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ABSTRACT

This paper reports theoretical, simulation and experimental works of rack angles effect (+15º, +5º, -5º, -15º) on cutting tool of shaping process. Three different velocities (0.2, 0.4, 0.9 m/sec) are used theoretically, assimilative and experimentally to show the effects of shear forces, shear stress and shear strain with cutting stroke. The visual Fortran program have been implemented in this study for different velocities. The auto desk inventor program is used also for different rack angles and velocities. The strain gages techniques are used to get strain readings of cutting tool during shaping process with interface equipment to translate resistance response for strain readings. There is convergence for theoretical, simulation and experimental results at positive values of rack angle and the chip moving is easily and also help to reduce the shear stress effect on cutting tool.

KEYWORDS

Rack angles, Shear stress, shaping process, Cutting tool

INTRODUCTION

The large production and high quality are required in parts manufacturing. The researchers are hearten to study the manufacturing parameters by using the simulation (FEM) in two and three dimensions. The advantages of these software are fast computations. The experimental work is very expensive, needs time and adept boomer. In present study is used three dimensions part in cutting processes and is used FEM software (deform 3D) to study rake angle effect on cutting force, strains, stresses and temperatures. The values of rake angle in research are (-15, -10, -5, 0, +5, +10, +15) with constant cutting velocity and feed velocity. The metal of work piece is FCD500 ductile cast iron, while the metal of tool is (DNMA432) with blade curve angle (55º). When rake angle is increase from negative to positive value due to decrease of cutting force, stresses and total strain Von Misses and less value when rake angle is (+15) [1, 2, 3]. Another research is deal with the effect of rake angle and cutting speed on the residual stress in tool cutting with different rake angle values (0, 5, 10, 15 and 20º) and fixing the clearance as (Relief angle) in value (8º) and is used bright mild steel as work piece which machined by Lath machine.

The number of experiments are 15 with three cutting velocity for any rake angle (37.69, 59.37 and 94.24 m/min), while the feed rate and cutting depth in constant value. The x-ray by diffractiometer is used to measure residual stresses. The aim of the present research is to select rake angle which produce optimum residual stresses on cutting tool to give long service life and save in energy [4, 5, 6]. The butt of another research is attained the best to fathom the micro geometric of tool cutting in different impact and stress distribution in section of tool cutting. In present study the principle and distribution stresses are researched. These have major effect to occur the damage of cutting tool such as, the crack incidence and developed it, flanking, chipping, breakage and plastic deformation. The development of slackness zone is investigated as well as cutting tool geometric effect. The model of finite element was used to study the cases in details. The standard deviation of cutting forces is appear in experimental results, distribution stresses and slackness zone. The study is appear the major geometric of cutting tool has high ability to reduce tensile stresses [7, 8, 9].

METHODOLOGY

Longitudinal vibration in shaping tool

In shaping process can be replace the detent in milling machine by dividing head device to perform cutting of streams in metal. The process is performed in two strokes, one of them is called (power stroke), the cutting is occurred in it, while the other is called (return stroke) without any cut. The sudden stop of cutting tool can be occur due to the hardness of work piece, cutting tool obsolescence or depreciation of incisor borders, these will deal with to occur longitudinal vibration due to appear displacements, strains and stresses will effect on cutting process. The stress is translating to bracing area of tool, this will be dislocate of clamping which is lead to inefficient cutting. The present case is studied in many researches and thesis to produce equations of displacements, strains and stresses which are combined of cutting processes[10, 11, 12].

$$\frac{D(\ell,t)}{D_0} = 8\sum_{i=1,3,5}^{\infty} (-1)^{\frac{i-1}{2}} . \frac{1}{\pi^2 i^2}[(-1)^{\frac{i-1}{2}} \cos(\frac{i\pi a}{2\ell})t + \frac{v_0}{\varepsilon_0 a}\sin(\frac{i\pi a}{2\ell})t] \tag{1}$$

$$\frac{\varepsilon(x,t)}{\varepsilon_0} = 4\sum_{i=1,3,5}^{\infty} \cos(\frac{i\pi x}{2\ell}).\frac{1}{i\pi}[(-1)^{\frac{i-1}{2}} \cos(\frac{i\pi a}{2\ell})t + \frac{v_0}{\varepsilon_0 a}\sin(\frac{i\pi a}{2\ell})t] \tag{2}$$

$$\frac{S(x,t)}{S_0} = 4\sum_{i=1,3,5}^{\infty} \frac{1}{i\pi}[(-1)^{\frac{i-1}{2}} \cos(\frac{i\pi a}{2\ell})t + \frac{v_0}{\varepsilon_0 a}\sin(\frac{i\pi a}{2\ell})t] \tag{3}$$

Three velocities are fixed in present experimental work and also are used in theoretical equations which is previous mention. The physical and mechanical properties of cutting tool and work piece must be known. The Von Misses theory is applied to calculate static shear stress ($\tau_{ult.} = 0.577\ \sigma_{ult.}$) of cutting tool metal (M12 Steel), and then compute dynamic shear stress and strain of cutting tool[12, 13, 14]. The results are illustrated in table(1).

Table 1. The theoretical results of dynamic shear stress and strain.

Velocities m/sec	$\frac{\tau_{dynamic}}{\tau_0}, \frac{\varepsilon_{dynamic}}{\varepsilon_0}$	$\tau_{dynamic}$	$\varepsilon_{dynamic}$
0.2	1.2	138.48	0.00132
0.4	1.6	184.64	0.00176
0.9	2.5	288.5	0.00273

The Cutting Theory

The Merchant s' circle theory for cutting process which is shown in figure 1, can be used there equations as following below to investigate rack angle changing effect on values of cutting tool stresses and strains. The face width of tool which is penetrate into the work piece metal (4mm), while the cutting depth for any power stroke (3mm). The knowing of rack angle (α) and tool angle (β), can be calculated shear angle (ϕ), and then calculate shear force that effect on work piece metal to get cutting [12, 13, 14].

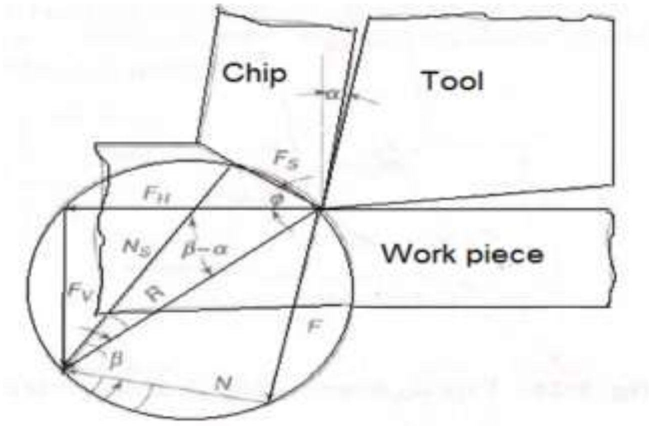


Figure 1. The Merchant s' Circle of Cutting Theory.

$$F_s = \frac{\tau . b . t}{sin\emptyset} \quad (4)$$

$$F_t = 2\tau . b . t . cot\emptyset \quad (5)$$

$$F_c = \tau . b . t . (cot^2\emptyset - 1) \quad (6)$$

$$\emptyset = 45 - 0.5\ (\beta - \alpha) \quad (7)$$

By getting the values of shear forces for different rack angle values. The cutting tool is simulated by auto desk inventor program and do stress analysis for all cases to get values of shear stresses and strain as shown in figures (2, 3, 4, 5, 6, 7, 8).

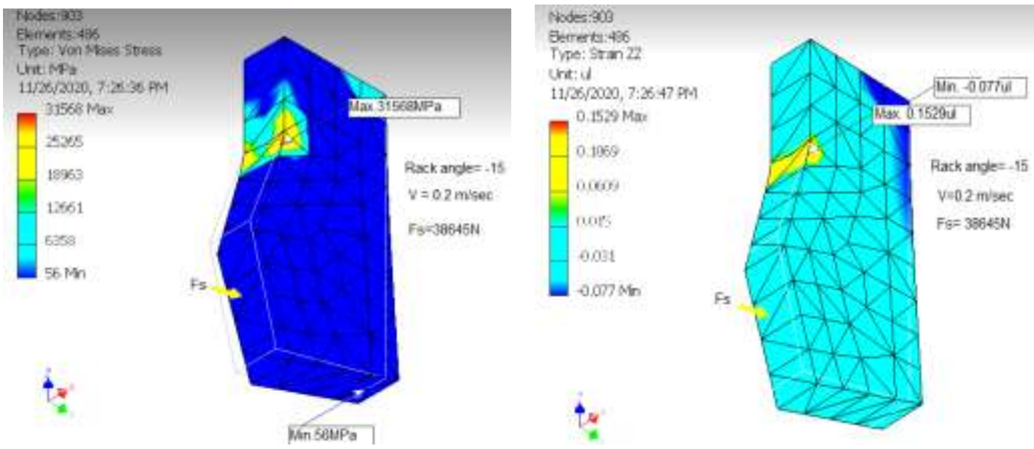


Figure 2. The stress and strain analysis of cutting tool at (α= -15º) , (V=0.2m/sec)and (Fs=38645N)

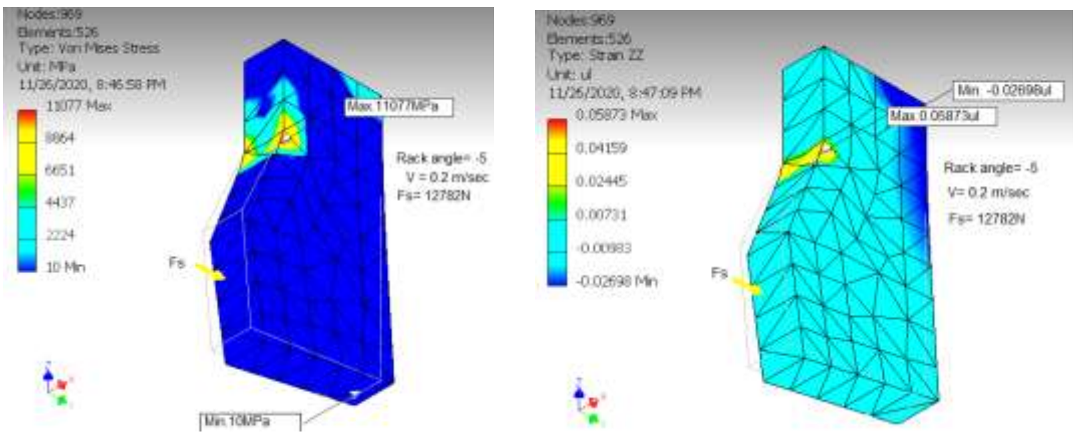
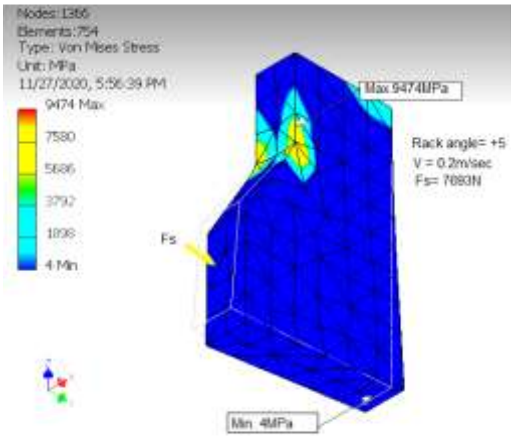


Figure 3. The stress and strain analysis of cutting tool at (α= -5°) ,(V=0.2m/sec) , (Fs=12782N) and (ϕ =7.5°).



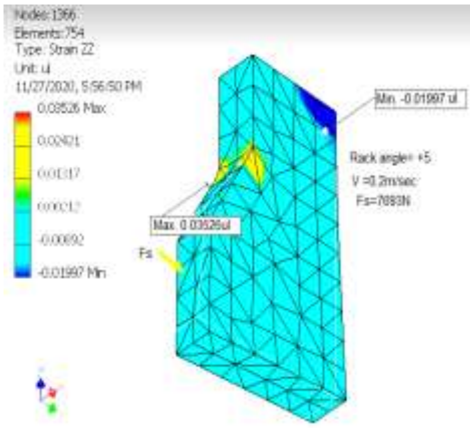
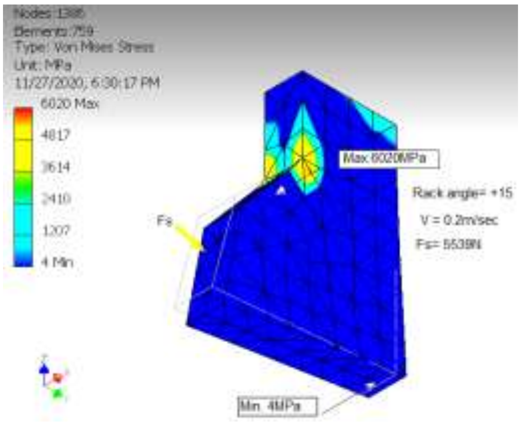


Figure 4. The stress and strain analysis of cutting tool at (α= +5) ,(V=0.2m/sec) , (Fs=7693N) and (ϕ=12.5°).



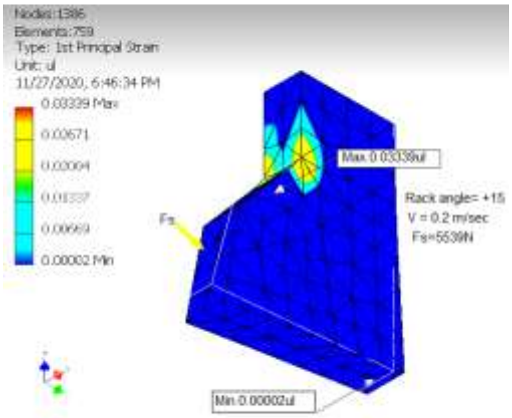
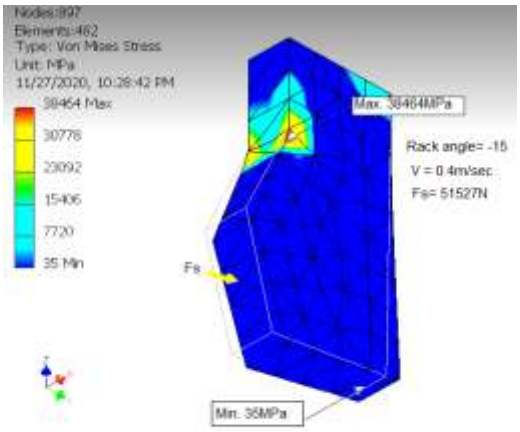


Figure 5. The stress and strain analysis of cutting tool at (□= +15) ,(V=0.2m/sec) , (Fs=5539N) and (□=17.5O).



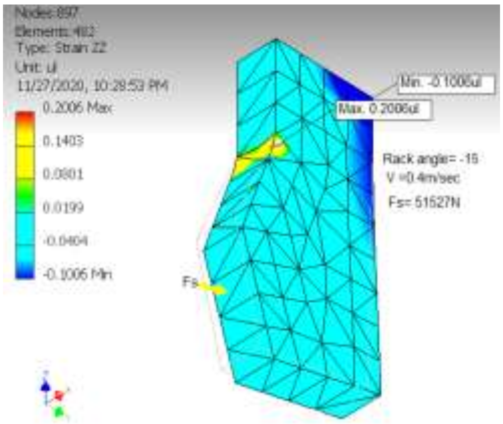


Figure 6. The stress and strain analysis of cutting tool at (α= -15), (V=0.4m/sec) , (Fs=5N) and (ϕ=2.5°).

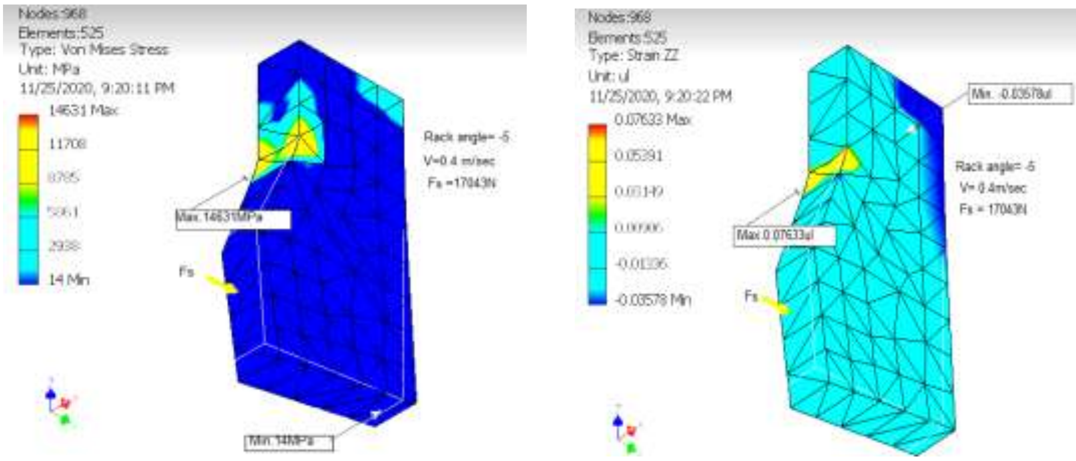


Figure 7. The stress and strain analysis of cutting tool at (α= -5º) ,(V=0.4m/sec) , (Fs=25467N) and (ϕ=7.5º).

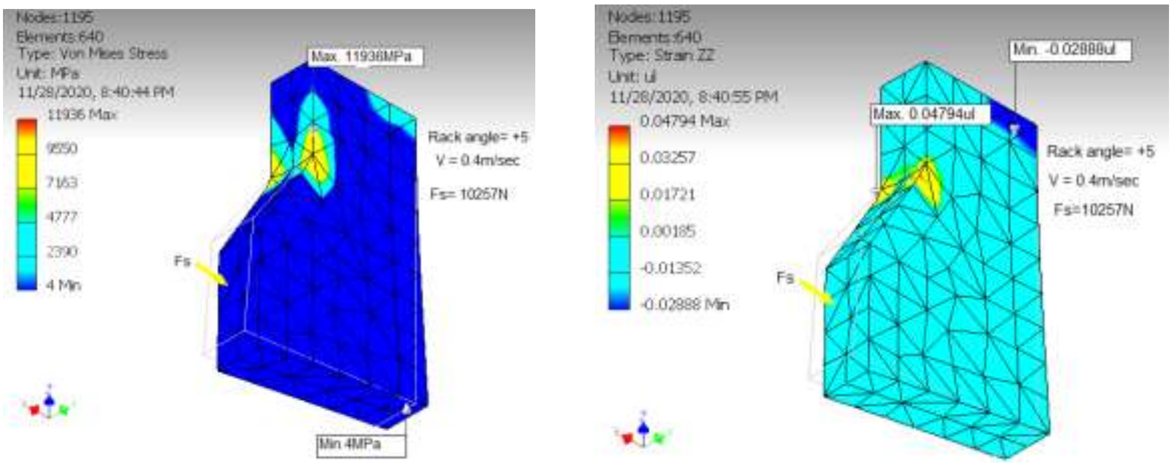


Figure 8. The stress and strain analysis of cutting tool at (α= +5) ,(V=0.4m/sec) , (Fs=10257N) and (ϕ=12.5º)

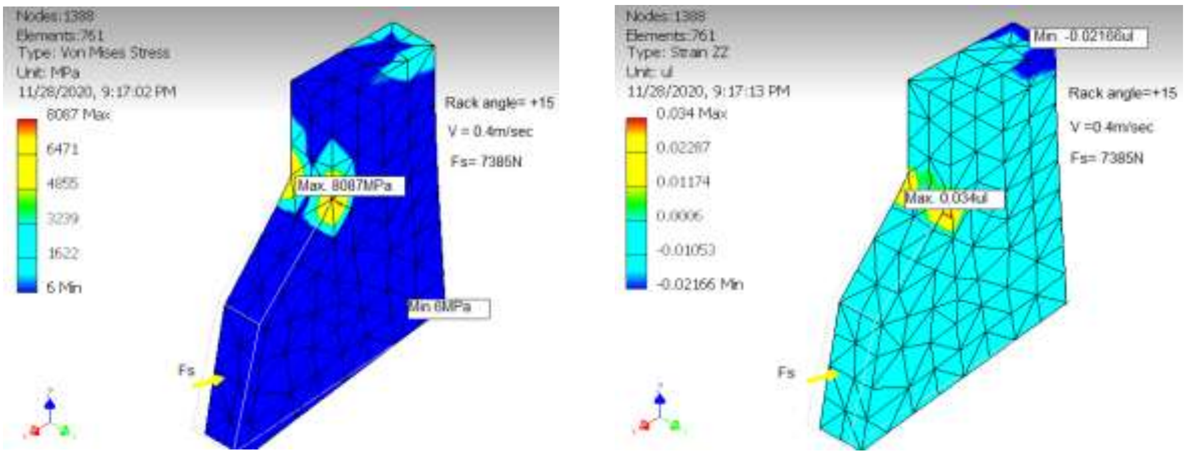


Figure 9. The stress and strain analysis of cutting tool at (α= +15) ,(V=0.4m/sec) , (Fs=7385N) and (ϕ=17.5º).

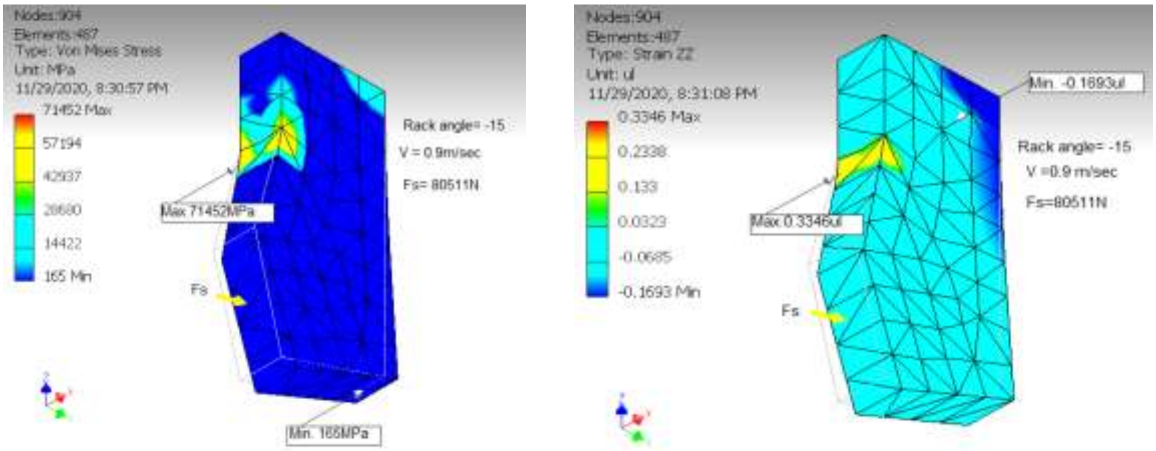


Figure 10. The stress and strain analysis of cutting tool at (α= -15) ,(V=0.9m/sec) , (Fs80511N) and (ϕ=2.5º).

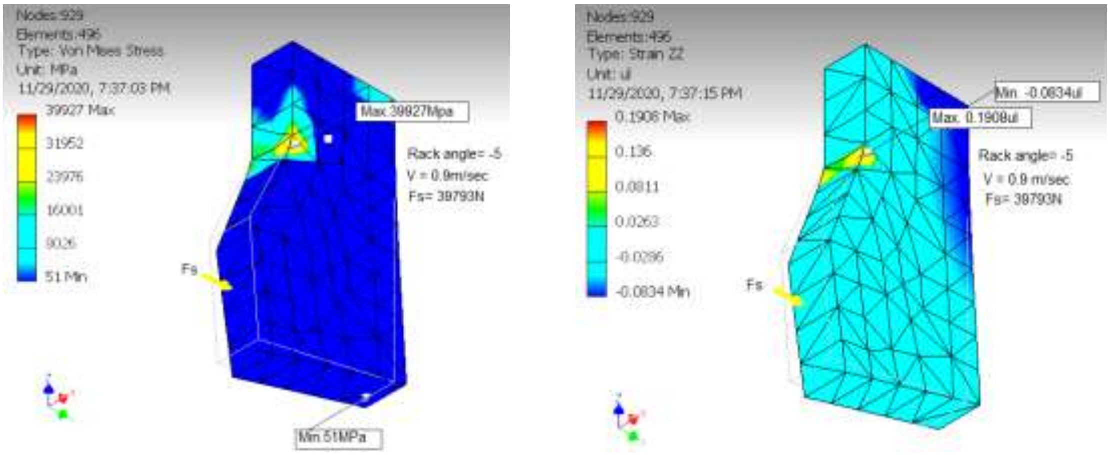


Figure 11. The stress and strain analysis of cutting tool at (α= -5), (V=0.9m/sec) , (Fs=39793N) and (ϕ=7.5º)

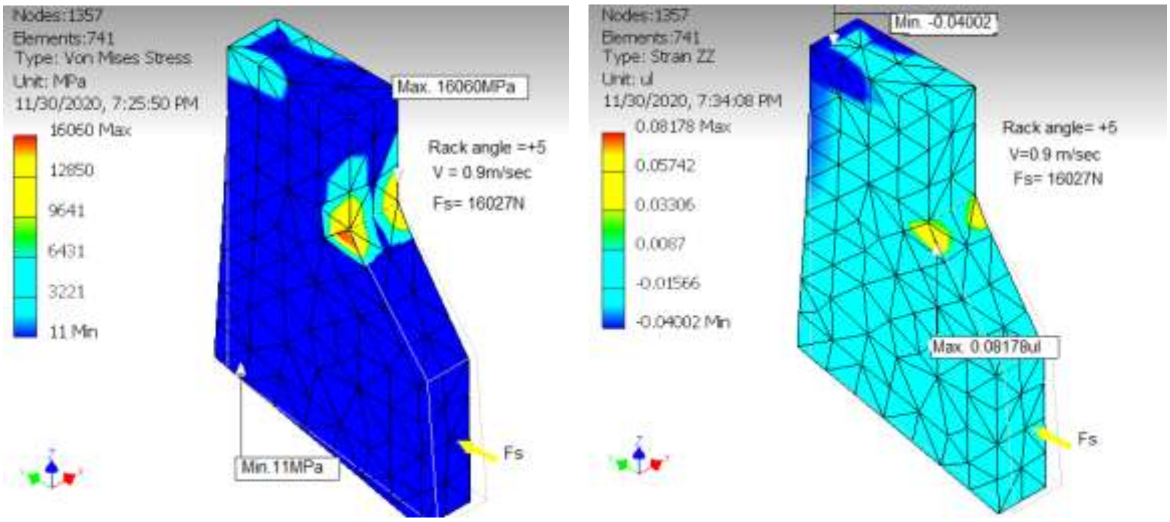


Figure 12. The stress and strain analysis of cutting tool at (α= +5) ,(V=0.9m/sec) , (Fs16027N) and (ϕ=12.5º).

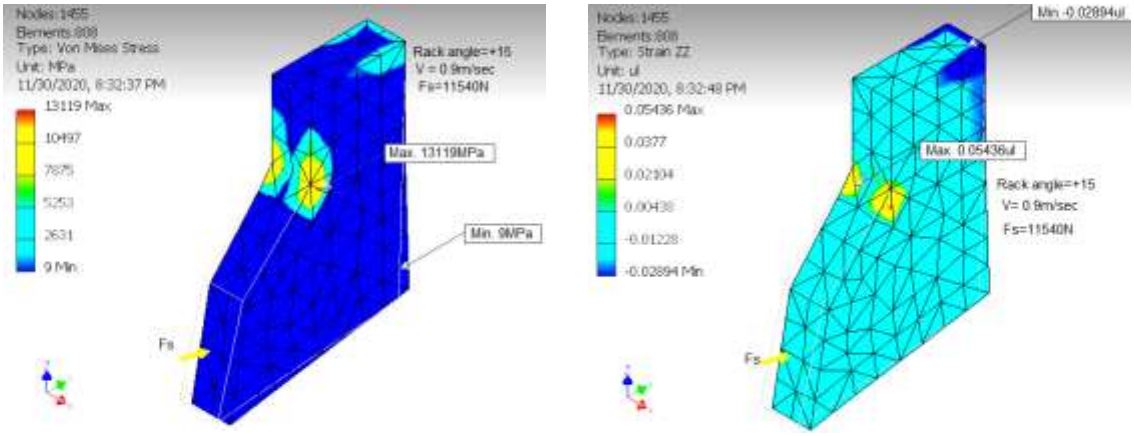


Figure 13. The stress and strain analysis of cutting tool at (α= +15) ,(V=0.9m/sec) , (Fs11540N) and (ϕ=17.5º)

To audition of theoretical and simulation results, was using different rack angles of cutting tool in suitable with theoretical research. The dimpling shaping machine is used that available in Almusaib technical institute workshop. The strain gages technique is used, whereby two strain gages are fixed on cutting tool near of tool blade to increase reading accuracy, which is converted by (digital dynamic strain device) to computer for readings saving as shown in figure 15.The metal of work piece s used in experimental work must be has good machining properties and was test its component by (photosynthesis spectrum analysis device) in General Company of mechanical industries in Babylon city, can be shown in table 2. Was allegation theoretical and practical results to achieve convergence to improve true simulation and can be depend on it, as shown in table 3.

Figure 14. Practical attaching of experimental parts for strain readings

Table 2. Chemical Compounding of Low Carbon Steel AISI C_{15} as Work piece.

Elements	C%	Si%	Mn%	P%	S%	Ni%	Cr%	Mo%	V%	Cu%	Zn%
Percentage ratio	0.25	0.2	0.5	0.016	0.024	0.114	0.09	0.01	0.002	0.03	0.002

Table 3. The results of stress analysis simulation

Velocities m/sec	Rack angle	Shear angle	Shear force	Shear stress by Von	Shear strain in	ExperimentalDynamic Shear Strain

	α	ϕ	Fs (N)	Misses(MPa)	zz plane	
0.2	-15	2.5	38645	31568	0.1529	0.1235
	-5	7.5	12782	11077	0.06873	0.08321
	+5	12.5	7693	9474	0.03526	0.03002
	+15	17.5	5539	6020	0.03339	0.2754
0.4	-15	2.5	51527	38464	0.2006	0.1899
	-5	7.5	17043	14631	0.07633	0.08221
	+5	12.5	10257	11936	0.04794	0.04233
	+15	17.5	7385	8087	0.034	0.02884
0.9	-15	2.5	80511	71452	0.3346	0.2996
	-5	7.5	39793	39927	0.1908	0.1922
	+5	12.5	16027	16060	0.08178	0.07669
	+15	17.5	11540	13119	0.05436	0.5119

RESULTS DISCUSSION

The equations 1, 2, 3 refer to clear that the ratio of displacements, strains and stresses dynamic to static values are represented inverse of safety factor, hence, any increasing of these ratio led to increase in transmission stress by longitudinal vibration to cutting tool root that represent catching zone. The equations 1, 2,3 have major variable is liner velocity of cutting tool and the mechanical properties of cutting tool metal that represented of stress translate velocity (a) which is equal to ($\sqrt{\frac{E}{\rho}}$) . The equations 1, 2, 3 are regarded time (t) and position (x) simultaneously variable, there for all the mechanical properties may be changing according to time and position due to change of stresses and strains which are produce on cutting tool. The Merchant circle theory in figure 1 is showed rack angle (α) has large effect to move smoothly of metal Reich on shear plane which is produced shear angle (ϕ) effect on cutting force value.

From figures (2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13) is showed that the cutting force for rimmed rack angle (-15) will increase with increase of cutting force and shear stress which are produced according to (Von Misses Theory). The simulation shear stress will increase with increase of practical shear stress. From the figures (2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13) and table 3 are showed that the rack angle change (α) from positive value to negative value (+15, +5, -5, -15) led to increase of simulation and practical shear cutting force, shear cutting stress and strain, that is represented proportional relationship. The increasing of shear angle (ϕ) (2.5º, 7.5º, 12.5º, 17.5º) led to decrease of shear forces and stresses values, that is represented inverse relationship. From the figures (11, 12, 13, 14) and table 3 are showed, there is convergence between the practical and simulation shear strain values when the velocity would be increase, hence, the correction factor approximates (0.8).

CONCLUSIONS

Based on the theoretical, simulation and experimental works:

1-The transmission longitudinal vibration to cutting tool root because of cutting forces led to dislocate catching of cutting tool and produce dirty of cutting process.
2-The density and modulus of elasticity of cutting tool metal can be regard important variable to reduce transmission stress along cutting tool.
3-The proportional relationship between cutting velocity in side and shear stress, shear strain on other side for fixed rack angle.
4-Rack angle changing from position values to negative values with increasing shear forces, stresses and strains in proportional relationship.
5-The relationship between shear angle and shear forces, stresses and strains is inverse.
6-The convergence between simulation and practical results refer to capability used of simulation stress analysis in factories and workshops.

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