Quality Estimate of cut surface with Oxygen cutting

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Efficiency of the separating oxygen cutting depends to a large extent on the requirements for the quality of cut surface. A number of works (1-6) deal with a problem of quality estimate of cut surface but until now the problem has not been agreed upon. The linear dependences of the cut quality figures in works 2-4 on the thickness of the steel to be cut and the exponential dependences in work 1 don't correlate. As suggested in some other provisions (5) cut quality should be estimated by standards. Under the classification proposed in work 6, cut quality is to be estimated by four following categories : accuracy, section, smoothness and change of edge metal properties (subsurface heat-affected zone).

As for the said categories, the section and smoothness in the most full degree bring out cut surface quality and are characterized with the following indices (Fig. 1): non-perpendicularity of the cut surface to the basic metal surface ; fusion radius of the upper edge ; falling behind (curving) of cut line ; number of grooves per 10 mm of the cut ; and groove depth (roughness) on its surface.

This work is intended for generalizing of the published data and experience of advanced enterprises as well as the results of the experiments conducted. The work is also aimed at working out of well founded criteria of cut surface quality depending upon the thickness of the steel to be cut.

The results obtained may be necessary for development of a classification of cut surface quality.

The results of this article have been used when preparing GOST 14792-69 "Oxygen and plasma electric arc cutting". During the tests, over 300 cuts of the steel St. 10, 30 and 60 mm thick and 1 m long have been effected.

The steel had been cut in the laboratory with ASSh cutter with the use of oxygen of 99.5% purity. The

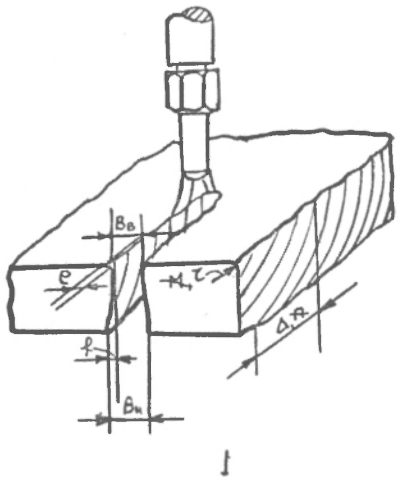

Fig. 1 Cut parameters

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Table 1

of sheet mm	Sizes of jet, mm			Gas consumption cum/hr			mm/min
	Diameter of neck opening	Diameter of outlet opening	Slot width	Cutting oxygen	Heating oxygen	Acetylene	
10	1.2	1.4	0.225	2.2	0.3	0.2	300-600
30	1.2	1.4	0.225	3.9	0.45	0.3	200-500
60	1.6	1.8	0.225	8.1	0.47	0.35	150-300

cutting conditions are given in table 1. The test results were checked, with cutting in production conditions with the use of steady-state and movable gas cutting machines. It took about 10,000 measurings to determine quantity values of some parameters characterizing cut surface quality. To determine non-perpendicularity of the cut surface the difference between the actual cut surface and the plane perpendicular to the sheet surface was measured. When determining the degree of rounding of the upper edge, use was made of the instrument offered by the I B Subcommission of International Institute of Welding. Falling behind of grooves was measured on the cut surface prints enlarged 8-10 fold by means of an epidioscope.

Non-perpendicularity of the cut surface is due to different heat and physico-chemical activity of the flame cutting jet apparatus. Upon optimum relation of speed of movement of cutting jet and iron oxidation rate, the cut width, value of surface non-perpendicularity and falling behind of the grooves can be expected to be the least. The results of the tests done (see the schedules in Fig. 2) confirm the said assumption. Upon increase of cutting rate over optimum, the cut width by the upper edge (B_6) reduces and by the bottom (Bu) increases (see Fig. 1) ; as such, non-perpendicularity of the cut surface depending on metal thickness shall increase from 0.6 up to 2.0 mm. Above that, it is established that for the studied range of rates and thicknesses there is a relation between non-perpendicularity and falling behind of cut line. The said relation can be described with the following equation :

$$f = \frac{1.8}{\delta} \triangle,$$

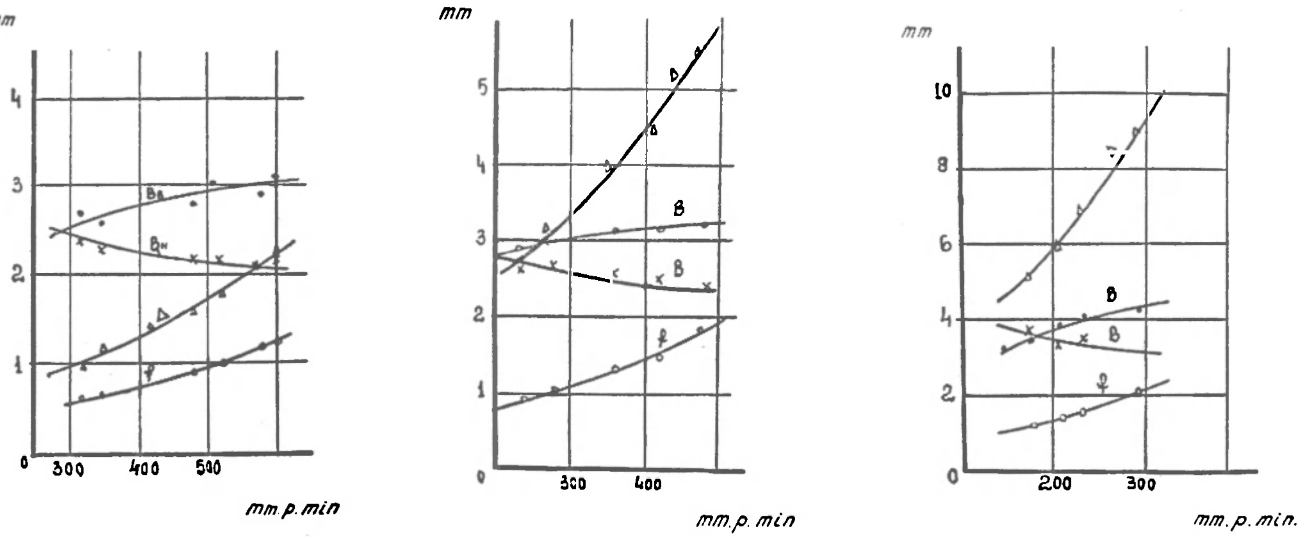

Fig 2 a) Fig. 2, b) Fig. 2, c)

Dependence of falling behind, non-perpendicularity and cut width on cutting speed with sheet thickness (mm) as follows ; a—10 ; b—30 ; c—60.

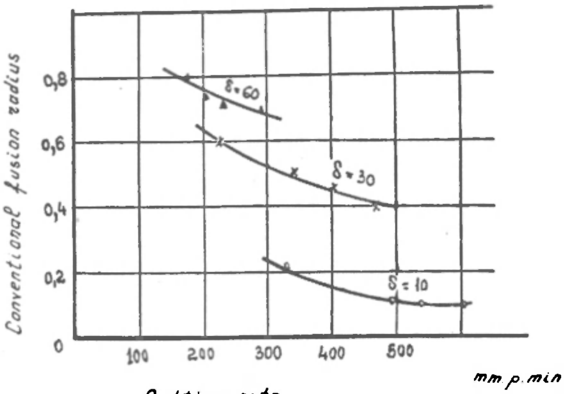

Fig 3

Y axis (mm) conventional fusion radius.
X axis (mm/min) cutting rate

Dependence of value of conventional radius of upper edge fusion on cutting rate with sheet thickness (mm) as follows : 1-60 , 2-30, 3-10.

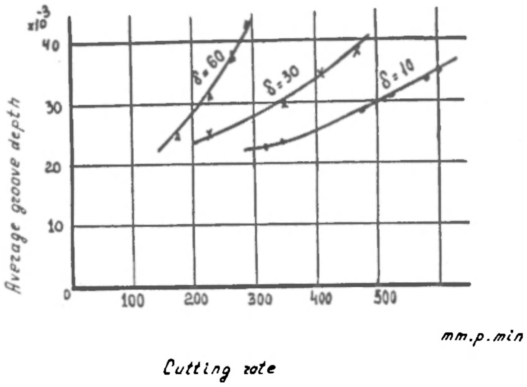

Fig. 4.

Y axis (mm) Average groove depth.
X axis (mm/min) cutting rate

Dependence of average groove depth on cutting rate.

in which f —non-perpendicularity in mm, δ — thickness of steel to be cut, Δ — falling behind of cut line in mm.

Radius of rounding of the upper edge

As a rule, blunting of the upper edge does not involve the shape of the rectilineal cylindrical surface ; therefore it was measured and re-calculated by a conventional value. Fusion of the upper edge is known to take place in the case when the power of the heating flame is too great or cutting rate is too low (Fig. 3).

Upper edge fusion arising upon cutting at optimum ratings does not involve deterioration of the surface condition and rather represents a supplementary but not basic parameter which characterizes cut quality.

In consequence of the tests conducted it has been proved that for the parts with the free edge undergoing, in operation, vibration (alternating) load the upper and bottom edges should be desirably made round up to a radius of 1.5—2 mm. In this case the endurance limit will be reduced by 13—14% while milling of the edges reduces the said limit by 20—25%.

Falling behind of cut line

When effecting oxygen cutting, there arise recesses on the cut surface. The said recesses (grooves) locate almost regularly one after another. The cause of the arising of the grooves is not quite clear until now. It is most likely that their formation is due to a value of the surface tension of melt metal and slag which are being driven back with the oxygen jet and then settle past it upon the cut surface. It is generally agreed that the falling behind depends on cutting rate.

According to the data obtained (see Fig. 2) in the studied range of thicknesses of the sheets to be cut there is an exponential relation between the falling behind and cutting rate which correlates the regularities recognized before. The thicker the metal to be cut, the more is the absolute value of the falling behind. At the same time, relative value of the falling behind (i.e. relation of the falling behind and the thickness of the metal to be cut) decreases. Thus, for instance, for 10 mm it is 25% whereas for a sheet 60 mm thick it reaches only 15%.

Density of Grooves

It is but logical to assume that the number of grooves per unit of cut length depends on cutting rate and they have a constant relation (8). But such an assumption has not appeared to be true in the course of experiments conducted. Similar data were observed by some other authors when cutting steel of 10-50 mm thick (7). Furthermore, as the cutting jet deepens into the metal some grooves discontinue and by the bottom edge other grooves either merge or disappear wholly.

Depth of Grooves

The breakdown of any parts in operation is known to begin in most cases in the upper layer of the metal. The quality of the surface layer results

Table 2

Thickness of sheet in mm	*Distance from upper edge in mm*	*Cutting rate mm/min*	*Depth of grooves in mm* ($\times 10^{-3}$)		
			Mean	*Maximum*	*Minimum*
10	5	320	23	32	11
		480	29	41	20
		600	35	46	22
30	5	230	22	52	11
	15		26	56	10
	25		27	58	16
30	5	470	35	58	16
	15		40	74	18
	25		42	68	15
60	5	175	20	32	12
	30		26	36	16
	55		30	55	18
60	5	290	34	45	18
	30		38	54	19
	55		42	62	20

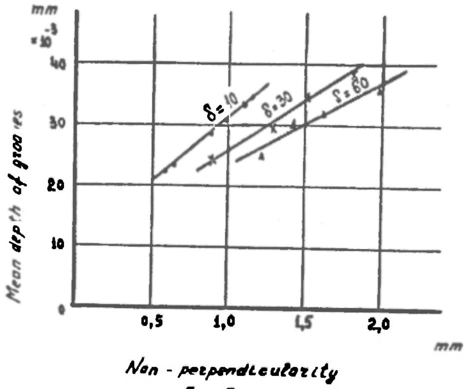

Fig. 5

Y axis mean depth of grooves (mm)
X axis Non-perpendicularity (mm).

Dependence of mean depth of grooves on non-perpendicularity of cut surface.

from its microgeometry (roughness) in which case the grooves upon the cut surface involving the roughness degree act as the concentrators of the tension influencing a value of the metal fatigue strength. This implies that roughness, i.e. depth of grooves, is one of the basic criteria characterizing the quality of the cut surface.

Dependence of the mean value of the roughness on the cutting rate and thickness of the steel to be cut is listed in Fig. 4 ; table 2 lists the averaged values of the roughness obtained as a result of more than 800 measurings effected at various distances from the upper edge of samples.

It follows from the quoted data that a depth of the grooves does not depend on a thickness of the metal to be cut. The former is in proportion to non-perpendicularity of the cut surface (Fig. 5). Therefore the more the non-perpendicularity the more shall be the depth of the grooves.

A roughness of the samples cut on serial machines in various production conditions was measured (table 3). The listed data show that with finishing cutting in production conditions the roughness of 30-100 mm which corresponds to the class of the smoothness of cut surface 4-2 under GOST 2789-59 can be practically obtained. At the same time the experience of some other enterprises has shown that the depth of the grooves on serial gas cutters reaches 160-600 mm.

Classification

The data obtained and regularities allow estimate criteria for the cut surface (section and smoothness)

Table 3

Thickness of sheet in mm	Depth of grooves in mm with oxygen cutting at various types of works				
	Shipbuilding in mm	*Diesel locomotive building works*	*Electromachine building works*		
	Odessa	*(ASP)*	*SGU*	*ASSh*	*"Raduga"*
10 — 16	33 — 77	28 — 58	37 — 60	59 — 61	—
25 — 30	—	51 — 105	59 — 93	56 — 71	28 — 39
40 — 50	—	—	31 — 86	36 — 38	30 — 38

in conformity with engineering possibilities of cutting means to be soundly chosen. Non perpendicularity of the surface on which the falling behind of the cut line and groove depth depend is a main generalizing criterion of section quality.

Besides that, non-perpendicularity of the surface shows a picture of geometrical features of the cut section. The rounding radius being a non-determining factor may be kept as an additional feature of the cut surface quality.

The falling behind of the cut line is also an important factor for choosing an optimum cutting rate.

As experiments have shown, this criterion is inter-related with non-perpendicularity of the cut surface. In production, the latter can be easier measured as against the falling behind. Therefore application of a value of the falling behind in the classification of cut surface quality would result in unnecessary complication. Density of the grooves hardly yields to quality analysis in production conditions, therefore this feature in all the authors' opinion may be kept as a minor index. From the considered indices of the cut surface smoothness, grooves depth characterizing a relief of the cut surface is the most important. By analogy with machining this index can be used for determining a class of the cut surface smoothness.

In some works when estimating quality of the oxygen cut surface presence and condition of slag on the edges shall be taken into consideration. In works 1.5 it is considered as a good practice to lessen a value of the quality when the slag is difficult to remove. The slag on the bttom edge may appear due to non-observance of a production process and therefore it can not characterise the cut surface quality. To an equal extent it is true for such indices as quantity and sizes of local chippings on the cut surface since they are due to an occasional non-observance of the process.

Any non-observance of the cutting rating shall involve a substantial decrease in the cut quality. Thus it appears that such subjective factors should not be fixed in general documents but be included in process documents. Taking into account the said considerations the cut surface quality indices are recommended to be regulated according to its non-perpendicularity value concerning the grooves depth.

Depending on a part technological duty, the requirements for the cut surface quality can be classified into : superior, heightened and common. As such for the said categories of the cut quality (section and surface smoothness), 3 classes can be set up to be characterized with the following requirements (6) :

1st class (superior) conforms to the best results which can be otbained against the most favourable conditions (optimum cutting ratings, high quality of jet, use of high class equipment and etc.).

2nd class (heightened) conforms to stable production results obtained with serial equipment assuming an increase in the efficiency as against the optimum value.

Table 4

Thickness of steel to be cut, mm	*Non-perpendicularity, mm*			*Depth of grooves, (roughness), mm* $\times 10^{-3}$		
	Classes of Quality					
	1st	*2nd*	*3rd*	*1st*	*2nd*	*3rd*
From 5 to 15	0.2	1.0	1.2	40	80	160
From 15 to 30	0.3	1.2	1.6	80	160	320
From 30 to 50	0.4	1.6	2.0	160	320	640

3rd class (common) conforms to stable production figures to be obtained with serial equipment with the ratings providing for optimum economical process figures.

Table 4 lists the classification of the cut surface quality indices in which each class is defined with limit values depending on the thickness of the steel to be cut.

The values of Table 4 hold for machine oxygen cutting of low carbon bearing steel with the thickness of 5-50 mm (not taking into account edges chamfering).

Conclusions

1. The main figures characterizing the cut surface quality are section and smoothness which under otherwise equal conditions depend on thickness of the steel to be cut and the cutting rate.

2. The most generalizing figure of the cut section is the non-perpendicularity on which the falling behind and the grooves depth also depend. The said values grow upon increase in the former value as well.

3. The depth of the grooves (roughness) is the most important index of the cut surface smoothness determining its quality characteristics.

4. The estimate qualification for the cut surface quality can be based on differentiated requirements for limit values of the two main figures of non-perpendicularity of the surface and the grooves depth (depending on the thickness of the metal to be cut), purposes and means by which the cutting shall be effected.

5. The practising of the proposed classification of the cut quality will allow a right application of oxygen cutting for production of parts with a given technological purpose and it will also order the requirements for their acceptance after cutting.

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