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점용접의 인장강도 개선에 관한 연구
A Study of Improving the Tensile Strength for Spot Welding

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<요약>

점용접은 자동차를 제작하는데 사용하는 가장 유용한 용접법이다. 그러나 산업현장에서 직면하고 있는 가장 큰 문제점 중의 하나는 점용접의 용접성에 관한 문제이다. 본 연구에서는 강판의 두께가 1.6mm인 경우와 1.2mm인 경우에 대해 2점 점용접을 실시하여 인장강도를 증가시키고 용접의 흔적을 남기지 않게 하기 위한 조건을 찾는 것을 목적으로 하였다. 용접성에 영향을 미치는 많은 요소들이 있다. 그중에서 용접전극의 형상이 인장강도를 증가시키는 요소로 집중을 하면서 연구를 수행하여 다음과 같은 결과를 얻었다. 인장강도는 용접전극의 형상 및 팁직경 거리와 전류가 클수록 증가하였다. 전극형상을 비교해보면 RF형이 CF형 보다 더욱더 효과 적이었다. 시행 착오법을 통해 최적용접조건을 찾았고 그에 따른 최적전류인 9,000A와 전극의 형상 RF형을 찾았다. 경도시험결과는 인장력이 시험편에 작용할 때 열 영향부인 HAZ부에서 왜 파괴가 일어나는지를 설명해 주었다.

Key Words : Spot Welding, Geometry of Electrode, HAZ, Nugget

1. Introduction

Spot welding is known as the most useful welding method for manufacturing automobiles. Approximately, from 4,000 to 5,000 times of spot welding is applied to manufacture an automobile. However, it has several defects in operation in the industrial fields. One of the problems that the industrial fields faced is the weldability of it.

In these days, the trends of automotive are going to change as a light ones. Owing to that problem, the welding methods are currently arisen as the hot issue in the manufacturing fields. The prior paper concerned with spot welding were tremendous and abundant. Among them, Song et al[1]. studied the optimal welding conditions by examining tensile tests of 1 mm mild steel sheet. Suh et al[2]. also studied the fatigue life for the galvanized steel sheets and the other sheets.

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In this paper, several techniques are adopted to improve the tensile strength for spot welding. Especially the geometry of electrode is mainly focused on this study. What this study is seeking for is the optimal conditions of high tensile strength, no color change in the welding area and no welding trace.

2. Specimen and test methods

2.1 Specimen

Fig.1 shows the configuration of specimen. The thickness of the specimen was 1.2 and 1.6 mm. it was welded for two points. The specimens used for this study are ferrite-martensite based high strength steel. Their characteristics are well known as follows; 1) low yielding ratio 2) work hardening rates are high in the early stage of the transformation 3) manifest yielding point.

The specimen is composed of three parts such as nugget which the metal melted and fused and HAZ which symbolizes heat affected zone and base metal.

Table 1 and 2 show the chemical composition and mechanical properties of the specimen. It's mild steel which has little carbon contents.

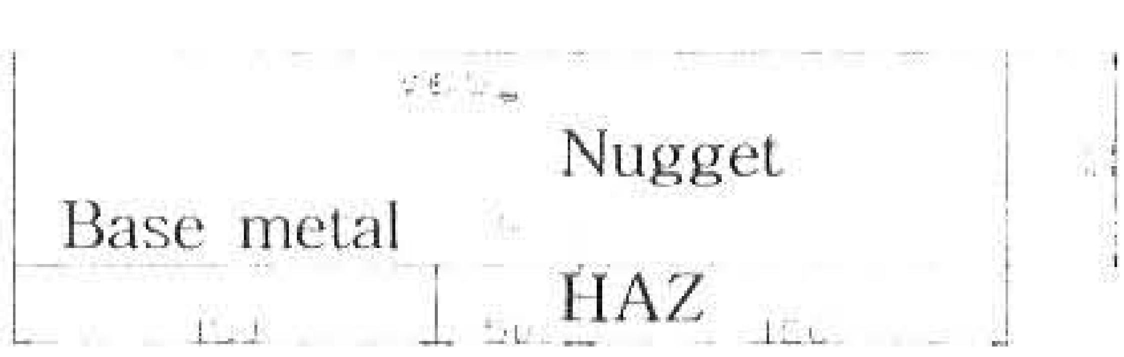


Fig. 1 Configuration of Specimen

Table 1 Chemical composition

Material	C	Mn	Si	P	S
Specimen	0.01	0.11	0.01	0.01	0.005

Table 2 Mechanical properties

Material	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation (%)
Specimen	186	300	49

Fig. 2 shows the micro-structure of specimen. It was eched by nital acid to eching the surface after buffing. The mean grain size was about 6.6μm which is compressed about 27.6% of base metal. The nugget parts had very small grain size owing to fusion and pressure among grains.

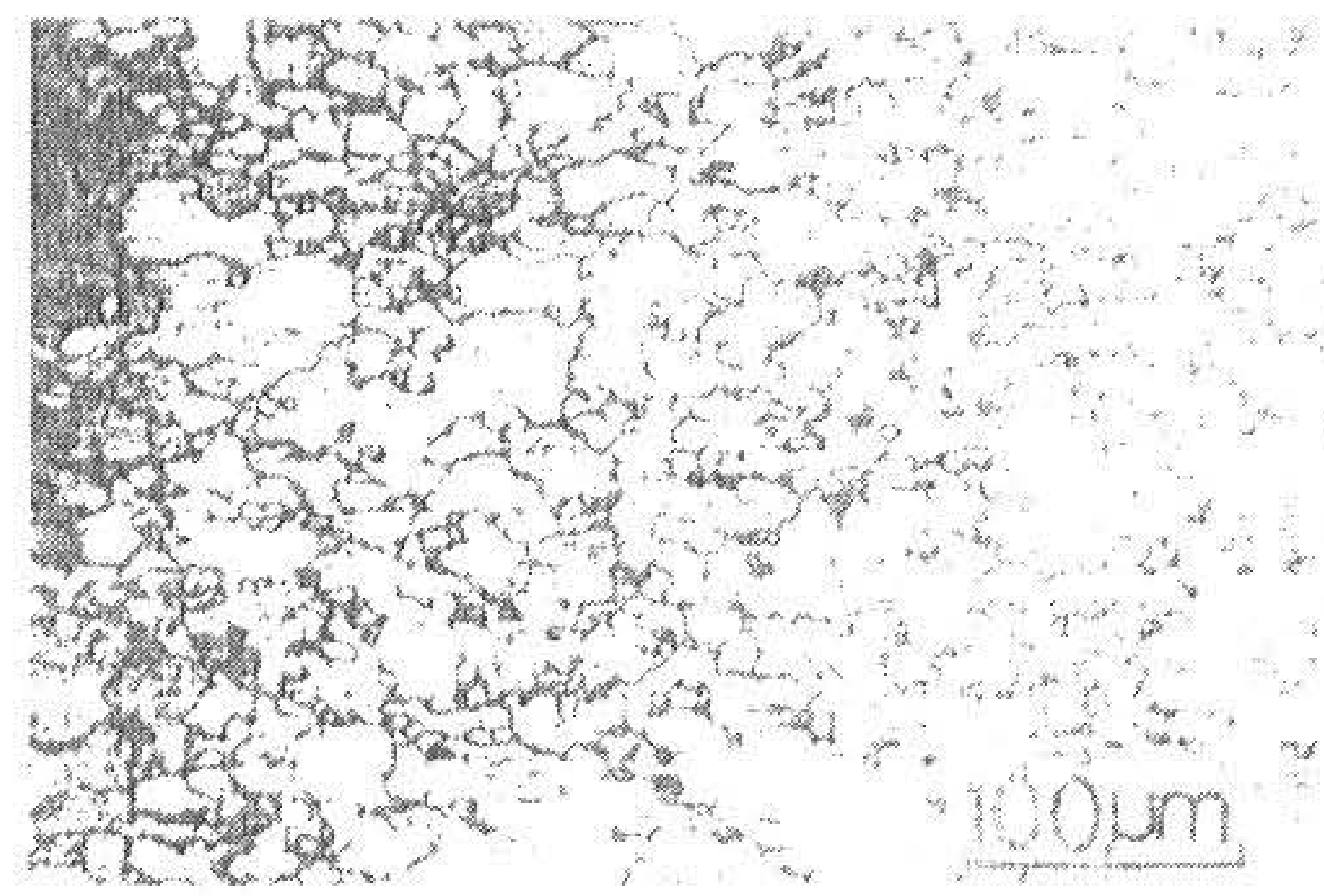


Fig. 2 Micro-structure of Nugget

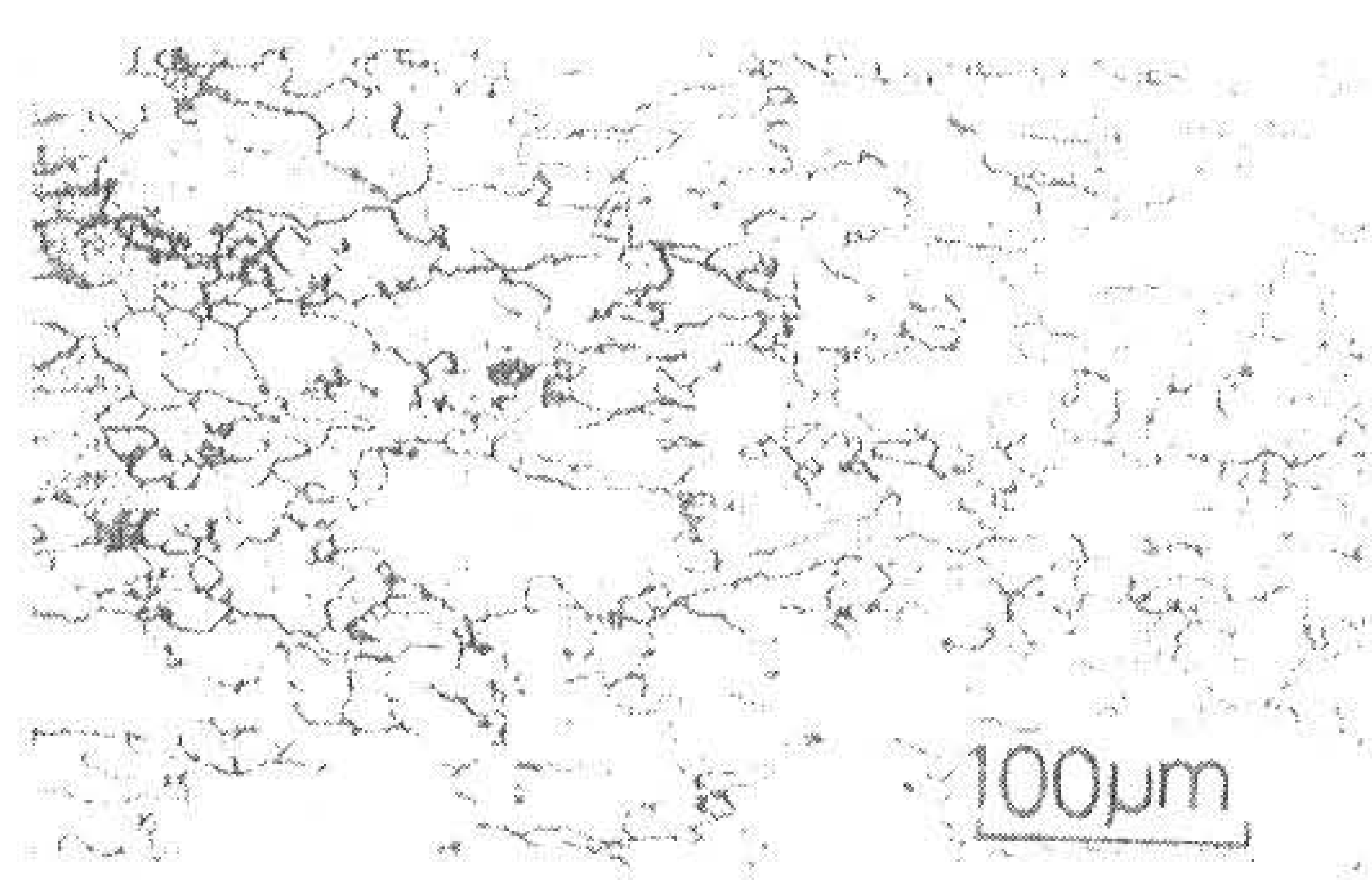


Fig. 3 Micro-structure of base metal

Fig. 4 Micro-structure of nugget

In Fig. 3, it was micro-structure of base metal which the mean grain size is 9.12μm.

As you may see in these two photos, the nugget part had more compressed structure than base metal.

Fig. 4, 5 and 6 shows the micro-structure of specimen which was cut in the cross sectional direction. In Fig. 4, the micro-structure of nugget shows a needle type structure that most of the structures are martensite. Fig. 5 has shown the micro-structure of HAZ which symbolizes heat affected zone. Most of the fatigue cracks were initiated at this part and fractured[3].

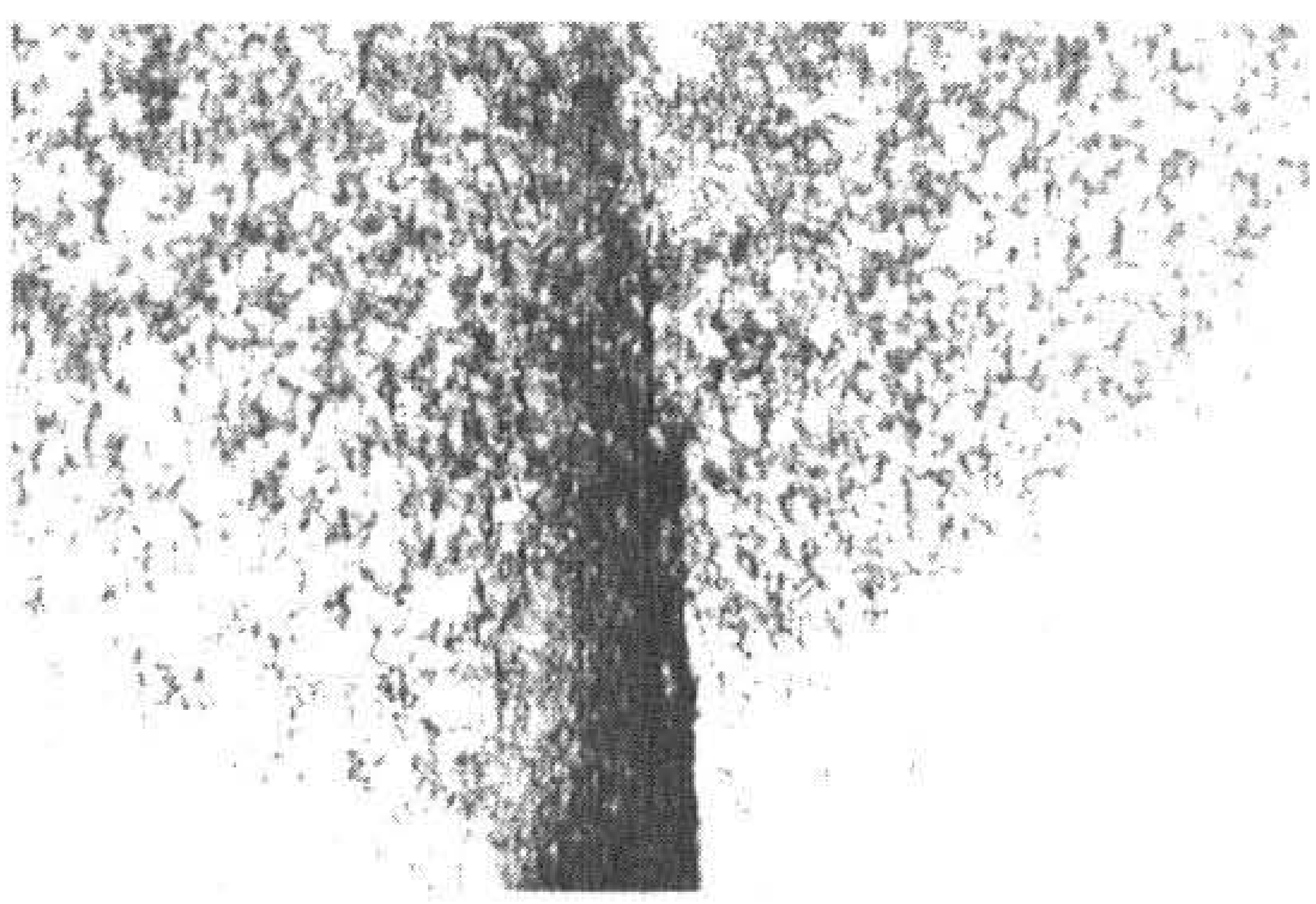


Fig. 5 Micro-structure of HAZ(heat affected zone)

2.2 Test Methods

Spot welding is very popular welding method in automotive engineering. Fig. 7 shows the schematic diagram of spot welding. One of the purposes of this study to seek for the optimal conditions for spot

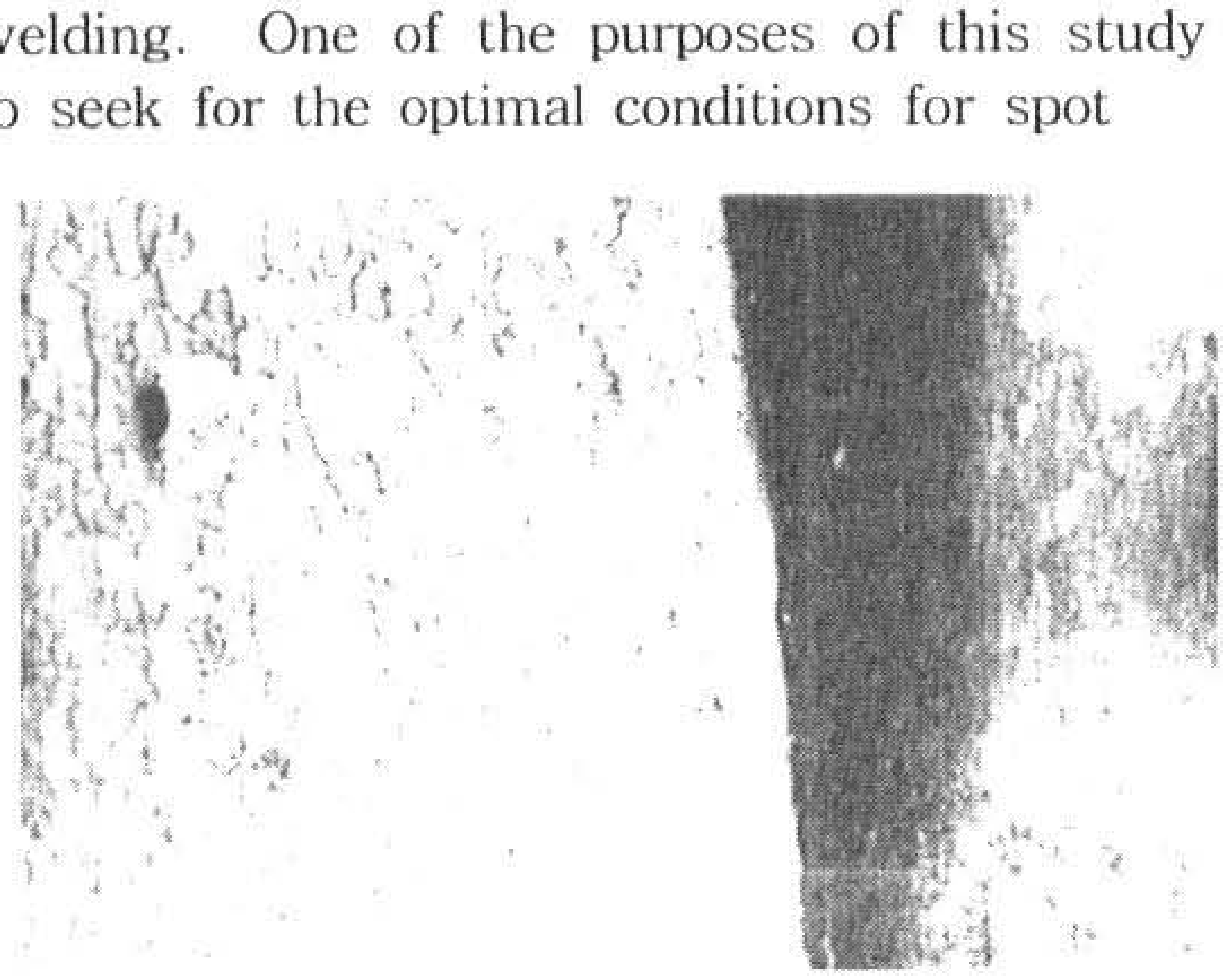


Fig. 6 Micro-structure of base metal

welding. After welding, hardness tests and tensile tests were carried out to examine the proper welding conditions. What is the best results are to get the good test results and surface conditions and color.

In the spot welding, there are several factors such as contact resistance, welding current, welding time, squeeze time and electrode which may influence the weldability. Among them, we used two conditions such as welding current and electrode.

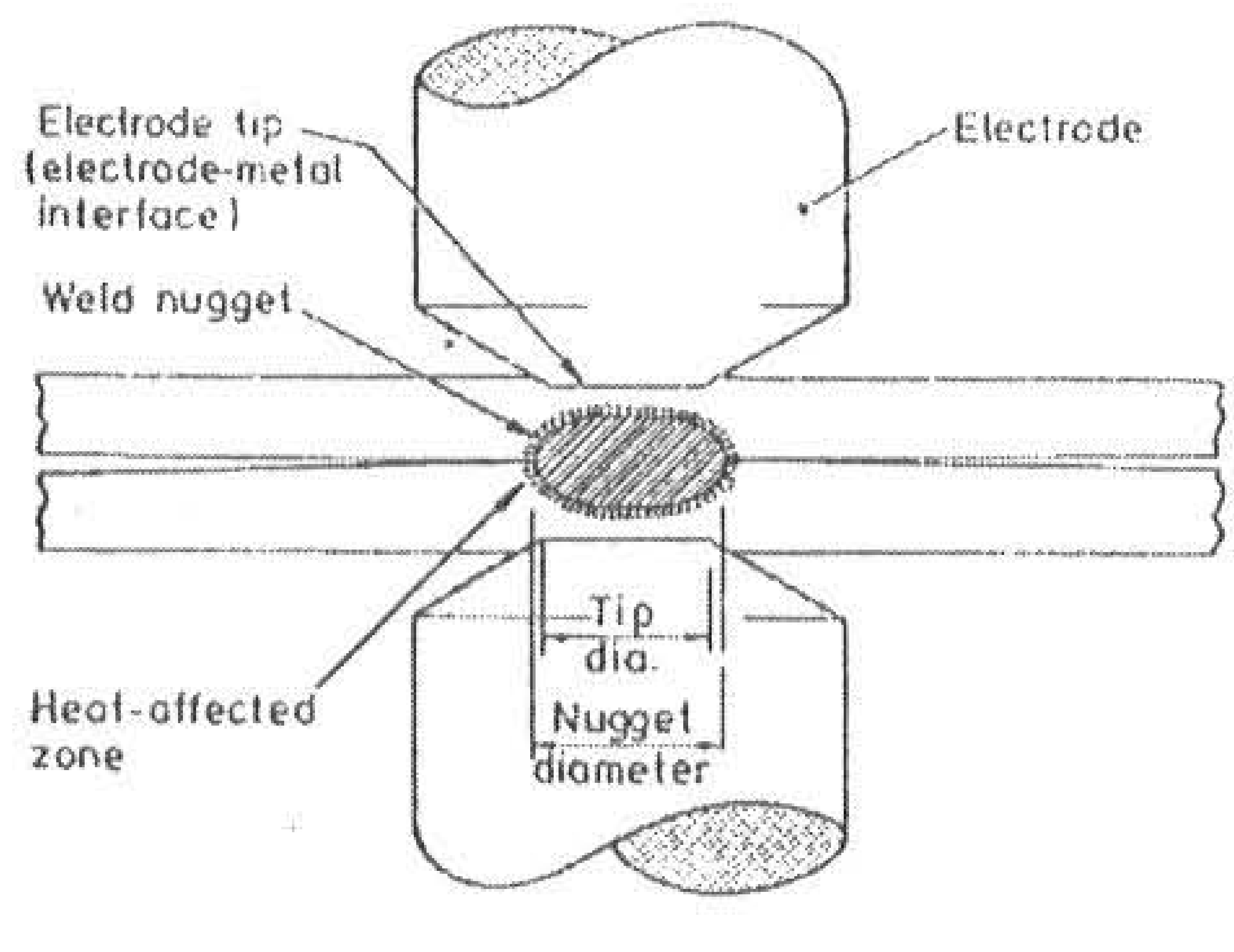


Fig. 7 Schematic diagram of spot welding

It is natural that higher current may cause stronger weldability. To prove that, two currents such as 7,000A and 9,000A are adopted.

In the case of electrode, two types were used such as type CF and RF. During the

Table 3 Welding conditions for both current 7000A and 9000A

Welding Current (A) / Welding Condition	7000	9000
Squeeze time	3.0	3.0
Welding time	6.0	2.5
Hold time	3.5	3.5
Off time	3.1	3.1

tests, the tip diameters were closely checked to seek for the best welding conditions. At the same time, hardness was measured by micro-Vickers to compare the hardness distribution among base metal, HAZ and nugget. The loading was 1.96N and interval was 0.5mm. The measuring section was cut after fracture and mounted by Epomica with hardener.

3. Results

3.1 Tensile strength according to Geometry of Electrode

The tensile testing machine was Shimazu with the capacity of 30 ton. It was warmed up for 1 hour before starting the test. Table 4 shows the results of tensile strength according to the geometry of electrode. The specimen, A means the sheet which the thickness was 1.2mm, and B means the 1.6mm thick sheets. The diameter of electrode were 4.5 and 6.5 mm.

The geometry of electrode were type CF and RF. The shape was changed by time. And so during the tests, its size and cleanness was double checked.

By the results, we could get the results. The thicker specimens and wider electrodes and higher currents are, the better results were obtained.

In the case of geometry of electrodes, type RF has strong point rather than type CF by judging the tensile strength.

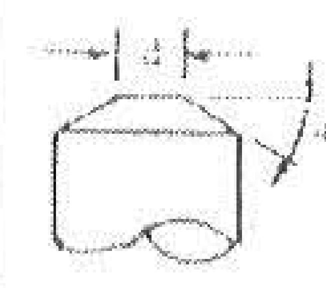
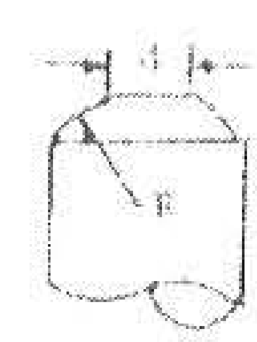
3.2 Geometry of Electrode

The geometries of electrode for spot welding plays an important roles especially in the increment of tensile strength. The materials for electrode have the characteristics of good conductivity. Those materials are aluminum and copper. The geometry of electrode has a strong relations with current distribution, pressure distribution and cooling effect. Even though a good conditioned electrode was prepared, it may change its original shape. That's why it needs clean-up and reforming. Fig. 8 shows various geometry of electrodes. Among them, we used Type CF and RF.

The distance on the tip, d was 5.25~5.85mm. When the specimen was welded the sheets with wider distance, the trace was very weak and the tensile strength was higher than before. The angle, α is usually 10~30°. As you may see Table 4, the tip diameters were 4.5 and 6.5mm.

By the results of the tensile tests, we can reach the conclusion that the geometry of the electrode of RF with 5.85mm distance on the top tip has good tensile strength.

Table 4 Test results according to tip geometry and diameter

Results / Specimens	Tip Geometry	Tip Diameter (Φ)	Tensile Strength (MPa)
AxA		4.5	399.5
AxA			426.8
BxB		6.5	495.1
AxB			390.7
AxB			369.1
AxB			363.7

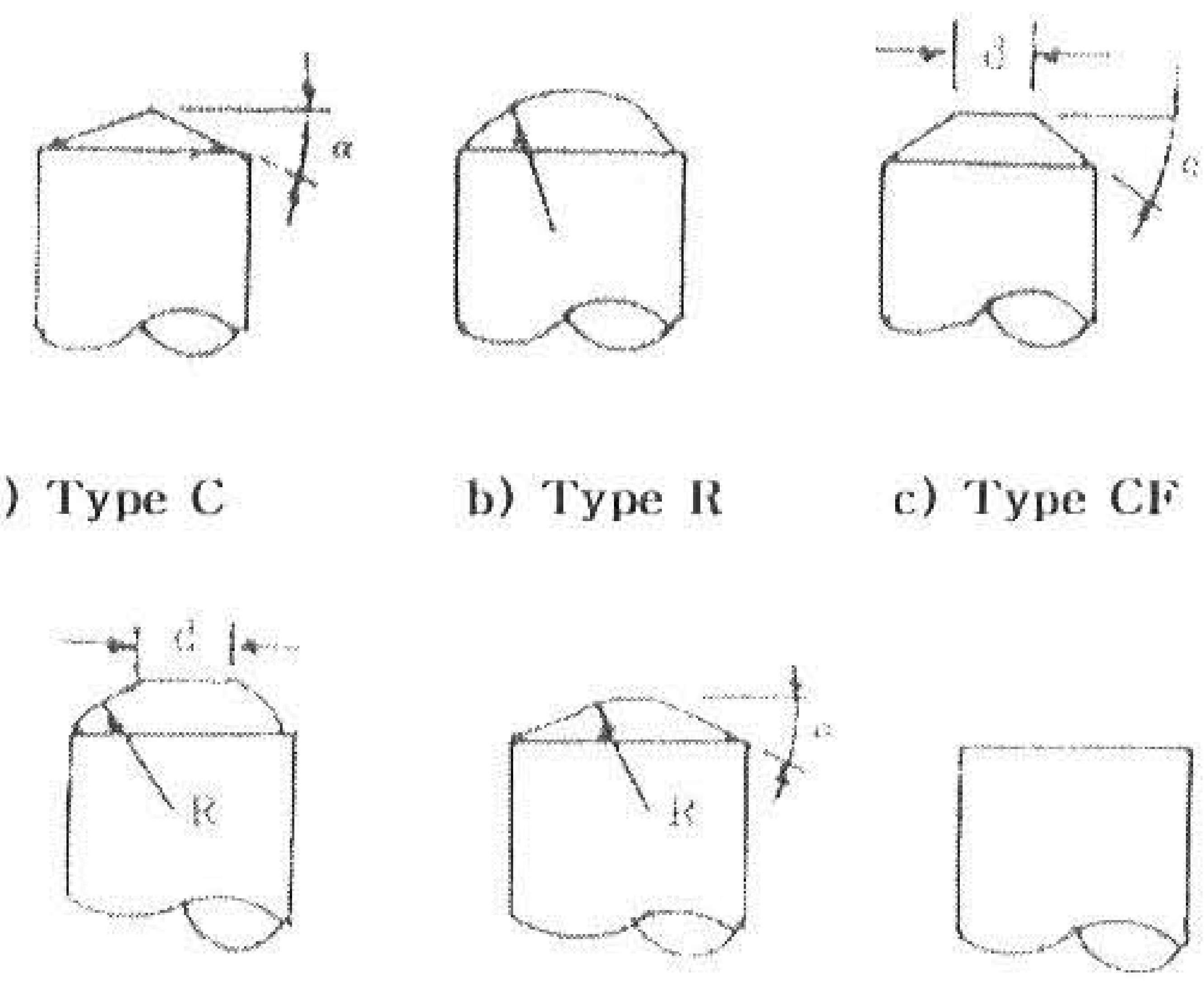


Fig. 8 Geometry of electrode for spot welding

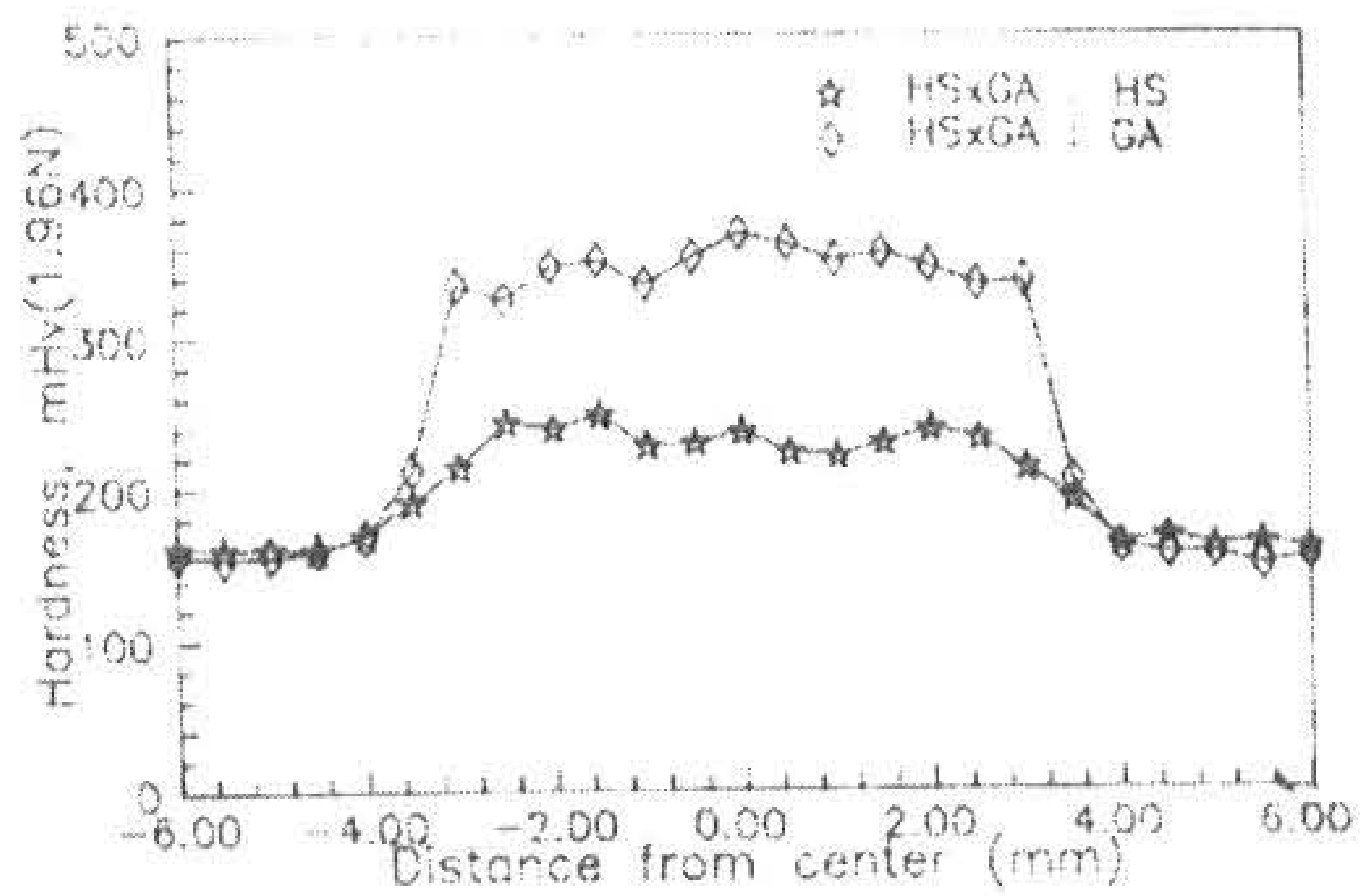


Fig. 9 Hardness tests results

3.3 Hardness tests

Fig. 9 shows the hardness tests results. After fracture, hardness tests were carried out to measure hardness of nugget, HAZ and base metal. The specimen was to cut to measure hardness along with nugget in the distance of 0.5mm.

In this figure, HS symbolizes high strength steel and GA means galvanized steel sheet. As it has shown in this figure, nugget part has most high in hardness. By the analysis of this test results, it is clear that HAZ part is the weakest part. That's why when the tensile force applied to the specimen, the HAZ part was torn off.

3.4 Analysis of tensile tests

Fig. 10a and 10b has shown the photos of the specimen after the tests. As you may see, the crack was initiated at the HAZ part where the heat affected during the spot welding.

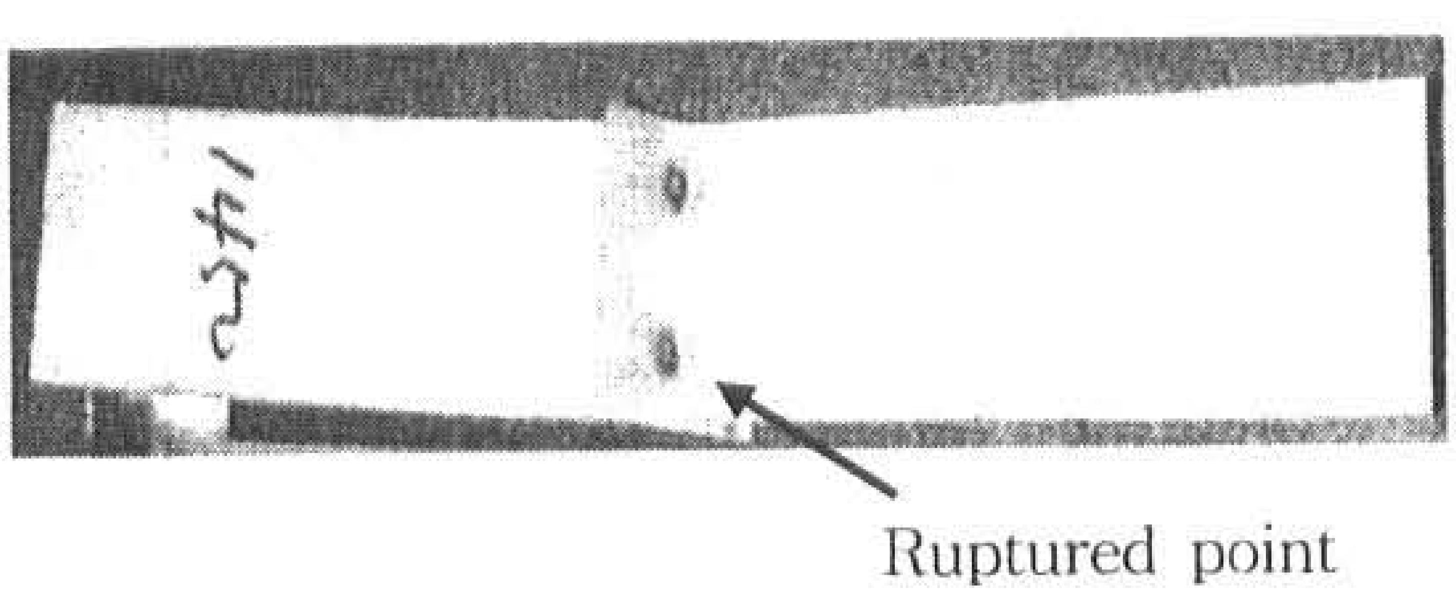


Fig. 10a Photo of specimen after the tensile tests(Specimen AxB, tensile load = 1,450kg)

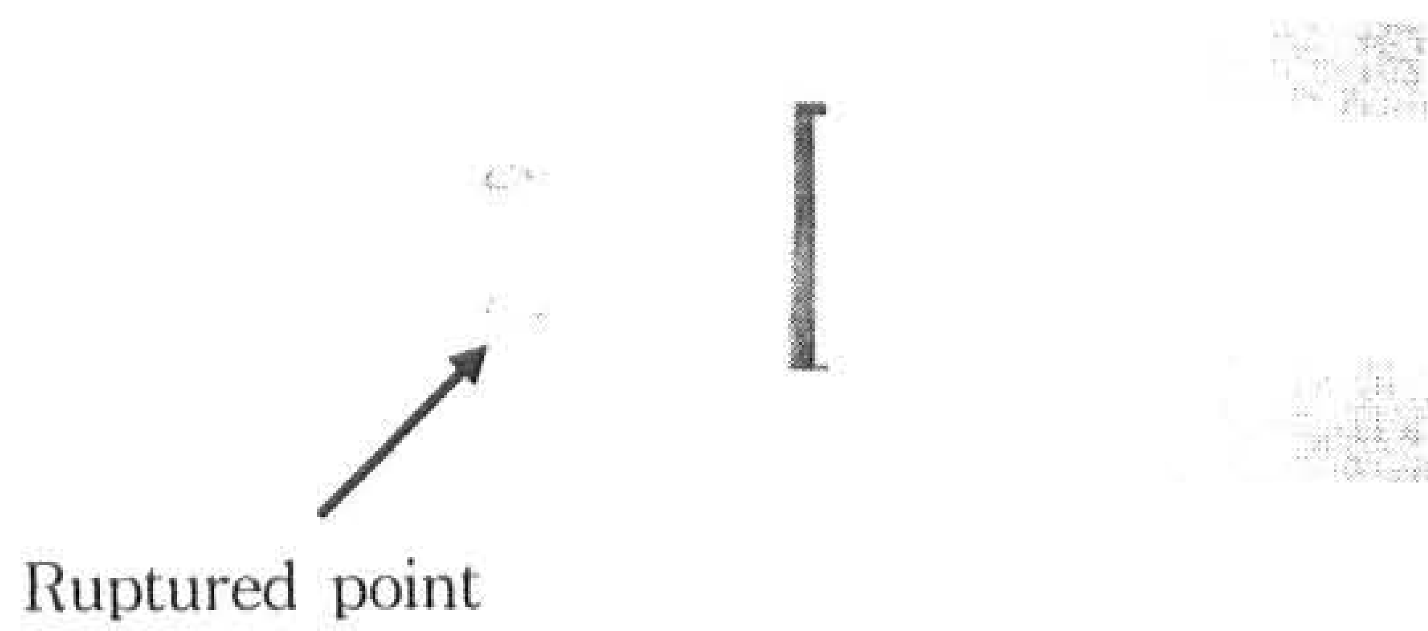


Fig. 10b Photo of specimen after the tensile tests(Specimen AxB, tensile load = 1,350kg)

3.5 Fracture angle

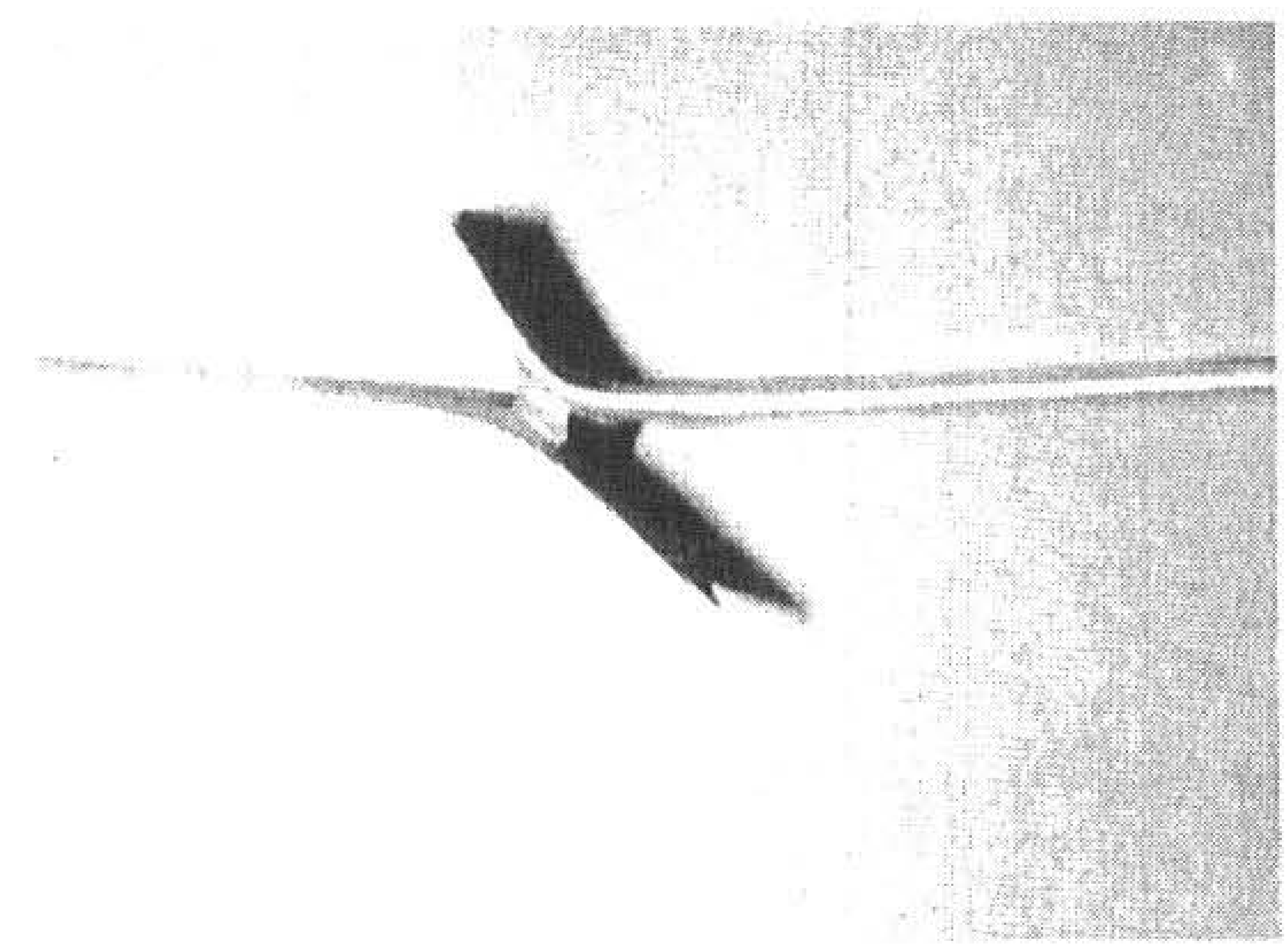


Fig. 11a Fracture of specimen AxB with the tensile load of 1,450kg

Fig. 11b Fracture of specimen AxB with the tensile load of 1,350kg

Fig. 11a and 11b has shown the fracture angle of specimen AxB. The tensile loads were different from each specimen. According to the geometry of electrodes, the fracture angles were differed. The fracture angles were greater when the tensile loads were high than the low tensile load.

By these experiments and results, we can get some important things about spot welding. Those are the characteristics of geometry of electrode. The same spot welding had different tensile loads up to 10%. The optimal conditions for this study was obtained as follows;

Table 5 The optimal conditions for spot welding

Conditions	Optimal Conditions(A)	Remarks
Welding current	9,000	
Geometry of Electrode	Type RF	Angle
Welding thickness	The thicker, the better	

4. Conclusions

The spot welding between 1.6 mm and 1.2 mm thickness sheet was examined to increase tensile strength and not to make trace of welding spot. There are many factors which may influence on the weldability. Among them, the geometry of electrode was mainly focused on increasing the tensile strength.

1. The tensile strength was increased by the geometry of electrode and distance of tip diameter and current.

2. By comparison of the indenter shape, type RF was more effective than type CF. And it has the characteristics not to make any trace on the surface of the welding spot.

3. Trial and error method was applied to get the optimal welding conditions. Optimal current was 9,000A and the geometry of electrode was type RF.

4. Hardness tests results showed why the HAZ part was torn off when the tensile load was applied to the specimen.

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