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Design and Manufacturing of Spindle of Universal Milling Head

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Abstract: ***All manufacturing industries require domestic machine as well as imported machines depending upon the process, accuracy, finishes of the product. Any machine or equipment after some time of use requires routine, breakdown, maintenance, delay in maintenance, availability of spacer skilled maintenance technique are of vital issue. If we produce the machine here in India definitely the cost of the machine will reduce. And obviously, maintenance and transport cost will definitely reduce. Also if any part or attachment of machine were out or damaged then it will be easier to reproduce the required part and change it. At Bharat Forge, Pune we got project as "Design & Manufacturing of Universal Milling Head for a CNC Horizontal Machine Centre". In this project we are designing and manufacturing the spindle shaft of Universal Milling Head of Soraluce made Universal Milling Machine. It helps them to restore machine spindle shaft indigenously in less time. It also helped them to generate confidence of repairing and proving of spindle shaft.***
Keywords: Cost utilization, reverse engineering.

I. INTRODUCTION

Milling machine is a machine tool that removes the metal as the work is fed against rotating multipoint cutter. The cutter rotate at high speed because of multiple cutting edges it removes metal at very fast rate. The machine can also hold one or more number of cutters at a time. This is why a milling machine finds wide operation in production work. This is superior to other machines as regard accuracy and better surface finish and design for machining for variety of tool room work. Universal milling machine is so named because it may be adapted to variety of wid range of milling operations.

II. REVERSE ENGINEERING METHOD

The process which involve disassembling something (mechanical device) and analyzing its components and working in detail to reproduce the device is called as reverse engineering

Reverse engineering process is not creating copy it only an analysis in order to deduce design feature from product with a little or no additional knowledge about the procedure involved in their original product.

So as I was doing reverse engineering process, initially I have disassembled the whole machine and taken the suitable needed date and started doing designing.

III. LITERATURE SURVEY

Due to widespread use of universal milling machine and their special functioning they have received considerable attention in last few years. Universal milling machine can perform variety of operation with high accuracy and surface finish. Hence they are widely used in every sector of industry. We have gone through several similar technical published papers while collecting out contents of this dissertation. The papers are as bellow

H holz, m malzkorn" [1], horizontal drilling and milling machine having a spindle head which can be rotated abomilling machineut an axis set at 45 degree to the horizontal

T oldani" [2], high speed milling machine with rotary table

W gstir, p haas" [3], spindle head for a universal

A. Motivation

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The reverse engineering of the universal spindle head allows the company to manufacture the milling head in India itself, hence it will economically beneficial for the company. The company wants in-house production of the Universal Milling Head of the Soraluce make machine. Hence by doing reverse engineering in house design and manufacturing of the head, looking ahead this vision it is important for company to carry out such type of projects

B. Need Of This Project/Objective

In Bharat forged Company, as their main objective is production of crankshaft, axels,etc. by forging technique. They also uses the process like milling, drilling, etc. to produce die as per the customer or client requirements. And then these dies are used for forging and producing the crankshaft, axeles, etc.

After doing three days induction program at Bharat forge, the project given to us was "Design and Manufacturing of Universal Milling Head for a CNC Horizontal Machine Center". This project of milling machine which is German make of Soraluce Company. This machine is old one and spare parts of this machine are not easily available. Hence it needs to be manufactured these parts in house and should be cost effective.

As the scope of project is very large, we selected to design and manufacture spindle shaft of the Soraluce make Universal Milling Head by using reverse engineering technique

IV. ASSEMBLY AND DISMANTLING

The universal head was dismantled from the machine by removing nuts and fuel pipes

With the help of eye bolts and fork lift the inclined part of the head is dismantled from the straight part where the spindle shaft fixed

The check nut was removed by using another nut which matches with the check nut

Spindle shaft was removed from the casing by using hammering operation.

After removal of spindle the gear and spacer were removed easily from the casing

Once the shaft has removed from the casing the fixed bearing has removed

The disc spring, collet, and draw bar assembly removed by using puller

After all disassembly, all part was cleaned using cleaning agent

After measurement operation and visual study the same part has assembled.

V. DESIGN AND ANALYSIS

The universal milling head consist of the following parts

Spindle shaft

Bearing

Spiral bevel gear

Disc spring

Collet (standard)

Spacer (standard)

Now with help of reverse engineering process we have started analysis

A. Spindle Power Design.

The original power of machine is 33KW. As we are doing reverse engineering, it is necessary to calculate the power of machine and verify it with the original power. Hence we have taken all the maximum conditions of roughness of the cutting tool for calculation .

Sr. No.	Parameters	Symbol	Value
1	Diameter of Cutter	D	80 mm
2	Revolution per minute	N	650 rpm
3	Number of teeth	Z	5
4	Feed rate	S_m	2500 mm/min
5	Depth of cut	B	3 mm
6	Width of Cut	t	80 mm
7	Chip thickness		1 mm
8	Approach angle		30^0
9	Unit power	U	34 $kW/cm^3/min$
10	Correction wear factor	K_L	1.03
11	Radial rake angle	λ	12^0
12	Correction wear factor for λ	K_λ	0.972
13	Efficiency	H	0.62

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Cutting Speed (V)

= (π * D * N)/1000

= (π * 80 * 650)/1000

= 163.3628 mm/s

Material Removal Rate (Q)

= (B * t * Sm)/1000

= (3 * 80 * 2500)/1000

= 600cm^3/min

Power at Spindle (P)

= (μ *Kh * Kλ * Q)/1000

= (34 * 1.03 * 0.972 * 600)/1000

= 21 KW

So the maximum power after consideri

The efficiency will be near to 32 KW

Forces on Cutting Tool

Let us take the power for calculating the forces on cutting tool as 32kw

Tangential Force

We know that

P = (P_t*V)/(60*102)

= 32*60*102/163.3628

= 11760.2685 N

2] Radial force on cutting tool

= 0.55 * 11760.2685

= 6468.1477 N

3] Axial force on the cutting tool

= 0.9 * 11760.2685

= 10584.2416 N

All forces are calculated and verified.

B. Bearing Design

As bearing is use to permit the relative motion between two part i have selected the angular contact bearing as angular contact bearing can sustain both radial as well as thrust load

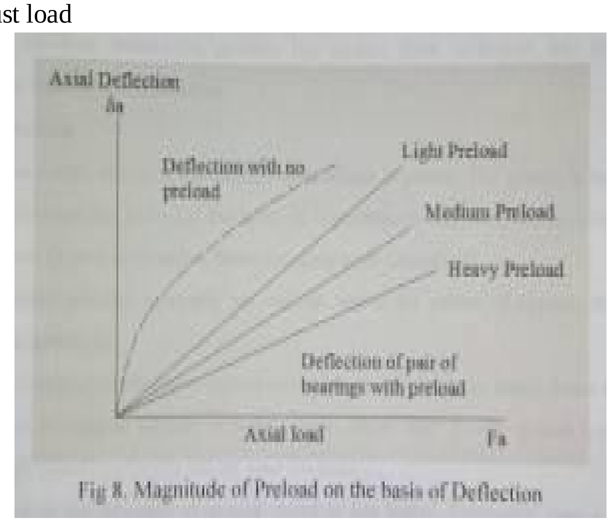

Fig 1 Magnitude of preload on the basis of deflection

Bearing calculation for triple unit bearing

Horizontal force analysis

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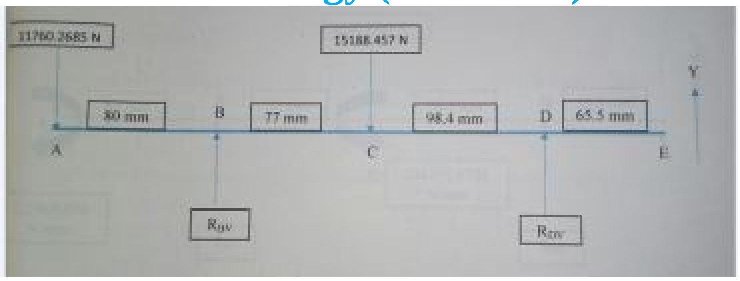

Fig 2 .Vertical force analysis for bearing design

After calculation

R_{DV} = 1303.818 N

R_{BV} = 25644.90 N

Vertical force analysis

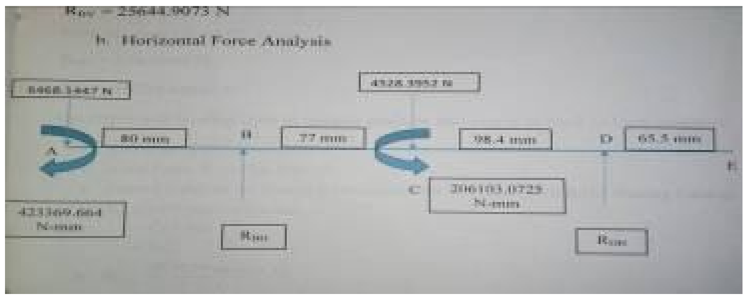

Fig 3. Horizontal force analysis for bearing design

R_{DH} = 276.5195 N

R_{BH} = 10720.02 N.

As per load calculation study I have selected three bearing two in tandem position and one in back to back position

Therefore selected bearing are

7217X2TAU (diameter = 72) and

7014X2TAU (diameter = 70)

C. Gear design

The tooth wheel which transmit the power and motion from one shaft to another by means of successive engagement of teeth. so to sustain the high load with smooth teeth engagement I have selected the type of gear which is spiral bevel gear

As after calculating pressure angle, service factor, application factor, diameter of pinion, diameter of gear, torque, design torque, Beam strength, bending stress on gear, bevel factor number of teeth, radial, axial and tangential force have selected the gear which have following parameter

Sr.No.	Parameter	Pinion	Gear
1	No. of Teeth	27	27
2	Pitch Diameter	130mm	130mm
3	Pitch cone angle	22.0522^0	22.9477^0
4	Addendum	4.296mm	4.065mm
5	Dedendum	4.9717^0	5.1484mm
6	Dedendum angle	3.097^0	3.2427^0
7	Addendum angle	3.247^0	3.097^0
8	Outer cone angle	25.294^0	26.0447^0
9	Root cone angle	18.955^0	19.705^0
10	Outside diameter	135mm	137.48mm
11	Pitch apex of crown	82.60mm	82.093mm

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12	Axial face width	28.11mm	27.933mm
13	Inner outside diameter	112.21 mm	113.832mm

Table 1. Detail of spiral bevel gear

D. Shaft Design

Shaft is a common and important machine element. It is a rotating member, in general has a circular cross section and is used to transmit power. The shaft may be hollow or solid. The shaft is supported on bearing and is rotates by gear for the purpose of power transmission. The shaft is generally acted upon by bending moment, torsion and axial force. The shaft use for this machine is step shaft for positioning element like gears, pulley and bearing

Vertical force analysis

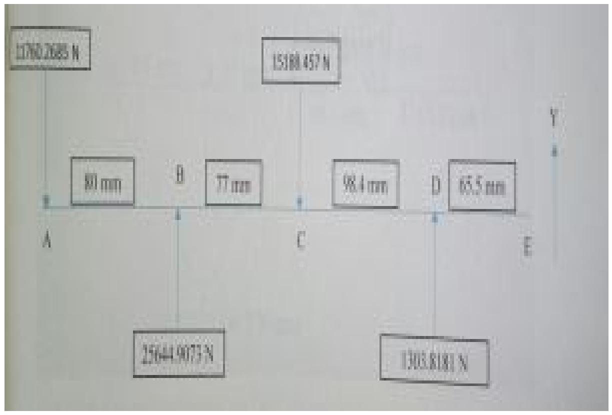

Fig.4 vertical force analysis for shaft design

Vertical bending moment diagram

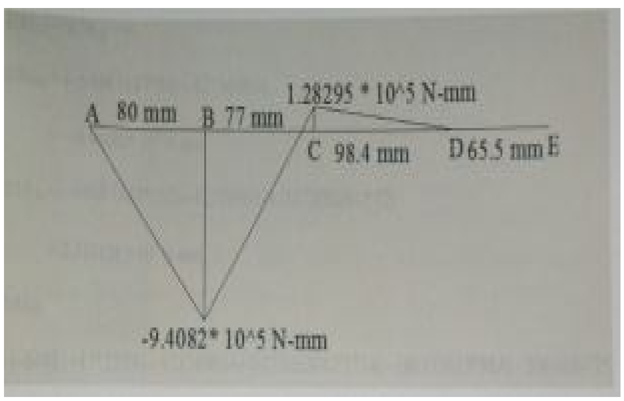

Fig.5 bending moment diagram for vertical force analysis

Horizontal force analysisi

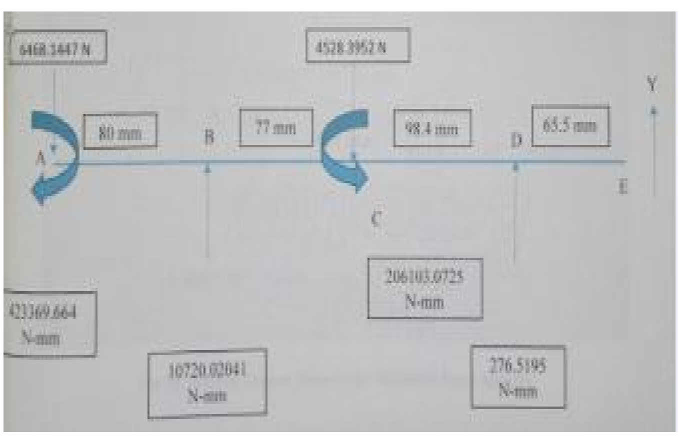

Fig.6 horizontal force analysis

After horizontal and vertical force analysis, thee outer and inner diameter of the shaft is
D_o = 82mm and
D_i = 33mm

E. Analysis

The following result were obtained after carrying out the analysis of spindle using Ansys

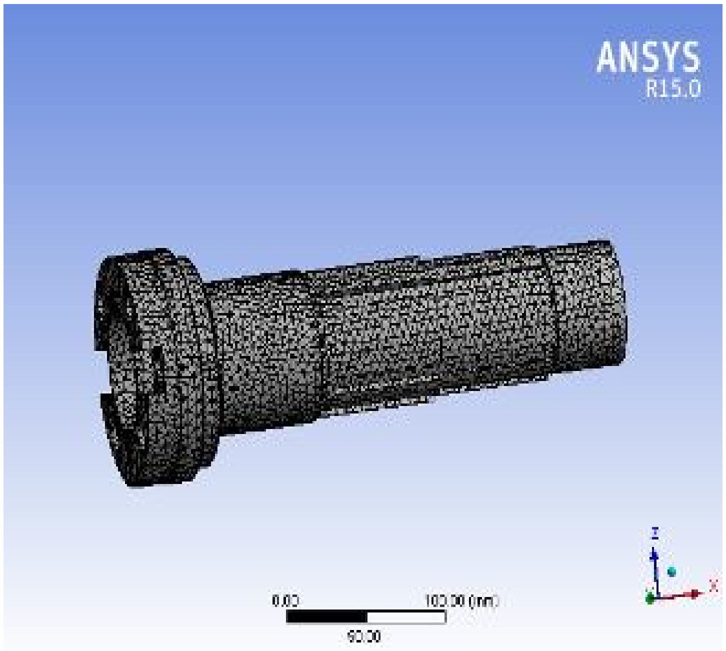

Fig 7. Meshing

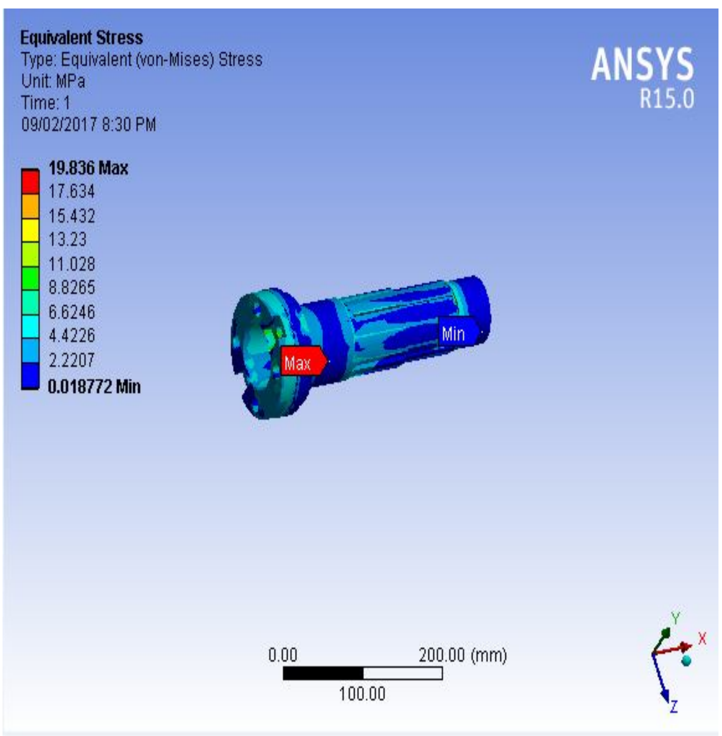

Fig 8. Stress distribution

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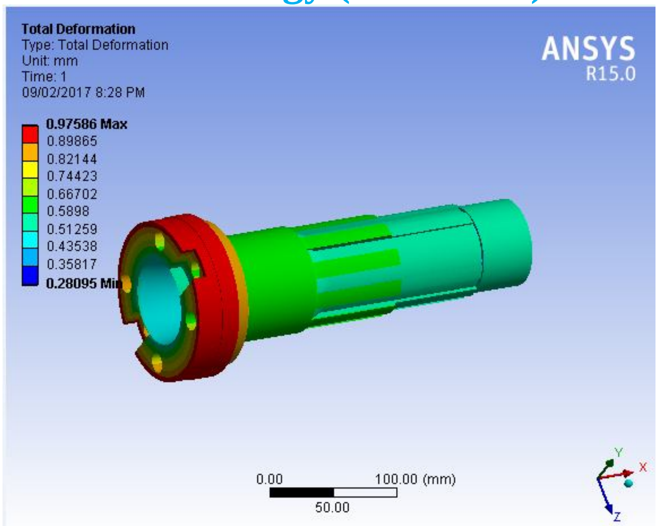


Fig9. Total deformation

From the above analysis I have concluded that the spindle which I have design for the Universal Milling Machine is under safety condition and It can withstand all the maximum load acting at respective position.

F. Disc Spring Design

Disc spring is a conical shell. This can be loaded along its axis either statically or dynamically.

The load is normally applied to the upper-inner edge and the lower outer edge.

It has high load capacity as compared to the compression and tension string, ability to function as an individual element, ability to provide varied force

Terminology of disc spring

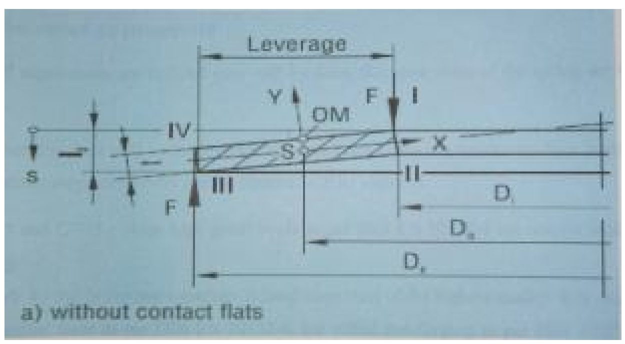
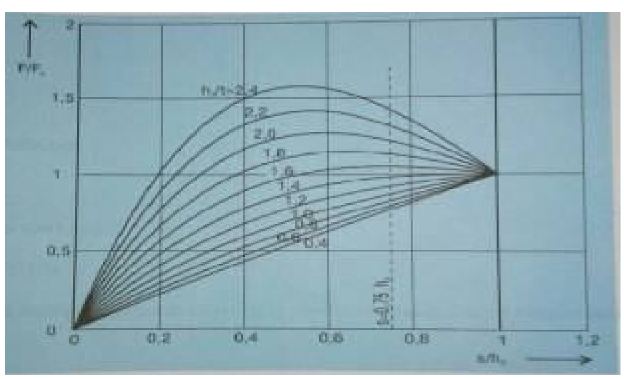


Fig 10. Terminology of disc spring

Characteristics of single spring



Graph 1. Characteristics of Disc Spring

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It indicate that as the force increase displacement also increases

When the spring are arrange in series then deflection add up and force remains same

Spring load

$F_T = F$

Spring deflection

$S_T = i*S$

Unload sketch length

$L_0 = i*l_0$

Only deflection is multiplied by the number of spring in series not the load

When the spring in parallel then their force add up.

Spring load

$F_T = n*F$

Spring deflection

$S_T =$

Unload stack length

$L_0 = l_0+(n-1)-t$

Load must be multiplied by the no. of spring in parallel whereas deflection remains same

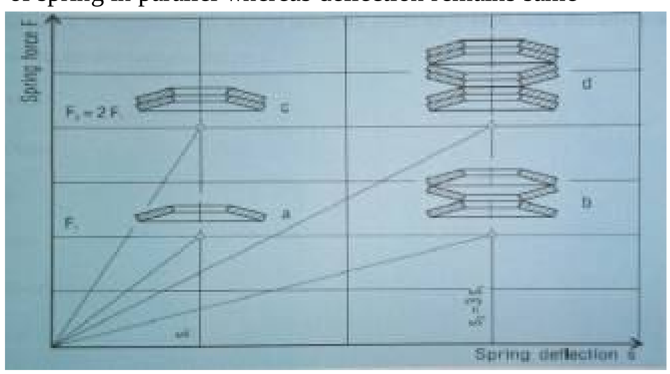

Fig 11. Disc spring in series and parallel

Selection of disc spring

As we know the diameter of disc spring on the draw bar, so we know the diameter the draw bar which is 25mm therefore by adding some clearance of 0.4mm we can get the inside diameter of disc spring

Therefore we can write

$D_i = 25.4mm$

Now from the following table following data has been given

Article no	D_e	D_i	t	l_0	h_0	h_0/t
013000	40	20.4	2.25	3.15	0.90	0.40
013250	45	22.4	1.25	2.85	1.60	1.28
014400	50	25.4	1.25	2.85	1.60	1.28
014600	50	25.4	2	3.6	1.60	0.8
014800	50	25.4	3	4.1	1.10	0.37

Table 1 Data of disc spring

The selected disc spring of single set will give the 3mm deflection as I know when I will put the disc spring in series the deflection add

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up and in parallel force add up, so I will select the order of disc spring in following manner

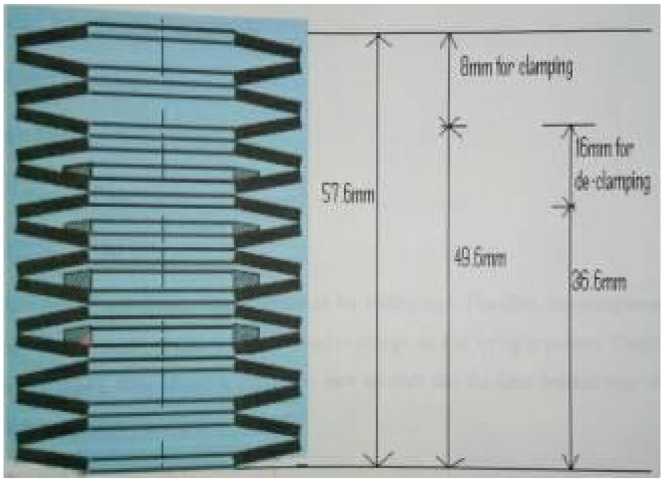

Fig 12. Disc Spring Arrangement

G. Modeling

Assembly of spindle shaft

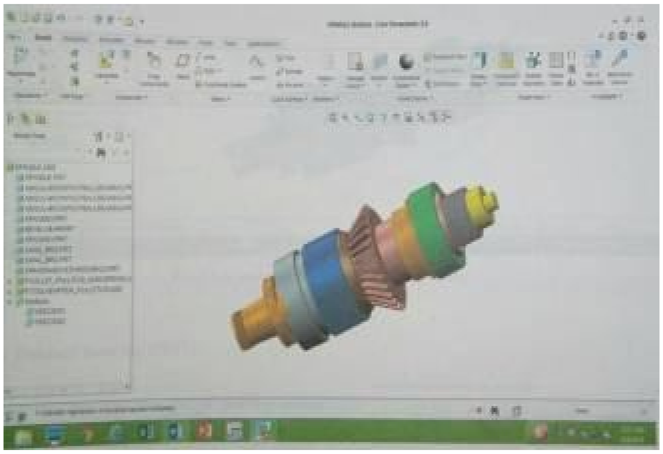

Fig 13 Assembly of Spindle Shaft

Cross Section of Spindle Assembly

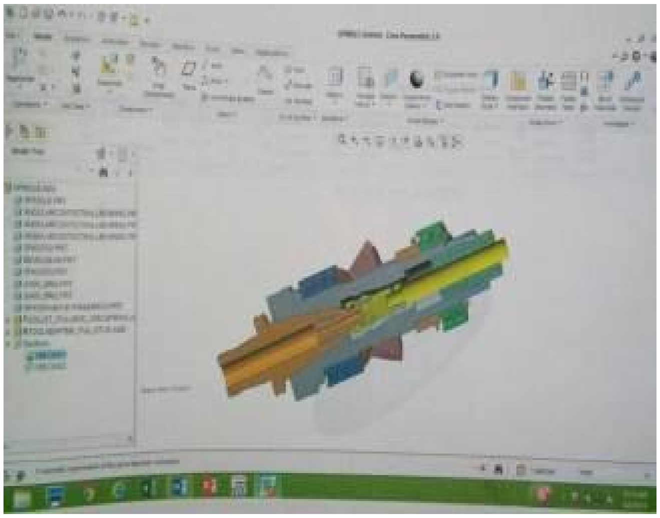

Fig 14. Cross Section of Spindle assembly

Angular Contact Bearing

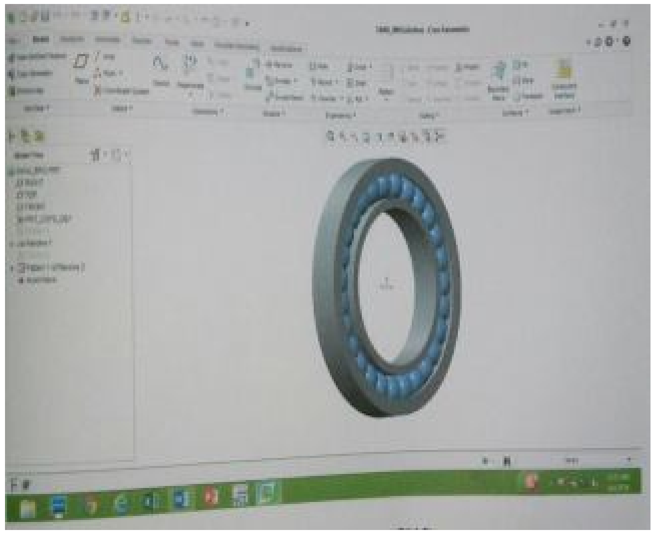

Fig 15 Angular contact bearing

Spiral Bevel Gear

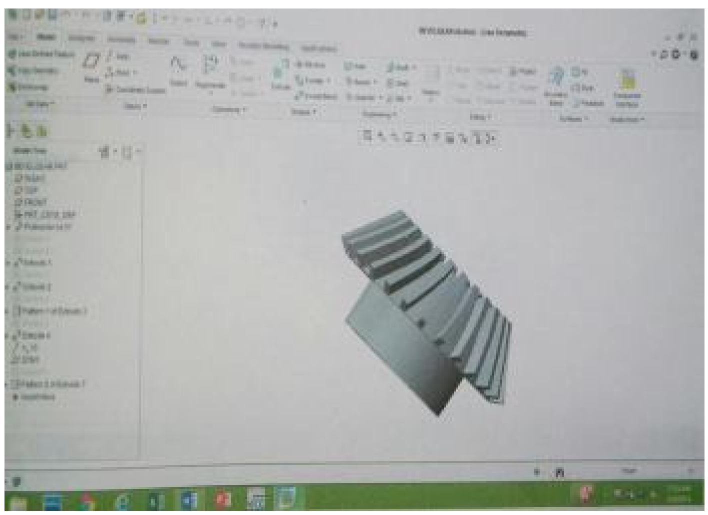

Fig 16 Spiral bevel Gear

VI. CONCLUSIONS

An old spindle from the Soraluce CNC machine was removed and by applying reverse engineering methodology I dismantled spindle assembly. During this process I noted different part such as pull stud, collet, draw bar, disc spring, gear, spacer, etc also I could not dimension. This helps me in cross checking the dimension when I design the part like spindle, spiral bevel gear, disc spring and bearing. Also this information helped me in drawing the part in Creo software I have design and manufactured the spindle and its parts. I have assembled the new parts in the machine and got approval. This new spindle and gear are the import substitution for original spindle and gear. It saved large amount of cost. It will also reduce delay in the importing the same. Now this spindle and its parts can be manufactured at any time in house.

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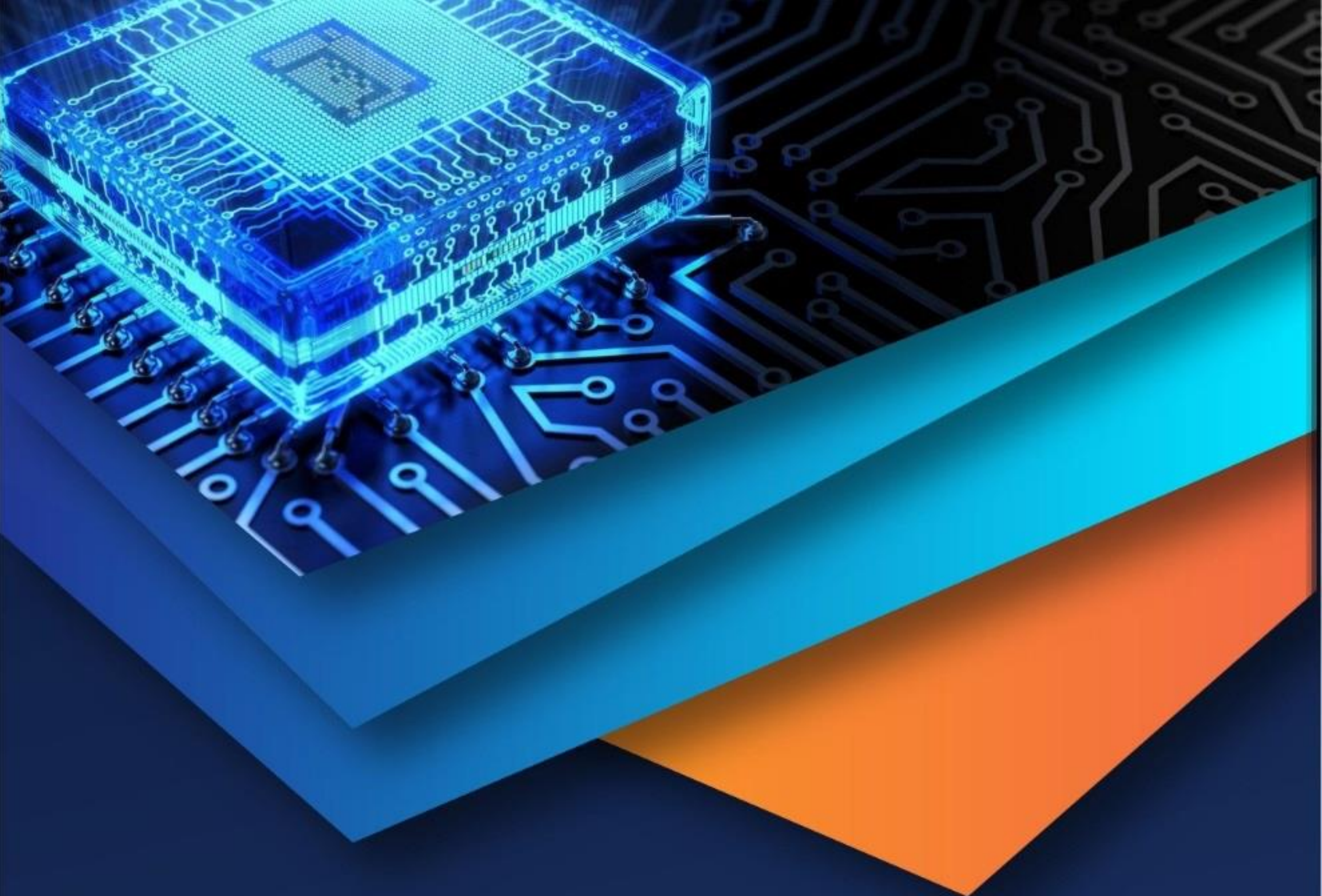

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