Cut quality of mild Steel by CO_2 laser

Asst.Instructor.Jasim Hassan Rasheed
Departanent of physics
Science College
University of Diyala

خلاصة مركزة :
تمت دراسة نوعية قطع الفولاذ بليزر ثاني اوكسيد الكاربون بصورة واسعة وقد تم تقديم مقترح جديد لتصنيف نوعية القطع . ان هذا التصنيف اسس على دمج ثلاثة عوامل لها صلة بنوعية القطع وهي : اخدود القطع والمنطقة المتأثرة حراريا والخشونة . اقترحنا علاقة رياضية (بصيغة المصفوفة) تشمل العوامل الثلاث اعلاه اضافة لذلك عرضنا مقارنة لنتائج تقنيات قطع عديدة لبحوث سابقة ومن ضمنها النتائج الحالية وقد اظهرت تمتع ليزر ثاني اوكسد الكاربون بنوعية قطع جيدة .

Abstract : Cut quality of mild steel by Co_2 laser is studied extensively and new approach to classify quality is presented . This approach is based on combining different parameters such as cut kerf, heat affected zone and roughness.

A mathematical relationship(in matrix form) has been developed to include all the above Parameters in one factor which is called the quality factor . In addition , cut quality by CO_2 laser is compared with many different machining techniques which are produced by previous researchers .This comparison shows that CO_2 laser are an excellent tool .

١. **Introduction** : many researchers gave attention to the cutting mild steel (١،٢,٦،١٠،١٢،١٣،١٤) . when reviewing the subject , it was found that the study of the present objective is still slim and deeper study is needed to fill gap.

Cut quality in particular receives little attention for research worker (٩،١٠،١١،١٣،١٤) . It is necessary to pay attention to this problem with a view to establish new approach and to define overall cut quality in a more systematic way than the previous workers had attempted . A good study of the cutting mild steel by carbon dioxide laser should include a comprehensive investigation of the factors involved roughness (R٠) , Cut kerf (k_w) and heat affected Zone (HAZ) in order to achieve a reasonable assessment for quality.

٢. **The equipment** (٧):

a. Carbon dioxide laser system:

The ٥٠٠w Co_2 laser system (٥٢٥ Ever laser model) is typical of equipment used for mild steel processing which is now regularly carried out in industry . Circular polarization laser beam is used during cutting process . The laser beam and gas were delivered through the nozzle (١mm) diameter assembly called cutting head as shown in figure (١) . Mode , beam alignment , focusing of the beam and assisting oxygen gas effect the out power of the laser.

Mild steel surface of ١,٦٨mm thickness was used , and (٥- ٤٠) psi gas pressures were applied.

b. Taly surface and Taly data (٣) : The instrument used to measure the cut quality for present work is called Taly surface and Taly data computer programmed with integral visual display and a portable keyboard . Taly surface is programmed for surface texture analysis combined with hard copy printer will make a printed copy of any data which is being displayed . Figures (٣،٤) were picked by this instrument .

c. ISDAM profile projector (٤) : This projector was used during the present experimental work to measure the kerf width and the colored area of the heat affected zone .The results are shown on a digital screen with high accuracy and reliability. Figure (٢) was produced by this technique.

٣. Results and Discussion : The over all study concerning cut quality of mild steel by CO_2 laser in the current work is quite important because mild steel is used heavily in industry . In addition, the results for mild steel can give a better indication for results to be expected when cutting stainless steel . During the literature survey it was found that there is gap in the study of the cut quality which needs be filled in spite a few attempts led by Powell (٢ ,٥) and Arata (٦) which required confirmation and widening . predicting overall quality which can be used to assess cost is vital for industry . For example , when

all three parameters are considered in the same degree of importance , and optimum conditions , the production cost should be higher than when three parameters are taken in different proportion . An extensive study in terms of economic (gas , water , electricity and labor cost) should be given more attention and link the results with the quality assess - ment . However , good study of the cutting mild steel by Co_2 laser should include a comprehensive investigation of the factors involved, such as Roughness (R_o) , cut kerf width (kw) heat affected zone (HAZ) in order to achieve a reasonable assessment for quality. There now follows a discussion for each of the cut quality parameters.

a. kerf width : A kerf is produced by removing material during the laser cutting process , A narrow cut is preferred to save material and usually gives better quality . The kerf width is defined as the average of maximum and minimum width. There are many factors that influence width of cut kerf , for instance :

i. The smallest laser spot size which correspond with maximum energy intensity on the material surface will give a narrow kerf.

ii. The maximum possible speed gives narrower kerf width in particular.

iii. pressure of oxygen gas employed.

Typical examples for cut kerf (top view) are produced in the present work and are shown in figure(٢- a,b,c,d,e,).

The kerf width is measured by using an ISDAM projectors

b. **Heal affected zone**(**HAZ**):It is another parameter considered during the investigation in order to build up solid information to achieve as good quality assessment as possible . The heat affected zone width is defined as the average distance from maximum kerf width line to the limit of the colored area, on either side of the cut .The area shows difference in physical , mechanical and metallurgical proportion from the equivalent properties in material body . The factors given in section (٣-a) , also influence the width of the heat affected zone which , from preference should be narrow and only occur adjacent to the kerf . As apart of overcall quality assessment, a classification appr - oach has produced . Figure (٢- a,b,c,d,e) also show different examples of the heat affected zone.

c. Roughness: It is the most important tool in assessing the cut quality and to provide information to be used in grading the laser cutting process a long side other thermal methods. Many investigation were carried out during this work . Roughness values have been divided into a number of ranges , each defined by a particular symbol . A nume - rical value is also given in an attempt to quantify the quality. Fig (٣ a, b , c , d ,e) and Fig (٤ - a, b , c , d ,e)are

produced by Telysurface show striation lines which decide the roughness of the cut edge. The striation lines were considered as a parameter of roughness by Tiruinala (٩) too. The definition and numerical Values as a part of the new classification to the cut quality are given in the following tables (١ , ٢ ,٣ and ٤) .

Table (١)

Roughness(Ro) in(um)	Symbol	Definition	Numerical value classification value
٠,٠٠-٢,٥	o	Fine	٨
٢,٥١-٥,٠	Δ	Good	٦
٥,١٠-٧,٥	✕	Accepted	٤
٧,٦٠-١٠,٠	□	Poor	٢
١,٠٠-	X	Unaccepted (Rejected)	٠

Table (٢)

Kerf width Kw in (mm)	Symbol	Definition	Numerical value or classification value
٠,٠ – ٠,٠٧٥	o	Fine	٨
٠,٠٧٦-٠,١٥٠	Δ	Good	٦
٠,١٥١ -٠,٢٢٥	✕	Accepted	٤
٠,٢٢٦ – ٠,٣٠٠	□	Poor	٢
٠٣٠١	X	Unaccepted	٠

		(rejected)	

Table (٣) (This table is produced according to the table) (٢)

Figure number	Kerf width classification
١	Fine
٢	Good
٣	Accepted
٤	Poor
٥	Unaccepted (rejected)

Table (٤)

Heat affected zone HAZ in (um)	Symbol	Definition	Numerical value or classification value
٠,٠ – ٠,٢٥	o	Fine	٨
٠,٢٥١- ٠,٥٠	Δ	Good	٦
٠,٥٠١ - ٠,٧٥	✕	Accepted	٤
٠,٧٥١ – ١,٠٠	□	Poor	٢
١,٠١	X	Unaccepted (rejected)	٠

For Combination , the combined facer (Q)is:

$Q = C_{Ro} + C_{kw} + C_{HAZ}$

Where C_{Ro} is the numerical or classified value of roughness

C_{kw} is the numerical or classified value of kerf width

C_{HAZ} is the numerical or classified value of heat affected Zone .

By Combining the three different parameters ,namely roughness, kerf width and heat affected zone, a new technique to achieve better assessment for overall cut quality is proposed The combination parameters called the combined fucter(Q). The idea is based on the Conclusion that each of these three parameters (C_{Ro} , C_{kw} , C_{HAZ}) is very important and can not be ignored . Although these parameters have been correlated separately , they jointly ,influence overall quality in same combination .The combination is based on the assumption that all three parameters have the same degree of importance in the industrial field.

The following definitions are used for the propose technique of combined quality factor as shown in table (٥)

Table (٥)

Symbol	Definition	Numerical or classification value Of combined quality factor(Q)
o	Fine	٢٤
Δ	Good	١٨-٢٣
✕	Accepted	١٢-١٧
□	Poor	٦-١١

X	Unaccepted	٠-٥

For those applications which consider a different degree of priority and attention to roughness , cut kerf and heat affected .The combined factor (Q) should be calculated according to each specific application .

A mathematical relationship (in matrix form) has been developed (٨) to include all the cut quality factors such as roughness , heat affected zone and kerf width in different combination in one factor which is called the combined quality factor .This equation is:

$$\begin{matrix} Q_1 \\ Q_2 \\ Q_3 \\ Q_4 \\ Q_5 \\ Q_6 \\ Q_7 \end{matrix} = \frac{1}{2} \left[R_a \;\; K_w \;\; H_{AZ} \right] \begin{pmatrix} 2 & 1 & 1 & 2 & 2 & 3 & 3 \\ 2 & 2 & 3 & 1 & 3 & 1 & 2 \\ 2 & 3 & 2 & 3 & 1 & 2 & 1 \end{pmatrix} \quad \ldots\ldots\ldots\ldots..(1)$$

$$Q_1 = \frac{1}{2} \; (2R_o + 2K_w + 2HAZ) \quad \text{———} \quad 1.a$$

$$Q_2 = \frac{1}{2} \; (R_o + 2K_w + 3HAZ) \quad \text{———} \quad 1.b$$

$$Q_3 = \frac{1}{2} \; (R_o + 3K_w + 2HAZ) \quad \text{———} \quad 1.c$$

$$Q_4 = \frac{1}{2} \; (2R_o + K_w + 3HAZ) \quad \text{———} \quad 1.d$$

$$Q_5 = \frac{1}{2} \; (2R_o + 3K_w + HAZ) \quad \text{———} \quad 1.e$$

$Q_٦ = (٣R_o + K_w + ٢HAZ)$ ———— ١.f

$Q_٧ = \frac{١}{٢} (٣R_o + ٢ K_w + HAZ)$ ———— ١.g

The above suggestion is considered important for industrial application in the sense that it gives flexibility and can be adjusted to suit the need of each specific applications.

Fig:(٥) shows different cut quality assessments and it can be seen that as the speed is lowered , the cut quality factor is also lower. Tirumala (٩) is also pointed out that the cut with higher cutting speed have coarse striation . He emphasized that the cut surface is influenced to a greater extent by the change in cutting velocity than with the variation of the insisting gas pressure . Fig(٦) shows the quality factor variation against power which is based an different degrees of priorities as shown in equation (١). Comparing each graph with the above equation will show the best quality fit required for each industrial applications . This first attempt to define quality and further work need to be done in this area , including comparison with other published work.

Fig (٧) shows the variation of the combined quality factor with both power and speed . Two regions are shown : The first region , which includes acceptable cut quality and the second good cut quality . Using the combined quality factor is apparent from the figure that overall cut quality is improved as power is reduced . changing the cutting speed shows no influences on the cut quality which in contract to the work published (٩) .

Figure (٨) shows comparison surface roughness for different machining methods including present work, and shows excellent results . laser cut quality fits between drilling (rougher than laser cutting) and internal grinding (smoother than laser cutting) (١٥).

٤. **Conclusion** : Cut quality parameters have been studied , and following points can be concluded from the present research.

a. The most significant achievement of the present work is that the kerf width is narrower than that of most published yet. The kerf width produced is close to that achieved by Nd- Yag lasers.

Normally the kerf width produced by Nd- Yag is much smaller than that achieved by CO_2 laser due to the difference in their wavelengths .Also heat affected zone width achieved during the present work is very narrow in comparison to that previously published .

b. The cut quality produced is good compared to that already reported by (٨) on the bases of his classification . However better cut quality always occurs near the initiation point of the cut. Striation lines are more regular in the upper portion than that in the lowest part of the work piece and remain straight for a longer distance when the cut is smoother (٧،٩،١٠،١٤,).

c. A mathematical relationship (in matrix form) has been developed to combine roughness , heat affected zone and

kerf width in one factor during cut quality assessment is an attempt as a new idea and considered be a correct step towards better assessment.

Fig:٨

(١٥)

REFERENCES

١. Gonsalvers, J. N. and Duley ,w,w " cutting thin metal sheets with the cw CO_2 laser " J . Appl. Vol (٤٣),no .(١١) pp.(٤٦ ٨٤ -٨٧)(١٩٧٢).

٢. King . T. and powell ,J " laser cut mild steel – factor , affecting edge quality " ٣rd Int . conf on Metrobgy and properties of Eng .surfaces ,Tesside polytechnicm (١٠ -١٢) April (١٩٨٥) .

٣. Operating instructions for Talysurf .٤ surface measuring instrument . The Rank organization , Rank Taylor Hobson Division .

٤. Technical instruction for the ISDAM profile projector M١١٨/M١١٩.

٥. Powell , J . and MenZies ,I.A"principle and applications of CO_2 laser cutting " Material Eng . conference , London , Nov.(١٩٨٥).

٦. Arata , Y . Muruo .H , Miy moto .I and Rakeuchi. S., " Dynamic behavior in laser gas cutting of mild steel " Trans – JWRI, part٢ , pp (١٥-٢٦) ,(١٩٧٩).

٧. Jasim . Hassan .Rasheed , " praivite work " dept. of mechnical Eng . Louthborough university . U K.(١٩٨٩)

٨. Arata .Y. Miyamato .I . and Kuboto . M "Some fundamendal properties of high power cw laser beam as a heat Source". IIW Document Iv /٤١٦٩ , Report , Dept . of welding Eng. Osaka Univ . Japan .(١٩٦٩).

٩. B . Tirumala RAO and A. K Nath " Melt flow char acteristice in gas assisted laser cutting " Sadhana, India Vol . ٢٧ . part ٥ . pp(٥٦٩-٥٧٥) (٢٠٠١).

١٠. Ivarson .A, Powell .J, Kamalu J , Magnusson . c "The oxidation dynamics of laser cutting of mild steel and the generation of striations on the cut edge " Journal of material processing Technology (٤٠) (٣٥٩-٣٧٤) , (١٩٩٤).

١١. Nagarajan .R." Paramatric Study of the effected of laser cutting variables on the cut quality " Master thesis , Wichits state University , Wicchits , Kansas .(٢٠٠٠)

١٢. Michaed L. Cndorette and Fredwalker " characterizing productivity of a ٤ kw co٢ laser cutting system for mild steel " the official Electronic publication of the national Association of industrial technology . www.nait.org.(٢٠٠٦)

١٣. Di Pietro .P. , Yao .Y.L "An investigation into characterizing and optimizing laser cutting quality – a review " International journal of machine tools and Manufacture V٠١.(٣٤), pp(٢٢٥-٢٤٣) , (١٩٩٤)

١٤. Di pietra .p. Yao . Y.L."A new technique to characterize and predict laser cut striation " International Journal of Machine tools and manufacture V٠١ .(٣٥) , no (٧١) pp(٩٩٣-١٠٠٢) ,(١٩٩٥).

١٥. Bill ngham ,k. " lectures at Leicester polytechnic , (١٩٧١)

١٦. Galyer , J .F and shotbolt , c. R. "Metrology for Engineers " ٤th edition , cassell , London (١٩٨٠) .