# STUDY AND IMPLEMENTATION OF HARMONIC DRIVE IN CNC LATHE

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**Abstract -** *Milling operations are difficult to perform in CNC turning centres due to lack of control over speed, positional accuracy, and repeatability and required machining torque. It is a secondary gear box which drives the spindle while the gearbox is in neutral. The key features we need while performing milling operation is high torque and high speed reduction for the better positioning of the work piece. C- Axis gear drive work on its worm wheel and gear assembly is able to satisfy this need to an extent. But the problem regarding this drive is that they are bulky and their repeatability and positional accuracy is less. Our aim is to study the existing c-axis drive and find a better drive that can replace c- axis drive. Harmonic drives are better technology which can provide better features than c-axis. A harmonic gear drive gives more speed reduction and power transmission capacity compared to conventional gear system. Harmonic drive provides accurate as well as precision with much less space as compared to any other power transmission drives.*

***Key Words*: *Harmonic drive, C-axis, CNC lathe, Stress analysis, Total Deformation***

## 1. INTRODUCTION

Usually CNC turning centers are used for turning, taper turning, drilling, boring, contouring with linear and circular interpolation, internal and external threading (parallel or taper) etc. Milling operations are difficult to perform in CNC turning centers due to lack of control over speed, positional accuracy, repeatability and required machining torque. Harmonic drive is a type of mechanical gear system also known as a “strain wave gear” which employs continuous deflection wave along a non-rigid gear to allow for gradual engagement of gear. The advantages include: compactness and light weight, high gear ratios, no backlash, reconfigurable ratios within a standard housing, good resolution and excellent repeatability when repositioning inertial loads, high torque capability, and coaxial input and output shafts. High gear reduction ratios are possible in a small volume .The strain wave gearing theory is based on elastic dynamics and utilizes the flexibility of metal.

## 2. DESIGN OF EXISTING GEARBOX

This arrangement consists of an input motor and the shaft is run by a motor. The shaft being a worm shaft transmit power to a worm gear. A spur gear is attached to the same spindle of worm gear. The output is carried out by a large spur gear to the different operations.The various parameters like no . of teeth, module, pitch diameters etc. should be designed.

$$\text{Module m} = 1.26 * \sqrt[3]{\frac{Mt}{\sigma * z_1 * \varphi * y}}$$

Where y, Ψ is chosen from PSG data book, σ is the stress and $Z_2$ no teeth on pinion. The material chosen is structural steel.

Table.1 Specifications of both gear pair

| | Wheel | Pinion |
|---|---|---|
| Material | Steel | Steel |
| Diameter | 288 mm | 144mm |
| No of teeth | 144 | 72 |
| Module | 2 mm | 2 mm |
| Addendum | 2mm | 2 mm |
| Dedendum | 3mm | 3mm |
| Face width | 18.84 mm | 18.84 mm |

Table.2 Specifications of worm gear

| | Worm | Worm wheel |
|---|---|---|
| Material | Steel | Bronze |
| Module | 6 mm | 6 mm |
| Reference diameter | 66 mm | 240 mm |
| Tip diameter | 78 mm | 282 mm |
| Root diameter | 51 mm | 225 mm |

| | | |
|---|---|---|
| Length of worm | 96.6 mm | - |
| Centre distance | 153 mm | - |
| No.of teeth | 2 | 40 |
| Face Width | - | 49.5mm |

**Oldham coupling:** a coupling for parallel shafts slightly out of line consisting of a disk on the end of each shaft and an intermediate disk having two mutually perpendicular feathers on opposite sides that engage slots in the respective shaft disks

Table.3 Specifications of Oldham coupling

| Description | Value (mm) |
|---|---|
| Shaft diameter | 20.90 |
| Outside Diameter | 80 |
| Hub Diameter | 40 |
| Thickness of Tongue | 9 |
| Axial Dimension | 4.5 |

Power of the spindle, P = 0.2504 kW
Torque of the spindle, T = 239.11
Nm Torque of the motor, T = 5.98 Nm

From the SIEMENS motor catalogue the selected servo motor is ,

Motor Type = IFK7062

Power , P = 1.34 kw

Current , A = 10.9 amp

Speed , N = 2000rpm

## 3. C AXIS DRIVE ASSEMBLY

C-axis drive is an attachment to the gear box which helps to do the milling operations in turning centers, to index the job at different angles required and also run the spindle at smaller rpm at high torque. With this attachment we can perform the various milling operations such as key way milling, counter hole drilling, offset drilling, groove cutting in different shape etc. This arrangement consists of an input motor and the shaft is run by a motor. The shaft being a worm shaft transmits power to a worm gear. A spur gear is attached to the same spindle of worm gear. The output is carried out by a large spur gear to do the different operations. Certain limitations of C axis drive are : C- axis drive assembly makes the lathe more bulky and increases the weight of the machine, higher ratio speed reduction is not possible, expected higher torque cannot be provided with C- axis assembly, repeatability is less, chances of wear is more, chances for increase in backlash error increase with time period of operation, less drive efficiency, load carrying capacity is less, lack of consistent performance due to backlash error .

The 3D model of the existing gear box of the c axis drive assembly made by using Autodesk Inventor software is shown below:

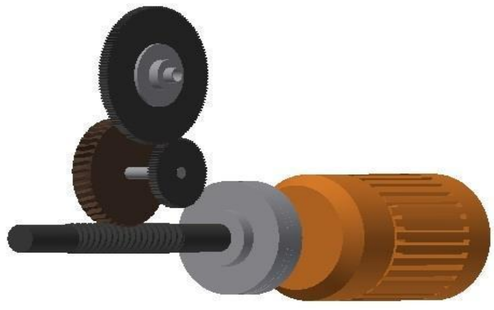

Figure 1 Isometric view of the model

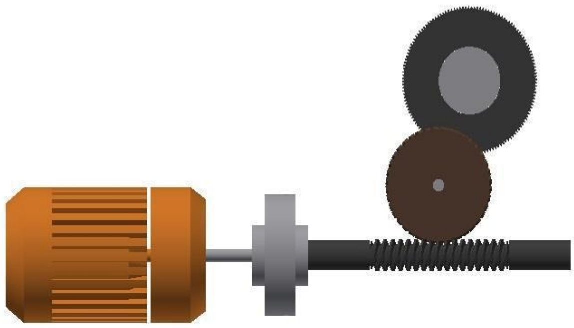

Figure 2 Front view of the model

## 4. SELECTION OF HARMONICDRIVE

After calculating the milling torque required , the harmonic drive has to be selected in the specific range . The company supplying harmonic drive is Harmonic drive AG

### HARMONIC DRIVE AG

The origins of Harmonic Drive AG lie in the invention of strain wave gearing by Walton Musser. Originally designed for space application, the particular characteristics of this gear principle , such as zero backlash , compactness and a high single stage gear ratio meant the technology was also of interest to many other application areas . Since its inception over 40 years , Harmonic Drive AG has transformed itself into company offering the solution of choice for high precision or planetary drives the more demanding the task , the better . The company offer more than 23,000 different products, of which more than 80% are customers specific solutions.

Harmonic Drive AG and its products are being used in many different industries . Currently we offer drive solution for use across many application sectors including : Robotics and Automation, Machine Tool, Semiconductor Technology, Medical Technology , Packing Machines, Defense Technology and Aerospace.

**HFUC – 2UH**

Harmonic Drive units combine the precision Harmonic Drive component sets consisting of three components - circular Spline , Flex spline and wave generator and integral high load capacity tilt resistant output bearings.

The available series of HFUC-2UH are listed in table below:

HFUC-2UH Series units are available in thirteen sizes with gear ratios of 30,50,80,100,120 and 160:1 offering repeatable peak torques from 9 to 9180 Nm. The output bearing with high tilting rigidity enables the direct introduction of high payloads without further support and thus permits simple and space saving design installations . The units are available as specific configurations tailored to application and can utilize standard servo motors. Unit and motor together form a compact and lightweight system capable of withstanding high loads. On request the series is available for ambient temperatures between -40 and 90 $^{0}$c and can be used with large selection of accuracy, stable machine characteristics with short cycle times are guaranteed. The main features of HFUC-2UH are

- Easy to customize
- Direct motor connection
- Excellent life time precision
- Compact , lightweight design
- High dynamics
- Integrated high capacity output bearing

| | Unit | HFUC-14-2UH | | | | HFUC-17-2UH | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ratio | i [] | 30 | 50 | 80 | 100 | 30 | 50 | 80 | 100 | 120 |
| Repeatable peak torque | $T_R$ [Nm] | 9.0 | 18 | 23 | 28 | 16 | 34 | 43 | 54 | 54 |
| Average torque | $T_A$ [Nm] | 6.8 | 6.9 | 11 | 11 | 12 | 26 | 27 | 39 | 39 |
| Rated torque | $T_N$ [Nm] | 4.0 | 5.4 | 7.8 | 7.8 | 8.8 | 16 | 22 | 24 | 24 |
| Momentary peak torque | $T_M$ [Nm] | 17 | 35 | 47 | 54 | 30 | 70 | 87 | 110 | 86 |
| Maximum input speed (oil lubrication) | $n_{in\,(max)}$ [rpm] | 14000 | | | | 10000 | | | | |
| Maximum input speed (grease lubrication) | $n_{in\,(max)}$ [rpm] | 8500 | | | | 7300 | | | | |
| Average input speed (oil lubrication) | $n_{av\,(max)}$ [rpm] | 6500 | | | | 6500 | | | | |
| Average input speed (grease lubrication) | $n_{av\,(max)}$ [rpm] | 3500 | | | | 3500 | | | | |
| Moment of inertia | $J_{in}$ [$x10^{-4}$ kgm$^2$] | 0.033 | | | | 0.079 | | | | |
| Weight | m [kg] | 0.49 | | | | 0.64 | | | | |
| Maximum hollow shaft diameter | $d_{H\,(max)}$ [mm] | 8 | | | | 7 | | | | |
| Transmission accuracy | [arcmin] | < 2 | < 1.5 | | | < 1.5 | | | | |
| Repeatability | [arcmin] | < ±0.1 | | | | < ±0.1 | | | | |
| Lost Motion | [arcmin] | < 1 | | | | < 1 | | | | |
| Torsional stiffness | $K_3$ [$x10^3$ Nm/rad] | 3.4 | 5.7 | 7.1 | | 6.7 | 13 | 16 | | |
| Ambient operating temperature | [°C] | Standard 0 ... 60, Special lubrication -40 ... 90 | | | | | | | | |
| **Output bearing** | | | | | | | | | | |
| Dynamic radial load | $F_{R\,dyn\,(max)}$ [N] | 1930 | | | | 2148 | | | | |
| Dynamic axial load | $F_{A\,dyn\,(max)}$ [N] | 2880 | | | | 3207 | | | | |
| Dynamic tilting moment | $M_{dyn\,(max)}$ [Nm] | 41 | | | | 64 | | | | |

Table 4 HFUC-2UH series (1)

In this desired range , the series matching to our motor torque is HFUC-17-2UH , where speed ratio is 100 . The illustration of HFUC-17-2UH is given below:

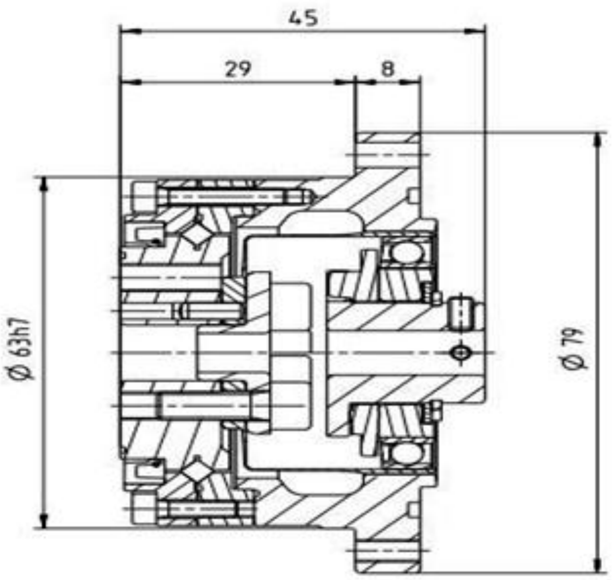


Figure 3 Drawing of HFUC-17-2UH

## 5. THE STATIC ANALYSIS OF THE MODEL

The safety of the design is a great factor. The modern powerful analysis software's help us to make detailed analysis on our design. The objective is to analysis the stress concentrated points in the model. A meshed view of the model is shown in figure 4, the results of the stress analysis is provided in figure 4 and the results of total deformation analysis is given in figure 5, distribution of equivalent stresses are shown in figure 6.

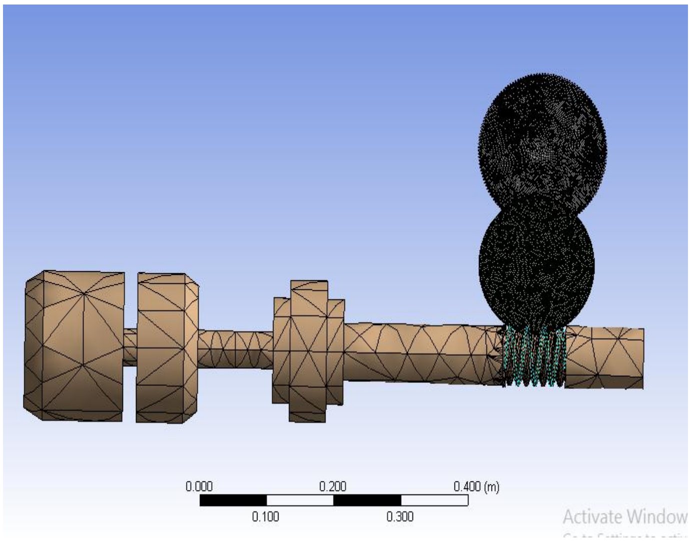


Figure 4 Mesh figure of model

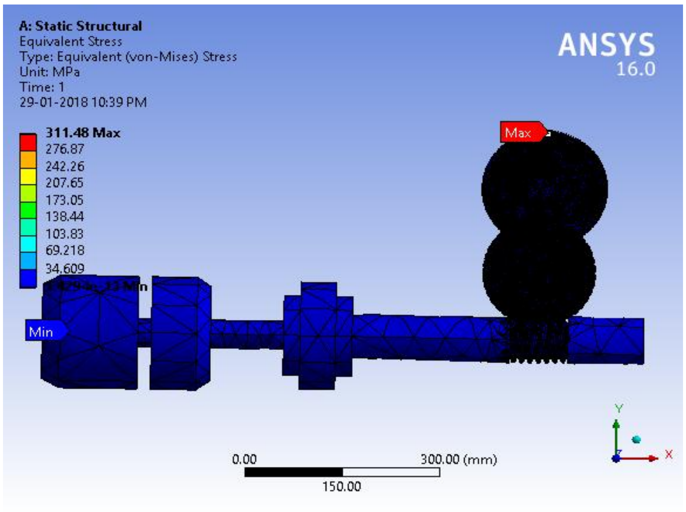


Figure 5 Contour of equivalent stress

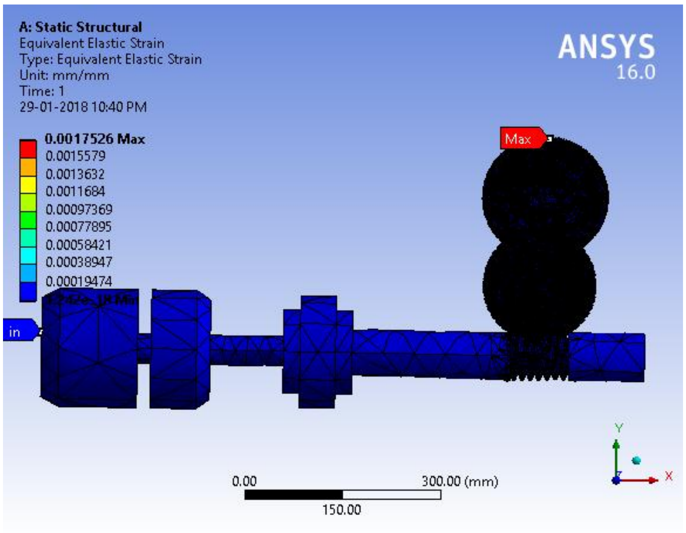


Figure 6 Contour of equivalent strain

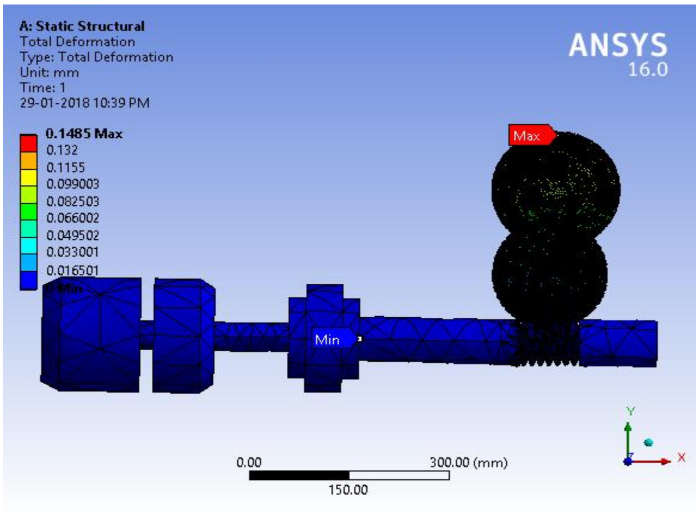


Figure 7 Contour of total deformation