International Journal of Machine Design and Manufacturing
Vol. 1: Issue 2
www.journalspub.com

Development of an Effective Uncemented Femoral Stem Implant with CNC Ball End Milling

Sadananda Chakraborty, Bidhan Chandra Biswas, Nirmal Kumar Mandal*
Mechanical Engineering Department, National Institute of Technical Teachers' Training and Research, Salt Lake City, Kolkata, India

ABSTRACT

Now a days uncemented total hip replacement (THR) is mostly used in surgery of hip joint. Quality and reliability of an uncemented femoral stem depends on many factors. The effect of roughness of the implant on the stress distribution, Von Mises Stress of the implanted femur with varying frictional co-efficient ranges from 0.2 to 0.4 have been studied through finite element analysis using commercial finite element analysis package ANSYS. Machining of the implant is very important because there are so many factors likes, quality of the product, combination of tool-work piece material, machinability of the work material, productivity etc. that depends on performance. The aim of the present study is to find out the optimum significant parameters of the machining operation of femoral stem implant for optimum surface roughness. SS316L has been taken as the work material as it is widely used as hip implant. Ball end milling cutter of coated carbide has been chosen as the cutting tool as it is used in the finish cut of complex shapes. Speed, feed rate and Step over are taken as the cutting parameters. MINITAB 16 commercial software package is used to determine the number of experiment through Design of Experiment (DOE). Total 20 no. of experiments are conducted and the collected data are analyzed to predict the surface roughness through regression analysis. Significance of input process parameters are tested by Analysis of Variance (ANOVA). A model equation is formed using coefficients obtained from Analysis of Variance (ANOVA) and this equation is used to find out optimum process parameters using Genetic Algorithms.

Keywords: CATIA model, CNC ball end milling, femoral stem implant, GA, secondary fixation

***Corresponding Author**
E-mail: sadananda116@gmail.com

INTRODUCTION

In hip replacement surgery it has been found that mainly some bone marrow top section and head of femur can be replaced. The total arrangement of these sections must be secured and comfortable John Charnley has introduced the use of polymetacrylate bone cement to secure the components to original living bone and high-density polyethylene is used as a bearing material in THA. This concept of cemented THA shows very good results even today. In the first generation of cemented hips early failure has been reported mostly of the cemented stem. These failures has been associated with localized areas of osteolysis mostly in the femur caused by the systemic inflammatory response believed to be a process by cement particles, a phenomenon called "cement disease". Several investigators therefore proposed that the future of THA should be the development of prostheses that are implanted avoiding the use of cement. This triggered the development of uncemented implants which allow bone ingrowth into the implant in order to enable biological stabilization. Characteristics such as the form and the finish of implants are crucial in order to achieve the best possible conditions for long-term implant survival. Force transmission and stability of the cemented THA are achieved by the cement mantle.

In case of cementless THR the press-fit is pledged that the stem and the prosthetic cup are gradually affixed to the bone in the abrupt post-operative period. The stem and cup are coated with a porous surface layer which mainly consists of sintered metal powder and electro sprayed metal. For improvement of biological fixation of porous implants, hydroxyapatite (HA) and tricalcium phosphate (TCP) are used as a coating of bio-active materials. Many researchers have been shown these coatings are beneficial for hip implant.[1–14]

LITERATURE REVIEW

For fixation of the uncemented femoral stem surface roughness plays an important role both for primary and secondary stabilization of the implant. Unlike most of the cases femoral stem implant needs some degree of roughness for longitudinal and rotational stability. CNC Vertical milling machine is the most productive option for manufacturing many products along with femoral stem implant.

The micro irregularities of the machined surface is known as surface roughness. Milling operation provides a wide range of surface roughness (0.4 µm -50µm) depending upon the cutting condition. Many researchers have studied the effect of surface roughness on the fixation of uncemented femoral stem implant. Many other researchers have studied the surface roughness features in end milling.

H. Derar qnd M. Shahiapoor[1] reviewed the patents of hip implant for the last few decades. They have also suggested some new design technique of the existing patent depending upon the longevity of the implant and discomfort of the patient. Anmol Kumar and M.K. Paswan[2] have been investigated the effect of cutting parameters on surface roughness in hard milling of AISI H13 steel with coated carbide tools. Based on face centered cubic method, three-factors (spindle *speed*, *feed rate* and *depth of cut*) and three-level experiments have been employed using commercial statistical software. It has been found that the spindle *speed* and the *feed* are the two dominant factors affecting the surface roughness. Vijay Kumar et al.[3] has been explored the effect of *cutting speed*, *feed rate* and *depth of cut* on surface roughness in ball nose end milling of LM6 Al alloy.

A second order mathematical model has developed to predict surface roughness in terms of the selected machining parameters. Prajina N.V.[4] has focused RSM for the multiple response optimizations in CNC end milling operation to get maximum material removal rate, minimum surface roughness and less force. Second-order quadratic models has been developed for cutting forces, surface roughness and machining time; considering the spindle *speed*, *feed* rate, and *depth of cut* and immersion angle as the cutting parameters using central composite design. Subhomoy Chatterjee et al.[5] has aimed to customize the geometry of the implant as per bone geometry and compared the stress and strain profile with varying stiffness as obtained by varying design of the implant so as to achieve a closer resemblance with the bone.

The geometry has obtained from CT data and zonal material property is assigned as per the bone. Two designs of implant were chosen as solid and internally hollow and both are subjected to same loading conditions. N.N. Bhopale and R.S. Pawade[6] have addressed the effects of cutting *speed* and *feed* on the work piece deflection and surface integrity during milling of cantilever shaped Inconel 718 plate under different cutter orientations. Surface integrity is assessed in terms of micro hardness beneath the machined surface. They have been introduced that at large *cutting speed* as well as *feeds*, thicker work piece with larger work piece inclination showed higher micro hardness as compared to the other machining conditions.

Muataz Hazza et al.[7] has developed a model for estimating the cutting parameters like *cutting speed, feed* rate, and axial *depth of cut* to minimize the machining temperatures and surface roughness. In this research work two objectives have been considered, minimum cutting temperature and minimum arithmetic mean roughness (Ra). Amit Joshi & Pradeep Kothiyal[8] have investigated the effects of various parameters of end milling process like spindle *speed, depth of cut, feed rate* to reveal their impact on surface finish using Taguchi Methodology.

The results of analysis of variance (ANOVA) indicated that the *feed rate* is most influencing factor for modeling surface finish. Harpal S. & Khanuja et al.[9] have reviewed the stem designs, geometries and shortened their continuing consequences. Damir Kakas et al.[10] has used ion beam assisted deposition to prepare hard TiN coatings. In order to provide appropriate adhesion of TiN film, a titanium nano-interfacial layer was introduced between coating and base material. The interfacial layer has produced by ion beam mixing of titanium atoms with atoms of steel substrate.

Here it is observed that critical load of coating detachment increases with increase in substrate roughness. M.R. Razfar et al.[11] have determined optimal cutting parameters to decide minimum surface roughness. They have used particle swarm optimization for the single optimization. Philipp Bergschmidt et al.[12] has studied the optimal fixation of uncemented hip stems for long-term stability. Primary stability of uncemented stem is accomplished by press-fit fixation and therefore a certain roughness of implant surface is required.

In this paper it has been found that the biological integration of the hip stem is improved by a newly structured surface with an average surface roughness of 3 µm –5 µm. R. Dhakshayani et al.[13] have carried out a research using rapid prototyping in dysplastic hip orthopedic surgery. They have used computed tomography. Wanget et al.[14] has investigated the influence of surface roughness on the cemented strength of HVOF sprayed NiCrBSi coating which is produced the surface roughness larger than Ra 1.7 µm.

Dean-Mo Liu et al.[15] has established that the sol–gel HAp coatings are firmly devoted to the sand blasted 316L stainless steel substrate, through both mechanical intertwining and degree of chemical bonding using the proper heat treatment at 3751–5001°C. C. Bitsakos et al[16] have used finite element technique to analyze the contact load of muscle and joint. They have proposed a strain adaptive remodeling technique to simulate the changes in bone after operation.

SCOPE OF THE PRESENT WORK

From the literature review and trial run it is clear that for the fixation of femoral stem in case of uncemented hip implant, roughness of the femoral stem is an important aspect. Coating of porous material such as hydroxyapatite (HA) is used for secondary fixation through bone in-growth into the coating material. For this coating and to have enough bonding strength, the stem surface needs to be rough enough. Again, this roughness should be even and clean. From the review, it is found that this Ra value of roughness should be between 5 µm to 7µm. CNC vertical milling machine provides a wide range of Ra from 0.4 µm to 50 µm. Roughness depends on many parameters. Among the cutting parameters, it is very important to decide a suitable range and optimize the parameters for maximum surface roughness. Therefore the objectives of this present work are as follow:

- Model uncemented femoral stem using commercial software CATIA.
- Analyze the model through finite element technique using ANSYS software.
- Manufacture the femoral stem with CNC milling machine.
- Study and select the factors which influence the surface roughness of femoral stem.
- Determine the number of experiment through Design of Experiment (DOE).
- Measure the surface roughness using surface profilometer (MARSURF PSI).
- Modeling surface roughness using Regression analysis method and validation using Analysis of Variance (ANOVA).
- Find out the optimum process parameters for maximum surface roughness using Genetic Algorithm (GA).

FINITE ELEMENT ANALYSIS OF FEMORAL STEM IMPLANT

The physical dimensions of the stem implant are obtained from the CT-Scan data of bone using commercial software package, MIMICS which generates 3D reconstructed geometry of the femur (Figure 2). A solid implant is designed with the commercial package CATIA V5. Commercial Finite Element Analysis (FEA) package ANSYS 14 (ANSYS Inc., Cecil Township, Pennsylvania, USA) is used for computational analysis of the mechanical environment. Before performing FEA, the implant and bone models are aligned to perform virtual implantation using ANSYS Workbench and a frictional contact is established between them (Figures 1–3).[5]

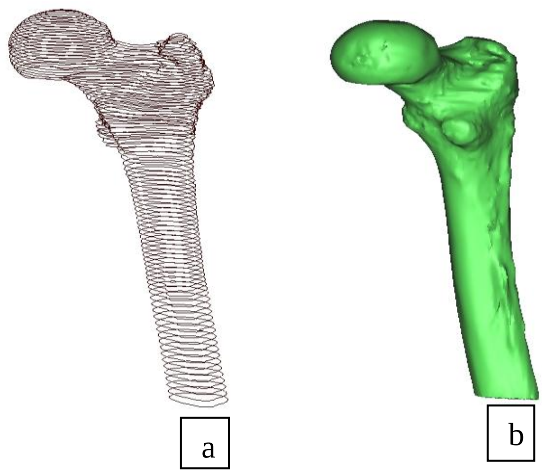


Fig. 1. *Solid modeling from CT scan by piling the scan slices. (a) Pilling of the scan slices; (b) The constructed 3D.*

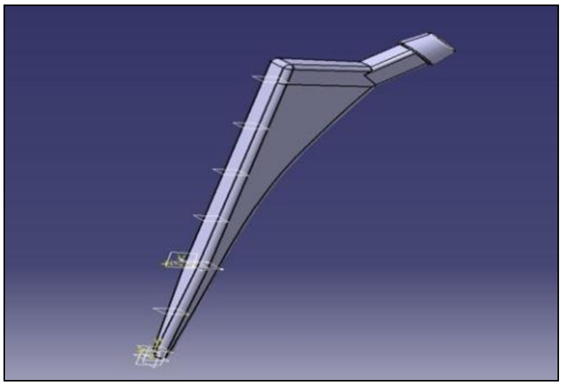


Fig. 2. *CATIA model of femoral stem.*

The element type SOLID 187 (10 noded, tetrahedral) has been chosen for both the bone and the implant for FEA. The material property of the bone is assigned from MIMICS, as obtained by an empirical equation using the image intensities obtained from the scan data, while that of the implant has been assigned as 200 GPa approximating surgical grade SS316L. The implant is meshed into 17,296 elements; 26,761nodes while the bone into 65,821 elements, 97899 nodes. For both the cases poison’s ratio have been taken as 0.3. Physiological load is applied at the implant head and loads included hip joint forces and selected muscle pull as according to Bitsakos et al (2005)[13] which is shown in Table 1.

Table 1. *Muscle forces and joint loading (Bitsakos et al. (2005)[13]) considered in the FEA.*

	Force component (N)		
Muscle name/joint	**X**	**Y**	**Z**
Gluteus medius	42.2	-4	-81.7
Gluteus minimus	21.5	7	-45.2
Priformis	113.4	-61.6	-38
Hip joint	-861.3	-250.8	2056.9

Von mises stress analysis of the implanted femur for fully bonded, for frictional co-efficient of 0.2, for frictional co-efficient of 0.4 and for the un-implanted femur have been performed. It has been found that the maximum von Mises stress of the un-implanted femur is much less than that of the implanted ones. Again, in case of friction with greater co- efficient of friction, the maximum stress is smaller.

For a frictional co-efficient of 0.2, the maximum von Mises stress is 268.8 MPa and for 0.4 it is 261.9 MPa. So, rough interface is favorable for better stress distribution. In all the three cases, other than the un-implanted femur the maximum von Mises stress is smaller than yield strength of the implant material (Figures 3–6). So, the design is safe.

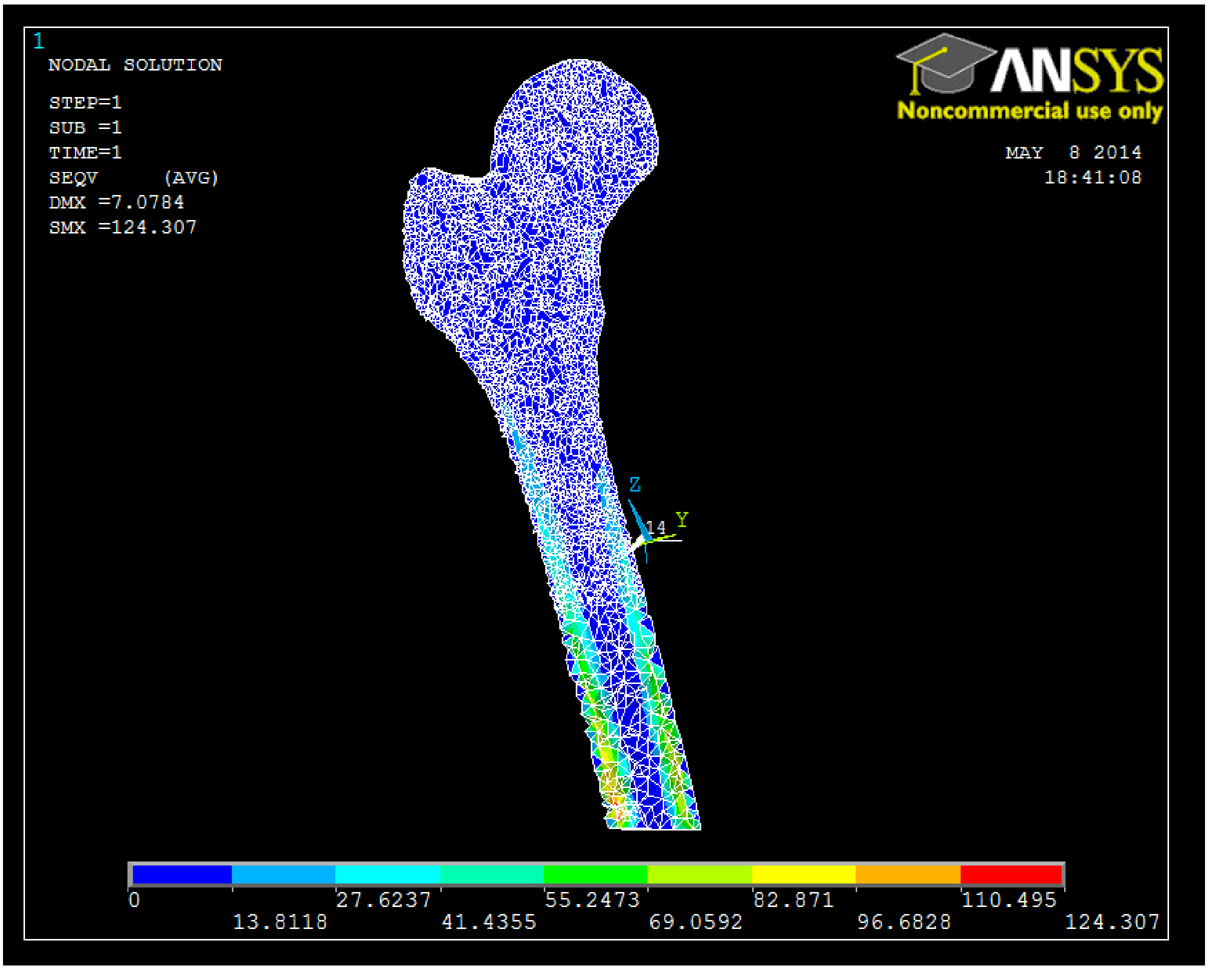


Fig. 3. *Von mises stress in un-implanted femur implanted femur.*

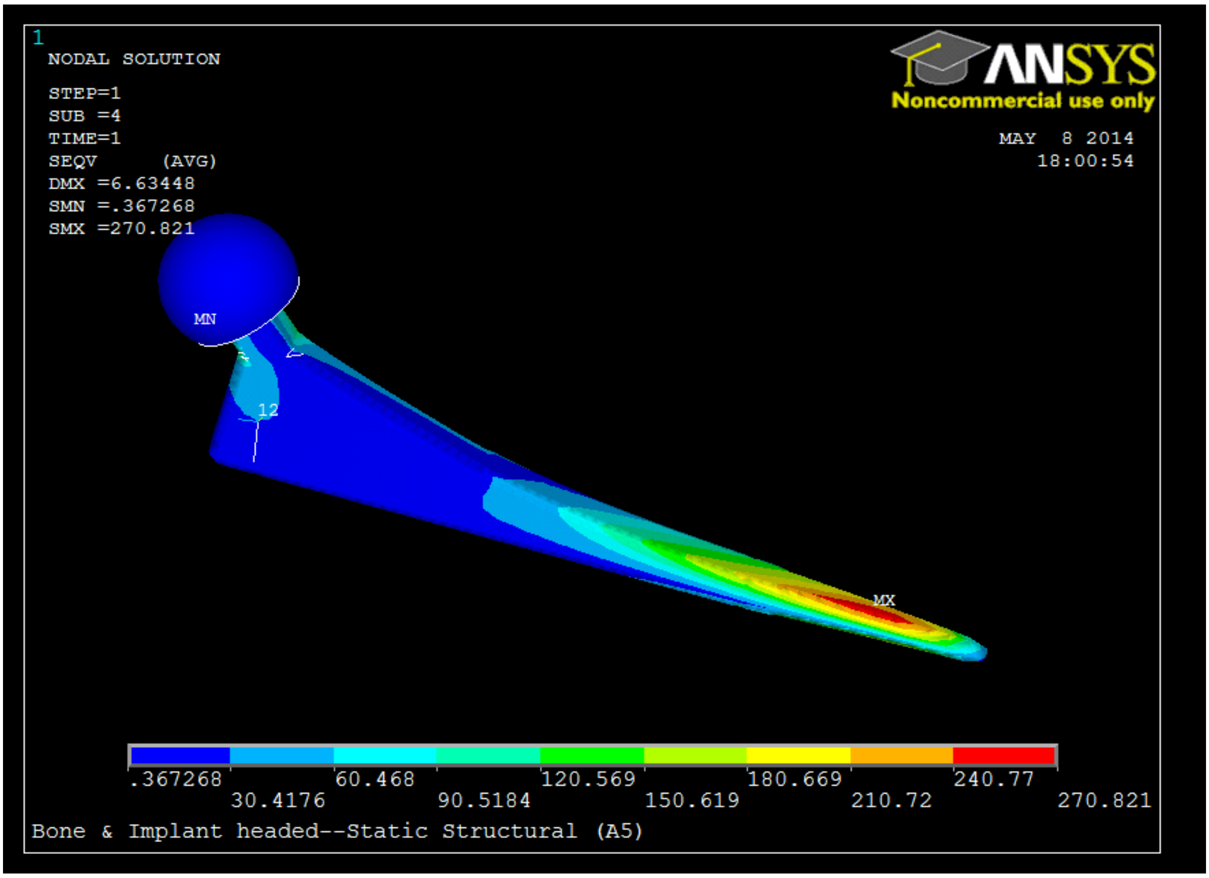


Fig. 4. *Von mises stress in a fully bonded.*

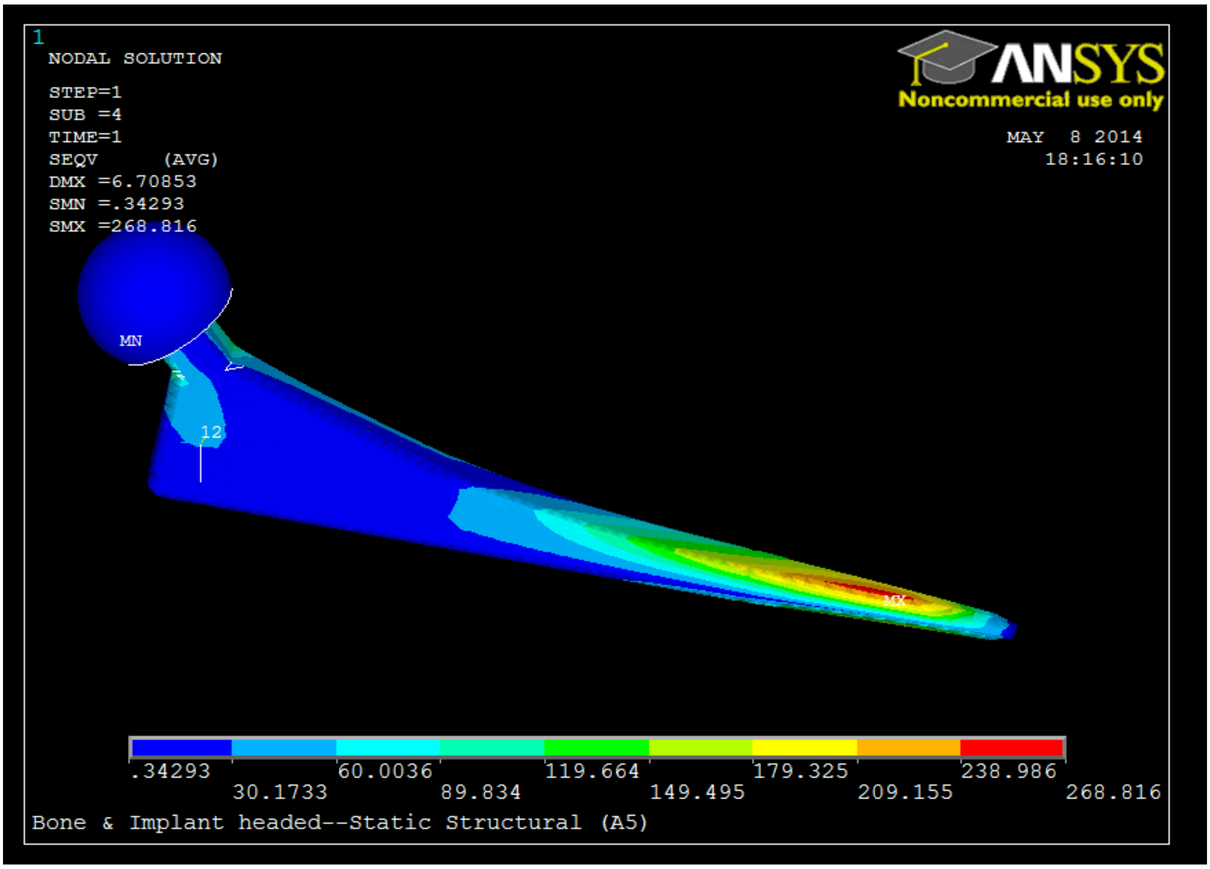


Fig. 5. *Von mises stress for frictional co-efficient 0.2.*

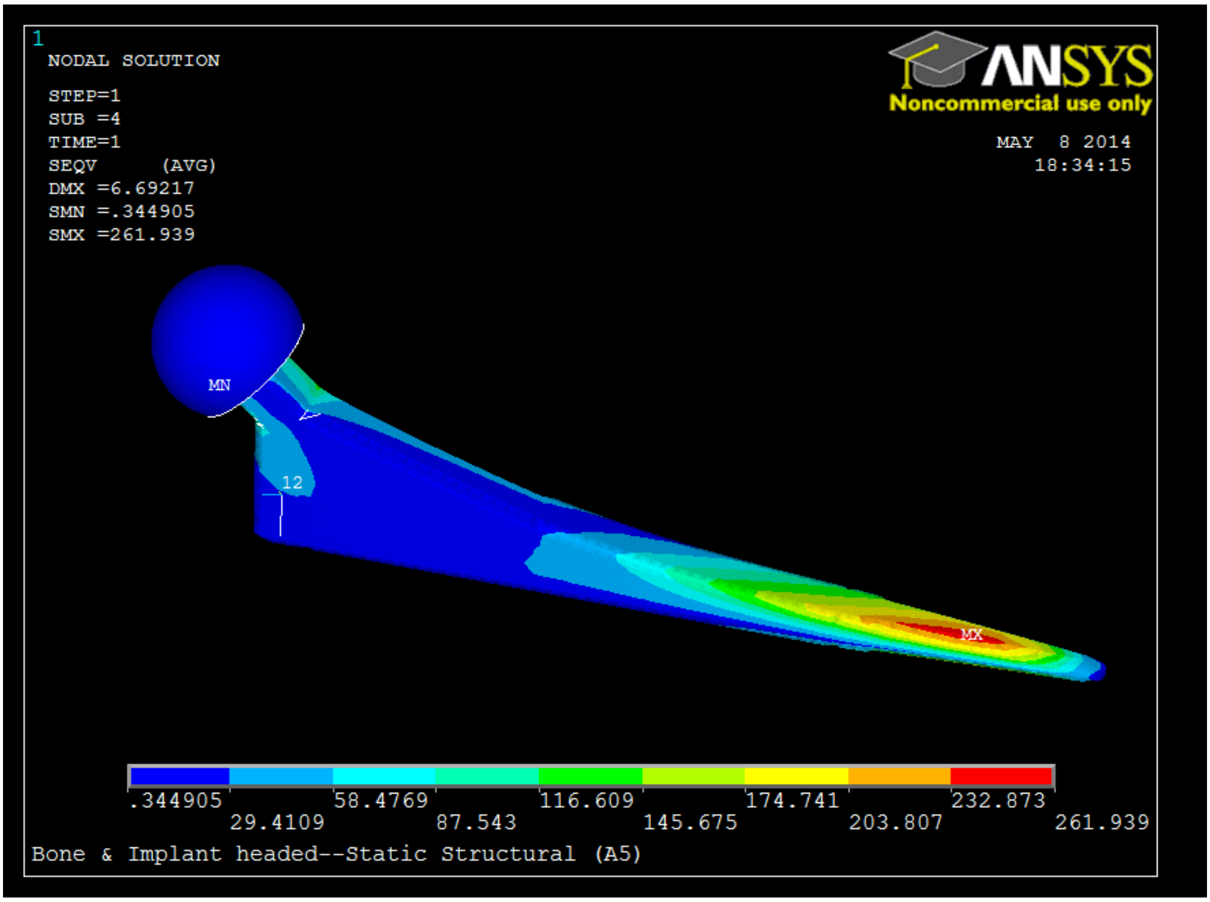


Fig. 6. *Von mises stress for frictional co-efficient 0.4.*

As the stress distribution in an implanted femur depends on many factors such as geometrical shape, material of the implant, press fit, etc., the implant can be improved by considering these factors along with the surface roughness of the implant.

EXPERIMENTAL SET UP

In the present study Design of Experiment (DOE) has been generated by Response Surface Methodology (RSM) because this Methodology is very useful for the modeling and analysis of different problems. 20 nos. of operations has been conducted in this experiment. Therefore, spindle *speed*, *feed rate* and *step over* have been considered as a machining parameters. The machining parameters with their units and their levels as considered for experimentation are listed in Table 2. Stainless steel 316L has been taken as the work piece material as it has been increasingly used as implant materials because of its similarities to human bone in terms of Young's modulus of elasticity, hardness and other mechanical properties. It is considered as one of the attractive metallic materials for biomedical applications.

Table 2. *Machining parameters and their limits.*

Symbol	Machining parameters	Unit	Level -1	Level 0	Level 1
A	Spindle speed	RPM	1000	1500	2000
B	Feed rate	mm/min	500	750	1000
C	Step over	mm	0.1	0.3	0.5

In this experiment commercially available PVD coated carbide solid end mill cutters are used since coated carbide tools are much better than uncoated carbide tools. Three machining processes are selected for facing operation, rough cutting operation and a ball nose end mill cutter for different roughness on a machined surface in a CNC vertical machining centre. Surface facing and first rough cut is performed using a 6 mm diameter end mill cutter. Then a 4 mm diameter end mill cutter is used. Finally a ball nose end mill cutter of diameter 4 mm is used for different roughness (Figure 7, Tables 3, 4).

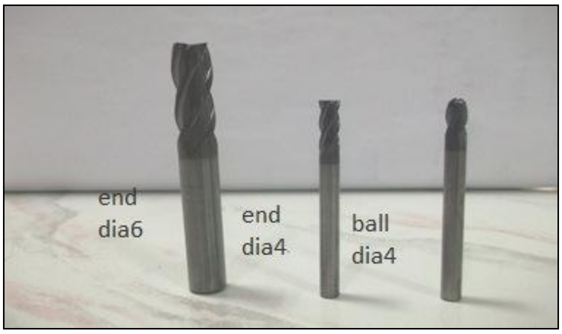


Fig. 7. *Cutting tool used.*

Table 3. *Chemical composition of SS316L.*

Carbon	0.03	Chromium	18.00
Manganese	2.00	Molybdenum	3.00
Silicon	0.75	Phosphorous	0.045
Nickel	14.00	Sulphur	0.03

Table 4. *Mechanical properties of SS316L.*

Tensile strength (MPa)		515
Yield strength (MPa)		290
Density (kg/m^3)		8000
Elongation % in 50 mm		40
hardness	(HRB)	90
	(HBC)	24
Young modulus (GPa)		200

These experiments are conducted using three levels of *speed*, *feed* and *width of cut* (*step over*) following Design of Experiment as shown in Table 5. Main purpose of the experimentation is to develop a model of surface roughness of the implant manufacturing. The maximum and minimum limits of cutting parameters are determined for the said combination of work piece and cutting tools available from the hand book and limits of the machineries available in the laboratory. The levels of the variables are determined from the sample experimentation and Design of Experiments. Thus, twenty no. of experiments have been performed; in each experiment, different CNC program is used according to the Design of Experiment. The surface roughness is measured using surface profilometer.

The principal aim is to conduct the experiment for maximizing the surface roughness of the femoral stem implant and finding the optimum values of the process parameters. For this, first preparation is to make a CAD model of the femoral stem in CATIA V5 using neck shaft angle 1280, femoral length 162 mm, linear diameter 32 mm, neck shaft diameter 14 mm, thickness 12 mm and frontal tapper angle 80 obtained from the output of MIMICS software Then the CAD model (.CAT part) is imported in DEL CAM POWER MILL software to prepare a CNC part program. This CNC part program is fed into the memory of the CNC milling machine through the control panel using a memory card reader. After that run the experiments according to DOE.

A block of SS316L alloy steel of dimension 250×80×20 mm^3 is first cleaned with sand paper to remove any rust over the surface. Then, it is firmly clamped on the work table of the CNC milling machine. First, face milling operations are performed over all the faces of the work piece to make it a perfect rectangle. Then determine the center point of the work piece by using an edge finder and set this point as the machine zero. It is required to cut the work piece from both the side so that first drilled two through holes on the work piece in suitable points by a center drill of 4 mm diameter and stored their coordinates.

Now declamp the tool holder and change the collet and cutter and set them in the arbor. The tool holder with the required cutter is then clamped properly. The memory card is read by using the command DNC SET to run the program and cut the work piece.

After rough cutting by using end mill cutter of diameter 6 mm and 4mm, the finishing cutting and experiments are conducted according to the Design of Experiment. Among these programs, it has been used first five programs to be implemented in one side of the implant as shown in the Figures 8, 9.

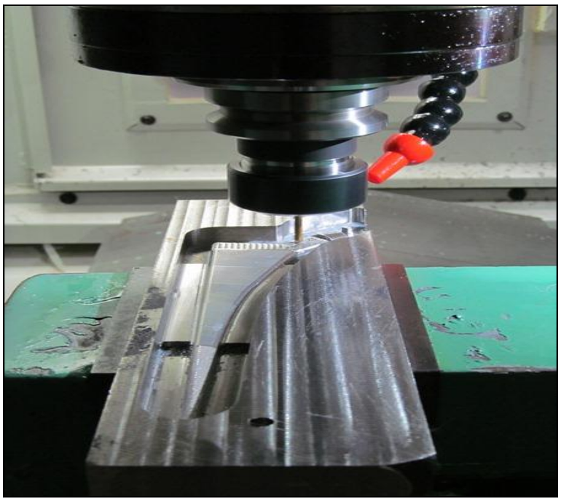


Fig. 8. *View of machining of work piece.*

Fig. 9. *Femoral stem implant.*

Then, the work piece is declamped and fixed it for machining from the opposite side and repeat the same steps. Thus, in one implant it has been taken ten runs and in another one same procedure has been followed. Surface roughness of the machining surface is measured using MarSurf PS1 for each run. The details of the data obtained after experimentation is given in the Table 5.

Table 5. *Data collected during experimentation.*

S.N.	Coded value input parameter			Uncoded value input parameter			Surface rough-ness R_a (µm)
	Speed (rpm)	Feed (mm/min)	Step over (mm)	Speed (rpm)	Feed (mm/min)	Step over (mm)	
1	0	0	0	1500	750	0.3	3.067
2	1	-1	1	2000	500	0.5	2.386
3	1	-1	-1	2000	500	0.1	0.607
4	-1	0	0	1000	750	0.3	3.667
5	0	0	1	1500	750	0.5	4.662
6	0	1	0	1500	1000	0.3	3.791
7	-1	-1	1	1000	500	0.5	4.467
8	1	1	-1	2000	1000	0.1	1.605
9	0	0	0	1500	750	0.3	3.068
10	0	0	-1	1500	750	0.1	1.522
11	0	0	0	1500	750	0.3	3.166
12	0	0	0	1500	750	0.3	3.210
13	0	0	0	1500	750	0.3	3.056
14	0	0	0	1500	750	0.3	3.122
15	1	0	0	2000	750	0.3	2.365
16	0	-1	0	1500	500	0.3	2.212
17	1	1	1	2000	1000	0.5	4.697
18	-1	-1	-1	1000	500	0.1	1.280
19	-1	1	1	1000	1000	0.5	6.627
20	-1	1	-1	1000	1000	0.1	2.128

ANALYSIS OF EXPERIMENTAL DATA

Regression analysis results are done with MINITAB 16 software. For that, full quadratic model is used, because it is thought that strong interactions between spindle *speed*, *feed rate* and *step over* exists. The analysis is done using coded units. R-Sq or R^2, the coefficient of determination, gives the greatest indication of the strength of relationship. The result shows that 99.94% of the variation in response variable can be explained in a linear relationship with the predictor. For the appropriate fitting of surface roughness, the non-significant terms (i.e. p-value are greater than 0.05) are eliminated by backward elimination process.

PRESS (predicted sum of squares) can be used as a data validation procedure by leaving out one observation, correcting a given model to the rest of the data and then predicting the one left out and obtaining the square of inconsistency, then repeating this for all single data point omissions. Thus, we get PRESS. The PRESS value shows that the model is significant (Table 6). The mathematical relationship for correlating the surface roughness using uncoded data and the considered process variables has been obtained as follows:

Ra = 3.10105 - 0.65090 * *Speed* + 0.78960 * *Feed rate* + 1.56970 * *Step over*-0.07886 * *Feed rate* * *Feed* rate-0.35187 * *Speed* * *Step over* + 0.32813 * *Feed rate* * *Step over* (1)

Table 6. *Estimated regression coefficients for surface roughness.*

Term	Coefficient	SE Coefficient	T	*P*
Constant	3.10105	0.0167	185.724	0
A	-0.6509	0.01536	-42.379	0
B	0.7896	0.01536	51.409	0
C	1.5697	0.01536	102.2	0
A*A	-0.06436	0.02929	-2.198	0.053
B*B	-0.07886	0.02929	-2.693	0.023
C*C	0.01164	0.02929	0.397	0.699
A*B	0.03763	0.01717	2.191	0.053
A*C	-0.35187	0.01717	-20.491	0
B*C	0.32813	0.01717	19.108	0
S=0.0485697, PRESS = 0.0416684, R-Sq=99.94%, R-Sq (pred)=99.89%, R-Sq (adj)=99.88%.				

Table 7. *Analysis of variance for surface roughness Ra.*

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regres-	9	37.0471	37.0471	4.1163	1744.94	0
Linear	3	35.111	35.111	11.7037	4961.24	0
A	1	4.2367	4.2367	4.2367	1795.96	0
B	1	6.2347	6.2347	6.2347	2642.92	0
C	1	24.6396	24.6396	24.6396	10444.85	0
Square	3	0.0729	0.0729	0.0243	10.31	0.002
A*A	1	0.0548	0.0114	0.0114	4.83	0.053
B*B	1	0.0178	0.0171	0.0171	7.25	0.023
C*C	1	0.0004	0.0004	0.0004	0.16	0.699
Interaction	3	1.8632	1.8632	0.6211	263.27	0
A*B	1	0.0113	0.0113	0.0113	4.8	0.053
A*C	1	0.9905	0.9905	0.9905	419.89	0
B*C	1	0.8613	0.8613	0.8613	365.12	0
Residual Error	10	0.0236	0.0236	0.0024		
Lack-of-Fit	5	0.0039	0.0039	0.0008	0.2	0.949
Pure Error	5	0.0197	0.0197	0.0039		
Total	19	37.0707				

The experimental results has been analyzed using analysis of variance (ANOVA) for identifying the most significant factors which affects the output responses. This analysis has been carried out for a significance level of α=0.5 (i.e. confidence level of 95%).

The basic principle of the F test is that the larger F value causes greater effect on the performance which is shown in analysis Table 7. ANOVA results show that all the parameters have significant effect on surface roughness but *step over* has the highest effect on surface roughness, *feed rate* and spindle *speed* has almost equal effect on roughness.

RESULTS AND DISCUSSIONS

The direct and interaction effect of these machining parameters on the surface roughness are presented in a graphical form for further investigation. The trend plotted in the direct and interaction effects helps us to analyze the cause and effect of the machining parameters on surface roughness during ball end milling. Adequacy checking for validation of surface roughness with respect to input parameters by response surface methodology (RSM) is also done to check whether the data set is approximately normally distributed or not.

To visualize the influence of the designed process parameters over the response variable and also to find its nature of variations with respect to designed parameters, main effect plot, interaction plot and three dimensional surface plots are developed.

Significance of above shown plots (Figure 12) is to show the special effects of machining parameters individually on surface roughness. Main effect plot indicates that surface roughness (R_a) increases with the increase in both *feed rate* and *step over* but decreases with increase in spindle *speed*. From the interaction plots for surface roughness the inter effect of machining parameters with respect to response is observed.

The presence of interaction of different factor level can be easily judged by Interactions plots. From the plot, it is found that *speed* and *feed rate* inter act with *step over*. The surface plots physically represent the variation of surface roughness with different machining parameters (Figures 10–14).

In each surface plot, two cutting parameters are varied simultaneously along X and Y axis while the response are recorded along Z axis. Surface plots show:

- Surface roughness varies with the different combinations of spindle *speed* and *feed rate* while *step over* 0.3 mm (uncoaded) is kept constant. It is found that surface roughness decreases with spindle *speed* and increases with *feed* rate.
- Surface roughness varies with different combination of spindle *speed* and *step over* while *feed rate* 750 mm/min. (uncoaded) is kept constant. It is observed that surface roughness increases with stepover and decreases with spindle *speed*.
- Surface roughness varies with different combination of *feed rate* and stepover when spindle *speed* 1500 rpm (uncoaded) is kept constant. It is found that surface roughness increases with both *step over* and *feed* rate.
- From the normal probability plot, it is found that the data plotted against the theoretical normal distribution is approximately straight line. So it can be said that the data set is normally distributed as illustrated in Figure 13.

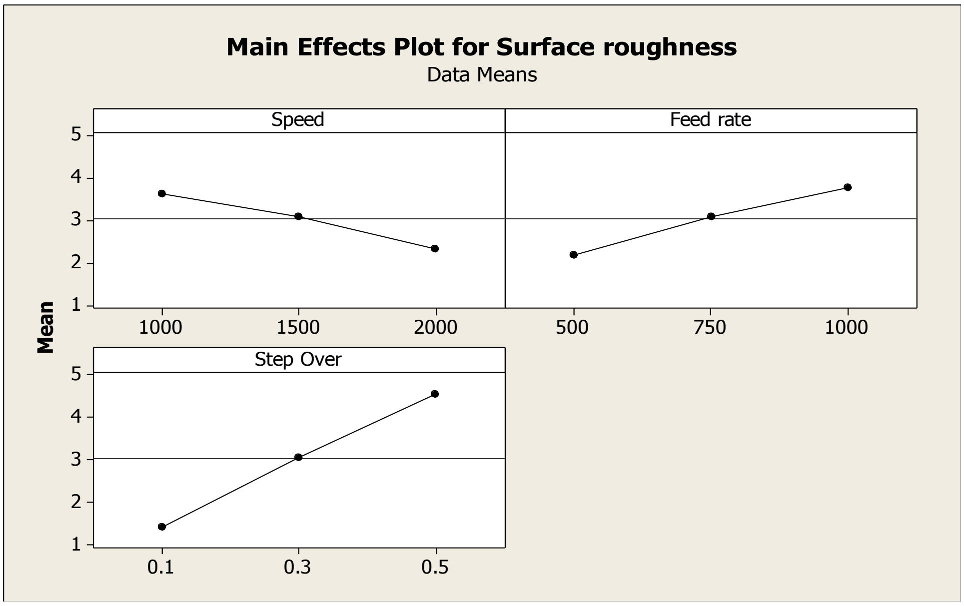


Fig. 10. *Main effect plots for surface roughness.*

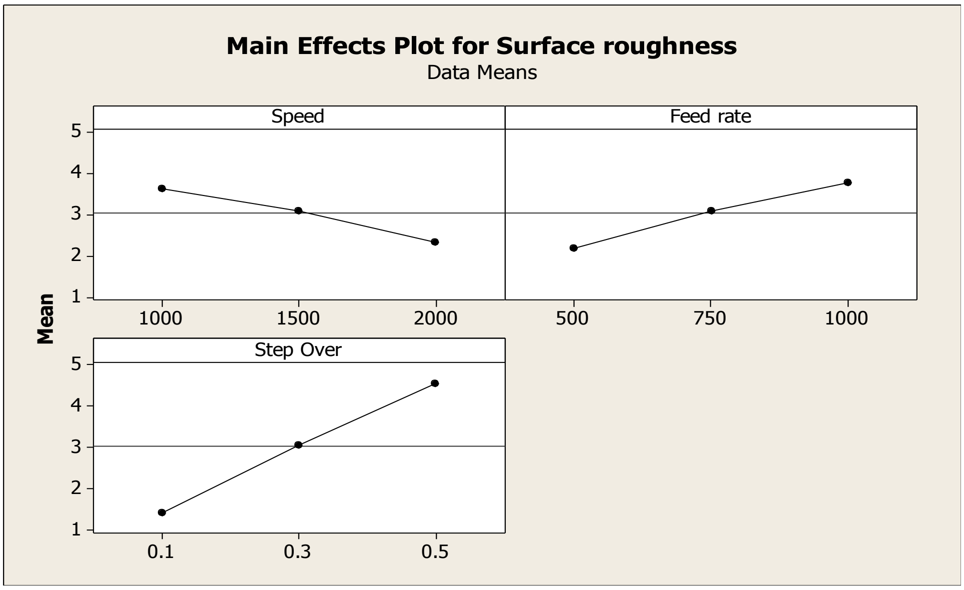


Fig. 11. *Interaction plots for surface roughness.*

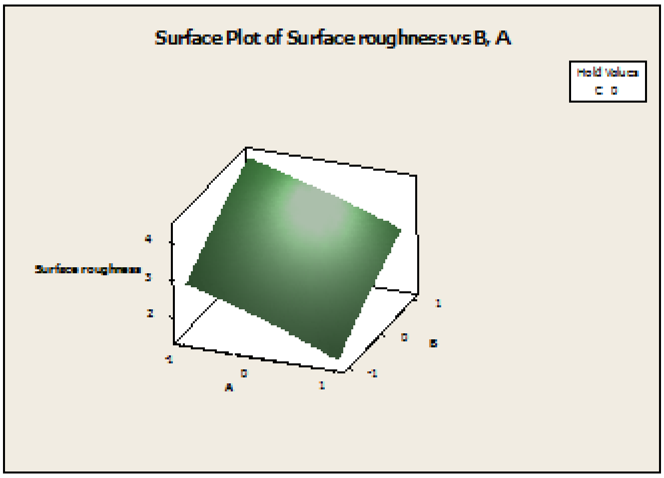


Fig. 12. *Surface plots of surface roughness.*

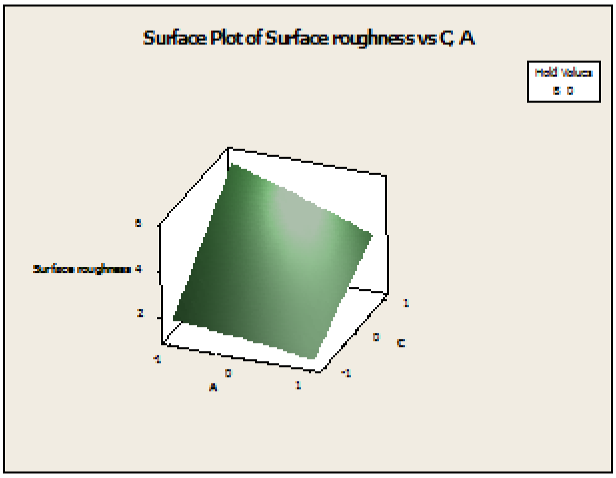
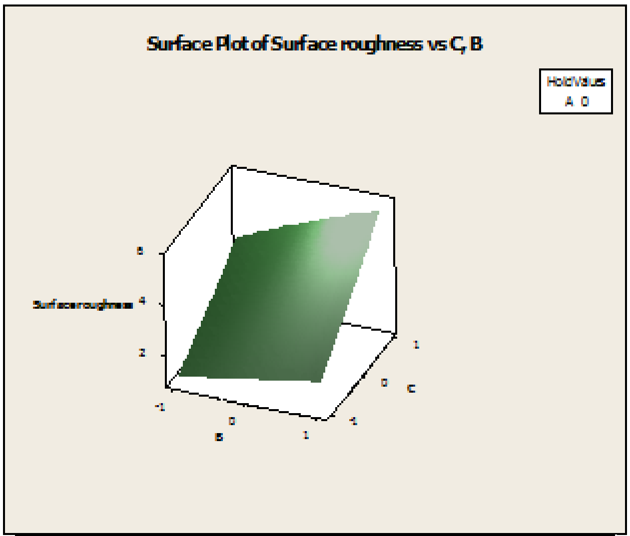


Fig. 13. *Surface plots of surface roughness.*



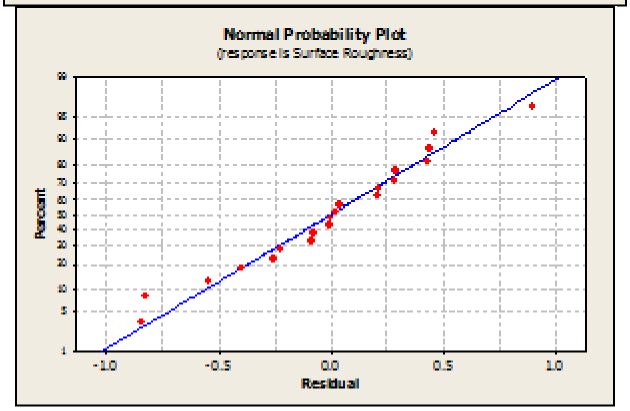


Fig. 14. *Normal probability plot of residuals for surface roughness.*

Genetic Algorithm is used to optimize the results obtained from experimentation. For optimization with Genetic Algorithm we need the fitness equation modelled previously by using RSM and as depicted by Equation (1). A genetic algorithm program is written for single objective optimization to get optimum value of cutting parameters for maximum surface roughness. The program for optimization is written using the commercial software package MATLAB. After executing the program with given input values the optimum cutting parameters are obtained in coded form. The optimized result is given in Table 8.

***Table 8.** GA optimized input variables.*

Spindle speed (rpm)	Feed rate (mm/min)	Step over (mm)	Surface roughness R_a (μm)
-0.9861	0.9995	0.9614	6.6113

Thus, the coded values of input parameters obtained after optimization are needed to be decoded, to obtain exact values of cutting parameters within the considered range. For decoding the coded values following formulae is used.

$$X_i = \frac{2(2X-(X_{max}+X_{min}))}{(X_{max}-X_{min})} \quad (2)$$

Where X_i $_{(i=1.2.3.4....n)}$ is required coded value of a variable X, X *is* any value of the variable(supplied from experiment Table 9), X_{min} *is* smaller limit of the variable and X_{max} is higher limit of the variable. After decoding the values the optimized machining parameters are obtained as:
Speed = 1253.475 rpm, *Feed rate* = 874.93 mm/min and *step over* = 0.396 mm.

***Table 9.** Conformation experimentation.*

Speed (rpm)		1250
Feed (mm/min)		875
Step over (mm)		0.4
Surface roughness ($R_{a)}$	Optimum value	6.6
	Experimental value	6.45
	Error	2.70%

CONCLUSIONS

Presently, effective stem manufacturing is a challenge to manufacturing industries as it depends upon so many factors like finishing of the surface and thereafter coating the same. In industries, these steps are carried out by different specialized personnel. In fact, these types of production processes are customized job production process. In this work, an attempt has been made to analyze the data obtained from CT scan and depending upon these data to develop a femoral stem and fixation of the same in uncemented in nature. Experimentations are designed and conducted on CNC end milling machine with PVD coated carbide solid ball end mill cutter as cutting tool and SS313L as work material. The numbers of experiments are determined through design of experiments (DOE).

The mathematical model for Surface roughness is generated through Response Surface Methodology (RSM). Genetic Algorithm is applied for optimization of surface roughness of the material based on the results of the present study. Finite element analysis gives the stress distribution on the femur and on the implant. It also conforms the need of a high rough surface of the femoral stem implant.

The von mises stress value indicates that the implant is safe as the yield strength of the implant is much higher than the von mises stress. Experimental results show that surface roughness of the workpiece material is a nonlinear equation of the parameters also it has been found that the spindle *speed* is inversely proportional to the surface roughness but the *feed rate* and *step over* is directly proportional to the surface roughness. Surface plots of surface roughness give the clear idea how surface roughness vary with different combination of depth of cut, *feed* rate, spindle *speed*, and *step over*.

The optimum combination of input parameters for maximization of surface roughness is found in single objective optimization technique using GA. The result of the confirmation test shows that surface roughness is maximum when optimum cutting parameters are chosen to be spindle *speed*, *feed rate* and *step over*. The model developed in equation (1) is suitable to measure the surface roughness for any application as long as the combination of work piece and cutting tool remains same.

REFERENCES

[1] Derar H., Shahinpoor M. Recent patents and designs on hip replacement prostheses, *Open Biomed Eng J*. 2015; 9: 92–102p.
[2] Kumar A., Paswan M.K. Optimization of surface topography for hard material machining with CNC end milling, *Int J Innov Res Sci Eng Technol*. 2014; 3: 8889–96p.
[3] Kumar V., Jatti S., Sekharand R., et al. Study of ball nose end milling of LM6 Al alloy: surface roughness optimisation using genetic algorithm, *Int J Eng Technol*. 2013; 5: 2859–65p.
[4] Prajina N.V. Multi response optimization of CNC end milling using response surface methodology and desirability function, *Int J Eng Res Technol*. 2013; 6: 739–46p.
[5] Chatterjee S., Ghosh U.B., Majumder S., et al. Customization of design for hip implants, *Indian J Biomechanic*. 2013; 4: 58–62p.
[6] Bhopale N.N., Pawade R.S. Investigation of surface integrity in high-*speed* ball end milling of cantilever shaped thin plate of Inconel 718, *J Achiev Mater Manuf Eng*. 2012; 55: 616–22p.
[7] Al Hazza M.H.F., Adesta E.Y.T., Superianto M.Y., et al. Cutting temperature and surface roughness optimization in CNC end milling using multi objective genetic algorithm, *Int Conf Adv Comput Sci Appl Technol*. 2012; 275–8p.
[8] Joshi A., Kothiyal P. Investigating effect of machining parameters of CNC milling on surface finish by Taguchi method, *Int J Theor Appl Res Mech Eng*. 2012; 60–5p.
[9] Khanuja H.S., Vakil J.J., Goddard M.S., et al. Cementless femoral fixation in total hip arthroplasty, *J Bone Joint Surg*. 2011; 93: 500–9p.
[10] Kakas D., Skoric B., Miletic A., et al. Influence of substrate roughness on adhesion strength of hard tin films, *34th International Conference on Production Engineering*. 28–30 September, 2011, Nis, Serbia.
[11] Razfar M.R., Asadnia M., Haghshenas M., et al. Optimum surface roughness prediction in face milling X20Cr13 using particle swarm optimization algorithm, *J Eng Manuf*. 2010; 224: 1645–53p.
[12] Bergschmidt P., Bader R., Finze S. Cementless total hip replacement: a prospective clinical study of the early functional and radiological outcomes of three diverent hip stems, *Arch Orthop Trauma Surg*. 2010; 130: 125–33p.
[13] Dhakshyani R., Nukman Y., Abu Osman N.A., et al. Rapid prototyping medical models for dysplastic hip orthopaedic surgery, *J Eng Manuf*. 2010; 224: 769–776p.
[14] Wang Y.-Y., Li C.-J., Ohmori A. Influence of substrate roughness on the bonding mechanisms of high velocity oxy-fuel sprayed coatings, *Thin Solid Films*. 2005; 485: 141–7p.
[15] Liu D.-M., Yang Q., Troczynski T. Sol–gel hydroxyapatite coatings on stainless steel substrates, *Biomaterials*. 2002; 23: 691–8p.
[16] Bitsakos C., Kerner J., Fisher I., et al. The effect of muscle loading on the simulation of bone remodelling in the proximal femur, *J Biomech*. 2005; 38: 133–9p.