Intelligent MATLAB Model for Predicting Surface Finish of Various Machining Processes

Vivekananda Reddi
Department of Mechanical Engineering
MVGR College of Engineering, Jawaharlal Nehru Technological University Kakinada

Mythra Varun A.V.
Department of Mechanical Engineering
MVGR College of Engineering, Jawaharlal Nehru Technological University Kakinada

Abstract

Surface finish is a prime factor for each and every machined product. Surface finish is an important factor in determining the satisfactory functioning of the machined components. A good surface finish improves the appearance, adhesion, corrosion resistance, wear resistance, hardness, modify electrical conductivity, remove burrs and other surface flaws, and controls the surface friction. Hence, the surface finish needs to be measured accurately to ensure the proper functionality of the machined component in the desired applications. Considering the importance of developing accurate and simple measurement techniques of surface finish, this work was undertaken to design a unique model which is enabled to measure surface roughness with the help of RGB values of the given images of the machined component using MATLAB. The objectives of the project include developing a model to classify the type of process the work piece has undergone and to develop a model to predict the cutting parameters of the machined work piece.

Keywords: Surface finish, MATLAB, Prediction Model, End Milling, Turning, Face Milling, CNC, RGB Values

I. INTRODUCTION

Surface finish is an important factor in determining the satisfactory functioning of the machined components. Surface finishing improves appearance, adhesion, corrosion resistance, wear resistance, hardness, modify electrical conductivity, remove burrs and other surface flaws, and control the surface friction. Over the last few years, advances in image processing techniques have provided a basis for developing image-based surface finish measuring techniques. Using a CCD camera and polychromatic light source, low-incident-angle images of machined surfaces with different surface finish values were captured. The RGB values of the images are produced and was processed using MATLAB software. A database of reference images with known surface finish values was established. Here an attempt is made to simultaneously classify the machined piece into a category as well as to predict its surface finish, using signal vector regression models developed in the MATLAB by suitably training them with machined surface finish values and corresponding RGB values obtained from Image Processing.

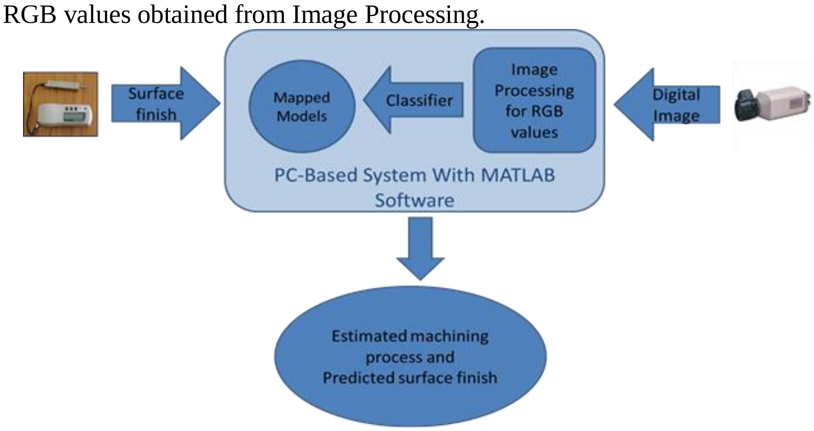

Fig. 1: Machining Process Flowchart

II. PROCESS DEVELOPMENT

A. Computer Numerical Control:

CNC use computer controls to cut different materials. They are able to translate programs consisting of specific number and letters to move the spindle to various locations and depths. Many use G-code, which is a standardized programming language that many CNC machines understand, while others use proprietary languages created by their manufacturers. These proprietary languages while often simpler than G-code are not transferable to other machines.

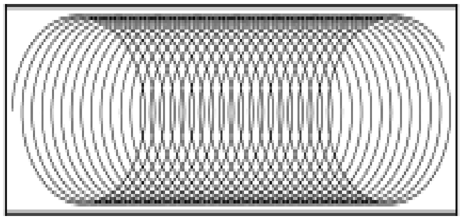

Fig. 2: Surface Finish Pattern Turning Process on CNC

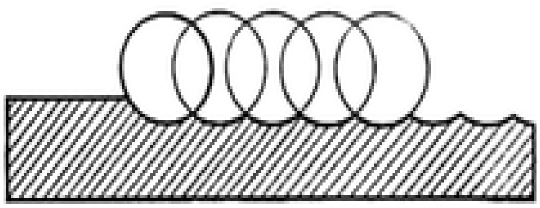

Fig. 3: Trochoidal Marks, characteristic of Face Milling Operation

The cutting parameters are chosen from the tool catalogues. Three Feeds , Three Depth of cuts and Three Speeds are taken in each machining process .Using CNC turning and milling machines the work is to be done so that the values are more accurate rather than the values obtained on conventional machining. This process is chosen because of the large database that can be generated and which results in an elegant model. The cutting parameters are implemented using the industrial CNC standards. The following tables consist the cutting parameters (Feed, Speed, Depth of Cut) :

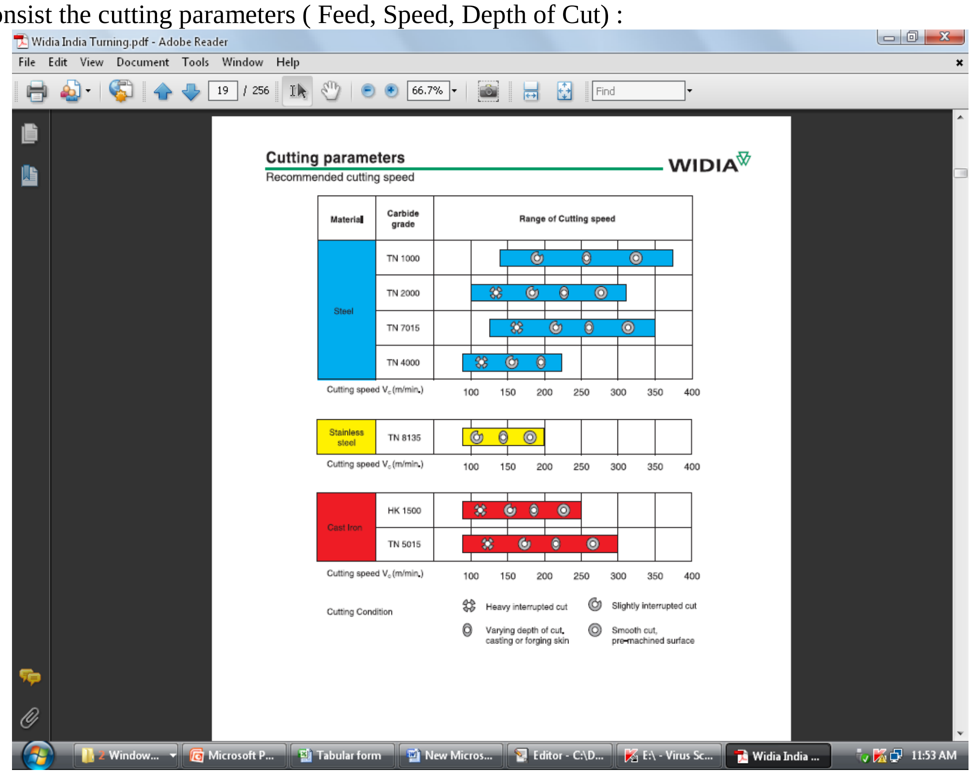

Fig. 4: Selection of Cutting Parameters

Table - 1
Cutting Parameters of Turning Operations

SPPED(mm/min)	*FEED(mm)*	*DEPTH OF CUT(mm)*
1500	*100*	*0.3*
2000	*125*	*0.5*
2500	*150*	*0.7*

Table - 2
Cutting Parameters of Face Milling Operations

SPPED(mm/min)	*FEED(mm)*	*DEPTH OF CUT(mm)*
2500	*300*	*0.3*
3000	*600*	*0.5*
3500	*800*	*0.8*

Table - 3
Cutting Parameters of End Milling Operations

SPPED(mm/min)	*FEED(mm)*	*DEPTH OF CUT(mm)*
1500	*300*	*0.3*
2000	*500*	*0.5*
3000	*650*	*0.8*

B. Surface Finish Measurement:

Conventionally the surface finish measurement is done with a stylus instrument. We are basically using Tally surf. Surface roughness measurement is done at 3 regions namely A, B, C. Surface finish is measured for Turned, End milled, Face milled work pieces.

Table - 4
Surface Finish Values of Turning Operation

W/P NO	*SPEED (rpm)*	*FEED (mm/min)*	*DOC (mm)*	*Ra (microns)*	*Ra (microns)*	*Ra (microns)*
1	*1500*	*100*	*0.5*	*1.1*	*1.2*	*1.1*
2	*1500*	*100*	*0.3*	*0.8*	*1.1*	*1.2*
3	*1500*	*100*	*0.7*	*0.9*	*1.0*	*1.0*
4	*1500*	*125*	*0.5*	*1.3*	*1.2*	*1.4*
5	*1500*	*125*	*0.3*	*1.4*	*1.3*	*1.4*
6	*1500*	*125*	*0.7*	*1.5*	*1.6*	*1.7*
7	*1500*	*150*	*0.5*	*1.6*	*1.7*	*1.7*
8	*1500*	*150*	*0.3*	*1.7*	*1.8*	*1.7*
9	*1500*	*150*	*0.7*	*2.1*	*1.9*	*1.9*
10	*2000*	*100*	*0.5*	*2.1*	*2.0*	*2.1*
11	*2000*	*100*	*0.3*	*2.1*	*2.0*	*2.0*
12	*2000*	*100*	*0.7*	*1.9*	*1.9*	*1.8*
13	*2000*	*125*	*0.5*	*1.9*	*2.0*	*2.0*
14	*2000*	*125*	*0.3*	*2.0*	*2.1*	*2.0*
15	*2000*	*125*	*0.7*	*1.67*	*1.7*	*1.7*
16	*2000*	*150*	*0.5*	*1.7*	*1.8*	*1.7*
17	*2000*	*150*	*0.3*	*1.8*	*1.7*	*1.7*
18	*2000*	*150*	*0.7*	*1.6*	*1.5*	*1.5*
19	*2500*	*100*	*0.5*	*1.5*	*1.4*	*1.4*
20	*2500*	*100*	*0.3*	*2.0*	*2.1*	*2.0*
21	*2500*	*100*	*0.7*	*1.9*	*2.1*	*2.0*
22	*2500*	*125*	*0.5*	*1.7*	*1.6*	*1.8*
23	*2500*	*125*	*0.3*	*1.5*	*1.6*	*1.7*
24	*2500*	*125*	*0.7*	*1.8*	*2.0*	*2.0*
25	*2500*	*150*	*0.5*	*1.9*	*1.7*	*1.9*
26	*2500*	*150*	*0.3*	*1.9*	*1.8*	*1.8*
27	*2500*	*150*	*0.7*	*2.0*	*1.9*	*1.9*

Table - 5
Surface Finish Values of Face Milling Operation

W/P NO.	*SPEED (rpm)*	*FEED (mm/min*	*DOC (mm)*	*Ra (microns)*	*Ra (microns)*	*Ra (microns)*
1	*2500*	*300*	*0.3*	*0.3*	*0.4*	*0.4*
2	*2500*	*300*	*0.5*	*0.5*	*0.6*	*0.7*
3	*2500*	*300*	*0.8*	*0.9*	*0.8*	*1.0*
4	*2500*	*600*	*0.3*	*1.1*	*1.2*	*1.0*
5	*2500*	*600*	*0.5*	*1.0*	*1.4*	*1.2*
6	*2500*	*600*	*0.8*	*0.9*	*0.8*	*0.9*
7	*2500*	*800*	*0.3*	*0.8*	*0.8*	*0.9*

8	*2500*	*800*	*0.5*	*0.8*	*0.8*	*1.1*
9	*2500*	*800*	*0.8*	*1.1*	*1.2*	*1.1*
10	*3000*	*300*	*0.3*	*0.7*	*0.8*	*0.7*
11	*3000*	*300*	*0.5*	*0.6*	*0.5*	*0.5*
12	*3000*	*300*	*0.8*	*0.5*	*0.6*	*0.6*
13	*3000*	*600*	*0.3*	*0.6*	*0.5*	*0.6*
14	*3000*	*600*	*0.5*	*0.8*	*0.7*	*0.8*
15	*3000*	*600*	*0.8*	*0.8*	*0.7*	*0.7*
16	*3000*	*800*	*0.3*	*0.9*	*0.7*	*0.7*
17	*3000*	*800*	*0.5*	*0.8*	*0.8*	*0.7*
18	*3000*	*800*	*0.8*	*0.8*	*0.7*	*0.7*
19	*3500*	*300*	*0.3*	*1.1*	*1.1*	*0.9*
20	*3500*	*300*	*0.5*	*0.5*	*0.6*	*0.4*
21	*3500*	*300*	*0.8*	*0.4*	*0.5*	*0.4*
22	*3500*	*600*	*0.3*	*0.6*	*0.6*	*0.6*
23	*3500*	*600*	*0.5*	*0.4*	*0.4*	*0.3*
24	*3500*	*600*	*0.8*	*0.5*	*0.5*	*0.5*
25	*3500*	*800*	*0.3*	*0.6*	*0.8*	*0.7*
26	*3500*	*800*	*0.5*	*0.5*	*0.6*	*0.5*
27	*3500*	*800*	*0.8*	*0.6*	*0.5*	*0.5*

Table - 6
Surface Finish Values of End Milling Operation

W/P NO.	*SPEED (rpm)*	*FEED (mm/min)*	*DOC (mm)*	*Ra (microns)*	*Ra (microns)*	*Ra (microns)*
1	*1500*	*300*	*0.3*	*1.6*	*1.5*	*1.5*
2	*1500*	*300*	*0.5*	*1.3*	*1.4*	*1.5*
3	*1500*	*300*	*0.8*	*1.2*	*1.2*	*1.5*
4	*1500*	*500*	*0.3*	*1.6*	*1.6*	*1.7*
5	*1500*	*500*	*0.5*	*1.9*	*1.8*	*1.8*
6	*1500*	*500*	*0.8*	*1.5*	*1.4*	*1.4*
7	*1500*	*650*	*0.3*	*1.5*	*1.6*	*1.6*
8	*1500*	*650*	*0.5*	*1.5*	*1.5*	*1.6*
9	*1500*	*650*	*0.8*	*1.6*	*1.6*	*1.5*
10	*2000*	*300*	*0.3*	*1.4*	*1.5*	*1.4*
11	*2000*	*300*	*0.5*	*1.3*	*1.5*	*1.7*
12	*2000*	*300*	*0.8*	*1.5*	*1.5*	*1.4*
13	*2000*	*500*	*0.3*	*1.7*	*1.6*	*1.6*
14	*2000*	*500*	*0.5*	*1.5*	*1.7*	*1.6*
15	*2000*	*500*	*0.8*	*1.3*	*1.3*	*1.4*
16	*2000*	*650*	*0.3*	*1.5*	*1.7*	*1.6*
17	*2000*	*650*	*0.5*	*1.3*	*1.5*	*1.6*
18	*2000*	*650*	*0.8*	*1.4*	*1.5*	*1.3*
19	*3000*	*300*	*0.3*	*1.4*	*1.5*	*1.3*
20	*3000*	*300*	*0.5*	*1.3*	*1.0*	*1.1*
21	*3000*	*300*	*0.8*	*1.0*	*1.0*	*1.1*
22	*3000*	*500*	*0.3*	*1.3*	*1.2*	*1.1*
23	*3000*	*500*	*0.5*	*1.3*	*1.4*	*1.3*
24	*3000*	*500*	*0.8*	*1.3*	*1.2*	*1.4*
25	*3000*	*650*	*0.3*	*1.4*	*1.3*	*1.3*
26	*3000*	*650*	*0.5*	*1.5*	*1.4*	*1.4*
27	*3000*	*650*	*0.8*	*1.5*	*1.4*	*1.5*

C. Optical Microscope:

The optical microscope, often referred to as the "light microscope", is a type of microscope which uses visible light and a system of lenses to magnify images of small samples. Basic optical microscopes can be very simple, although there are many complex designs which aim to improve resolution and sample contrast. The optical microscope used has a 10X resolution.

D. MATLAB:

MATLAB is a multi-paradigm numerical computing environment and fourth-generation programming language. Developed by math works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, JAVA, FORTRAN. The MATLAB application is built around the MATLAB language, and most use of MATLAB involves typing MATLAB code into the Command

Window (as an interactive mathematical shell), or executing text files containing MATLAB codes, including scripts and/or functions.

E. Mapping a Model using SVM and MSVR:

In this a SVM based AI regression model is developed to map surface finish and camera Image. SVM regression models developed in MATLAB for mapping the image data namely RGB values and the measures surface finish as RGB values are given as the input data for the model. Classing the given data into groups and finding the class even when a random work piece is given is the function of MSVR toll in MATLAB. This particular tool helps to classify the given work piece under which machining process has it been undergone. i.e., TURNING, FACE MILLING, END MILLING. For FACE MILLING the class which we have given is "1" for END MILLING its "2" and for TURNING its "3". According to these classifications the code is generated.

Table - 7
RBG Values for Face Milling

S.No	*'R' Value*	*'G' Value*	*'B' Value*
1	28.3134	46.2456	25.4411
2	29.1535	48.5542	22.2923
3	27.7918	47.1347	25.0736
4	30.4155	40.3321	29.2524
5	32.7107	41.5601	25.7292
6	33.1869	41.3248	25.4883
7	31.2538	38.8154	29.9308
8	31.1986	39.5798	29.2216
9	33.5631	40.0642	26.3727
10	32.4262	42.0821	25.4719
11	32.7273	38.5155	28.7571
12	33.1745	38.501	28.3245
13	28.9765	51.3655	19.658
14	34.2104	39.3716	26.4179
15	33.0291	39.0423	27.9286
16	31.58	42.3567	26.0633
17	32.6328	40.1334	27.2339
18	32.8901	40.2573	26.8526
19	31.8655	42.6472	25.4872
20	31.9562	39.8885	28.1553
21	33.8394	40.2336	25.927
22	31.9753	41.3751	26.6496
23	32.5502	41.5107	25.9392
24	32.45	41.3571	26.1929
25	31.7241	40.468	27.8079
26	32.7891	39.8037	27.3981
27	29.9373	40.3082	29.7544

Table - 8
RGB Values for End Milling

S.No	*'R' Value*	*'G' Value*	*'B' Value*
1	32.1915	40.7345	27.074
2	32.683	41.5711	25.7458
3	32.761	40.3522	26.8869
4	32.381	41.4716	26.1474
5	33.736	41.9824	24.2815
6	33.7221	40.2032	26.0746
7	31.6084	40.7434	27.6479
8	32.9992	39.0532	27.9476
9	31.6788	38.2205	30.1007
10	31.47	40.6367	27.8934
11	32.071	40.3159	27.5771
12	30.7337	39.0264	30.23999
13	33.3338	42.3069	24.3593
14	33.3427	39.7909	26.8664
15	33.6864	41.2799	25.0336
16	32.4847	39.3931	28.1222
17	31.8972	38.6663	29.4365
18	31.464	39.4831	29.0529
19	31.5173	38.0436	30.4391

20	*31.7774*	*43.563*	*24.6597*
21	*32.3932*	*42.2137*	*25.3931*
22	*33.3705*	*44.2317*	*22.3978*
23	*33.0878*	*43.5948*	*23.3175*
24	*34.5172*	*43.6232*	*21.8596*
25	*32.8954*	*45.1242*	*21.9804*
26	*34.7245*	*44.0847*	*21.1908*
27	*37.7085*	*44.7196*	*17.5719*

Table - 9
RGB Values for Turning Operation

S.No	*'R' Value*	*'G' Value*	*'B' Value*
1	*33.9877*	*39.4568*	*26.5555*
2	*35.8965*	*44.539*	*19.5645*
3	*33.5715*	*41.8569*	*24.5716*
4	*36.1261*	*41.8569*	*18.2716*
5	*39.6274*	*42.6024*	*13.6637*
6	*34.4797*	*41.709*	*26.7338*
7	*37.8757*	*38.7865*	*20.3456*
8	*39.1181*	*41.7788*	*18.4513*
9	*33.6592*	*42.4307*	*25.4028*
10	*34.5414*	*40.938*	*24.2131*
11	*30.4533*	*41.2455*	*28.927*
12	*33.5584*	*40.0576*	*26.384*
13	*31.6093*	*39.8741*	*28.5166*
14	*31.5467*	*40.3029*	*28.1504*
15	*31.1093*	*40.8512*	*28.0395*
16	*31.7459*	*41.5914*	*26.6627*
17	*33.4773*	*40.8836*	*25.639*
18	*33.7561*	*40.6223*	*25.6216*
19	*34.4646*	*40.4027*	*25.1327*
20	*33.8125*	*40.6552*	*25.5323*
21	*32.0488*	*41.4607*	*26.4906*
22	*33.3686*	*42.074*	*24.5574*
23	*33.5427*	*40.7325*	*25.7248*
24	*32.0567*	*40.7045*	*27.2388*
25	*34.8997*	*40.9951*	*24.1052*
26	*32.3069*	*41.1751*	*26.518*
27	*33.714*	*40.887*	*25.3991*

F. Code Generation for Surface Finish Prediction:

Using MATLAB a code is generated Through which the SVM and MSVR tools are called in the main program and the pictures taken to the work pieces at the three different positions are mapped to the Surface Finish and cutting parameters of the respective work pieces. The code generated in the MATLAB and the RGB values obtained. Each work piece will have a different RGB value when compared to that of the other and the range of values for turning, face milling and end milling will also differ from each other which helps us to differentiate the process.

III. RESULTS

- These RGB values are tabulated with their respective classes such that when the code is executed the program first displays the class of the test work piece given and then the name for the class and then the surface roughness, cutting parameters of the given test work piece.
- In order to check our model developed some random RGB values are taken from our data and given to the program and then executed where we get the class of the machining process i.e., Class “2” is fro End Milling Class “1” is fro Face Milling and Class “3” is for Turning. The name of the class is also displayed and the output surface finish values are displayed and the error percentage is calculated.
- The error percentage must be below 5% for an accurate model so that it can be used for further research process.

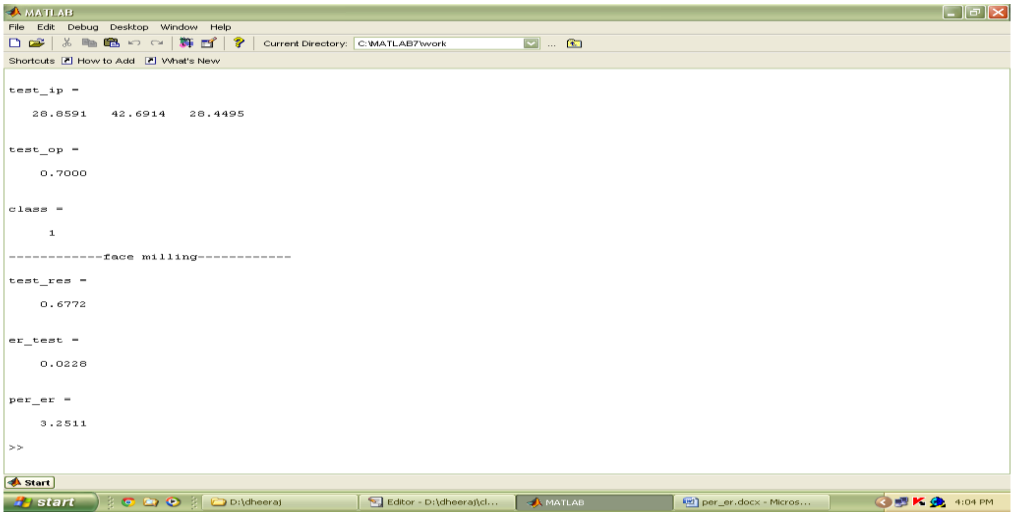

Fig. 5: Surface Finish Output of Face Milling Operation

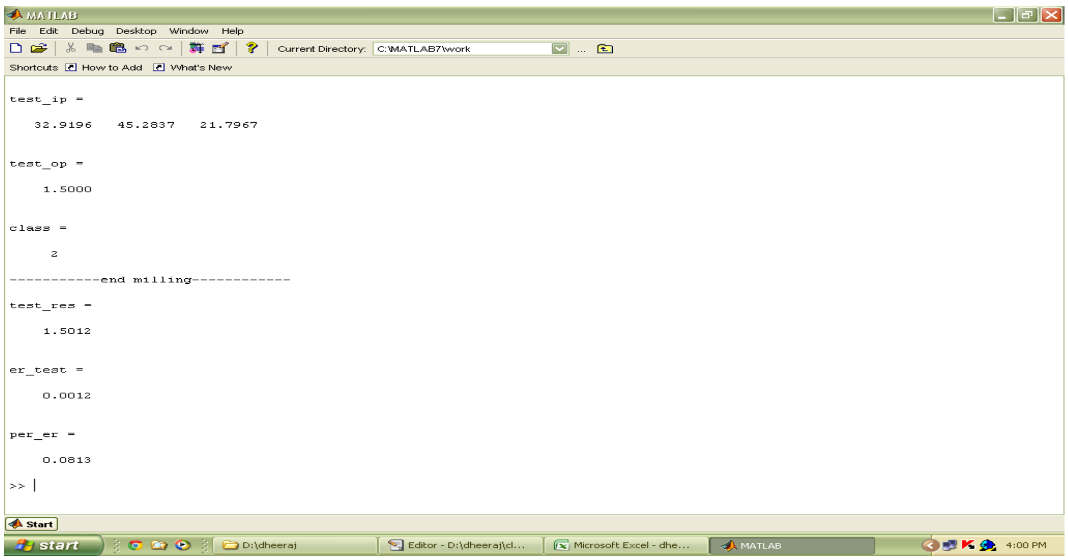

Fig. 6: Surface Finish Output of End Milling Operation

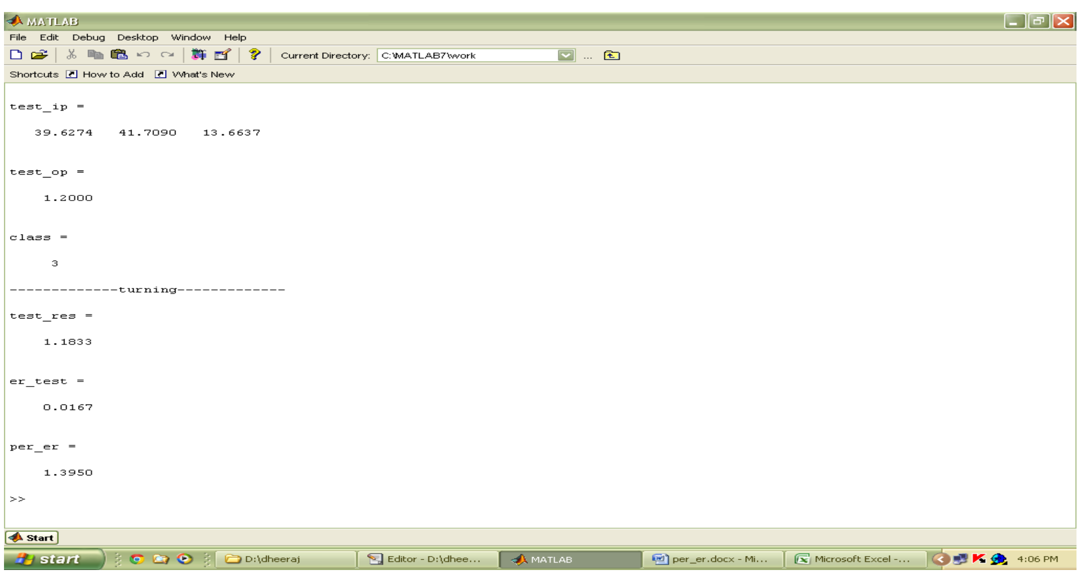

Fig. 7: Surface Finish Output of Turning Operation

Table 10:
Test Results

S.No.	*Machining Process*	*Generated RGB Values*	*Actual Surface Finish*	*Predicted Surface Finish*	*Percentage Error*
1	*Face Milling*	*28.8591* *42.6914* *28.4495*	*0.7*	*0.6772*	*3.2511*
2	*End Milling*	*32.9166* *42.6914* *28.4495*	*1.5*	*1.5012*	*0.0813*
3	*Turning*	*39.6274* *41.7090* *13.6637*	*1.2*	*1.1833*	*1.3950*

IV. CONCLUSION

An Intelligent MATLAB Model to predict the surface finish of any machined component has been developed. The machined processes that could be identified with this MATLAB Model are as follows:

- Face Milling Operation
- End Milling Operation
- Turning Operation

The MATAB model implements image processing techniques to predict the surface finish with a high degree of accuracy and precision. The surface finish has been predicted accurately with a slight error margin of 3.25% in the case of Face Milling Operation. Likewise, the surface finish of End Milling machined component has been predicted with an error of 0.081%. Similarly, the components machined in Turning Operation were predicted to possess a surface finish with an error of 1.39%.

This MATLAB model can be adapted to various other machining processes and all kinds of surfaces to predict their surface finish. This model would immensely help in reducing the time for measurement of surface finish as well as the requirement of skilled labor for the task. This would directly result in better production cycles and faster delivery of products at optimum costs.

REFERENCES

[1] Hasegawa, M., A. Seireg and R.A. Lindberg, 1976. "Surface roughness model for turning"". Tribology International, pp: 285-289.

[2] Mike, S.L., C. Joseph C. Chen and M. Li, 1998. "Surface roughness prediction for CNC End milling. Materials and processes quality control manufacturing". J. Ind. Technol., 15: 2-6. Myers, R.H. and D.C. Montgomery, 1995. Response Surface Methodology Process and Product Optimization Using Designed Experiments. 2nd Edn., John Wiley and Sons Inc., New York, USA.

[3] Ozel, T. and Y. Karpat, 2002. "Predictive modeling of surface roughness and tool wear in Hard turning using regression and neural networks"". Int. J. Mach. Tools Manuf., 42: 595-605.

[4] Suresh, P.V.S., K. Venkateswara Rao and S.G. Desmukh, 2002. " A genetic algorithm approach for optimization of the surface roughness prediction model. Int. J. Mach. Tools Manuf., 42: 675-680.

[5] P.G. Benardos, G.C. Vosniakos, 2002. " Prediction of surface roughness in CNC face milling using neural networks and Taguchi's design of experiments". Robotics and Computer-Integrated Manufacturing Vol. 18, Issues 5–6, October–December 2002, Pages 343–354

[6] Dae Kyun Baek, Tae Jo Ko, Hee Sool Kim, 1998. "A dynamic surface roughness model for face millinng". Precision Engineering Vol. 20, Issue 3, May 1997, Pages 171–178

[7] B. lela, D. Bajic', S. Jozic', 2008. "Regressoin analysis, support vector machine, and Bayesian neural network approaches to modeling surface roughness in face milling". Int J Adv Manuf Technol (2009) 42:1082-1088