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Influence of Machining Parameter on Surface Roughness and Tool Life While Machining EN24 Grade Alloy Steel

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Abstract

The requirements of high quality machined surface as well as demand of enhanced contact time of cutting tools drive towards adopting multilayer coated carbide inserts. The industry requires higher productivity, hence higher machining parameters need to be used in order to meet the industry requirements. The alloy steel material used to fabricate machine parts consists of alloying elements like nickel, chromium and molybdenum difficult to machine, since the cutting tool fails by high tool wear, if we use uncoated carbide inserts to machine alloy steels. Hence in the present research work it is intended to use tungsten carbide inserts coated with different coatings for the experiments. The turning experiments were carried out using different grades of uncoated and coated carbide inserts of identical tool signature. The cutting speed selected for the experiments was 100 to 500 m/min in steps of 100 m/min, and the feed per revolution was 0.1 mm to 0.4 mm in step of 0.1 mm. The experimentation was carried out following ISO3685 standards. The results of the experiments revealed that the surface roughness measured was the least at cutting speed 500 m/min and feed per revolution of 0.1 mm, however the chip breaking found better when the feed used was greater than 0.2 mm/revolution.

Keywords

EN24, Uncoated Inserts, Coated Inserts, Turning, Surface Roughness, Tool Life Test

1. Introduction

Turning operation is carried out to produce cylindrical parts used in manufacturing sector; however the surface texture of the work piece as required by the assembly can be obtained when proper machining parameters are used to machine the parts. The nomenclature of the cutting tool plays vital role in obtaining good surface texture, the dimple texturing on the upper surface of the inserts results in reducing the surface roughness when compared to inserts having plain rake face [1]. The parts manufacturing plants aim at producing components of required quality at reduced cost per component and delay time [2]. The cost of the component can be reduced if the tool wear is less or longer contact time of the tool per index which results in better productivity [3] [4] [5]. Higher cutting speed and lower feed resulted in better surface texture when varied inserts geometry was used for the machining test [6]. While machining dry orthogonal cutting tests method for finishing turning the authors observed that the higher hardness implies worse machinability [7]. The main machining parameters which affect the surface texture of the component are the cutting speed, feed per revolution and depth of cut [8]. The surface roughness of the component increases with the increase of feed rate followed by the radial depth of cut, however the surface roughness decreases with the increase in cutting speed and the tool nose radius respectively [9]. Factors such as cutting tool vibrations, insert wear dramatically change the variation of the surface roughness of the machining component [10] [11] [12]. The contribution of cutting speed is more significant parameter which is required to produce good surface roughness [13] [14]. The coating surface of the inserts helps to reduce the friction between the chip and tool interface and hence increased tool life of the cutting tools [15]. The tool life of the cutting tool is also affected by the hardness of the work material, however coated inserts can be used effectively in such application [16] [17] [18]. During continuous turning of alloy steel material, coated carbide inserts of grade M15 performs better than grade M20 [19]. In this direction various coating materials are used to enhance the tool life of the carbide inserts [20] [21] [22].

The above review revealed that a limited number of research work was done on the study of machinability pertaining to machining of alloy steel materials. The aim of the research work is therefore to investigate the influence of machining parameter on tool life and surface roughness using uncoated and coated carbide inserts during turning of alloy steel materials at varied feed per revolution and cutting speed using single point tools.

2. Experimental Details

The details of work materials used to carry out the experimental work and the methods followed during machinability study are briefly discussed in this part.

2.1. Work Materials

The work material used for the research work was EN24 grade alloy steel. **Table 1** shows the chemical composition of work material.

2.2. Brinell Hardness Tester

The Hardness measurement of EN24 grade alloy steel was carried out on Brinell hardness tester following ASTM standards. The specification of Brinell hardness tester is presented in **Table 2**. The Brinell hardness tests were conducted in accordance with the ASTM E10 standard.

3. Machine Tool & Cutting Tool

3.1. Machine Tool

The machine tool used for the experiments was ACE designers make, Jobber XL CNC Lathe, and the machine is shown in **Figure 1**, and the specification of the CNC Lathe is presented in **Table 3**.

3.2. Cutting Tool

The cutting tool used for the experiment was Kennametal make throw way type turning tool holder. The Nomenclature of Tool holder is presented in **Table 4**.

Table 1. Chemical composition of work material used for the experimentation.

	Carbon	Chromium	Molybdenum	Nickel	Iron
Specification	0.36% - 0.44%	1.00% - 1.40%	0.20% - 0.35%	1.30% - 1.70%	Rest
Actual	0.42%	1.24%	0.28%	1.56%	Rest

Table 2. Specification of Brinell hardness tester.

Make	Krystal Elmec
Model	KB3000H
Range	500 Kgs to 3000 Kgs
Minor load	500 kgs
Major load	3000 Kgs
Ball indenter sizes	10 mm

Figure 1. JOBBER XL CNC Lathe used for the experiment.

The tool holder used for the experiment was PCLNL2020K12 and the same is shown in Figure 2.

3.3. Tungsten Carbide Inserts

The cutting tool used for the experiment was Kennametal make throw away type tungsten carbide inserts. The CNMG120408 style tungsten carbide insert of grade P20 were the insert's used for the experiments. The details of the tungsten carbide inserts used for the experiment is tabulated in Table 5.

3.4. Surface Roughness Tester

The work material selected for the research work was EN24 grade alloy steel. The surface roughness of the work material was measured after machining at varied machining parameters. The surface roughness tester is shown in Figure 3.

Table 3. Specifications of CNC lathe used for the experiments.

Maximum diameter which can be machined	270 mm
Maximum length can be machined	400 mm
Spindle speed range	50 - 4000 RPM
Job clamping system	Hydraulic
Dimension of CNC lathe in mm	2200 × 1750 × 1750

Table 4. Nomenclature of cutting tool used for the experiment

Description	Throw way type tool holder
Back rake angle	6˚ Negative
Side rake angle	6˚ Negative
End cutting edge angle	95˚
Side cutting edge angle	95˚

Figure 2. Tool holder used for the experiment.

Table 5. Tungsten carbide inserts used for the experiment.

Description	ISO Grade	Inserts application	Inserts style
Uncoated carbide inserts	P20	Medium roughing	CNMG120408
Coated carbide inserts	P20	Medium roughing	CNMG120408

4. Results & Discussion

The experimental results pertaining to the hardness, microstructural studies, surface roughness and tool life while continuous turning of EN24 grade alloy steel material are discussed in this part.

4.1. Hardness Test Measurement

The hardness test was carried out on KB3000H model Brinell hardness tester. Measurement of hardness was carried out following ASTM E10 standard. The average hardness of the EN24 grade alloy steel material is shown in the Table 6.

4.2. Measurement of Surface Roughness

The machining parameters used for the conduction of the experiments are shown in Table 7. The surface roughness measurement was carried out using Mitutoyo make SJ201P model surface roughness tester.

The effect of cutting speed and feed per revolution on surface roughness when uncoated tungsten carbide insert was used for turning EN24 grade alloy steel is shown in Figure 4. The effect of cutting speed and feed per revolution on surface

Figure 3. Surface roughness tester used for the experiment.

Table 6. Hardness of EN24 grade alloy steel.

Material	BHN
EN24-Sample 1	234
EN24-Sample 2	232
EN24-Sample 3	232

Table 7. Machining parameters used for the experiments.

Type of test	Continuous turning test				
Insert type	Uncoated carbide insert/Coated carbide insert				
Cutting speed	100 m/min	200 m/min	300 m/min	400 m/min	500 m/min
Feed/revolution	0.1 mm	0.2 mm	0.3 mm	0.4 mm	
Depth of cut	1.5 mm				

roughness when coated tungsten carbide insert was used for turning EN24 grade alloy steel is shown in Figure 5. From, Figure 4 & Figure 5, it can be observed that when EN24 grade alloy steel material subjected to continuous turning application, the surface roughness increases as the feed per revolution increases irrespective of the type of inserts. The surface roughness decreases as the cutting speed decreases irrespective of the type of inserts. The surface roughness found marginally lower when coated inserts used under identical machining conditions.

4.3. Tool Life Test

The continuous turning test was carried out after skin turning of outside diameter

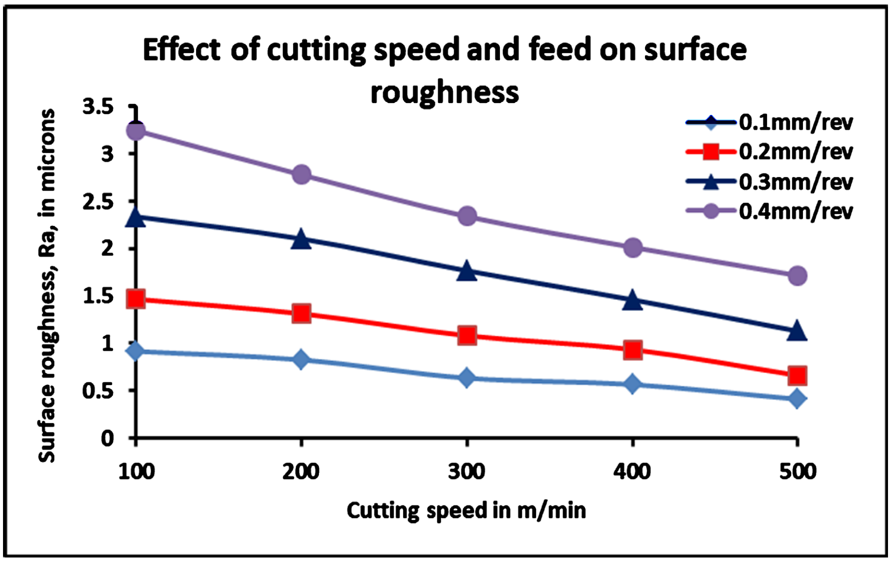

Figure 4. Effect of cutting speed and feed on surface roughness when uncoated carbide inserts are used for turning experiments.

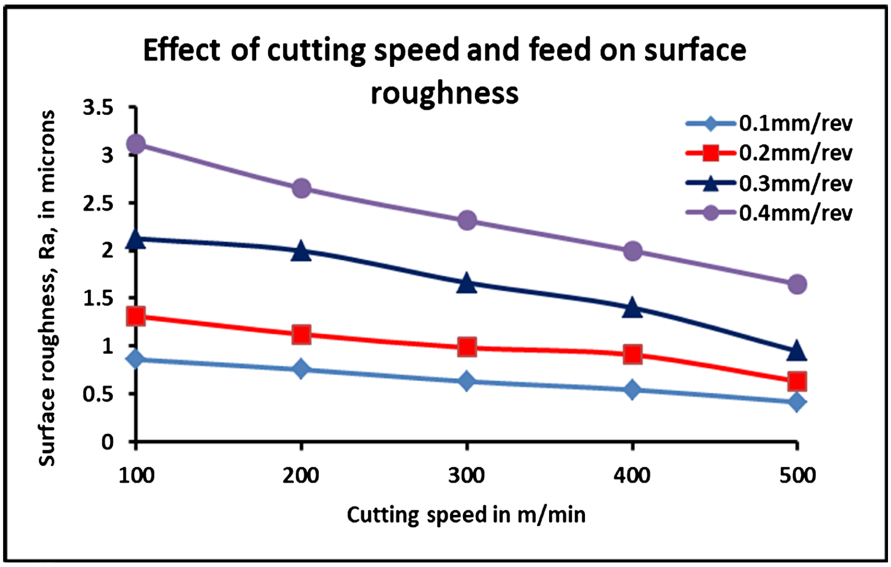

Figure 5. Effect of cutting speed and feed on surface roughness when coated carbide inserts are used for turning experiments.

and P20 Grade carbide inserts were used for continuous turning experiment. The machining parameters used for the conduction of the experiments are shown in Table 7. The continuous turning of EN24 grade alloy steel material, at varied cutting speed and feed per revolution were carried out for Grade P20 inserts by keeping depth of cut and cutting tool over hang constant.

From Figures 6-9, it can be observed that when EN24 grade alloy steel material subjected to continuous turning application, the tool life reduces as the feed per revolution increases. It is also observed that increased cutting speed leads to rapid reduction of tool life and. Tool life found high when uncoated carbide insert was used to machine alloy steel at 100 m/min and feed of 0.1 mm/revolution.

From Figures 10-13, it can be observed that when EN24 grade alloy steel material subjected to continuous turning application, at lower cutting speed the tool life found high, however the amount of metal removed per minute found lower.

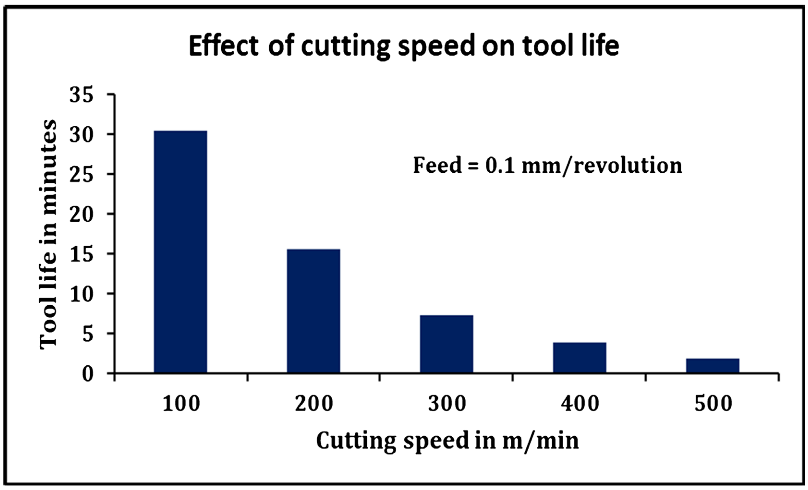

Figure 6. Effect of cutting speed on tool life when uncoated carbide inserts are used for turning experiments at feed of 0.1 mm/revolution.

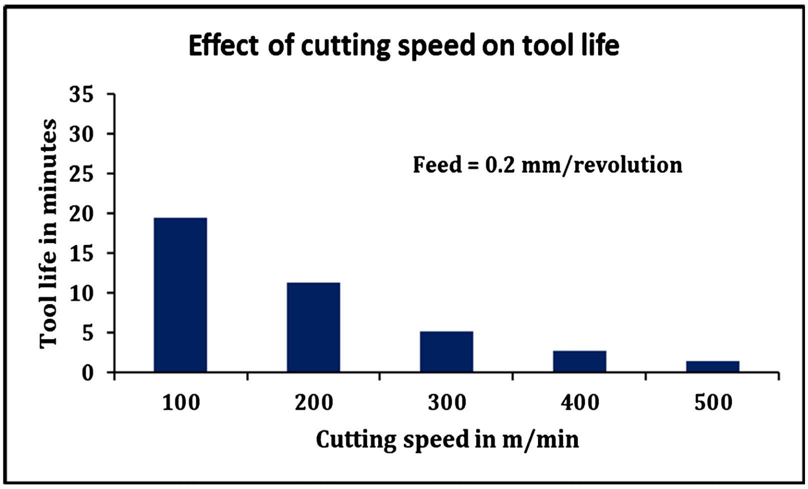

Figure 7. Effect of cutting speed on tool life when uncoated carbide inserts are used for turning experiments at feed of 0.2 mm/revolution.

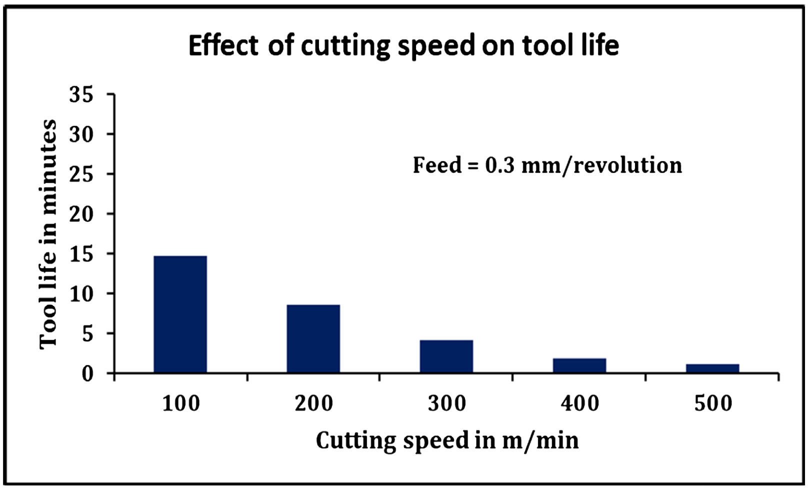

Figure 8. Effect of cutting speed on tool life when uncoated carbide inserts are used for turning experiments at feed of 0.3 mm/revolution.

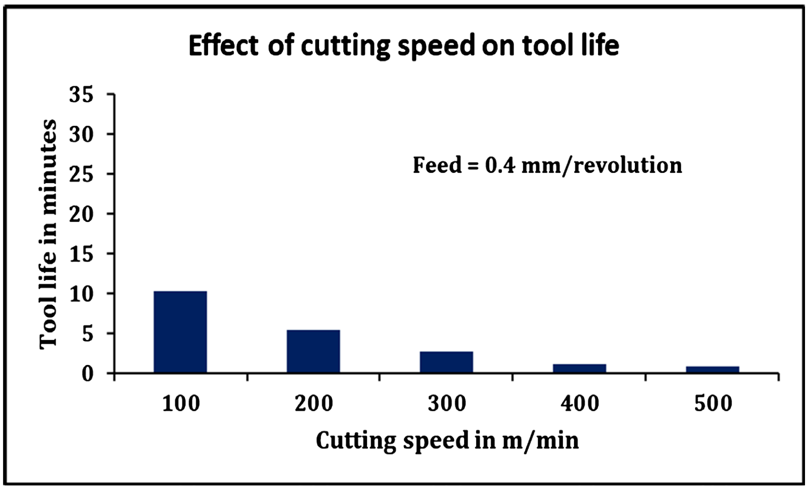

Figure 9. Effect of cutting speed on tool life when uncoated carbide inserts are used for turning experiments at feed of 0.4 mm/revolution.

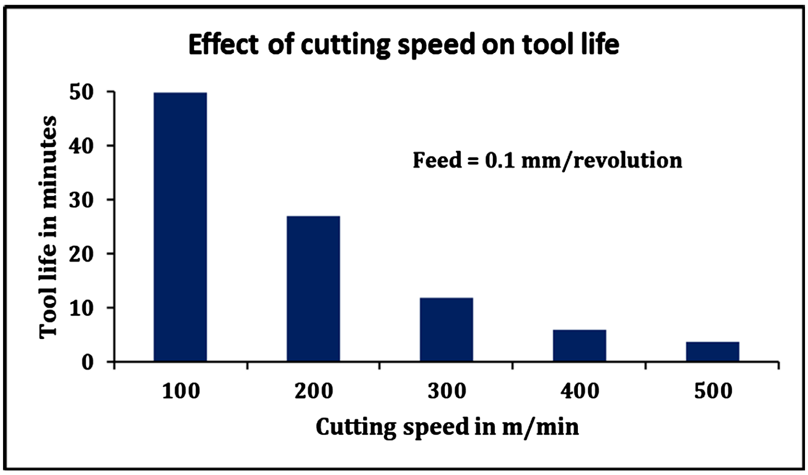

Figure 10. Effect of cutting speed on tool life when coated carbide inserts are used for turning experiments at feed of 0.1 mm/revolution.

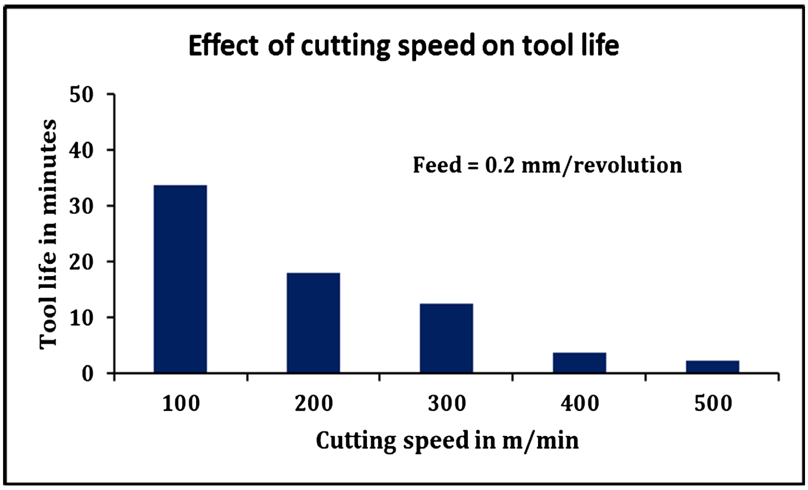

Figure 11. Effect of cutting speed on tool life when coated carbide inserts are used for turning experiments at feed of 0.2 mm/revolution.

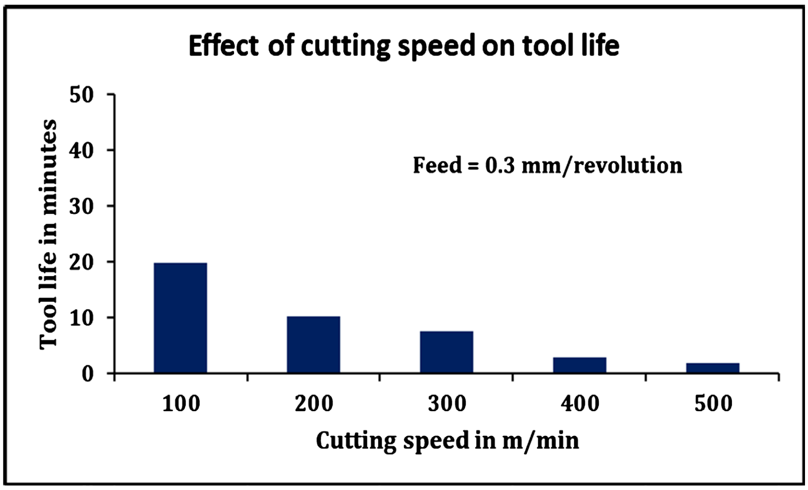

Figure 12. Effect of cutting speed on tool life when coated carbide inserts are used for turning experiments at feed of 0.3 mm/revolution.

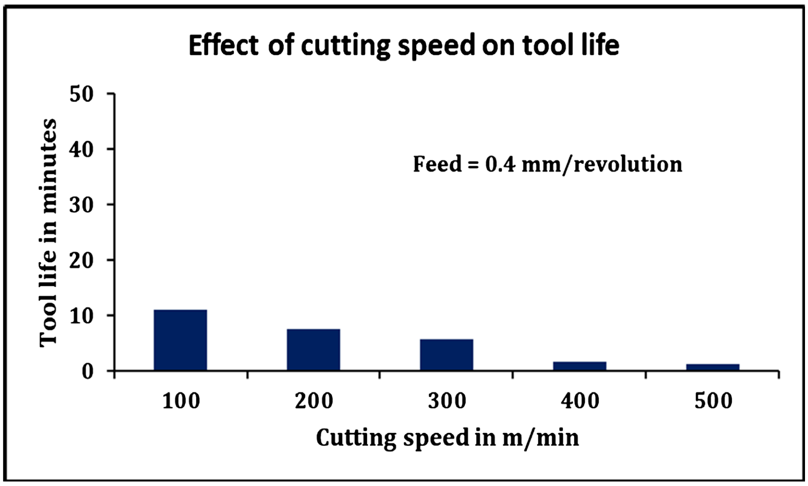

Figure 13. Effect of cutting speed on tool life when coated carbide inserts are used for turning experiments at feed of 0.4 mm/revolution.

When the cutting tool used for machining at higher cutting speed the contact time found lower. Tool life found high when coated carbide insert was used to machine alloy steel at feed of 0.1 mm/revolution and lower at 0.4 mm/revolution feed, this may be due to the increased forces on the tool at higher feed rates.

5. Conclusion

From the experimental results, we can conclude that coated carbide inserts performed better than uncoated inserts at identical machining parameters. Best surface roughness was obtained at a cutting speed of 500 m/min and feed of 0.1 mm/revolution when coated carbide inserts were used for the experiments. The surface roughness, Ra value increases as feed per revolution increases and the surface roughness, Ra value decreases as cutting speed increases. Increased cutting speed leads to rapid reduction of tool life irrespective of insert type used for the experiments. Increased feed rate results in lower tool life during continuous turning application. The results of the experimentation revealed that use of coated carbide inserts at higher cutting speed and lower feed gives excellent surface texture, however at 300 m/min cutting speed and 0.2 mm/revolution feed gives greater than 10 minutes tool life, good surface texture as well as good chip breaking.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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