapped grits. Every single trapped grit particle is searched and the removed away. This result into more labour requirement and stock piling takes place, which consumes a considerable portion of floor space wherein the synchromesh rings are waiting for the grit removal. This process is time consuming and quality consistency is not achieved. In addition, it might result into mitigation of roughness value and creates scratches over the surface.

The trapped Grit Particles in the Synchromesh Ring is removed by wire brush and blade tool manually. This process has many limitations.

The major limitations of the present grit removal system are-

• More Time Requirement for the manual process. It takes 3 minutes per ring.

• Stock Pilling and Idol hoarding of the Rings.

• Improper Quality Consistency.

• High Labor Requirement.

• The cost requirement is more; thus non-economic process.

• The Productivity and Overall Efficiency of this process is less.

Fig -4: Name of the figure

4. GRIT REMOVAL TOOL

The Grit removal tool is used for knocking out the grit particles trapped between threads of synchromesh ring. The design of this tool is carried out by solid modelling package. The developed tool geometry was analyzed for stress consideration using FEA software package. The tool is integrated with necessary fixture and pneumatic actuator for its operation

4.1 GRIT REMOVAL TOOL DESIGN AND ANALYSIS

4.1.1 MATERIAL SELECTION AND PROPERTIES

The grit removal process of synchromesh ring can be done by using an Aluminum tool, as its hardness is considerably less than that of brass. Thus, there will not be any damage to the ring threads. In addition, aluminum is cheap and readily available. The tool material is aluminum 64430(Al-Mg-Si 1) (B-51), whose chemical composition is: Aluminum (Al) - 97.5%, Magnesium (Mg) - 1.2%, and Silicon (Si) - 1.3%. 16

The beneficial properties of aluminum 64430 are high resistance to corrosion and good workability [1]. These properties make it possible to work in wide range of environmental conditions. The shape and size of the tool have to be maintained accurately during its manufacturing, so good machinability of aluminum 64430 assists to achieve the intended shape and size. The Stress Strain curve [1] for Aluminum 64430 indicates that the material fails at 4.5 N/mm2. In this case, maximum force imposed over the Grit Remover Tool is by the pneumatic arrangement. This can be estimated to about 0.7 N/mm2. Thus, the material selected is fit for the application.

The force applied over the tool is equally shared by the nine teeth, thus the tool is safe. Thus as per the stress strain curve and the determined applicative stress, the material is fit for the purpose

4.1.2 CHARACTERISTICS OF ALUMINIUM

Table -1: Characteristics of Aluminum 64430

Sl.No	CHARACTERISTICS	VALUES
	Hardness-Brinell	95
	Poisson's ratio	0.35
	Tensile Strength (MPa)	285
	Ultimate Tensile Strength (MPa)	310
	Density (g cm^{-3})	2.70
	Specific heat (cal/gm^{o}C)	0.219
	Thermal conductivity @23^{o}C (W/mK)	237
	Elongation on 50 mm gauge length	8%
	0.2%Proof stress(MPa)	270

5. DESIGN CALCULATIONS FOR GRIT REMOVAL TOOL

5.1 RING DIMENSIONS [2]

i. Tooth Thickness - 3.00-0.1 mm
ii. P.C.D run out - 0.16 maximum
iii. Face runout - 0.2 maximum
iv. Face run out - 0.1 maximum (on back face)
v. Groove diameter - 108.5-0.2 mm
vi. Thread Angle - 75o

vii. Thread Depth - 0.35+0.1

viii. Chamfer - 0.5 x 45o

5.2 TOOL DESIGN CALCULATION

The tool has been designed based on metric thread standards, which is a negative of the thread profile of the ring

Table -2: Tool Specifications

Sl. No.	Parameters	Dimensions (mm)
	Length of the tool	15
	Breadth of the tool	5
	Groove Depth of the tool	0.35
	Groove Width of the tool	0.8
	Groove Pitch of the tool	1.3
	Tool Thread Angle (180°-75°)	105°
	Base thickness of Tooth	0.35
	Tip thickness of Tooth	0.16

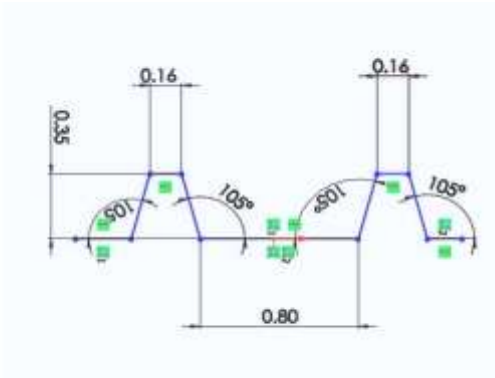

Fig -5: Section model of tool

Groove and Tooth Dimensions

Length of a Single Groove =0.80+0.35

=1.15 mm

For 11 Grooves =1.15 x 11

=12.65 mm

Therefore, the overall length is assumed 15 mm

5.3 FORCE CALCULATION

The Analysis of tool is done by Analysis Software Package ANSYS 16.0. This gives assurance of effective working of the tool. Thus, chances of failure or losses are avoided. The Finite Element Analysis of tool is carried out in following way.

The tool material is aluminum. Thus, the required parameters of the tool material are considered for the analysis.

Force =Pressure×Area

Area =Length of Tooth×Thickness of Tooth

Area =15×0.16

=2.4 mm^2

Pressure = 2 bar from Pneumatic Supply

$Force$ = 2 × 2.4

$Force$ = 4.8N

The force applied is considered 5 N.

5.4 WEAR CALCULATION [3]

By Archard equation

The common equation for the wear rate is

$vi = ki \times F \times s$

Where

ki =Specific wear rate coefficient

F =normal load

s =sliding distance

For moderate load, Aluminum, class 3 is chosen.

Range (0.1-1) m^3/Nm

vi =1× 1.68 × 0.015

=0.00252 $m3$

5.5 TORQUE CALCULATION

Required Speed =20 rpm (For slow ring rotation)

Power of the

Motor =0.25 HP

$Power$ =2πNT 60

$0.25 \times 745.7 = 2\pi \times 20 \times T\ 60$

$Torque = 89.056\ Nm$

Table -3: Specifications of motor

Sl. No.	Parameters	Description
	Type	3 Phase AC Gear Motor
	Speed	20 rpm
	Power Rating	0.25 HP
	Torque	90 Nm

6. DESIGN AND ANALYSIS

6.1 AUXILIARY COMPONENTS

1. **Taper Plate (7⁰)**

The taper plate is used to provide a 70 inclination to the total assembly of the grit removal tool. This enables the grit removal tool to mesh in the taper surface of synchromesh ring (GBS-40). Below figure shows the design of the taper plate.

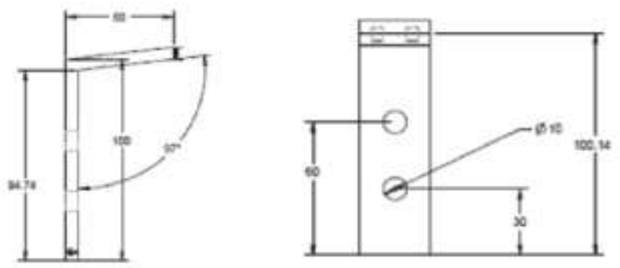

Fig -6: Taper Plate

2. **Tool holder**

The Tool holder is mounted on Taper Plate. The Tool Holder is provided with an internal bore for holding the Mat Holder in its required position. The tool holder is used to hold the Mat holder. The mat holder extruded part is immersed into the tool holder this enables to hold the assembly.

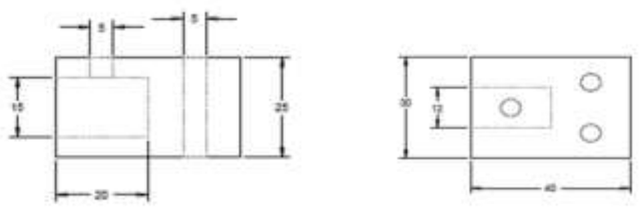

Fig -7: Tool holder

3. **Ring Fixture**

The grit particles, which are stuck in the groove of Synchromesh Ring (GBS40), threaded portion that are necessary to remove. This can be automated by constraining the ring all directions. In the design of the ring, the lower part of the ring has three slots, which enable to the grip the ring.

The internal diameter being larger helped us to enhance in constraining the degree of freedom. The ring when held in the fixture has zero degree of freedom, as to remove/clean the grit particles circular motion about the axis was needed. To attain the desired motion i.e. rotary motion about the axis, the fixture is coupled with AC Gear motor.

Fig -8: Ring Fixture

6.2 MODEL OF THE TOOL

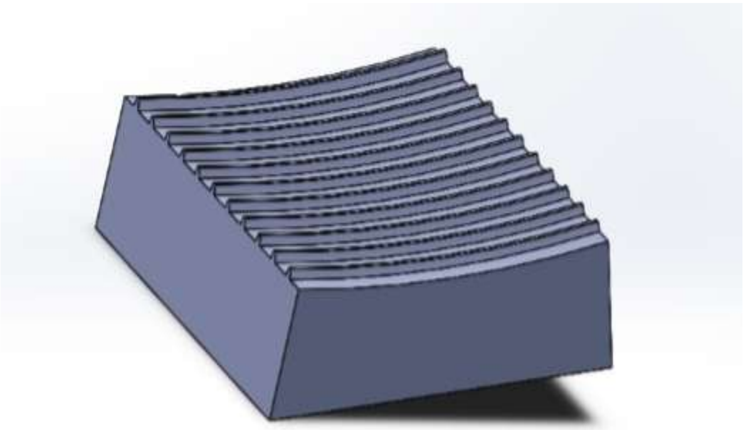

Fig -9: Solid modelling of the Grit removal tool

6.3 FINAL ASSEMBLY

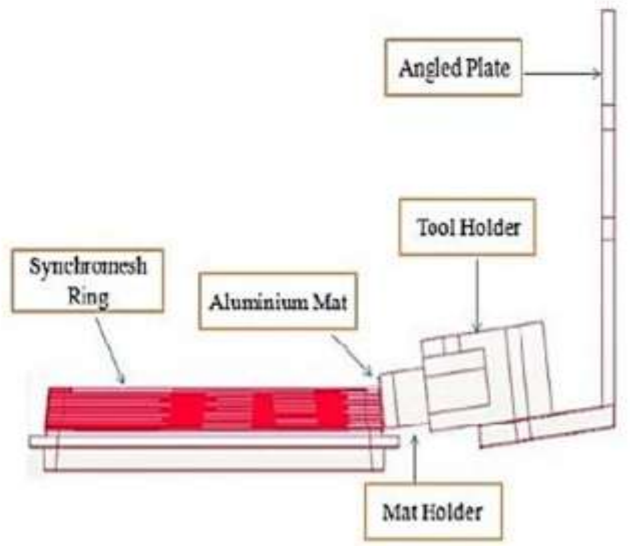

Fig -10: Final assembly

Fig -10: Model of the final assembly

6.4 RESULTS FROM FEA

Tool has to sustain the dynamic force applied due to the engagement of threads on synchromesh ring and tool thread profile. Thus, it was necessary to test it for stress considerations and for total deformation of tool in turns.

The results obtained for FEA of tool ensures the safety and life of tool, results obtained are as follows.

1. **Deformation Analysis**

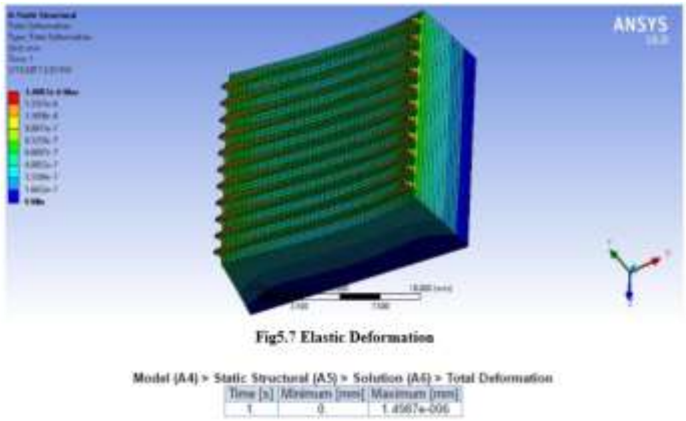

Fig -11: Deformation analysis

2. **Stress Analysis**

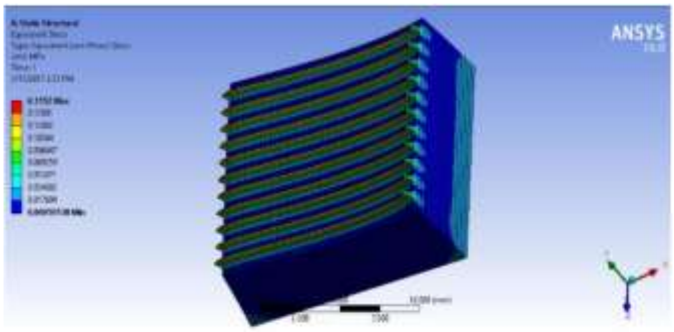

Fig -12: Stress analysis

Table -4: Boundary conditions

Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	Total Deformation	Equivalent Stress
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Total Deformation	Equivalent (von-Mises) Stress
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Suppressed	No	
Results		
Minimum	0. mm	5.0538e-004 MPa
Maximum	1.4987e-006 mm	0.1552 MPa
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	
Integration Point Results		
Display Option		Averaged
Average Across Bodies		No

7. TOOL MANUFACTURING

7.1 FUSED DEPOSITION MODELLING TECHNOLOGY (FDM)

FDM Technology works with production-grade thermoplastics to build strong, durable and dimensionally stable parts with the best accuracy and repeatability of any 3D printing technology.

How FDM Works:

3D printers that run on FDM Technology build parts layer-by-layer from the bottom up by heating and extruding thermoplastic filament. The process is simple:

1. **Pre-processing:** Build-preparation software slices and positions a 3D CAD file and calculates a path to extrude thermoplastic and any necessary support material.
2. **Production:** The 3D printer heats the thermoplastic to a semi-liquid state and deposits it in ultra-fine beads along the extrusion path.
3. **Post-processing:** The user breaks away support material or dissolves it in detergent and water, and the part is ready to use.

FDM benefits:

- The technology is clean, simple-to-use and office-friendly
- Supported production-grade thermoplastics are mechanically and environmentally stable
- Complex geometries and cavities that would otherwise be problematic become practical with FDM technology

3D Printed tool:

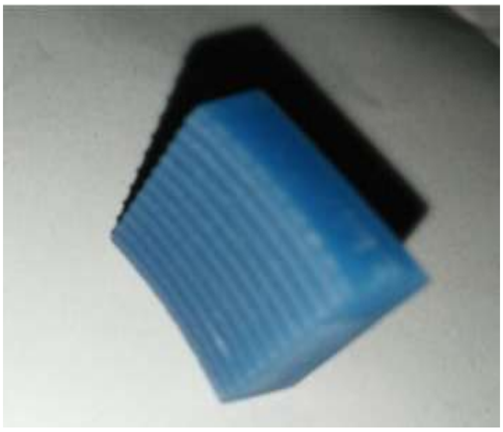

Fig -13: 3D printed tool

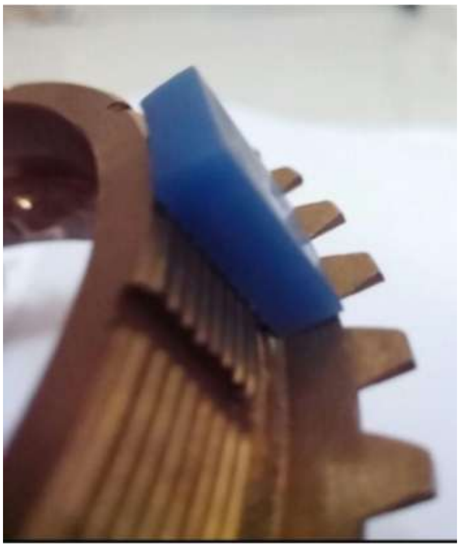

Fig -14: Tool engaged with the thread profile in the ring

8. DESCRIPTION

The grit remover tool is assisted by various components for efficient execution of the intended purpose. The major components are Tool Holder, which includes a male and a female part; an Angled Plated and Ring Fixture. A Pneumatic Cylinder and an Electric Motor assist these parts. The Tool holder which comprises both of male and female parts is made up of Mild Steel. The male part has a flat head where the Aluminum Tool would be glued. The rear end of the male part has an extruded section, which is inserted into the female Tool Holder and held in its position by Allen Screws. The female part has three bores for this purpose. The entire assembly is mounted over the Angled plate made up of Mild Steel. The Angled plate has an inclination of 970; which is in accordance to the 70 inclination of the synchromesh ring thread profile. This inclination holds the Aluminum Tool exactly tangential to the ring periphery. The angle is maintained with high accuracy while manufacturing for proper meshing of the grooves. This Angled Plate is clamped to the Saddle. Saddle is provided reciprocating motion with the help of a Pneumatic cylinder. This cylinder works on 7 bar air pressure and has 25 mm internal diameter and maximum stroke of 50 mm. The Ring Fixture made up of mild steel is designed in accordance to the internal diameter of the ring. It holds the ring in its position with the help of three equidistant slots present on the lower periphery of the ring. The Fixture is provided with the slots made separately by Milling and then bolted to the base. This fixture along with the ring is provided rotary motion by an Electric Motor. The motor is an AC Geared Motor of 0.25 HP rating whose output is 20 rpm.

Fig -14: Fabricated working model

9. RESULTS, BENEFITS AND FUTURE SCOPE

9.1 RESULTS

For manual process:

Cleaning of one ring takes=**3minutes**

Therefore per shift (considering 6 hours of working)

No. of rings cleaned=**120 rings**

For automatic process:

Cleaning of one ring: **1 minute** (by trial and error method)

Therefore Per shift,

No. of rings can be cleaned will be=**360 rings**

Table -5: Results comparison with manual process

PARAMETER	MANUAL PROCESS	AUTOMATIC PROCESS
Time	3min per ring	1min per ring
No. of components	120 rings per shift	360 rings per shift
Man power	20 men per shift	No man power

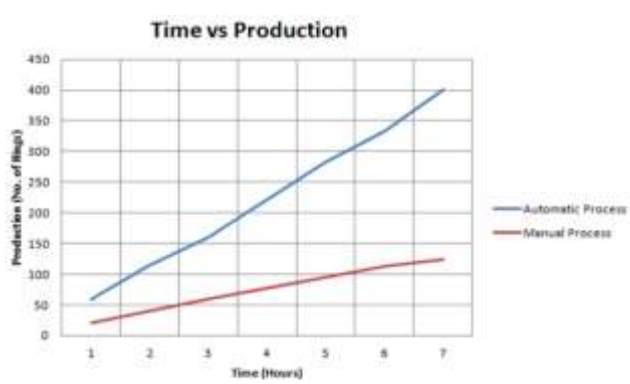

Chart -1: Comparison graph

Therefore,

- The production rate is increased.
- Cost of labor has been reduced.

9.2 BENEFITS

The Automated Grit Removal process by the aluminum tool possess many advantages over the manual method. The manual method of grit removal is by using wire brush and blade. The consistent approach of aluminum tool gives quality assurance and improvement in the overall productivity. After real time testing it has been observed that the Automated Grit Removal process poses following advantages:-

I. The Time requirement for the grit removing process is drastically reduced from 3mins per ring to 60seconds per ring.

II. Quality is improved by uniform and consist grit removal.

III. The process neither creates friction with ring nor scratches over the surface.

IV. The inspection time is reduced and hence there is less Labor requirement

9.3 FUTURE SCOPE

The Automated Grit Removal process is efficient, time saving, and consistent over all other present practices. Thus, the proposed and developed tool could be considered as an innovation in the field of automotive technology. This technology can be further developed for achieving higher productivity. This can be done by following ways:- Automated robotic arm can be used for loading and unloading of synchromesh ring. This would add functionality and greater flexibility to the system.

10. CONCLUSION

The project emphasizes on improvement in productivity and quality of the Grit Removal Process. The Aluminum Tool removes the trapped grit particles maintaining the desired roughness value. In addition, it does not create friction or scratches over the ring surface. Time required for the process is reduced as the process is completely automated. The Idle time and inspection time is reduced. In addition, piling of stock is avoided. The reduced time and labor requirement makes this process cheaper. In addition, the process is highly efficient. This project would increase company's overall profit. The project delivers a mistake proof process. Thus, this project is important and beneficial for the company. The Automated Grit Removal process has achieved the planned requirements. The project thus would be used in actual production line of Synchromesh Ring. Thus, the developed system could be considered as an innovation in the field of automotive technology

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