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Machining Performance estimation Model Based on Vibrations

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Abstract: *Manufacturing industry poses several challenges in addressing tolerance for geometry, dimensional accuracy and surface finish. Former two can be controlled by integrating CAD-CAM and machining, whereas surface finishestimation need to be integrated and automated. A real time vibration based systems yet to be developed to control and monitor open architectural machine tools to achieve the desired surface finish. In this work an attempt has been made to develop a technology that could provide relation between overall vibration andsurface finish. A curve fitting model is developed to estimate surface finish. The results are encouraging and the estimation model is 99.9% accurate with very less percentile error. This model can use for estimation of surface finish and develop control systems for open architectural machine tools.*
Keywords*: Vibrations, Surface finish, Curve fitting Model.*

I. Introduction:

The need for quality components to meet the market demand has become essential in contemporary manufacturing. The components are usually quantified for their dimensional accuracy and surface finish for proper life of the components. Dimensional accuracy of the products can be measured in line with the manufacturing as said by many researchers. Co-ordinate measuring machines (CMM) can be used in line to measure the dimensional accuracy of the components manufactured. Surface finish even being prime factor cannot be measured real time in line with the manufacturing systems. Due to the advantages of computers and advanced computational tools developing adaptive system for open architectural machine toolsbecame easier. Systems as such can really reduce the number of trial errors experiments in achieving the required performances and in turn reducing the cost. Rapid Cam Approach is such a system developed by [1].

Conventional stylus probe instruments are used, human efforts and intervention is definite for measurement. The surface finish will be measured manually a destructive way where the probe physically moves on the component In order to overcome to this problem a vibration based evaluation technique for an open architectural machine tool is suggested to estimate the surface finish. Vibration affects the surface finish and in order to estimate the surface finish various elements of surface finish are selected Lin and Chang [1]. Surface finish depends on many parameters like rigidity of the machine tools used; tool geometry and its condition, type of cutting fluid used, machining conditions used like speed, feed and depth of cut (DOC) and even vibrations [2]. Vibration is the prime factor for determining the performance and tool wear in boring operations due to its tool length. Theeffect of cutting parameters on component vibration and surface finish are investigated [3].In processes surface finish estimation using vibration was done for turning of Ti-Al-V alloy. Vibrations are measured in multiple directions and a regression model is developed for the estimation of surface finish [4].Precision End Milling operation is performed and vibration signal is measured from the sensors and processed through singular spectrum analysis. Mathematical model is developed [5].

Turning operation is performed using diamond, tool vibration signal and surface roughness is measured. D-optimal technique is used to design the experimentation. Response surface methodology (RSM) is developed to mapping the data of vibration and surface roughness [6].Optimization of turning operation cutting parameters is done to achieve the desired surface roughness. Signal to noise ration and anova techniques are used for model development [7].High speed milling operations are performed and an online surface finish monitoring system is developed using artificial neural networks (ANN) [8].

Machining process is uncertain and complex; in order to estimate the performance of the machine tools several researched are using optimization tools for estimation in this author reviews various machining processes and computational tools used for estimation [9]. Ceramic tool is used for machining cast iron. Various elements of machining performance like Surface roughness, tool wear and vibration is measured. Surface roughness is at constant state even the progression of vibration and tool wear [10]. Turning operation is performed, surface roughness and vibration are measured while machining. A mathematical model is developed for mapping the roughness and vibration [11].

The main aim of this work is to develop an intelligent system that could estimate the machining performance from the vibrations. The purpose of this work is to develop system that could automatically estimate the surface finish online while the machining operation is performed. The vibration sensors connected to the machine table will be able to give the ready data to the open architectural machine tools. The data obtained can be feed to the advanced computational tools for optimization and estimating the performance ahead machining is done. Such systems reduces the off line destructive type of measurement of surface finish, reduce cost, time and human efforts. In open architectural machine tools intelligent system can even monitor the vibration signal from the sensors and auto compensate the cutting parameters in order to achieve the required performance [12 and 13].

II. Experimentation:

Milling operation is performed on aluminium on CNC Max-mill, cutter being Cloro-Mill R-245 from sandvick. The sandvick coated carbide insetsR245-12-T3-H10 are used for machining aluminium. The range of cutting parameters used for machining are selected from the sandvick catalogue as shown in the table 2.1. Five different speeds (S), feed rates (F) and depth of cut (DOC) are selected. Design expert D-optimal technique is used for generation of the machining data and totally 74 different experiments are performed.

Table 2.1 various cutting condition selected.

Sl.	Speed (rpm)	Feed (mm/min)	DOC (mm)
1	1560	470	0.1
2	1623	600	0.2
3	1688	750	0.3
4	1750	800	0.4
5	1815	1000	0.5

III. Surface Roughness Measurement:

A standard stylus probe instrument called Taly-surf is used for the measurement of the surface roughness. The stylus is held manually on the work piece and probe is made in contact with the surface of the work. The sampling length selected is 10mm and totally at three places on the work piece is measured for each and every workpiece in order to have a better average value of the surface roughness (SR). The surface roughness values for various cutting condition are shown in the table 4.1

IV. Vibration:

The overall vibrations (OV)of a face milling operation are measured using a FFT ANALYZER (DC-12MTester). The accelerometer is placed on the work table as shown in the Figure4.1.This tester combine's advanced technology with high precision and value for efficient measurement of vibrations in the work table. This probe is placed at work bench so as to gather the best possible information about the behavior of the work bench while face milling. The vibration OV values for various cutting conditions are shown in the table 4.1

Figure 4.1 the vibration accelerometer placed on work table.

Table 4.1

Sl.	S (rpm)	F (mm/min)	DOC (mm)	OV (m/s2)	SR (Microns)	Predicted SR	% Error
1	1623	750	0.1	0.03769	0.45	0.435	0.033
2	1688	870	0.1	0.03958	1.2	0.9	0.25
3	1560	870	0.1	0.04563	0.25	0.236	0.056
4	1750	1000	0.3	0.04973	0.3	0.286	0.047
5	1560	870	0.5	0.05559	0.6	0.6	0
6	1623	470	0.3	0.5498	0.45	0.35	0.222
7	1623	600	0.1	0.06703	0.4	0.4	0
8	1688	470	0.3	0.07898	0.35	0.35	0
9	1750	750	0.5	0.07992	0.4	0.4	0
10	1815	600	0.3	0.08026	0.2	0.199	0.006

11	1623	750	0.3	0.09876	0.35	0.35	0
12	1688	1000	0.3	0.908	0.4	0.4	0
13	1815	750	0.1	0.1127	0.4	0.389	0.028
14	1750	870	0.5	0.134	0.5	0.5	0
15	1560	600	0.1	0.1353	0.3	0.289	0.037
16	1815	750	0.3	0.1375	0.25	0.25	0
17	1688	600	0.3	0.1383	0.3	0.285	0.05
18	1560	470	0.1	0.1456	0.3	0.3	0
19	1560	1000	0.1	0.2104	0.3	0.44	0.467
20	1750	600	0.1	0.6789	0.65	0.65	0
21	1560	750	0.3	0.2305	0.58	0.6	0.034
22	1688	1000	0.5	0.234	0.7	0.6	0.143
23	1560	870	0.3	0.2546	0.5	0.3	0.4
24	1688	470	0.1	0.2357	0.3	0.4	0.333
25	1750	470	0.1	0.2641	0.4	0.4	0
26	1750	1000	0.5	0.6832	0.5	0.317	0.367
27	1560	1000	0.3	0.2952	0.7	0.7	0
28	1560	750	0.1	0.3138	0.4	0.397	0.008
29	1623	750	0.2	0.3512	0.5	0.498	0.004
30	1688	870	0.1	0.3654	0.5	0.5	0
31	1560	870	0.1	0.3865	0.3	0.3	0
32	1750	1000	0.3	0.76898	0.4	0.45	0.125
33	1560	870	0.5	0.4109	0.2	0.2	0
34	1623	470	0.3	0.456	0.5	0.498	0.004
35	1623	600	0.1	0.458	0.6	0.6	0
36	1688	470	0.3	0.4946	0.3	0.289	0.037
37	1750	750	0.5	0.5064	0.4	0.4	0
38	1815	600	0.3	0.5226	0.4	0.367	0.083
39	1623	750	0.3	0.4965	0.35	0.35	0
40	1688	1000	0.3	0.5498	0.3	0.35	0.167
41	1815	990	0.1	0.5768	0.7	0.7	0
42	1750	1000	0.5	0.6034	0.6	0.6	0
43	1560	601	0.1	0.6089	0.5	0.5	0
44	1815	750	0.3	0.6547	0.5	0.3	0.4
45	1689	600	0.3	1.019	0.5	0.5	0
46	1560	470	0.1	0.6852	0.25	0.317	0.267
47	1560	1000	0.1	0.6872	0.2	0.321	0.607
48	1750	600	0.1	0.5498	0.3	0.35	0.167
49	1560	750	0.3	0.65467	0.3	0.3	0
50	1688	1000	0.5	0.76898	0.5	0.45	0.1
51	1560	870	0.4	0.8425	0.4	0.4	0
52	1688	470	0.1	0.8562	0.6	0.6	0
53	1750	470	0.1	0.8569	0.5	0.5	0
54	1750	1000	0.5	1.786	0.6	0.6	0
55	1560	1000	0.3	1.386	0.4	0.4	0
56	1560	750	0.1	0.918	0.3	0.276	0.08
57	1623	750	0.3	0.8675	1.2	1.2	0
58	1688	870	0.1	1.004	0.5	0.5	0
59	1560	870	0.1	0.9568	0.3	0.278	0.073
60	1750	1000	0.3	1.634	0.5	0.5	0
61	1560	870	0.5	1.041	0.25	0.25	0
62	1623	470	0.3	1.059	0.7	0.68	0.003
63	1623	600	0.1	1.127	0.4	0.4	0
64	1688	470	0.3	0.986	0.6	0.6	0
65	1750	750	0.5	1.219	0.7	0.68	0.029
66	1815	600	0.3	1.763	0.4	0.378	0.055
67	1623	750	0.3	1.367	0.5	0.5	0
68	1688	1000	0.3	1.453	0.5	0.5	0
69	1815	1230	0.1	2.078	0.35	0.359	0.026
70	1750	1350	0.5	1.54	0.45	0.45	0
71	1560	602	0.1	1.345	0.4	0.4	0
72	1815	750	0.3	1.634	0.5	0.498	0.004
73	1690	600	0.3	1.98	0.3	0.3	0
74	1560	470	0.1	1.754	0.4	0.4	0

V. Curve Fitting:

The data obtained in machining is unique and it’s difficult to establish a correlation in manufacturing as it depends on several other parameters as said by many researches. In order to overcome such problems in manufacturing, advanced models are developed in order to establish a proper relationship. In this work the

Curve Fitting in MAT-Lab is basically used to establish anaffiliation. Curve fitting interpolates the uneven data into a plane and fits a smooth curve to these data points. This method is a unique the resultant curve passes through all the data points and appears to be natural and smooth. It's a polynomial function of third order piecewise at succeeding disruptions of the data given locally the slope is determined. Curve looks to be similar as that of the manually drawn curve and mathematically developed.

Based on the curve obtained for surface finish vs. Vibrations in MAT-LAB there exists a relationship between surface finish and vibrations. The curve that fits to both the output parameters is smoothing spline.The function that satisfies the fit is as follows and shown in equation (1).

F(x) =piece wise continuous computed at p. (1)

Where p varies between 0and1.

Based on function obtained incurve fitting module the predicted values of surface finish (f(x)) have been calculated using analysis technique in curve fitting module as shown in figure 5.1. Curve fitting model could predict the surface finish with average percentage of error of 0.06deviations as shown in table 4.1 and the model accuracy of 99.9%.

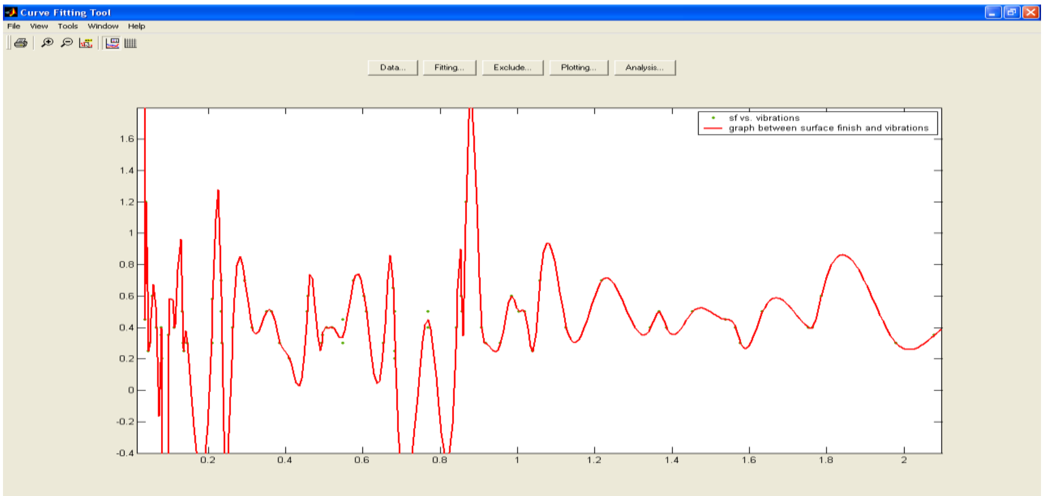

Figure 5.1 MAT-LAB Curve fitting model.

VI. Result:

In this work the objective is to develop an intelligent system that could predict the machining performances using machine table vibration signal. The system of this type being rare was the motivation factor to this work. In this work face milling operation is performed on aluminium work piece. Five different cutting conditions like S, F and DOC are selected, design of experiments are conducted using design expert and totally 74 different experiments are performed. Surface roughness and overall vibration signal is measured for each experiment. Curve fitting model is developed in MAT-LAB for mapping the vibration and surface roughness obtained. The vibration values are given as input to the model and surface roughness is estimated. The results are encouraging the average percentile error is as low as 0.06. This model can be developed and implemented in open architectural machine tools for estimating the surface finish automatically without any human intervention.

VII. Conclusion:

In this work an attempt has been made to develop an intelligent system for open architectural machine tools for estimating the machining performance from online measured vibration. This system will help in reducing the human interventions, efforts, cost, ideal time and even the process being nondestructive no scratches are formed unlike conventional stylus probe instruments. As vibration signal can be measured online while machining operation is being performed. The signal can be sent to the modules that are developed in open architectural machine tools to monitor and control the machine tool by adjusting the cutting parameters in order to achieve the desired surface finish.The model estimated with better accuracy and can be used in developing Rapid-Cam approaches where the product design to the final product can be prototyped in an individual machine tool.

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