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THE FRACTURE TOUGHNESS TESTS OF WELDED STRUCTURES-SPECIAL PROBLEMS THAT ARE MET AND THE APLICATION FOR COD

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SUMMARY

The weld metal fracture toughness value of welded structure is evaluated by fracture mechanics parameters which are K_{IC} and COD. In preparing of K_{IC} and COD specimens may occur very difficulties. The COD method applied to the two different steel plates materials which are arc welded manually. From the test results, it was observed that there is no relation between the hardness and critical COD (δ_c).

ÖZET

Kaynaklı yapıların kırılma tokluğu değeri K_{IC} ve COD kırılma mekaniği parametreleriyle değerlendirilir. K_{IC} ve COD için gerekli numunelerin hazırlanmasında zorluklar doğabilir. COD yöntemi, el ile kaynak yapılmış iki farklı saca uygulandı. Test sonuçlarından sertlik ile kritik COD arasında herhangi bir ilişkiye rastlanmadı.

INTRODUCTION

In welded materials, the contemporary and quantity measurements of the weld metal fracture toughness are made by the methods of experimental frac-

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ture mechanics. The most important two methods are K_{IC} and COD. The COD method can be applied to the welded structures. In that manner that application of COD occured some difficulties because of the inhomojen structures of welded materials and contained "residual stresses" based on crack geometries in the linear elastic fracture mechanics change due to plasticity at the crack tip and the equivalent of the changed these crack geometries are no in elasto-plastic fracture mechanics. In recent this difficulties had been removed by developing non-dimensional COD (Φ)[3].

In this paper, the general conditions of K_{IC} and COD tests and special problems are met in preparing of the test specimens have been explained. Seperately the COD method application results have been expressed by welding to the two different steel plates manually.

1. The General Reqiurements for K_{IC} and COD:

To take valid results need forming of service conditions in weld metal fracture toughness tests. Because a weld metal fracture toughness is affected by such factors as the base metal composition, the welding process different weld grooves, postweld heat treatments and the time lapse between welding and testing.

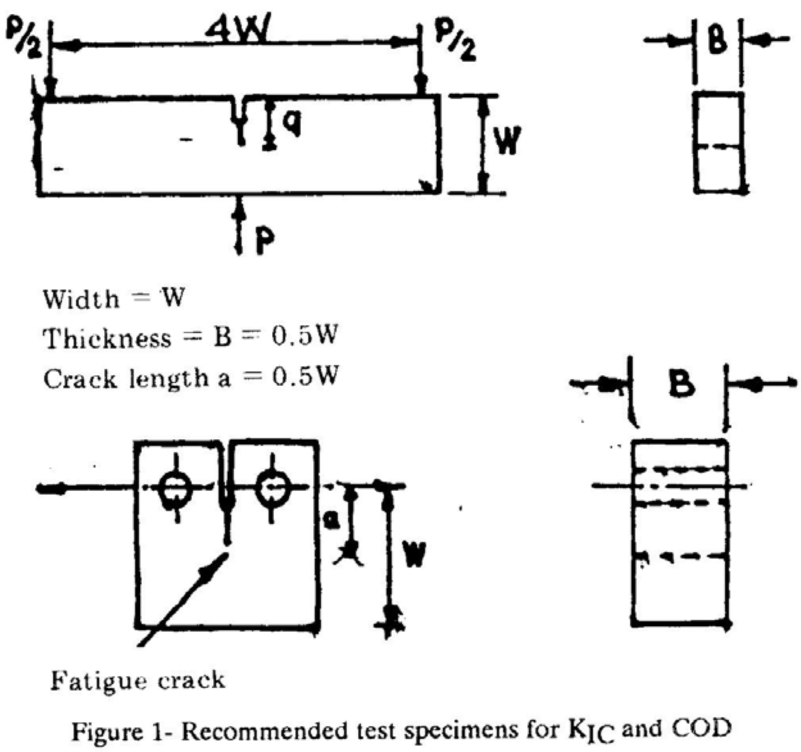


Figure 1- Recommended test specimens for K_{IC} and COD

In figure 1, recommended three point bending and CT (compact-tension) test specimens for K_{IC} and COd methods have been given. Preferred specimen dimensions are a = B = W–a. These dimensions are minimum values and obtained optimum fracture toughness values with them. In order to obtain low fracture toughness and to occur natural crack is formed fatique precrack. Requirements of fatique pre-crack have been given in standards for K_{IC} and COD[2.1].

When fracture occurs in a relative brittle manner, the relevant toughness parameter will be K_{IC}. The importance of the crack tip plasticity in determination of K_{IC} has been explained in ASTME 399-74 standard, and there is $B \geq 2,5 (K_{IC}/\sigma_{ak})^2$ request in it. That means that the plastic zone dimension (r_p) doesn't exceed % 2 of the specimen dimension (B) and (a). If there are significant plastic deformation at the crack tip the relevant parameter will be COD. In the most of ferritic steel that can be welded will be very appropriate standardialized COD method, because of including a little plastic deformation at the crack tip of them.

In figure 1, the fracture toughness values for recommended specimens are only valid for cracks that have dimensions within the center third of the section thickness. (B) = (W) having the subsidiary three point bending test pieces are used to measure fracture toughness in regions shallow surface cracks and buried cracks close to the weld surface. But in this situations, it is necessary to analysis detailed fracture mechanics[4].

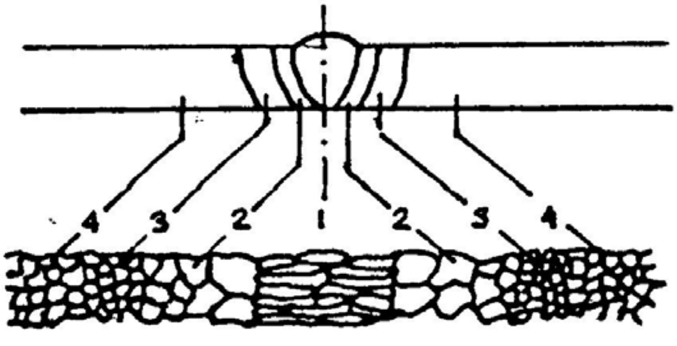
The idea that is used to design of fracture toughness tendencies us to find only the weakest region of fracture toughness. After producing the notch and fatique crack in this region, the test is made. Obtained results will give us the critical or maximum allowable crack sizes and safe stresses in all regions within welding.

2. Special Problems That are Met in Fracture Toughness Tests of Welded Structures:

In the fracture toughness tests have problems because of the microstructure in welded material which show differences as thin layers adjacent to the weld metal. Therefore the test result obtained only one specimen in weldedd materials doesn't comprise all varied microstructures. If possible the each microstructure must be assesed as apart a toughness. Thus the weakest region for brittle fracture of welded structure is found.

In service conditions, IEA (heat affected zone) zone is the most problem. But this zone seems rather narrow. Passing the portion of the crack front through this zone the fracture may occur. So the idea that to make know the weak zone is more realistic.

In selection of the notch and fatique crack places create problems due to be complex structure of weld metal and it's circumference. General opinion is to select the coarse grained region adjacent to weld of IEA. If the region which



1. Weld metal zone
2. Coarse-grained zone
3. Fine-grained zone
4. Base metal zone

of IEA

Figure 2.The varied microstructures in weld metal and it's circumference regions.

will select is the weld metal region and this region is narrow; solition may be to grow by additional passes. But to grow a region in IEA creates only by using thermal cycle simulation. So an artifical zone is created. Simulated heat affected zone is available only in small specimen size.

The fatique pre-crack are opened to specimens to form natural crack. These cracks at the notch tip may not grow flatly. The end of crack which will open in IEA can be present in the weld metal or base metal region. At the result it isn't represented the fracture toughness of IEA zone, only presented the other regions. So the propagating of fatique crack must be controlled hardly. Because it's ready to change any direction any moment by the residual stresses.

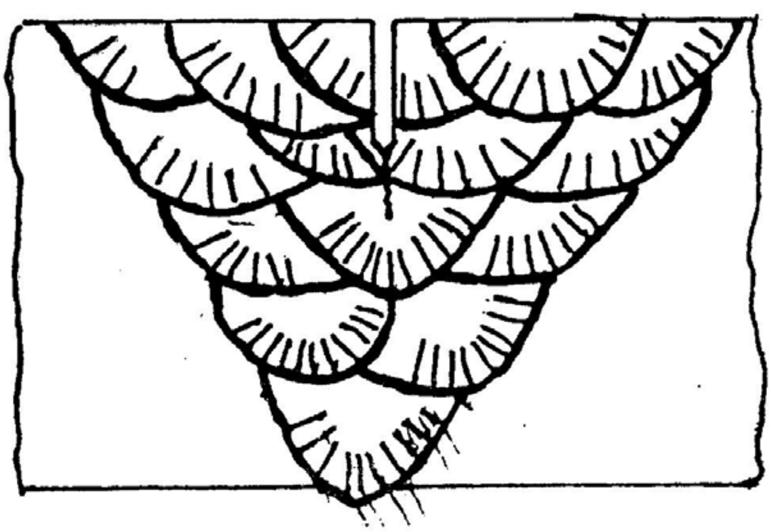


Figure 3- The propagating of fatique crack in weld metal zone

The geometric problem in fracture toughness test of welded structure is solved by using of "K" type weld groove. It isn't frequently seen this "K" type weld grooves in true service conditions. But the fracture toughness values may be found minimum in this types. In any case, the main aim is to obtain the fracture toughness in minimum values. In the "X" and "V" type weld groove joints, the tension stress is larger than that of the "K" type in which the tension stress is come with angle 45°-60° to the IEA zone (see figure 4).

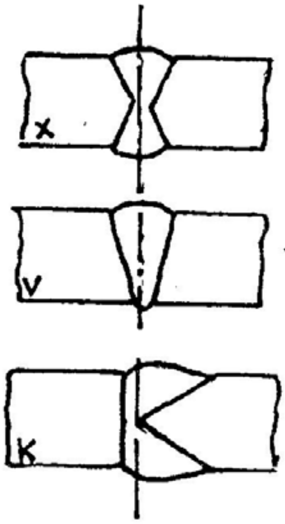


Figure 4- The joints which are made by "X", "V", "K" type weld grooves

3. The Application for COD:

In the following Table 1, are given chemical composition of two different steel plates which having 6 mm thick and are used to produce reactive tower and the weld electrodes types. Arc weld was made to these steel plates manually. The welding was formed by two passes.

Table: 1
The chemical composition and electrode Typefor the Steel Plates Which are Made Arc Weld to Produce a Reactive Tower

			Steel plate of central heating funnel (DIN 1623)				
%	C	Mn	Si	P	S	Cu	
	0,05-0,09	0,30-0,40	0,010	0,020	0,035	0,030	
			Electrode type: Overcord S				
	0,06-0,10	0,40-0,60	0,30	0,020	0,020	—	
			Steel plate of a factory funnel (DIN X 12 Cr Ni 18,8)				
%	C	Mn	Si	P	S	Cr	Ni
	0,12	0,60	0,60	0,030	0,030	18	9
			Electrode type: Inox AW + Cb				
	0,17	1	—	—	—	18-20	8-10

The preparing specimens for COD test are shown in figure 5. In preparing specimen was confirmed to the BSI 5762 standard concerned with specimen sizes.

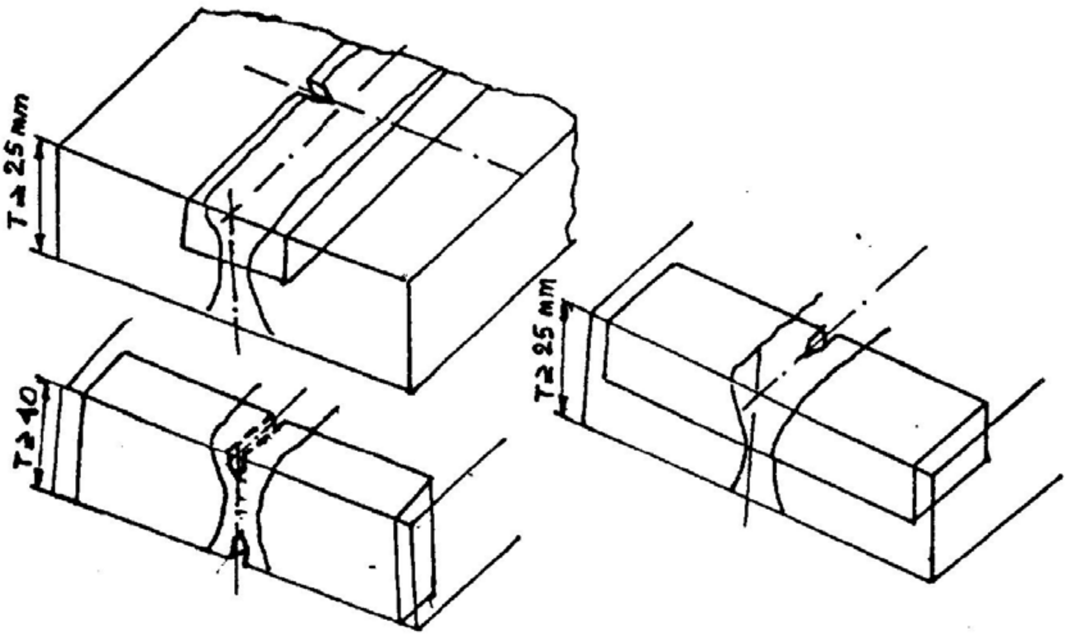


Figure 5- Test specimens taken out from welded steel plate for COD

Prepared test specimens that have B = 6 mm thick. The following factors based on for sepcimens:

a) In case unwelded,

b) In case welded,

c) Applied heat treatment after welding,

d) X, V and K type of weld grooves,

e) The notch has been opened to weld metal, IEA and base metal zones,

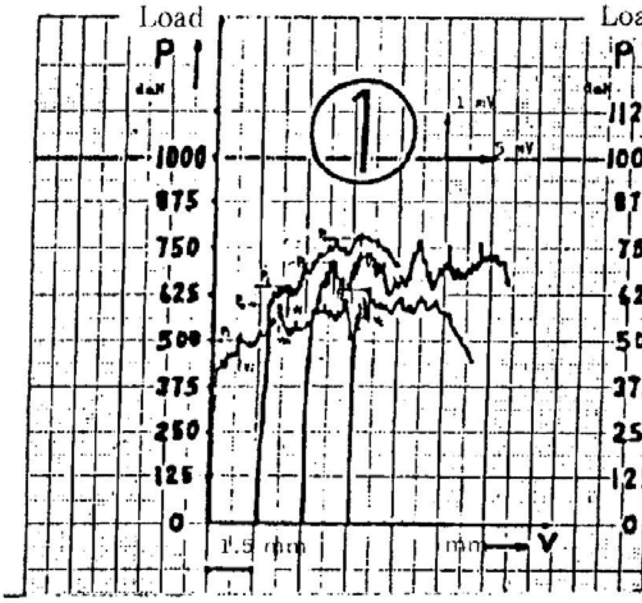
f) Applied the different heat inputs,

g) Having notch and slug.

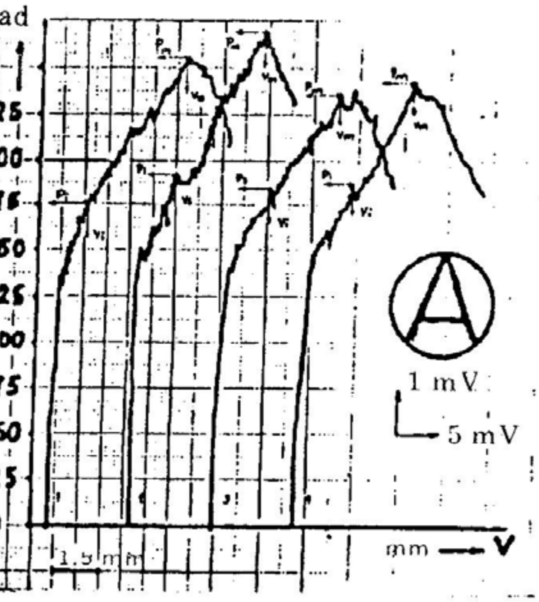
At the result of the test, the load-crack opening displacement (P-v) curves were recorded. These curves were compared with the curves in the BSI 5762 standart. As the defined in table 1, the weld metal zone of the welded steel plates and it's circumference developing the crack initation points; (see figure 6).

a) (P_c, V_c) The critical maximum applied force and the critical displacement,

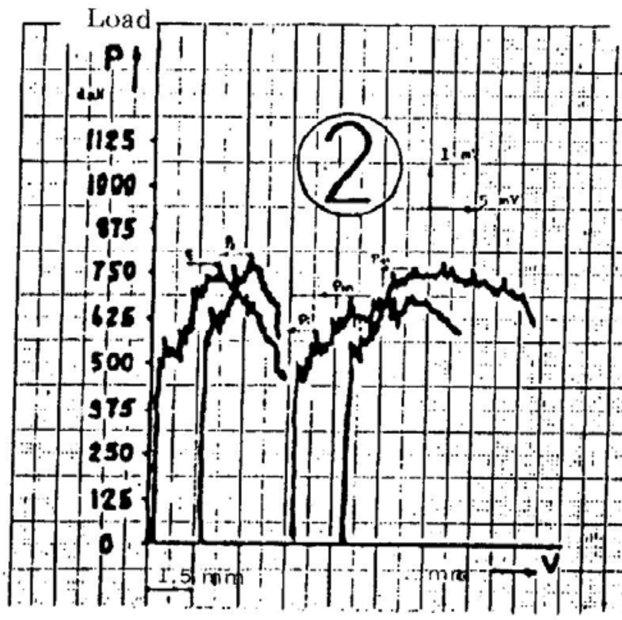
b) (P_i, V_i) Applied force at which slow crack commence and displacement,



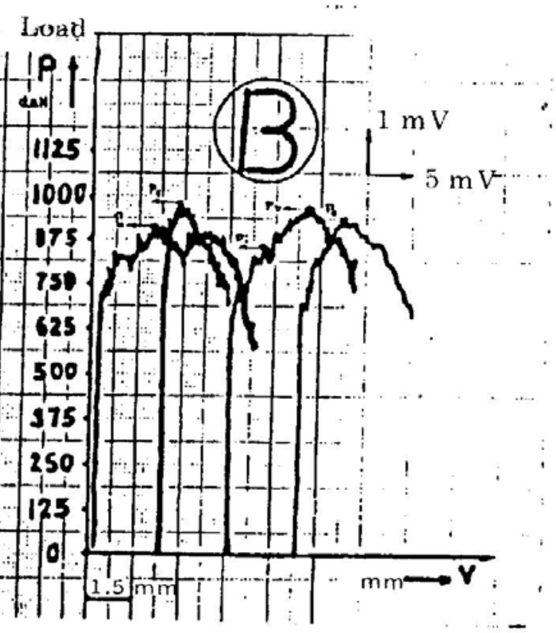
Steel plate of central heating funnel, (P-V) curves in unwelded test specimens.
1-2-3-4': Base metal zone



Steel plate of a chemical factory funnel, (304 type of stain less steel plate), (P-v) curves in unwelded test specimens.
1-2-3-4 : Base metal zone

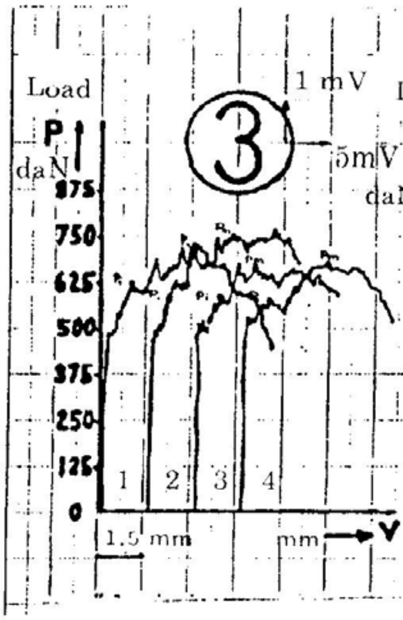


Steel plate of central heating funnel, (P-v) curves of the welded test specimens which are "K" type.
1-2: Weld metal zone
3-4: Heat affected zone

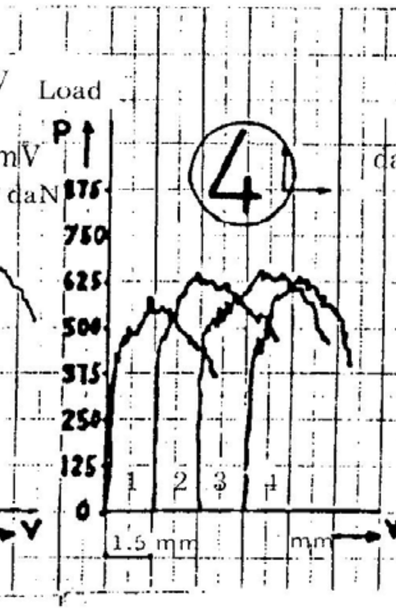


Steel plate of a chemical factory funnel (304 type of stainless steel plate), (P-v) curves of the welded test specimens which are "K" type.
1-2-3-4: Weld metal zone

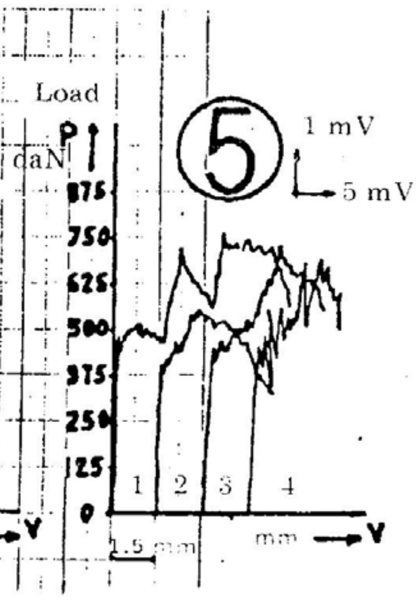
Figure 6-



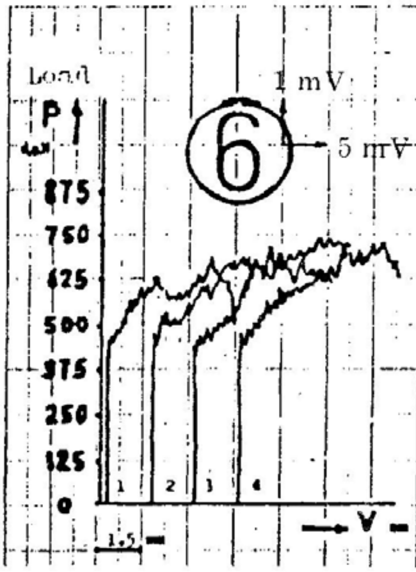
Steel plate of central heating funnel, (P-v) curves of the welded test specimens which are tempering at 600°C.
1-2-3-4: Weld metal zone.



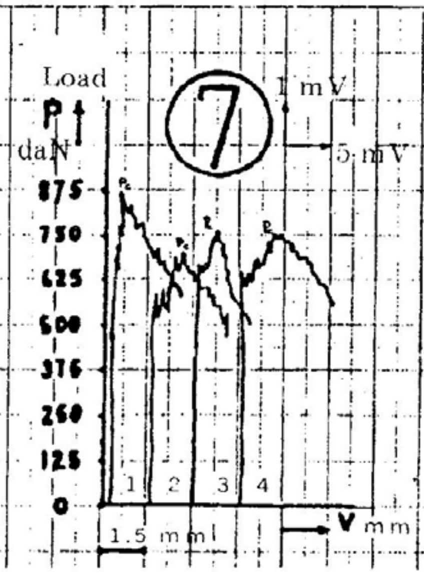
Steel plate of central heating funnel, (P-v) curves of the welded test specimens which are applied 100 ampere.
1-2-3-4: Weld metal zone.



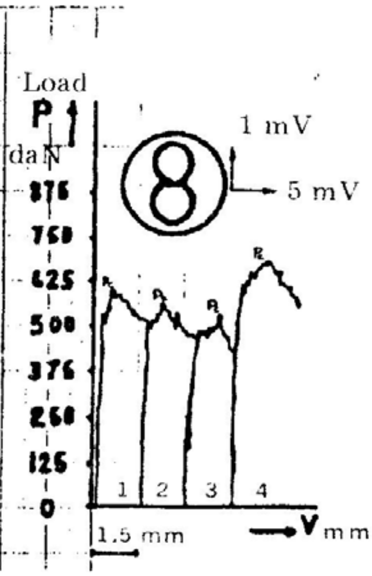
Steel plate of central heating funnel, (P-v) curves of the welded test specimens which are applied 150 ampere.
1-2-3-4: Weld metal zone.



Steel plate of central heating funnel, (P-v) curves of the welded test specimens which are "K" type.
1-2-3-4: Heat affected zone.



Steel plate of central heating funnel, (P-v) curves of the welded test specimens which are having slag and "X" type.
1-2-3-4: Weld metal zone.



Steel plate of central heating funnel, (P-v) curves of the welded test specimens which are having slag and "V" type.
1-2-3-4: Weld metal zone.

c) (P_u, V_u) Applied force at either unstable fracture or onset of pop-in and displacement at that moment,

d) (P_m, V_m) Applied force at the maximum force plateau and displacement at the first attainment of maximum force,

were confirmed.

The following results were obtained from these curves (P-v) recorded to estimate of the critical COD (δ_c).

1. For the ferritic steel plate of center heating funny,
   in case unwelded P_c = 500-600 daN
   in case welded P_c = 500-550 daN
   For the austenitic stainless steel plate of factory funny
   in case unwelded P_c = 1000-1200 daN
   in case welded P_c = 800-900 daN

According to these information, it may be told there is decrease of force in the austenitic stainless steel after welding and is brittle more according to the other.

2. The following formula is used to calculate the critical COD (δ_c).

$$\delta_c = K^2 \frac{(1-\nu^2)}{2\,\sigma_{ak} \, . \, E} + \frac{0{,}4\,(W-a)\, . \, V_p}{0{,}4W + 0{,}6a + z}$$

Where;

W, a, z : Specimen sizes (mm)

ν : Poission's ratio

σ_{ak} : 0,2 % yield stress

$$K = \frac{Y.P}{B.W^{1/2}}$$

Y : Compliance coefficient

V_p : Plastic component of displacement

E : Young modülüs

The calculated critical COD values are;

for the ferritic steel plate:

in case unwelded $\delta_{c\ min}$ = 0,23 mm

$\delta_{c\ max}$ = 0,.38 mm

in case welded $\delta_{c\ min}$ = 0,18 mm

$\delta_{c\ max}$ = 0,.28 mm

for the austenitic stainless steel plate

in case unwelded $\delta_{c\ min}$ = 0,40 mm

$\delta_{c\ max}$ = 0,.80 mm

in case welded $\delta_{c\ min}$ = 0,36 mm

$\delta_{c\ max}$ = 0,.58 mm

It has been that the fracture toughness values (δ_c) are decreased by welding process in both of steel plates.

3. In figure 7, the relationship between hardness and critical COD (δ_c) was studied, although hardnesses in the weld metal region and the fine grained region of IEA increased also the critical COD (δ_c) increased in the fine grained region of IEA but decreased in the weld metal region. So we don't say that there is relationship between the hardness and the critical COD (δ_c) (see figure 7).

4. In figure 8, the fracture analysis curves were shown for two each steel plates. As it's shown in the figure curves, tracking of the austenitic stainless steel plate curve in a smooth way shows us inside of austenitics stainless steel plate doesn't permit dislocation acts and it's strength and rijid structure.

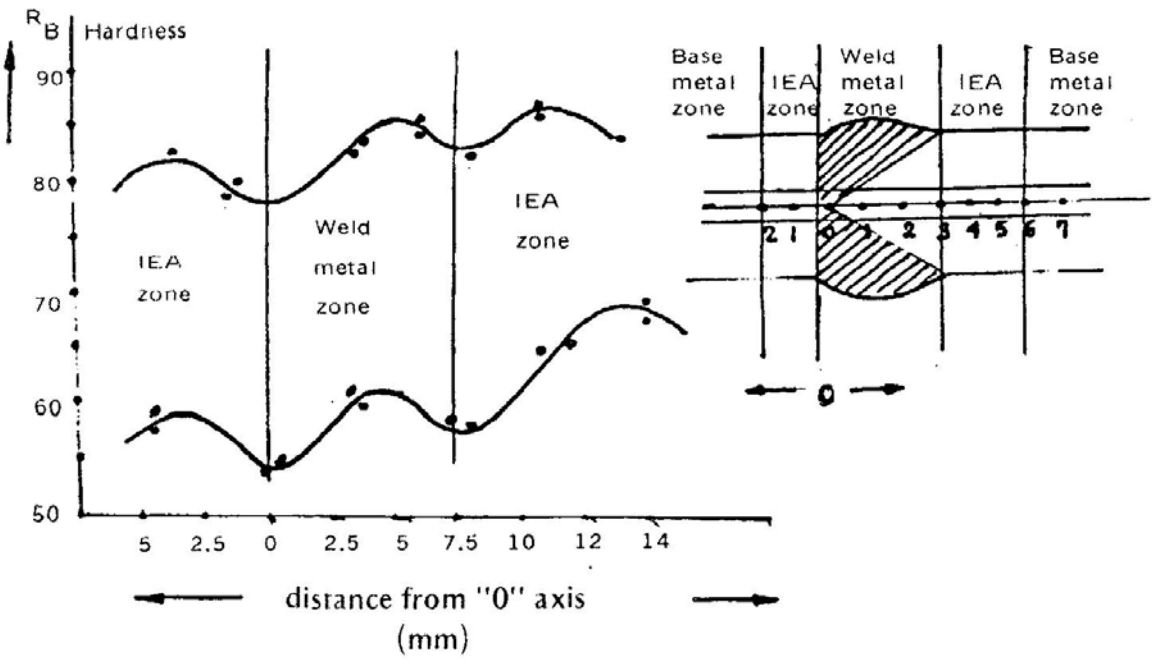


Figure 7- The varied hardnesses according to -0- axis in "K" type weld groove joints of two each steel plates

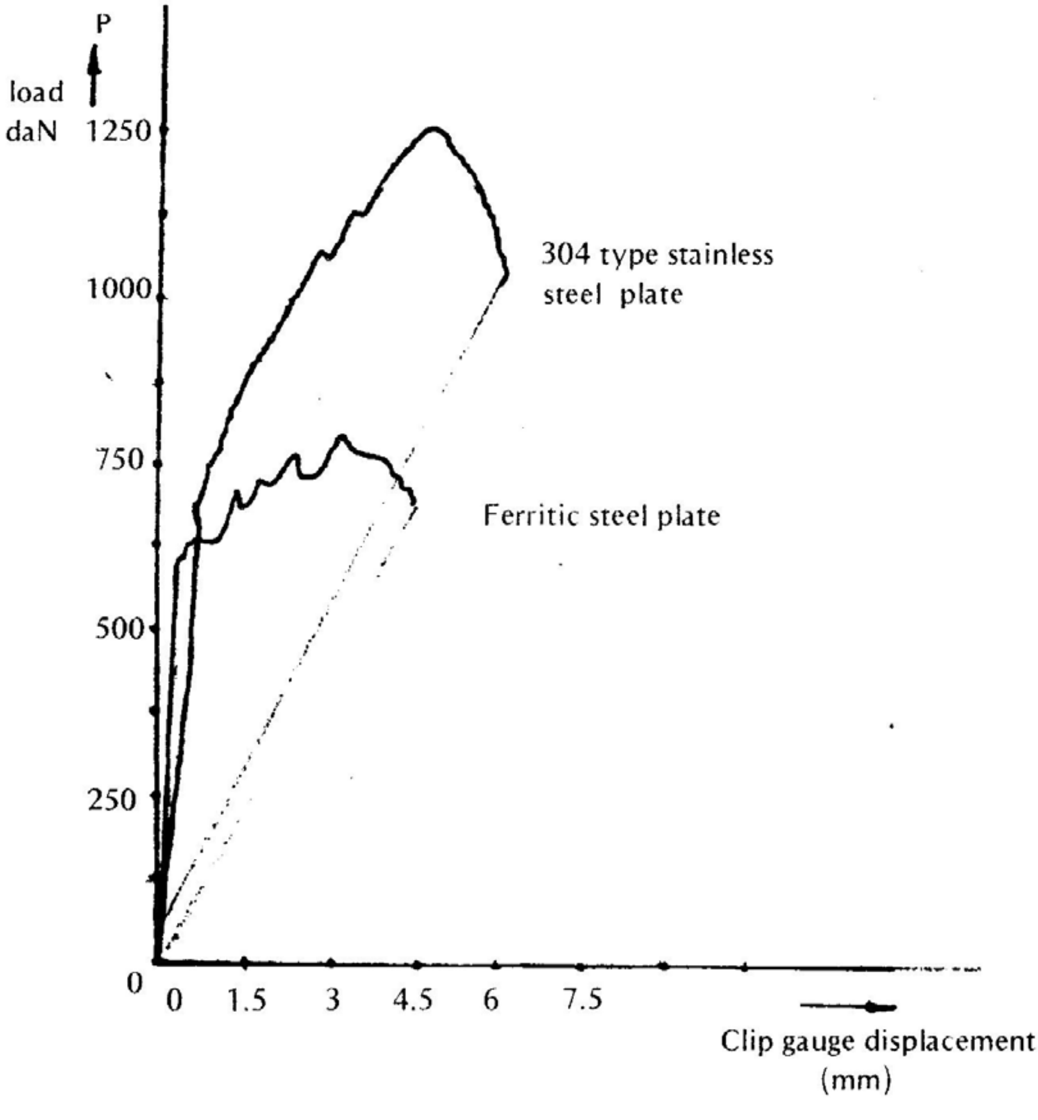


Figure 8-The fracture analysis curves for different two steel plates

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