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PERFORMANCE EVALUATION AND ANALYSIS STRESS (THEORETICAL AND PRACTICAL) OF AUXILIARY PARTS (COULTER KNIVES) LOCALLY MANUFACTURED FOR MOLDBOARD PLOW DURING TILLAGE

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Abstract

This study was conducted at two stages, firstly were tested and analyzed stresses affecting on the structure of the sliding and disc coulter in similar conditions to the field conditions in which plow works with the coulter by using the F.E.M in the Ansys program where the Von mises stress and displacement ratio were adopted as a theoretical stage, In the secondly stage the performance evaluation of the plow with coulters at three levels were the sliding, disc and without coulter at two levels of moisture content 9.73%, 16.22% and with a depth of tillage 15-20cm and 25-30cm, the following indicators were investigation: stress, specific resistance, specific energy, and specific energy efficiency, Results showed that the plow without coulter recorded the highest values of stress, specific resistance, specific energy and specific efficiency, while the plow with the sliding coulter achieved the lowest values for the mentioned traits, and the low moisture content recorded the highest value for both specific resistance and specific energy of the unit area, and the increase in depths of tillage gave the highest value to the specific energy and the specific energy efficiency and the interaction among the plow without coulter at moisture content 9.73% with depth 25-30cm recorded the highest value of the specific resistance and the specific energy efficiency.
***Keywords*:** Von mises stress, moldboard plow coulter, specific resistance, and specific energy efficiency

Introduction

The tillage of soil is considered one of the biggest farm operations as it requires the most energy and it represents about 30-50% of the total energy spent which aims at creating a desired final soil condition for seeds (AL Suhaibani and Ghaly, 2010). Jeshvaghani *et al.* (2013) indicated in a study of the design and manufacturing of moldboard plough bottom a three dimensional model of the new designed bottom was designed using CATIA V5R16, Results showed that method decreased the weight of the bottom due to the reduction of the overdesigned surface of it Therefore based on this developed method the price and magnitude of energy consumption of the moldboard plough decreases due to reduce of the weight of bottom and its friction with soil. Garus *et al.* (2014) indicated that the greatest stress distribution in the moldboard shin, mouldboard and leg in a study they performed with it about the influence of pressure to the stresses inside the plough body, highest stresses on mouldboard occur in the area, which is also the most exposed to the abrasive wear. Abdullah (2014) showed that the decrease in moisture content from 16.02% to 10.03% led to an increase in the stress value from 56.07 to 59.57MN.m^{-2} in study mechanical performance and stress analyses of locally manufactured moldboard plow share under the effect of moisture content and the reason showed the increase in soil resistance when the moisture content of the soil decreased which increased the load on the working parts during the process of penetration of shares into the soil and thus increased the stress value. Mare *et al.* (2014) showed in study effect of soil forces on the surface of moldboard plow that soil force increased with tillage depth increased and maximum soil force were applied on share part of moldboard plow while minimum forces were applied on moldboard plow. Arvidsson and Keller (2011) stated that the specific resistance increased with decreasing the moisture content due to the increase in the cohesion and penetration resistance of the soil and the soil cohesion was the most influencing the specific resistance, they also showed that the increase in soil moisture content above 16% led to a significant decrease in specific resistance. Alele (2019) in a study comparing the performance of a moldboard plow with of a disc plow that specific resistance of the moldboard plow decreased from 43.81 to 43.13 and then to 40.69 kN.m^{-2} whenever the tillage depth is increased from 6.5 to 12.5 to 22.5 cm, respectively this could be due to increased disturbed area of soil as we move deeper into the soil more than the increase in draught reducing the magnitude of the specific resistance (draught force/disturbance) is a better indicator of overall tillage efficiency. Thakur and Jagadale, (2018) indicated a decrease in the specific energy per unit area when the soil moisture content increases from 6.6% to 12% to 20% using the moldboard plow. Khader (2008) showed that the specific energy per unit area in case of using moldboard plow recorded higher values than chisel plow and disk harrow, that may be due to the high operating depth compared with the chisel plow and the disk harrow that requires higher operating power from the tractor also the operating width of the moldboard plow is less than that in case of using both of the chisel plow and the disk harrow which decreases the actual field capacity thus increases the specific energy It was noticed that the specific energy efficiencies for the implements as indicated ranged from 11.24% to 20.08% these values depends on the tractor condition, tillage implement and condition, the experimental field type and condition, previous crop and the operating factors, the maximum specific energy efficiencies were 20.08, 15.48 and 17.47% at plowing speeds of 1.92, 1.58 and 2.06 m.s^{-1} in case of using chisel plow, moldboard plow and disk harrow respectively we may say that the optimum operating conditions which gave the maximum specific energy efficiency.

Materials and Methods

The study was conducted in one of the agricultural fields in the area of Rahmaniyah (city of Mosul)of the agricultural season(2019). where the area of the field actually used two hectares and the field was planted with barley in the seasons that preceded the season of implementing the experiment, note that the experiment field was irrigated and the soil texture was a silty mixture, Massey Ferguson 290 was used when implementing the experiment, and the front plowing speed is 3.54 $km.h^{-1}$, AYDIN PULLUK type Turkish moldboard plow was used, the plow weight was 290 kg, the number of bottom(general purpose) was three, Auxiliary parts were used with the plow disc coulter and the Locally manufactured-sliding coulter, Figure 1,A shows the design schema of the disc coulter knife with the parts attached to it, and Figure 2,B of the sliding coulter knife that designed with the parts attached to it and then manufactured by the researcher at Al-Baraka Factory in the Mosul industry, Iraq, the metal test from which the sliding coulter was made and conducted in the laboratories of the Mechanical Engineering Department/ College of Engineering-University of Mosul, table (1) shows the chemical composition and mechanical properties of the metal sliding coulter and disc coulter, after fixing the dimensions and measurements of the coulters and the type of metal used for them, the construction and design of them were carried out using the method of finite elements F.E.M in the program Ansys, to show the distribution of stresses affecting the coulters as a result of loads and forces placed on it, and the second stage, the experiment was carried out in fields, where the design R.C.B.D method Split-Split Plot was used to implement the experiment (Daoud and Elias, 1990), the experiment was factorial and with three factors: Firstly, the moisture content at two levels 9.73% and 16.22%, and secondly, the type of coulter knife used with the plow at three levels (sliding coulter, disc coulter, without using the coulter) and thirdly the depth of plowing at two levels 15-20cm and 25-30cm,the variance was analyzed to show the significant differences, and the Duncan's multiple range test was used at the probability level (0.05) and (0.01) to compare the averages for the different parameters. the following indicators were studied:

1-**Stress:** (Mulla Ali, 1989):

$$\sigma = F / A \qquad ...(1)$$

where:

σ :Stress ($N.m^{-2}$)
F : Force (N)
A : Area (m^2).

Direct strain: It is the change that occurs in the length of the body (mineral) after stress, strain is calculated as in the following equation:

$$\varepsilon = \delta L / L \qquad ...(2)$$

ε : strain
δL : change in length
L : original length.

Strain can be expressed as a percentage (Mulla Ali., 1989) as follows:

$$\varepsilon = \delta L / L \times 100 \qquad ...(3)$$

2. Specific resistance: It is part of the total resistance (draft force) to the unit area of the tillage section (Al-Banna., 1990):

$$Sr = Ft / Wp \text{ x } Dp \qquad ...(4)$$

Sr : specific resistance ($KN.m^{-2}$) Ft : Draft force (KN)
Wp : actual tillage width(m)
Dp : actual tillage depth (m).

3- The specific energy per unit area: it was calculated with the following formula (Al-Hamid., 2004):

$$SEA = E.p / EFc \qquad ...(5)$$

SEA : Specific energy ($kW.h\ .ha^{-1}$)
E.p : Fuel equivalent power (kW)
EFc : actual field productivity ($ha.h^{-1}$)

The Fuel equivalent power were calculated from the following equation (Embaby, 1985)**:**

$$E.p = F.c \times D.f \times C.v.f \times T.e \qquad ...(6)$$

E.p : Fuel equivalent power (kw)
F.c : Fuel consumption per unit time ($L\ .h^{-1}$)
F.c : Fuel density (0.85) $kg.L^{-1}$
C.v.f : calorific value of fuel (45460) $Kj.kg^{-1}$
T.e. : Thermal efficiency (25%).

Actual field productivity (Al-Tahan *et al.*, 1991):

$$EFc = S \times W \times E / AC \qquad ...(7)$$

EFc : Actual field productivity ($ha\ .h^{-1}$)
S : Actual forward speed ($m\ .h^{-1}$)
W : actual tillage width(m)
E : Efficiency (80%) (Roth, *et al.* 1977).
AC : Unit area (10,000 m^2).

4. Specific energy efficiency: the following equation has been adopted to calculate the specific energy efficiency, (Khadr., 2008):

$$SEE = (3.6 \times SEA / 35.17 \times F.c) \times 100 \qquad ....(8)$$

SEE : specific energy efficiency(%)
SEA : Specific energy per unit area ($kW.h\ .ha^{-1}$)
35.17 : Energy consumed per liter of fuel ($MJ.L^{-1}$).
F.c : Fuel consumption per unit area ($L\ .ha^{-1}$).

The specific energy per unit area (Smith, 1993) and (AL-Hamed *et al.*, 2013):

$$SEA = F \times V \times 1000 / 3600 \times Efc \qquad ...(9)$$

F : draft force (KN)
V : practical tillage speed ($km.h^{-1}$)
EFc : Practical productivity ($ha\ .h^{-1}$).

Table 1 : The chemical composition and mechanical properties of manufactured sliding coulter metal and disc coulter

AISI metal type	Chemical composition								Mechanical properties					Coulter type
	Phosphorous (%)	Sulfur (%)	Nickel (%)	Molybdenum (%)	Chromium (%)	Silicon (%)	Manganese (%)	Carbon(%)	Charpy test (J)	Tensile strength (Mpa)	Hardness (HRC)	Yield stress (Mpa)	Elongation ratio (%)	
1074	0.05	0.18	0.02	0.23	0.88	0.29	0.74	0.71	43	270	38	170	17	Slider
1040	0.03	0.02	0.03	0.01	0.04	0.02	0.2	0.39	72	600	75	400	19	Disc

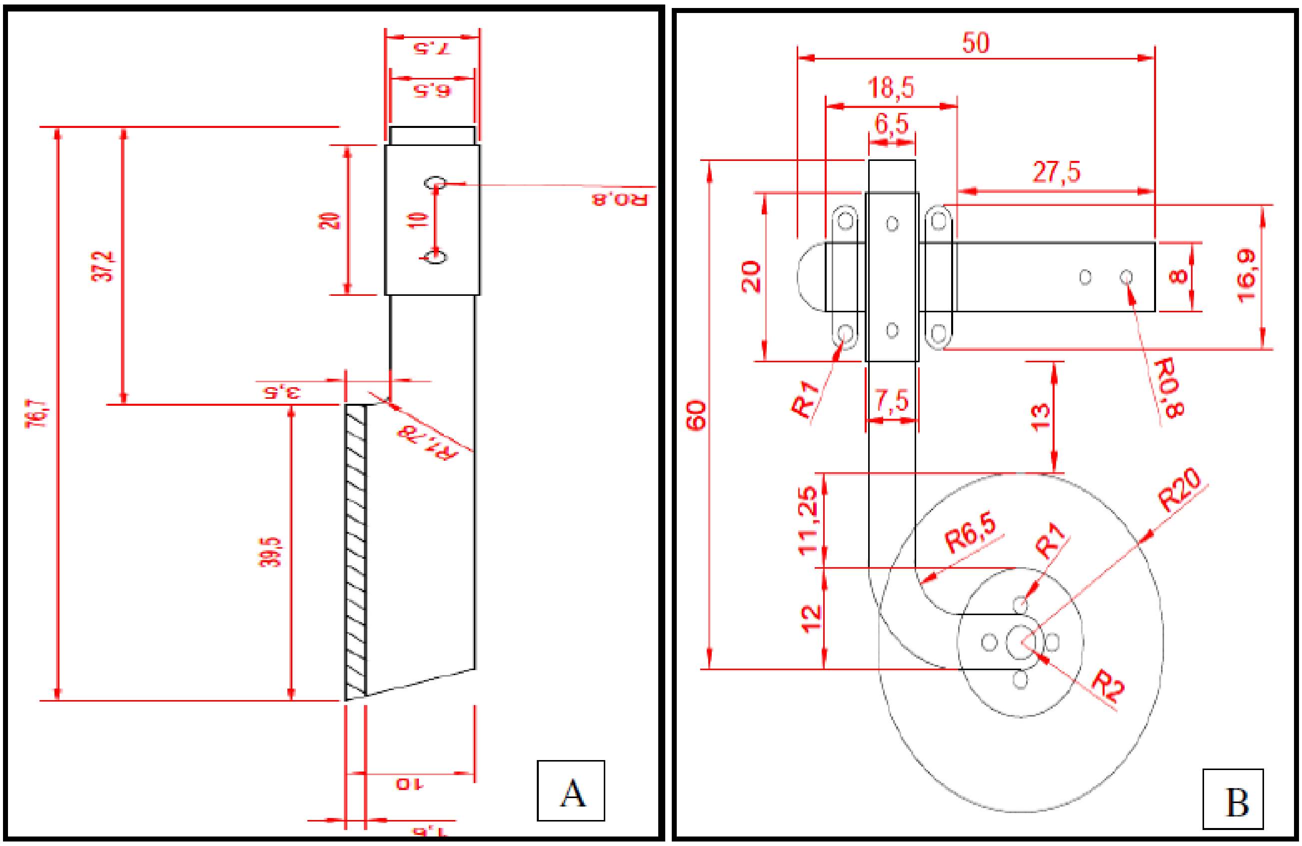
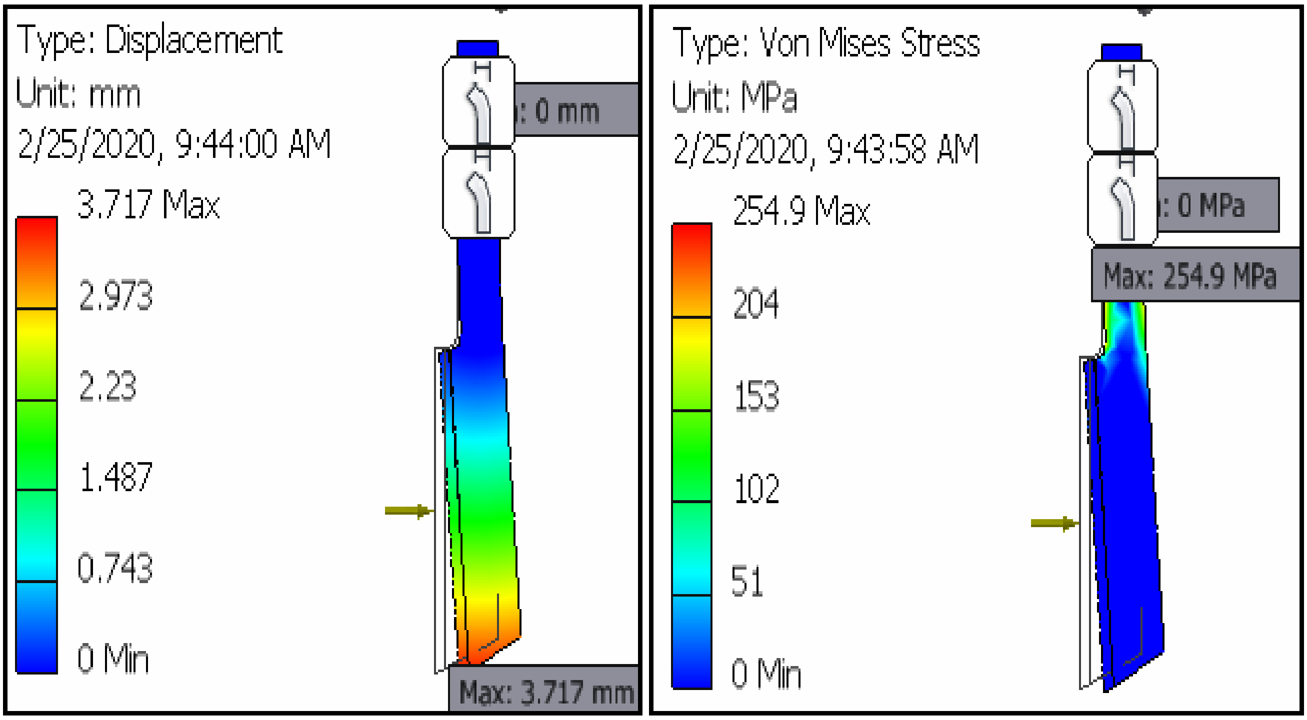


Fig. : (1)A and Figure(2)B design schema of the disc, sliding coulter with the parts attached to it

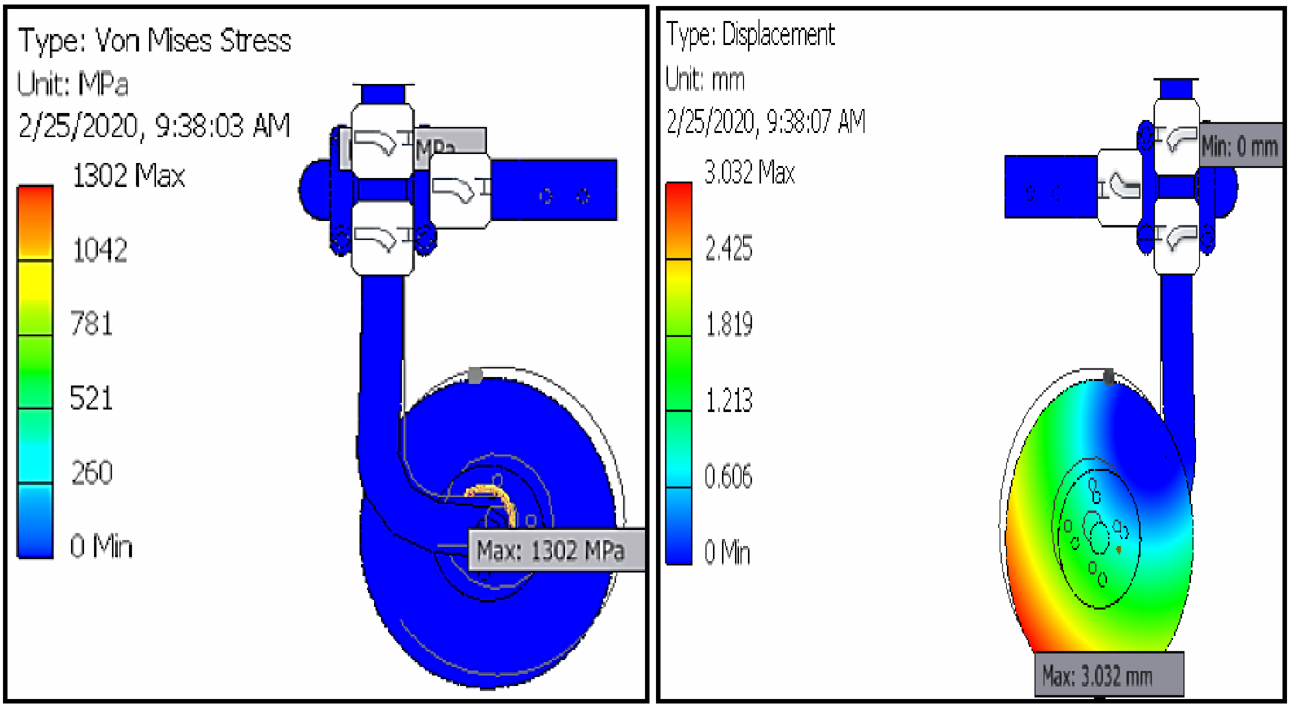
Results and Discussion

1. Stress (MN.m^{-2}): The von mises and displacement ratio for the locally manufactured sliding coulter and disc coulter were determined using the finite element method F.E.M In the program Ansys, analysis allows pre-testing of the properties of the part before manufacturing to show the distribution of stresses affecting the coulter as a result of loads and the forces applied it under conditions as similar as possible to the field conditions, theoretical values were determined, Figures (3,4) showed the distribution of stresses and displacement ratio, where the sliding coulter achieved the lowest von mises stress was 254.9MPa and the disc coulter recorded the highest von mises stress was 1302 Mpa, the displacement ratio of the sliding and disc coulter was 3.717mm and 3.032mm respectively, these theoretical results are generally less than field results and the reason was due to the possibility of instability of forces in the field due to the soil stress increased



Displacement **Von mises stress**

Fig. 3 : Sliding coulter



Von mises stress **Displacement**

Fig. 4 : Disc coulter

Figure (3,4) The distribution of stresses and displacements on the coulters

Figure 5,6 shows that the stress was increased by decreasing the moisture content and increasing the depth of tillage of the moldboard plow with the sliding ,disc and without coulter respectively, the plow by the sliding coulter achieved the lowest stress at all level depths and soil moisture content, where achieved at the moisture content 16.22% and depth 15-20 cm less stress was 41.05 MN.m^{-2},It was followed by a disc coulter then a plow without a coulter and it was 43.16 and 46.11 MN.m^{-2} respectively,while these values increased by increasing the depth of tillage to 25-30 cm at the same moisture content to be 44.46, 47.57 and 50.08 MN.m^{-2} for the plow with the sliding, disc, and without a coulter respectively,It was noticed that stress was in an increased state when the moisture content decreased and the depth of tillage increased,where the plow by sliding coulter and disc and without a coulter knife with the moisture content 9.73% and depth 15-20 cm recorded the largest values were 42.97, 45.35 and 48.29 MN.m^{-2} respectively, The highest stress values were recorded at depth 25-30 cm and moisture content 9.73% and reached 46.72, 49.84 and

53.42 MN.m⁻² for the plow with the sliding and disc coulter knife and without a coulter, respectively. The reason for this is because the design of the sliding coulter and later the disc coulter It facilitated the penetration of the plow bottom into the soil and it reduced part of the pressure on him and in doing so achieved the least stress.It was also found that the higher moisture content and reach the limits of optimum humidity and depths of tillage decreased leads to a reduction in soil resistance and size and weight of soil blocks facing the bottom surface which reduced the load and draft strength and thus this led to decrease in a stress.

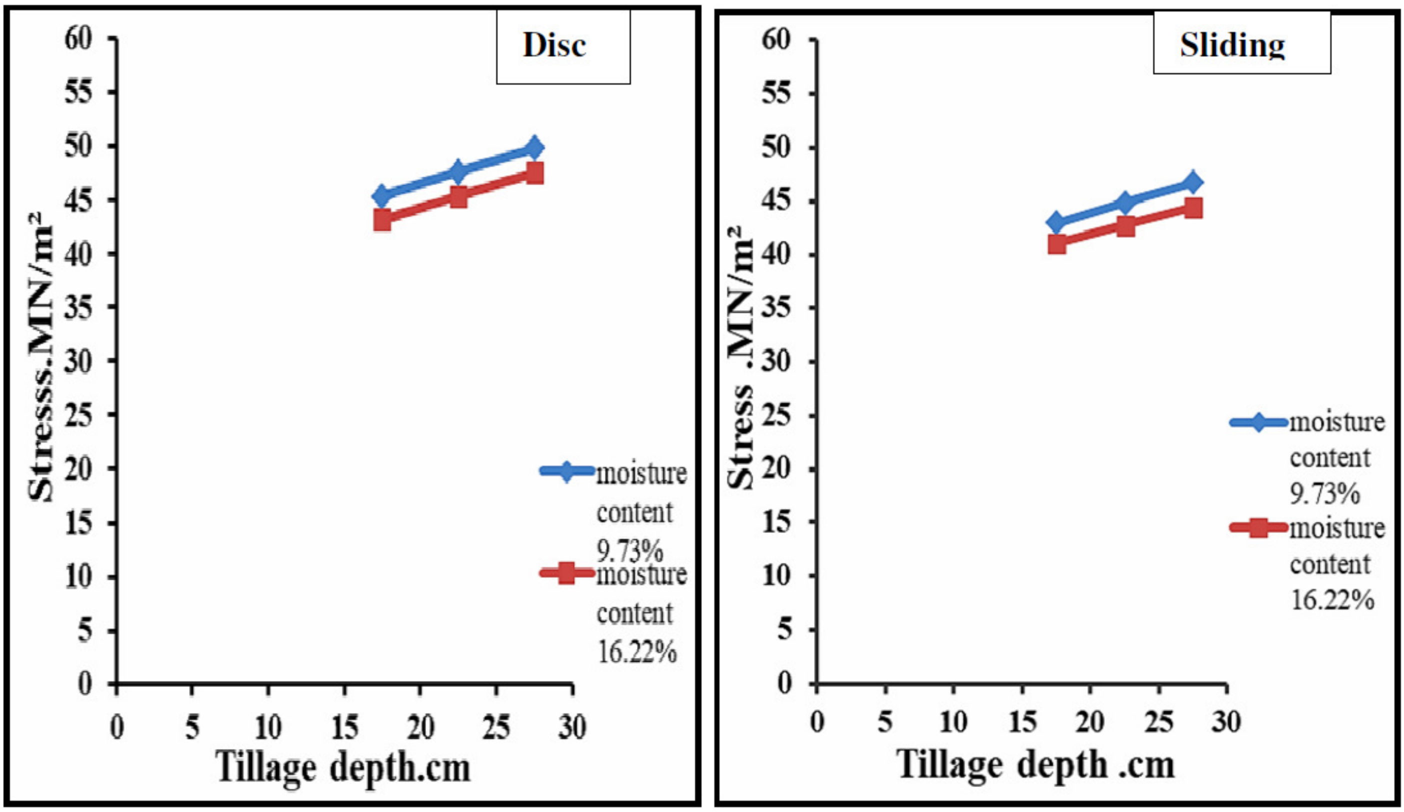


Fig. 5 : The influence of the interaction among tillage depth, soil moisture content and the stress on the plow bottom with coulter type

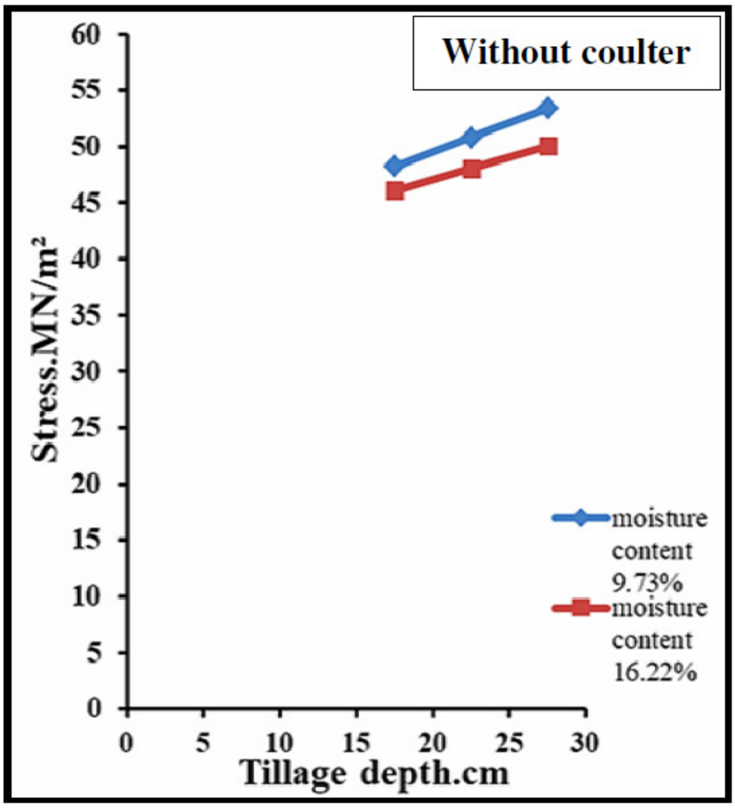


Fig. 6 : The influence of the interaction among tillage depth, soil moisture content and the stress on the plow bottom without coulter

2- Specific draft resistance (KN.m^{-2}):

Table(2)shows that the moisture content 16.22% significant superiority in achieving the lowest value was **32.37**KN.m^{-2} compared to the moisture content 9.73% which recorded the highest value reached 42.18KN.m^{-2} of the specific resistance this may due to the fact that the low moisture content reduces the soil volume disturbed which is a component of specific resistance where the relationship is opposite between them, which leads to an increase in the specific resistance that agreement with the researchers (Arvidsson *et al*., 2004) and (Arvidsson and Keller, 2011).

The sliding coulter with the moldboard plow achieved the lowest specific resistance and reached 31.39 KN.m^{-2} compared to the plow with a disc coulter 37.27 KN.m^{-2}, and the highest value was for a moldboard plow without a coulter and was 44.14 KN.m^{-2} .This is due to the fact that the shape, type and size of the coulter have an important role in penetrating the plow bottom to the soil, the sliding coulter supported the plow bottom to cut the soil with a small penetration angle that enabled it to penetrate more easily than the plow with the disc and without a coulter and that the width of the cross section of the soil facing the bottom is relatively low due to the longitudinal distance of the sharp edge of the sliding coulter, this led to less pressure, stress, and resistance on the plow bottom and the ease of its depth inside the soil, which reduced the draft force and thus obtaining the least specific resistance this is consistent with the results found by the researchers (Rucins *et al*., 2006), (Arvidsson and Hillerstrom, 2010), The tillage depth 15-20 cm recorded the highest specific resistance was 40.22 KN.m^{-2} While the depth 25-30cm achieved the lowest significant value was 35.31KN.m^{-2} the reason due to the increasing in tillage depths led to increase in soil volume disturbed when the plow moves deep inside the soil and more than the increase in draft force, consequently the draft force is one of the compounds of specific resistance, it reduces the specific resistance this is consistent with (Nasser *et al*., 2016) and (Alele, 2019). while for the effect of dual interaction between the moisture content of 16.22% with the plow by the sliding coulter where It resulted in recorded the lowest significant value of specific resistance was 25.50KN.m^{-2} compared with the rest of the parameters this is due to the low draft force of the plow with the sliding coulter which reduced the pressure on the bottom and increased the tillage depth and increasing in the soil volume disturbed at optimum humidity, and moisture content 16.22% with depth 25-30 achieved the lowest significant value of specific resistance was 30.41KN.m^{-2} compared to the rest of the parameters, The plow by the sliding coulter with depth 25-30 cm achieved the lowest significant value of specific resistance reached 28.44KN.m^{-2},compared to the rest of the parameters, due to the reasons mentioned previously.

Table 2 : The effect of the studied factors in specific resistance (KN.m^{-2})

Coulter type	Soil moisture (%)		Tillage depth(cm)		Effect coulter type
	9.73	16.22	15-20	25-30	
Sliding	36.29 cd	25.50 e	33.35 b	28.44 c	31.39 c
Disc	40.22 b	34.33 d	41.20 a	34.33 b	37.27 b
Without coulter	50.03 a	38.25 bc	44.14 a	44.14 a	44.14 a
Effect soil moisture	42.18 a	32.37 a			
Overlap between soil moisture and depth	9.73%		44.14	41.20	
	16.2 %		35.31	30.41	
Effect tillage depth			40.22 a	35.31 b	

Figure (7) shows The influence of the interaction among the studied factors in specific resistance that the plow by sliding coulter recorded the lowest value of the specific resistance was 21.58 KN.m^{-2} at moisture content 16.22% for depth 25-30cm, while the moldboard plow without coulter recorded the highest value of the specific resistance reached 50.03KN.m^{-2}at moisture content 9.73% for both depths.

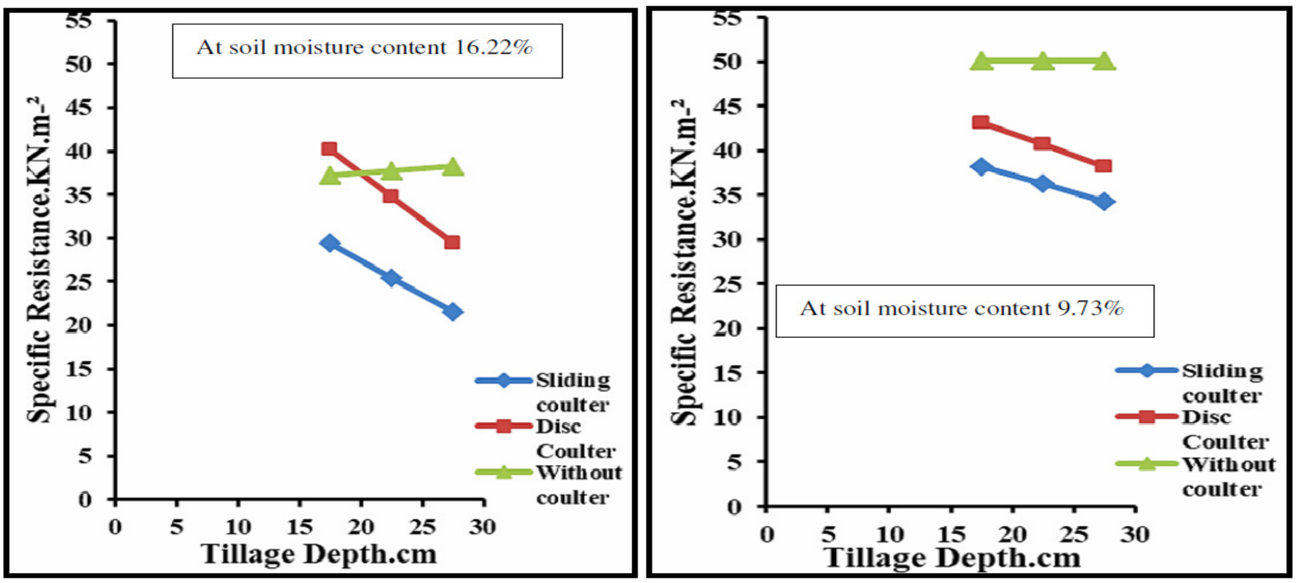


Fig. 7 : The influence of the interaction among the studied factors in specific resistance

3- Specific energy (kw.h .ha^{-1}):

Table(3)shows that the moisture content 16.22% achieved the lowest significant value of specific energy was 98.9 kw.h.ha^{-1}compared with the moisture content 9.73% it was recorded the highest significant value reached 113 kw.h.ha^{-1}, that may be due to the fact that low soil moisture content has increased the tractor wheel slippage with the plow as a result increased the draft force which led to an increase in fuel consumption and decreased the actual field capacity to increase the time period during the plowing process, thus increases specific energy. this is consistent with the results indicated by the researchers (AL-Iraqi et el., 2009) and (Thakur and Jagadale., 2018).

The modboard plow with sliding coulter significant superiority in achieving the lowest significant value of specific energy reached 99.2 kw.h.ha^{-1}, compared to the rest of the parameters, due to the fact that both coulter types use different soil cutting techniques, As the design of the sliding coulter with the plow bottom has worked as an integrated unit in performance to cut and disturb the soil slice and reducing pressure and resistance on the plow bottom led to required power decreased for the tillage process, thus obtaining the lowest specific energy value, The disc coulter recorded significantly value greater than the sliding coulter and less than the plow without coulter The reason is due to the work mechanism and dynamic rotary disc movement in cutting soil in part front of the plow bottom, and this contributed to reducing part of pressure on the plow bottom, That is consistent with (Kheiralla *et al*., 2004) and (Celik *et al*., 2007). depth 15-20 cm achieved the lowest significant value of specific energy reached 93.4 kw.h.ha^{-1}, compared with the depth 25-30cm which recorded the highest significant value of specific energy 118.5 kw.h.ha^{-1}, and the reason for that is due to the increase in tillage depth accompanied by an increase in specific soil resistance and fuel consumption as a result of slipping and increase the load on the tractor when the tillage depth increased which leads to a high power which is a component of specific energy that increases with the power and this consistent with (Al-Hashemi., 2012), (Zidan., 2018) and (Himoud., 2018). interaction between the moisture content 16.22% with the sliding coulter recorded the lowest specific energy value was 90.2 kw.h.ha^{-1} compared to other parameters. and moisture content 16.22% with depth 15-20cm in registered the lowest significant value of specific energy was 84 kw.h.ha^{-1} compared with the rest of parameters, this is due to the slip index and the power as in the previous reasons, the plow by the sliding coulter with depth 15-20cm recorded the lowest value of specific energy reached 85.6 kw.h.ha^{-1}, compared to the rest of parameters.

Table 3 : The effect of the studied factors on the specific energy (kW.h.ha^{-1})

Coulter type	Soil moisture (%)		Tillage depth(cm)		Effect coulter type
	9.73	**16.22**	**15-20**	**25-30**	
Sliding	108.1	90.2	85.6	112.7	99.2 c
Disc	113.3	97.6	93.7	117.2	105.4 b
Without coulter	117.5	108.8	100.9	125.5	113.2 a
Effect soil moisture	113.0 a	98.9 b			
Overlap between soil moisture and depth	9.73 %		102.7	123.3	
	16.2 %		84	113.7	
Effect tillage depth			93.4 b	118.5 a	

Figure (8) shows The influence of the interaction among the studied factors in specific energy that the plow by sliding coulter recorded the lowest value of the specific energy was 72.9kw.h.ha^{-1} at moisture content 16.22% for depth 15-20 cm, while the moldboard plow without coulter recorded the highest value of the specific energy was 128.9 kw.h.ha^{-1} at moisture content 9.73% for depth 25-30cm.

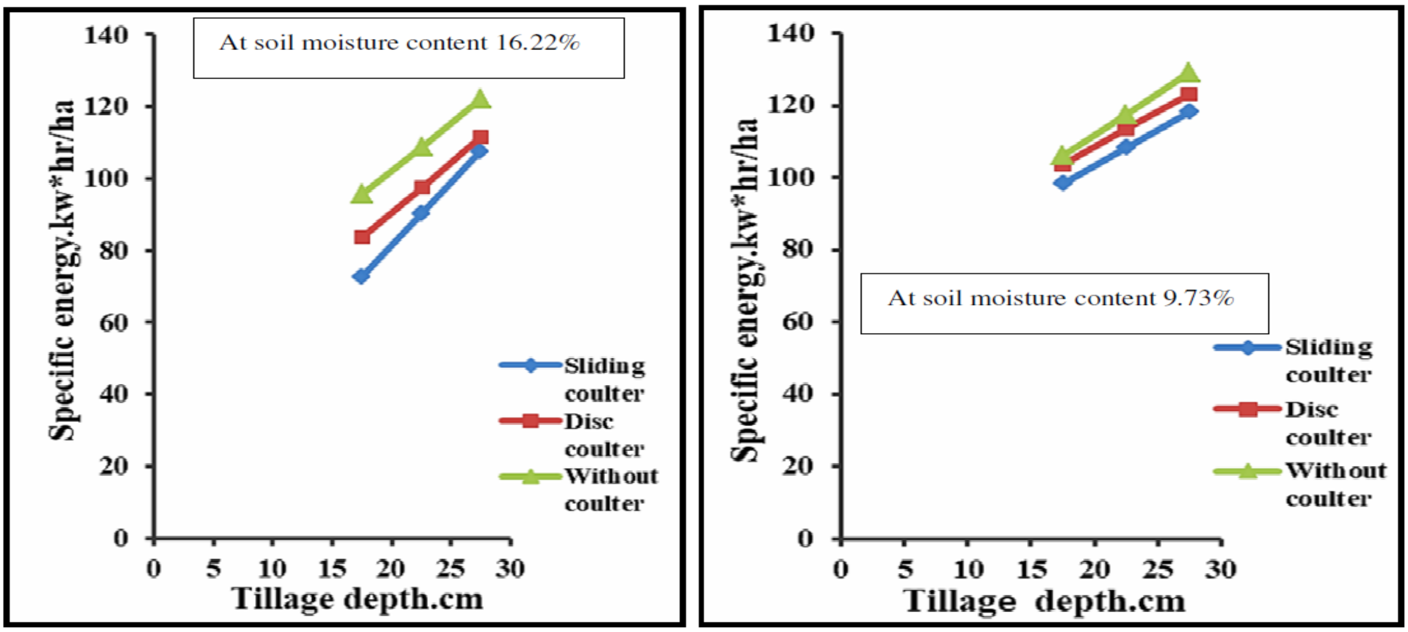


Fig. 8 : The influence of the interaction among the studied factors in specific energy

4-Specific Energy Efficiency (%):

Table(4)shows there was no significant effect of the moisture content on the specific efficiency, the moisture content 16.22% recorded the highest specific efficiency reached 9.24%, while the moisture content 9.73% recorded lowest specific efficiency was 8.93%, The plow with the sliding coulter recorded the lowest significant value of specific efficiency was 8.60% and the plow with the disc coulter recorded greater value reached 9.11%, while the plow without coulter recorded highest significant value was 9.55% which at the same time did not different significantly from the plow with disc coulter, that is due to the low drawbar power of the plow with sliding coulter accompanied by increase in actual productivity that led to specific energy decreased relative to fuel consumption It is one of the specific efficiency compounds, that is to consistent with (Celik *et al.*, 2007), (Ranjbarian *et al.*, 2015). The plowing depth 15-20cm recorded lowest specific efficiency reached 8.65% while the depth 25-30 cm recorded the highest specific energy efficiency of 9.52%, this is due to the fact that increasing the tillage depth leads to the load increases on the tractor and slippage increased and fuel consumption per unit time that is led to specific energy efficiency increased this is consistent with (Khadr, 2008) and (Zidan, 2018). Interaction between the moisture content 9.73% with the plow without coulter gave the highest value of specific efficiency reached 9.82%, while the same moisture content with the sliding coulter recorded the lowest value for the specific energy efficiency of 8.40%, this is due to specific energy decrease of the plow with the sliding coulter and the low power that is led to specific efficiency decreased. The moisture content 9.73% with the depth 25-30cm recorded the highest specific efficiency was 9.94%, while the same moisture content with depth 15-20cm recorded the lowest specific efficiency reached 7.93%, This is due to the fact that increasing the tillage depth leads to the load increases on the tractor this led to an increase in the draft force due to the low speed used and it led to increased slippage and specific resistance, thus increasing specific energy and specific efficiency. the plow without a coulter with depth of tillage 25-30cm recorded the highest value of specific energy efficiency was 10.60% while the plow by the sliding coulter with depth 15-20cm recorded the lowest specific efficiency reached 8.41%, This is due to the fact that the plow with the sliding coulter reduced the pressure generated on the plow bottom when cut the soil with the lowest power required at depth 15-20cm, which led to the registration of the lowest specific efficiency.

Table 4 : The effect of the studied factors on the specific energy efficiency (%)

Coulter type	Soil moisture (%)		Tillage depth(cm)		Effect coulter type
	9.73	**16.22**	**15-20**	**25-30**	
Sliding	8.40 d	8.80 cdb	8.41 b	8.79 b	8.60 b
Disc	8.58 cd	9.64 ab	9.06 b	9.16 b	9.11 ab
Without coulter	9.82 a	9.28 cab	8.49 b	10.60 a	9.55 a
Effect soil moisture	8.93	9.24			
Overlap between soil moisture and depth	9.73 %		7.93 b	9.94 a	
	16.2 %		9.38 a	9.10 a	
Effect tillage depth			8.65 b	9.52 a	

Figure (9) shows The influence of the interaction among the studied factors in specific efficiency that the plow without coulter recorded the highest value of the specific efficiency was 11.25% at moisture content 9.73% for depth 25-30cm, while the moldboard plow with sliding coulter recorded the lowest value of the specific efficiency was 7.64% at moisture content 9.73% for depth15-20cm.

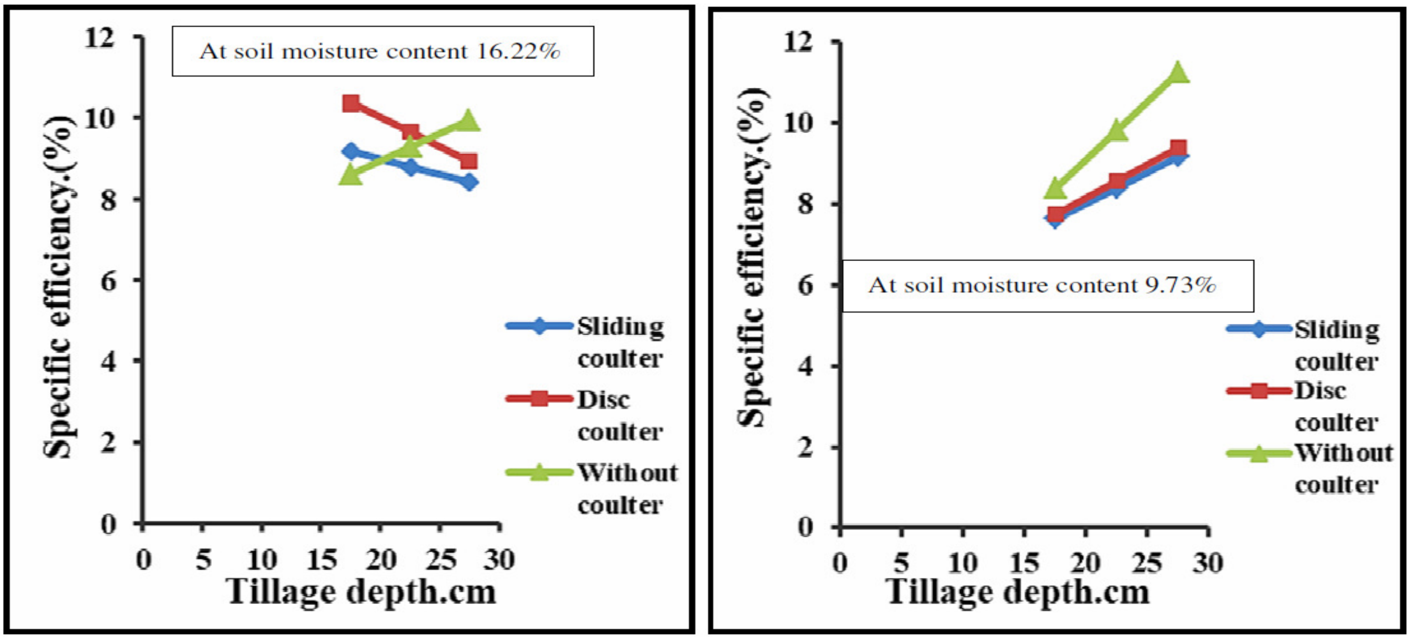


Fig. 9 : The influence of the interaction among the studied factors in specific energy efficiency

Conclusions

- The sliding coulter with the moldboard plow achieved the lower stress on the plow bottom.
- The sliding coulter, the moisture content (16.22%) led to decrease the specific resistance and specific energy.
- The depth of tillage (15-20) cm with the plow by sliding coulter gave the lowest significant value of the specific energy efficiency.
- The plow without coulter with depth (25-30) cm and also with moisture content (9.73) gave the highest value of the specific energy efficiency.

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