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# Effects of Cutting Tool Parameters on Surface Roughness

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**Abstract:-** This paper presents of the influence on surface roughness of Co28Cr6Mo medical alloy machined on a CNC lathe based on cutting parameters (rotational speed, feed rate, depth of cut and nose radius).The influences of cutting parameters have been presented in graphical form for understanding. To achieve the minimum surface roughness, the optimum values obtained for rpm, feed rate, depth of cut and nose radius were respectively, 318 rpm, 0,1 mm/rev, 0,7 mm and 0,8 mm. Maximum surface roughness has been revealed the values obtained for rpm, feed rate, depth of cut and nose radius were respectively, 318 rpm, 0,25 mm/rev, 0,9 mm and 0,4 mm.

**Keywords:-** Co28Cr6Mo, Cutting Parameters, Machinability, Surface roughness.

## I. INTRODUCTION

With the advancing technology, chip cutting based machining (turning, milling, drilling etc.) methods still conserve their importance. Steel materials used in manufacturing industries keep improving progressively. Steel enjoys its diverse applications in areas such as food industry, health sector, automotive industry and space craft industry. It is for this reason that researches involving machinability of steel materials, their manufacturing efficiency and cost reduction are still among the most important studies [1]. Yallese et al.[2], specified statistical models of cutting forces in dry turning operation of AISI H11 hot work-piece steel (50 HRC). To achieve this, they carried out 27 experiments and specified effects of parameters like cutting speed, feed rate and depth of cut. Ultimately; they came out with the result that the most important factor affecting the components of the cutting forces is depth of cut. Aouici et al. [3], conducted a study where they used CBN tools to machine AISI H11 steel (X38CrMoV5-1) and under cutting force conditions they measured tool wear and values of the surface roughness. In that study, it was found that in tool wear, the most influential factor is cutting time interval while for surface roughness, the feed rate was the most effective parameter. Suresh et al. [4], investigated effects of cutting speed, feed rate, depth of cut and machining time on cutting forces, tool wear and surface roughness during turning operation of an AISI 4340 hardened steel by using the RSM method. They stressed that in order to minimize cutting force and surface roughness, it is necessary that high cutting speed, low feed rate, low depth of cut and short machining time are employed whereas minimization of tool wear requires low feed rate and low cutting speed.

In their study, Chavoshi and Tajdari [5], machined AISI 4140 steel with CBN cutting tool on a lathe and with hardness (H) and cutting rate as variables, they measured $Ra$ values. The feed rate and depth of cut were kept constant. They found that hardness has significant effect on surface roughness. In another study by Aruna et al. [6], Taguchi and RSM optimisation methods were used for the purpose of optimizing cutting parameters with respect to the data obtained from high speed lathe machining of INCONEL 718 material, a nickel based super alloy by making use of cermet cutting tools. It was then determined that the most effective parameter affecting surface roughness and tool wear is the cutting speed. Sahoo [7], conducted an experimental study to investigate effects of cutting speed, feed rate and depth of cut on the formation of surface roughness for AISI 1040 steel when the material was machined on a CNC turning machine (lathe). ANOVA analysis was used in order to specify the role of three input parameters and genetic algorithm was used for the purpose of optimising the parameter results.

In another study Zhou et.al. [8] found that the application of a 5% semi-synthetic emulsion reduced surface damages of Inconel 718 under high speed turning conditions with ceramic tools. Sahin and Motorcu [9] presented a paper in which the surface roughness model was developed in terms of main cutting parameters such as cutting speed, feed rate and depth of cut, using response surface methodology. Machining tests were carried out in turning AISI 1050 hardened steels by cubic boron nitride (CBN) cutting tools under different conditions. The model predicting equations for surface roughness of $R$a, $R$z and $R$max were developed using an experimental data when machining steels. The results indicate that the feed rate was found out to be dominant factor on the surface roughness, but it decreased with decreasing cutting speed, feed rate, and depth of cut for these tools. In addition, average surface finish of $R$a value produced by CBN cutting tool was about 0.823 µm when machining hardened steels. However, the $R$a value decreased about 0.55 µm in terms of trial conditions.

In order to produce any machine part at a certain quality by any metal removal technique, cutting parameters should be arranged properly. Dependent upon work piece material and geometry to be desired, surface roughness has important influence on determining the machining cost related to nose radius, rake angle, clearance angle, cutting speed, feed rate, unformed chip thickness, cutting tool material etc. [10,11]. In metal removal operations, many researches were carried out in the past and many are continuing for the purpose of decreasing production cost without reducing product quality. It was seen in all works on surface roughness by chip removal methods that the surface roughness is influenced by cutting parameters such as nose radius, clearance angle, cutting speed, feed rate, depth of cut, rake angle [12].

Many researchers spent effort to determine optimum tool combination of rake angle, clearance angle, cutting speed, feed rate, depth of cut and nose radius for better surface finish. Problems during cutting process have been reduced to an acceptable level by transferring computer knowledge for CNC turning machine [13].

In this study involves the influence of rotational speed, feed rate, depth of cut and nose radius on surface roughness was determined during machining of Co28Cr6Mo medical alloy. A computer numerical controlled (CNC) machine is used for machining Co28Cr6Mo medical alloy in the present study.

## II. EXPERIMENTAL WORK

### 2.1. Machining conditions and roughness measurements

In the experimental study an annealed Co28Cr6Mo ASTM F 1537 steel having hardness of 40 HRC was used. The specimen with dimensions of Ø50x500 mm was prepared. Turning process was carried out on a TC25-L type Sogotec CNC lathe and surface roughness values were measured on a SJ-201 mitutoyo device (with cut-off distance of 2.5 mm). The tests were conducted under dry machining conditions and in every test a new cutting bit was used to machine longitudinally along the work-piece. The tool holder used was MTJNR-L 2525 M16, cutting bits were TNMG 160404 MT, TNMG 160408 MT and TNMG 160412 MT form produced by Taegutec company and cladded with TiCN by the PVD method and at the quality of TT 8020. With the recommendations from the manufacturer cutting parameters given on Table 1 were specified then the experiments were conducted by using combinations of parameters presented on Table 2. At the end of every feed of turning operation, average surface roughness values were taken on three sections of the cylindrical surface along the work-piece. Mitutoyo SJ-201 measuring device (cut-off gap 2.5 mm) was used for the roughness measurements.

**Table 1. Cutting parameters and their levels**

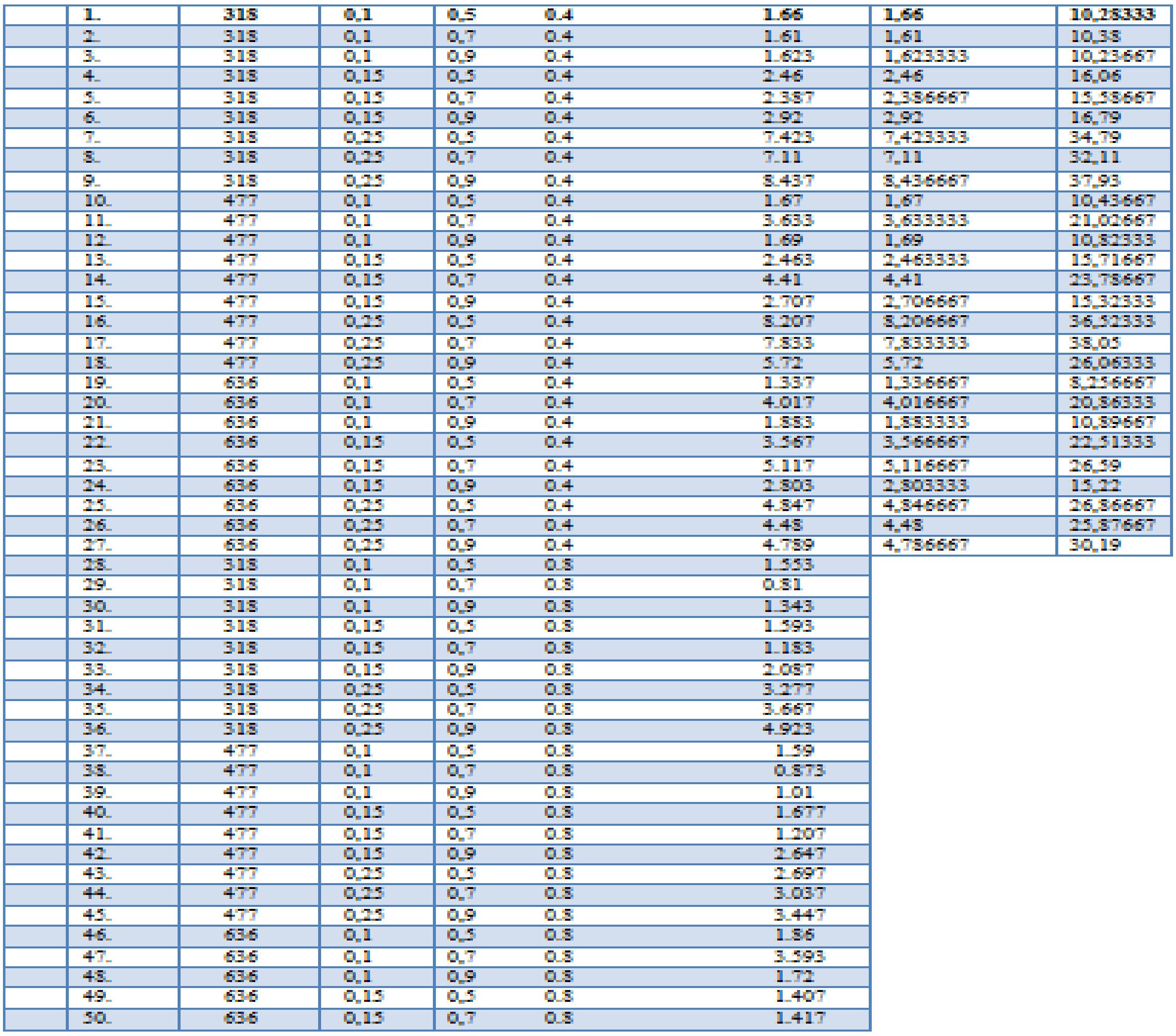
| **Symbol** | Parameter | Unit | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|---|
| ***n*** | Rotational speed | rpm | 318 | 477 | 636 |
| ***f*** | Feed rate | mm/rev | 0.1 | 0.15 | 0.25 |
| ***a*** | Depth of cut | mm | 0.5 | 0.7 | 0.9 |
| ***r*** | Nose radius | mm | 0.4 | 0.8 | 1.2 |

### 2.2. Experimental Design

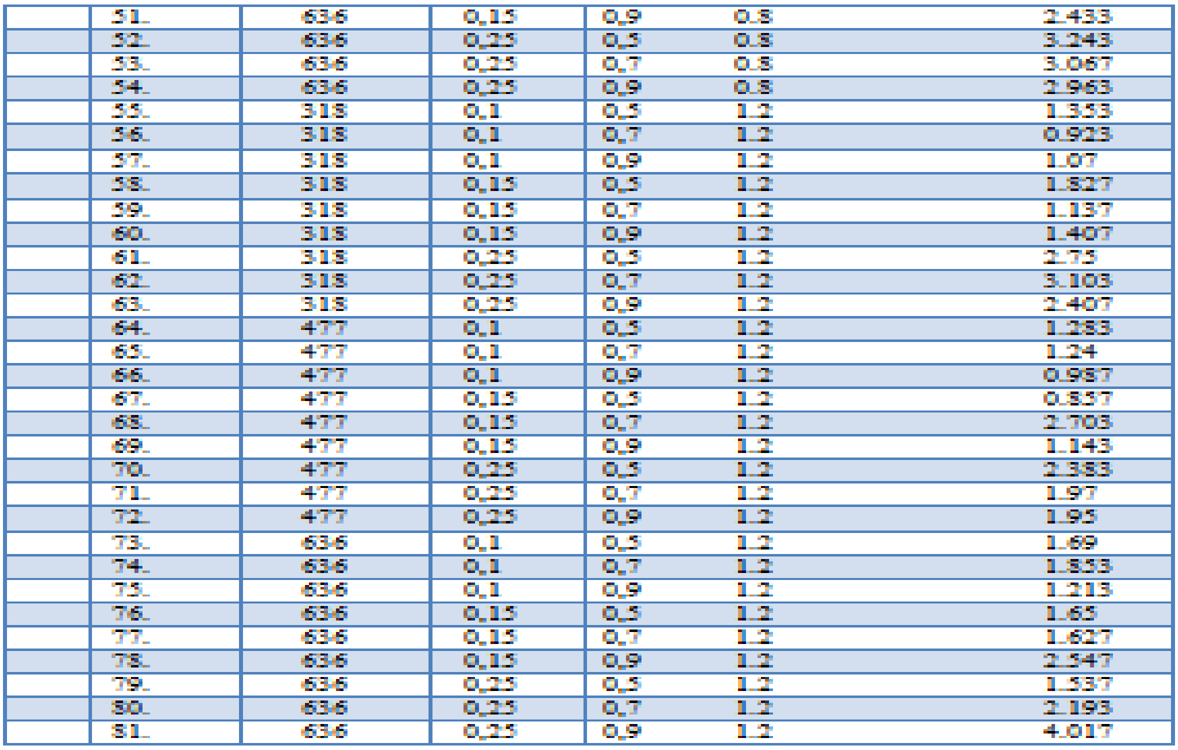
In this study, a total of 81 physical experiments were conducted. The design arrangement suitable for the study carried out ($3^4$) together with its corresponding reactions is given in Table 2. The first parameter column of the table shows the rpm (*n*), the second column gives feed rate (*f*), the third column is for depth of cut (*a*) and the last column lists the nose radius (*r*). The farthermost right of the table is the roughness values *R*a.

**Table 2. Experimental parameters and the recorded average roughness values.**

| **Number of tests** | Parameter | | | | | Roughness | |
|---|---|---|---|---|---|---|---|
| | *n* (rpm) | *f* (mm/rev) | *a* (mm) | *r* (mm) | | *R*a (µm) | |



| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1. | 318 | 0,1 | 0,5 | 0.4 | 1.66 | 1,66 | 10,28333 |
| | 2. | 318 | 0,1 | 0,7 | 0.4 | 1.61 | 1,61 | 10,38 |
| | 3. | 318 | 0,1 | 0,9 | 0.4 | 1.623 | 1,623333 | 10,23667 |
| | 4. | 318 | 0,15 | 0,5 | 0.4 | 2.46 | 2,46 | 16,06 |
| | 5. | 318 | 0,15 | 0,7 | 0.4 | 2.387 | 2,386667 | 15,58667 |
| | 6. | 318 | 0,15 | 0,9 | 0.4 | 2.92 | 2,92 | 16,79 |
| | 7. | 318 | 0,25 | 0,5 | 0.4 | 7.423 | 7,423333 | 34,79 |
| | 8. | 318 | 0,25 | 0,7 | 0.4 | 7.11 | 7,11 | 32,11 |
| | 9. | 318 | 0,25 | 0,9 | 0.4 | 8.437 | 8,436667 | 37,93 |
| | 10. | 477 | 0,1 | 0,5 | 0.4 | 1.67 | 1,67 | 10,43667 |
| | 11. | 477 | 0,1 | 0,7 | 0.4 | 3.633 | 3,633333 | 21,02667 |
| | 12. | 477 | 0,1 | 0,9 | 0.4 | 1.69 | 1,69 | 10,82333 |
| | 13. | 477 | 0,15 | 0,5 | 0.4 | 2.463 | 2,463333 | 15,71667 |
| | 14. | 477 | 0,15 | 0,7 | 0.4 | 4.41 | 4,41 | 23,78667 |
| | 15. | 477 | 0,15 | 0,9 | 0.4 | 2.707 | 2,706667 | 15,32333 |
| | 16. | 477 | 0,25 | 0,5 | 0.4 | 8.207 | 8,206667 | 36,52333 |
| | 17. | 477 | 0,25 | 0,7 | 0.4 | 7.833 | 7,833333 | 38,05 |
| | 18. | 477 | 0,25 | 0,9 | 0.4 | 5.72 | 5,72 | 26,06333 |
| | 19. | 636 | 0,1 | 0,5 | 0.4 | 1.337 | 1,336667 | 8,256667 |
| | 20. | 636 | 0,1 | 0,7 | 0.4 | 4.017 | 4,016667 | 20,86333 |
| | 21. | 636 | 0,1 | 0,9 | 0.4 | 1.883 | 1,883333 | 10,89667 |
| | 22. | 636 | 0,15 | 0,5 | 0.4 | 3.567 | 3,566667 | 22,51333 |
| | 23. | 636 | 0,15 | 0,7 | 0.4 | 5.117 | 5,116667 | 26,59 |
| | 24. | 636 | 0,15 | 0,9 | 0.4 | 2.803 | 2,803333 | 15,22 |
| | 25. | 636 | 0,25 | 0,5 | 0.4 | 4.847 | 4,846667 | 26,86667 |
| | 26. | 636 | 0,25 | 0,7 | 0.4 | 4.48 | 4,48 | 25,87667 |
| | 27. | 636 | 0,25 | 0,9 | 0.4 | 4.789 | 4,786667 | 30,19 |
| | 28. | 318 | 0,1 | 0,5 | 0.8 | 1.553 | | |
| | 29. | 318 | 0,1 | 0,7 | 0.8 | 0.81 | | |
| | 30. | 318 | 0,1 | 0,9 | 0.8 | 1.343 | | |
| | 31. | 318 | 0,15 | 0,5 | 0.8 | 1.593 | | |
| | 32. | 318 | 0,15 | 0,7 | 0.8 | 1.183 | | |
| | 33. | 318 | 0,15 | 0,9 | 0.8 | 2.087 | | |
| | 34. | 318 | 0,25 | 0,5 | 0.8 | 3.277 | | |
| | 35. | 318 | 0,25 | 0,7 | 0.8 | 3.667 | | |
| | 36. | 318 | 0,25 | 0,9 | 0.8 | 4.923 | | |
| | 37. | 477 | 0,1 | 0,5 | 0.8 | 1.59 | | |
| | 38. | 477 | 0,1 | 0,7 | 0.8 | 0.873 | | |
| | 39. | 477 | 0,1 | 0,9 | 0.8 | 1.01 | | |
| | 40. | 477 | 0,15 | 0,5 | 0.8 | 1.677 | | |
| | 41. | 477 | 0,15 | 0,7 | 0.8 | 1.207 | | |
| | 42. | 477 | 0,15 | 0,9 | 0.8 | 2.647 | | |
| | 43. | 477 | 0,25 | 0,5 | 0.8 | 2.697 | | |
| | 44. | 477 | 0,25 | 0,7 | 0.8 | 3.037 | | |
| | 45. | 477 | 0,25 | 0,9 | 0.8 | 3.447 | | |
| | 46. | 636 | 0,1 | 0,5 | 0.8 | 1.86 | | |
| | 47. | 636 | 0,1 | 0,7 | 0.8 | 3.393 | | |
| | 48. | 636 | 0,1 | 0,9 | 0.8 | 1.72 | | |
| | 49. | 636 | 0,15 | 0,5 | 0.8 | 1.407 | | |
| | 50. | 636 | 0,15 | 0,7 | 0.8 | 1.417 | | |



| | | | | | | |
|---|---|---|---|---|---|---|
| | 51. | 636 | 0,15 | 0,9 | 0.8 | 2.433 |
| | 52. | 636 | 0,25 | 0,5 | 0.8 | 3.243 |
| | 53. | 636 | 0,25 | 0,7 | 0.8 | 3.067 |
| | 54. | 636 | 0,25 | 0,9 | 0.8 | 2.963 |
| | 55. | 318 | 0,1 | 0,5 | 1.2 | 1.353 |
| | 56. | 318 | 0,1 | 0,7 | 1.2 | 0.923 |
| | 57. | 318 | 0,1 | 0,9 | 1.2 | 1.07 |
| | 58. | 318 | 0,15 | 0,5 | 1.2 | 1.827 |
| | 59. | 318 | 0,15 | 0,7 | 1.2 | 1.137 |
| | 60. | 318 | 0,15 | 0,9 | 1.2 | 1.407 |
| | 61. | 318 | 0,25 | 0,5 | 1.2 | 2.75 |
| | 62. | 318 | 0,25 | 0,7 | 1.2 | 3.103 |
| | 63. | 318 | 0,25 | 0,9 | 1.2 | 2.407 |
| | 64. | 477 | 0,1 | 0,5 | 1.2 | 1.283 |
| | 65. | 477 | 0,1 | 0,7 | 1.2 | 1.24 |
| | 66. | 477 | 0,1 | 0,9 | 1.2 | 0.987 |
| | 67. | 477 | 0,15 | 0,5 | 1.2 | 0.857 |
| | 68. | 477 | 0,15 | 0,7 | 1.2 | 2.703 |
| | 69. | 477 | 0,15 | 0,9 | 1.2 | 1.143 |
| | 70. | 477 | 0,25 | 0,5 | 1.2 | 2.383 |
| | 71. | 477 | 0,25 | 0,7 | 1.2 | 1.97 |
| | 72. | 477 | 0,25 | 0,9 | 1.2 | 1.95 |
| | 73. | 636 | 0,1 | 0,5 | 1.2 | 1.69 |
| | 74. | 636 | 0,1 | 0,7 | 1.2 | 1.853 |
| | 75. | 636 | 0,1 | 0,9 | 1.2 | 1.213 |
| | 76. | 636 | 0,15 | 0,5 | 1.2 | 1.65 |
| | 77. | 636 | 0,15 | 0,7 | 1.2 | 1.627 |
| | 78. | 636 | 0,15 | 0,9 | 1.2 | 2.547 |
| | 79. | 636 | 0,25 | 0,5 | 1.2 | 1.537 |
| | 80. | 636 | 0,25 | 0,7 | 1.2 | 2.193 |
| | 81. | 636 | 0,25 | 0,9 | 1.2 | 4.017 |

## III. RESULTS AND ANALYSIS

### 3.1. Influence of Nose Radius on Surface Roughness

#### 3.1.1. Graphs of Surface Roughness for n=318 rpm, f= 0,1-0,15-0,25 mm/rev

In Fig.1, graphs of surface roughness are shown in the nose radius (0,4-0,8-1,2 mm), *n* = 318 rev/min, *f* = 0.1-0,15-0,25 mm/rev, and *a* = 0,5-0,7-0,9 mm.

*n* = 318 rev/min, *f* = 0.1 mm/rev, and *a* = 0,5 mm, nose radius of the tool was increased, value of surface roughness was decreased.

*n* = 318 rev/min, *f* = 0.1 mm/rev, and *a* = 0,7 mm, nose radius of the tool was increased 0.4 to 0.8 mm, value of surface roughness is suddenly decreased; nose radius of the tool was increased 0.8 to 1.2 mm, there wasn't a significant increase in value of surface roughness.

In the same way, *n* = 318 rev/min, *f* = 0.1 mm/rev, and *a* = 0,9 mm, nose radius of the tool was increased 0.4 to 0.8 mm, value of surface roughness was suddenly decreased; nose radius of the tool was increased 0.8 to 1.2 mm, there wasn't a significant increase in value of surface roughness.

*n* = 318 rev/min, *f* = 0.15 mm/rev, and *a* = 0,5 mm, nose radius of the tool was increased 0.4 to 0.8 mm, value of surface roughness was suddenly decreased; nose radius of the tool was increased 0.8 to 1.2 mm, there wasn't a significant increase in value of surface roughness.

*n* = 318 rev/min, *f* = 0.15 mm/rev, and *a* = 0,7 mm, nose radius of the tool was increased 0.4 to 0.8 mm, value of surface roughness was suddenly decreased; nose radius of the tool was increased 0.8 to 1.2 mm, there wasn't a significant decrease in value of surface roughness.

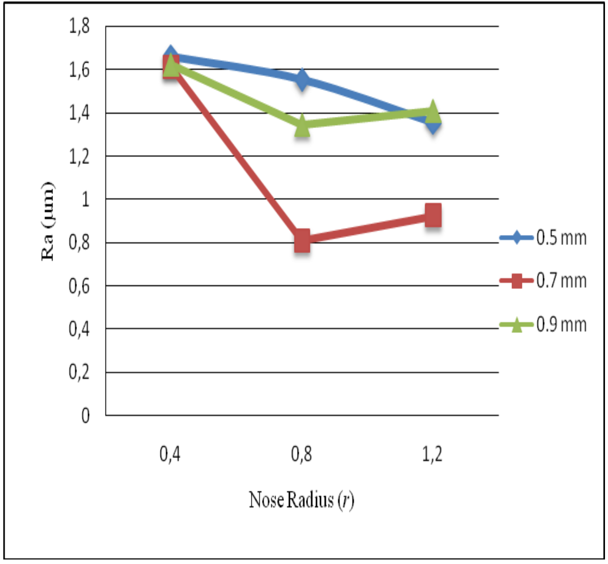
*n* = 318 rev/min, *f* = 0.15 mm/rev, and *a* = 0,9 mm, value of surface roughness was decreased with increase in nose radius.

*n* = 318 rev/min, *f* = 0.25 mm/rev, and *a* = 0,5 mm, nose radius of the tool was increased 0.4 to 0.8 mm, value of surface roughness was suddenly decreased; nose radius of the tool was increased 0.8 to 1.2 mm, there wasn't a significant decrease in roughness values.

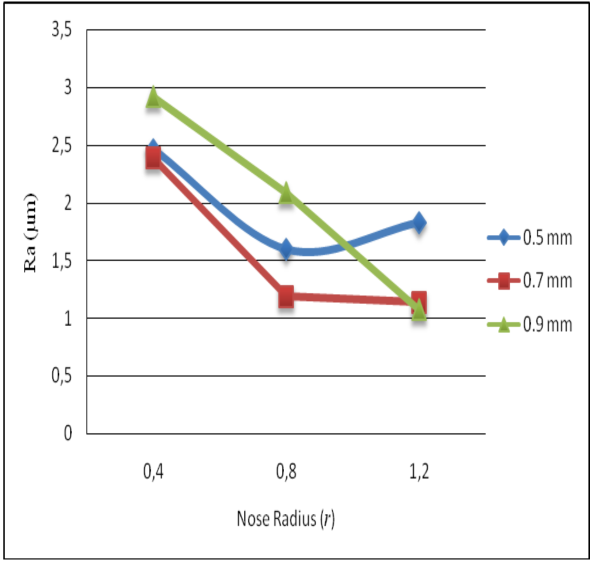
*n* = 318 rev/min, *f* = 0.25 mm/rev, and *a* = 0,7 mm, nose radius of the tool was increased 0.4 to 0.8 mm, value of surface roughness was suddenly decreased; nose radius of the tool was increased 0.8 to 1.2 mm, there wasn't a significant decrease in value of surface roughness.

*n* = 318 rev/min, *f* = 0.25 mm / rev, and *a* = 0,9 mm, value of surface roughness was decreased with increase in nose radius.

**f= 0,1 mm/rev**



**f= 0,15 mm/rev**



**f= 0,25 mm/rev**

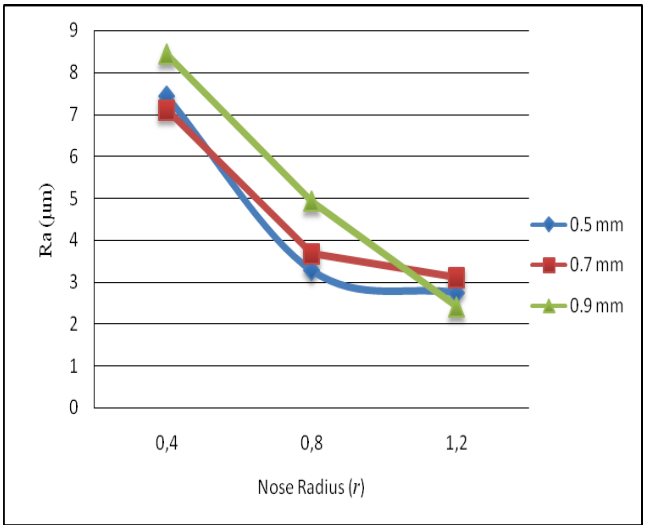


**Figure 1. Graphs of Surface Roughness for *n*=318 rpm, *f*= 0,1-0,15-0,25 mm/rev**

### 3.1.2. Graphs of Surface Roughness for n=477 rpm, f= 0,1-0,15-0,25 mm/rev

In Fig.2, graphs of surface roughness are shown in the nose radius (0,4-0,8-1,2 mm), *n* = 477 rev/ min, *f* = 0.1-0,15-0,25 mm / rev, and *a* = 0,5-0,7-0,9 mm.

*n* = 477 rev/min, *f* = 0.1 mm/rev, and *a* = 0,5 mm, nose radius of the tool was increased, value of surface roughness was decreased.

*n* = 477 rev/min, *f* = 0.1 mm/rev, and *a* = 0,7 mm, nose radius of the tool was increased 0.4 to 0.8 mm, value of surface roughness was suddenly decreased; nose radius of the tool was increased 0.8 to 1.2 mm, there wasn't a significant increase in value of surface roughness.

*n* = 477 rev/min, *f* = 0.1 mm/rev, and *a* = 0,9 mm, value of surface roughness was decreased with increase in nose radius.

*n* = 477 rev/min, *f* = 0.15 mm/rev, and *a* = 0,5 mm, nose radius of the tool was increased, value of surface roughness was decreased.

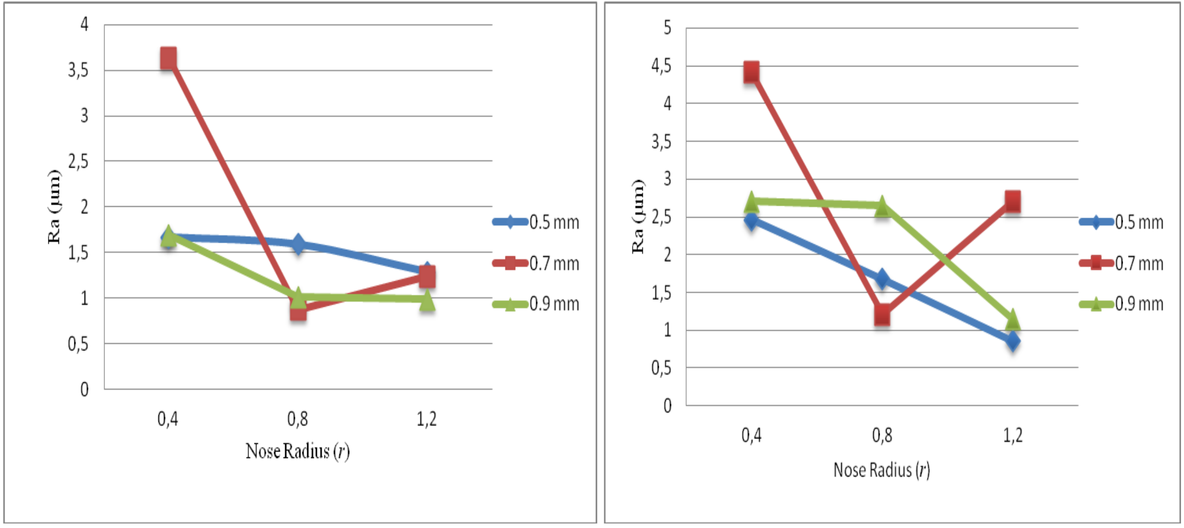
*n* = 477 rev/min, *f* = 0.15 mm/rev, and *a* = 0,7 mm, nose radius of the tool was increased 0.4 to 0.8 mm, value of surface roughness was suddenly decreased; nose radius of the tool was increased 0.8 to 1.2 mm, value of surface roughness was suddenly increased.

*n* = 477 rev/min, *f* = 0.15 mm/rev, and *a* = 0,9 mm, value of surface roughness was decreased with increase in nose radius.

*n* = 477 rev/min, *f* = 0.25 mm/rev, and *a* = 0,5 mm, nose radius of the tool was increased 0.4 to 0.8 mm, value of surface roughness was suddenly decreased; nose radius of the tool was increased 0.8 to 1.2 mm, there wasn't a significant decrease in value of surface roughness.

*n* = 477 rev/min, *f* = 0.25 mm/rev, and *a* = 0,7 mm, nose radius of the tool was increased 0.4 to 0.8 mm, value of surface roughness was suddenly decreased; nose radius of the tool was increased 0.8 to 1.2 mm, value of surface roughness was decreased.

*n* = 477 rev/min, *f* = 0.25 mm/rev, and *a* = 0,9 mm, value of surface roughness was decreased with increase in nose radius.



**f= 0,1 mm/rev** **f= 0,15 mm/rev**

**f= 0,25 mm/rev**

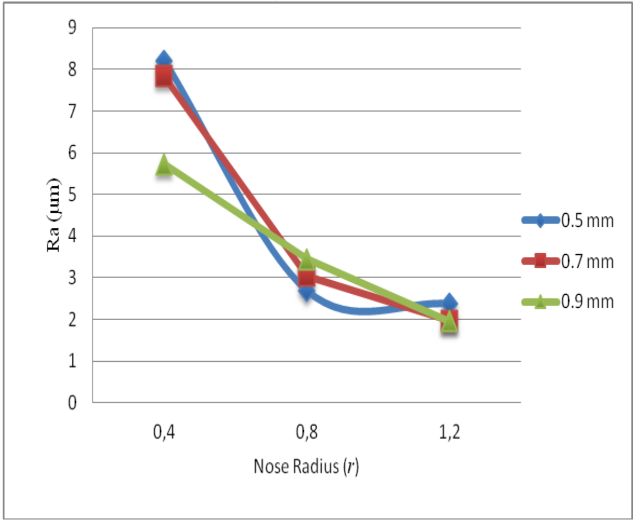


**Figure 2. Graphs of Surface Roughness for *n*=477 rpm, *f*= 0,1-0,15-0,25 mm/rev**

### 3.1.3. Graphs of Surface Roughness for n=636 rpm, f= 0,1-0,15-0,25 mm/rev

In Fig.3, graphs of surface roughness are shown in the nose radius (0,4-0,8-1,2 mm), *n* = 636 rev/min, *f* = 0.1-0,15-0,25 mm/rev, and *a* = 0,5-0,7-0,9 mm.

*n* = 636 rev/min, *f* = 0.1 mm/rev, and *a* = 0,5 mm, nose radius of the tool was increased 0.4 to 0.8 mm, value of surface roughness was decreased; nose radius of the tool was increased 0.8 to 1.2 mm, value of surface roughness was decreased.

*n* = 636 rev/min, *f* = 0.1 mm/rev, and *a* = 0,7 mm, value of surface roughness was decreased with increase in nose radius.

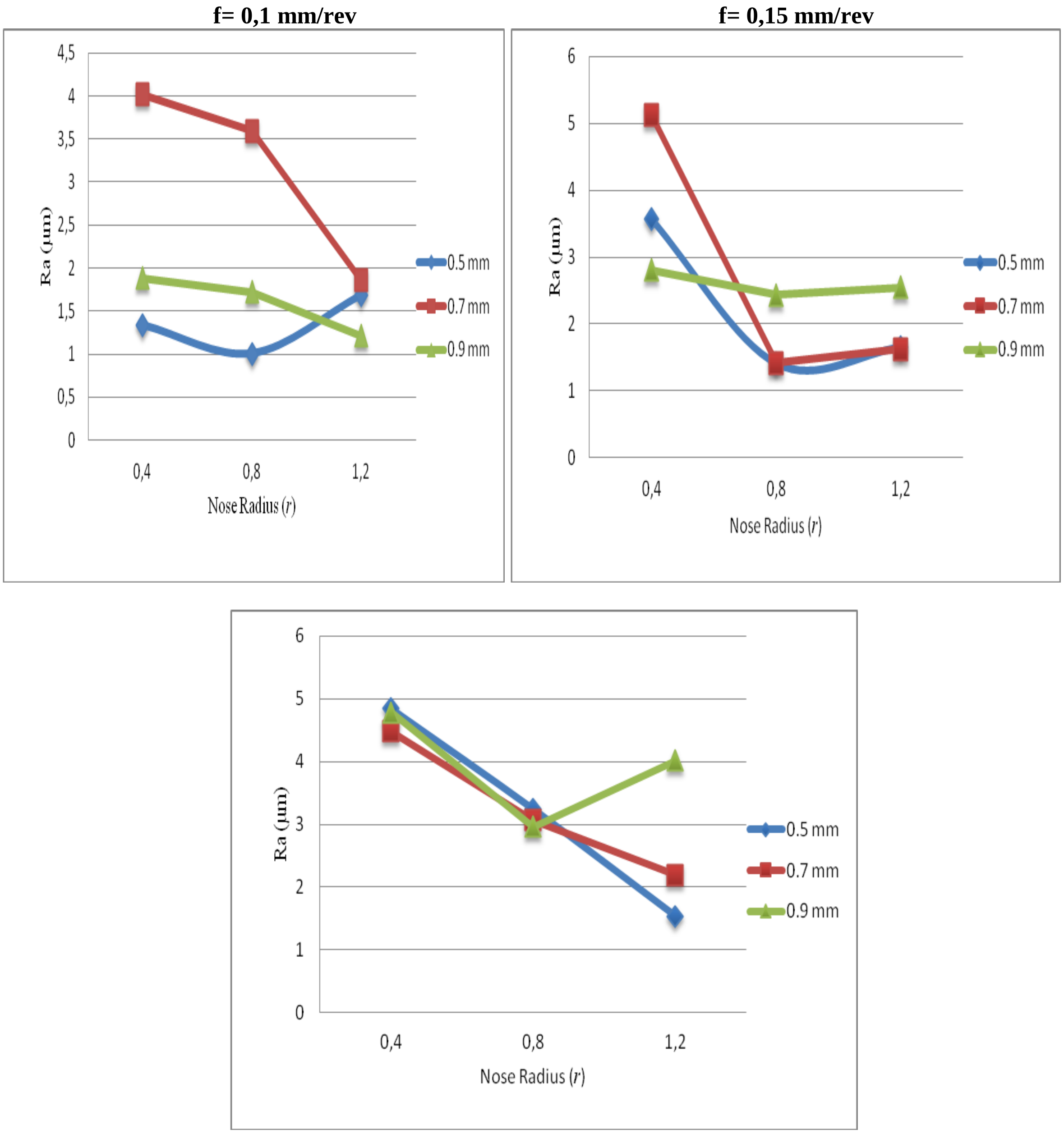
In the same way, *n* = 636 rev/min, *f* = 0.1 mm/rev, and *a* = 0,9 mm, value of surface roughness was decreased with increase in nose radius.

*n* = 636 rev/min, *f* = 0.15 mm/rev, and *a* = 0,5-0,7-0,9 mm, nose radius of the tool was increased 0.4 to 0.8 mm, value of surface roughness was suddenly decreased; nose radius of the tool was increased 0.8 to 1.2 mm, there wasn't a significant increase in value of surface roughness.

*n* = 636 rev/min, *f* = 0.25 mm/rev, and *a* = 0,5 mm, nose radius of the tool was increased, value of surface roughness was decreased.

In the same way, *n* = 636 rev/min, *f* = 0.25 mm/rev, and *a* = 0,7 mm, value of surface roughness was decreased with increase in nose radius.

*n* = 636 rev/min, *f* = 0.25 mm/rev, and *a* = 0,9 mm nose radius of the tool was increased 0.4 to 0.8 mm, value of surface roughness was suddenly decreased; nose radius of the tool was increased 0.8 to 1.2 mm, value of surface roughness was suddenly increased.



**f= 0,1 mm/rev**

**f= 0,15 mm/rev**

**Figure 3. Graphs of Surface Roughness for *n*=636 rpm, *f*= 0,1-0,15-0,25 mm/rev**

## IV. CONCLUSION

Surface roughness usually decreases with increase in nose radius. The minimum value of surface roughness obtained is 0.81 µm at *n*= 318 rpm, *f*= 0,1 mm/rev, a= 0,7 mm and r= 0.8 mm. Maximum value of surface roughness is 8.437 µm at *n*= 318 rpm, *f*= 0,25 mm/rev, a= 0,9 mm and r= 0.4 mm.

The relationship between cutting speed and surface roughness is inversely proportional. Generally, increasing the cutting speed decreases the surface roughness. The relationship between feed rate and surface roughness is proportional. Generally, increasing the feed rate increases the surface roughness. The relationship between depth of cut and surface roughness is proportional. Generally, increasing the depth of cut increases the surface roughness. The relationship between nose radius and surface roughness is inversely proportional. Generally, increasing the nose radius decreases the surface roughness.

## ACKNOWLEDGEMENTS

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