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A Study on the Effects of Cu Addition for Strength in Cast Iron

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SUMMARY

It was one of the most important studies in materials to obtain high strength in cast iron. Therefore, malleable cast iron and spheroidal graphite cast iron were developed. However, due to the large demand of gray cast iron, a study on the development for high strength is very important.

The author published a paper on the study on the effect of Al addition.

In this study, the effect of Cu addition will be assessed on strength improvement in cast iron. Copper is known as the element of graphitization and pearlitization, so it is expected to obtain valuable results.

The results obtained from this study are as follows ;

1. When copper was added to cast iron, tensile strength increased by 30%, and hardness increased by 13 %.
2. The tensile strength showed a maximum when copper was added 1.0 %.

1. Introduction

The cast iron has a long history. But it has not been a object of interest until the use of machinery parts was made.

Basically, it has merits such as good castability, superiority in machinability and high wear resistance, but it shows brittleness, weak impact and low strength.

In addition, the strength of the cast iron is low compared with that of steel.

Therefore, the studies of high class cast iron were gradually made, and the methods for the improvement of strength were studied in various ways. The authors have continued the studies in a series to improve the strength of ordinary cast iron by small addition of other component, and they have already published the results on the effects of Al addition.

The present study was designed to investigate how and why the addition of small of amount of copper would alter the strength, especially tensile strength, of cast iron.

It was thought that Al and Cu etc. are all graphitizer and have a large effect on graphitization in cast iron.

On the basis of the results obtained from the study on the effect of Al addition which was published already, study on the variation of strength and hardness by Cu addition and the fundamental problems of obtaining high strength cast iron were made.

Comparison of the effect of Al addition with that of Cu addition was also made.

2. Experimental Methods

The chemical analysis of the starting pig iron and final specimens used in this study is listed in Table 1,2 and 3.

The pig iron was melted in the No. 20 graphite crucible using a 50 KVA Kryptol furnace, and it was poured into the cast iron mould to obtain the ingots. These ingots were remelted and controlled in the No. 4 graphite crucible inserted into the above No. 20.

Table 1. Chemical Composition of Materials (wt%)

Comp / Material	C	Si	Mn	P	S	Cu
Pig Iron	4.1	1.6	0.15	0.05	0.03	
Electrolytic Iron	0.015	0.015	0.05	0.008	0.001	
Ferro - Silicon		70～75				
Cu						99.9

Table 2. Chemical Composition of Samples (wt%)

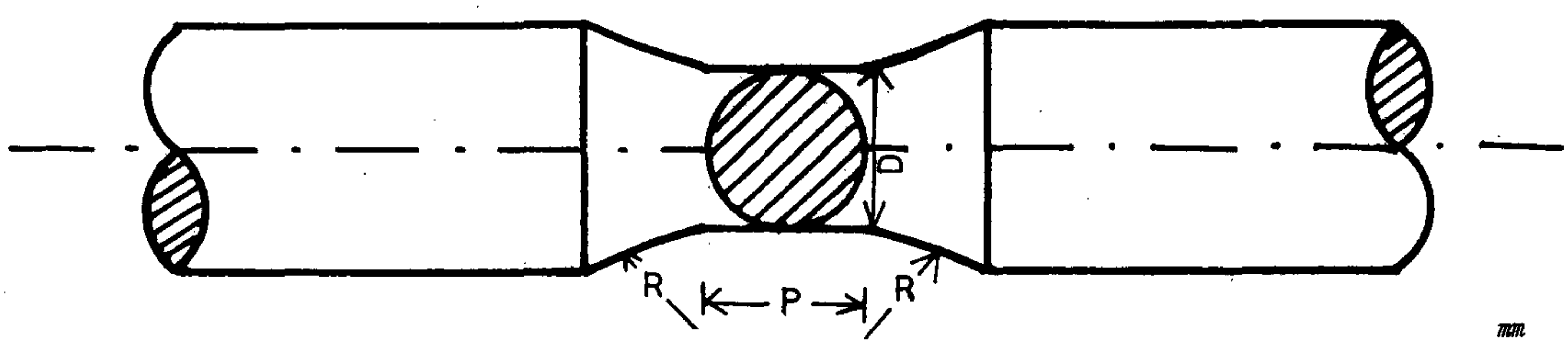
Comp / Sam. No.	C	Si	Mn	P	S	Cu	Remarks
1	3.02	2.36	0.36	0.05	0.02	0.9	Si : 2.4 %
2	2.98	2.22	0.41	0.07	0.02	0.9	C : 3.1 %
3	3.08	2.31	0.30	0.06	0.03	0.8	Const
4	3.06	2.34	0.31	0.06	0.03	0.9	
5	3.04	2.29	0.34	0.05	0.02	1.4	
6	2.97	2.33	0.37	0.07	0.02	1.2	
7	3.36	2.32	0.35	0.06	0.02	1.4	
8	3.04	2.19	0.37	0.07	0.02	1.4	
9	2.94	2.24	0.30	0.06	0.03	1.3	
10	2.89	2.30	0.33	0.07	0.03	1.4	
11	3.05	2.24	0.35	0.04	0.02	0.0	
12	3.01	2.28	0.30	0.05	0.03	1.9	
13	2.94	2.36	0.34	0.06	0.02	2.8	

Table 3 . Chemical Compositon of Samples (wt%)

Sam.No. \ Comp	C	Si	Mn	P	S	Su	Remarks
1	2.70	2.34	0.40	0.05	0.02	0.41	
2	2.97	2.29	0.31	0.05	0.03	0.31	
3	3.26	2.31	0.36	0.07	0.02	0.65	
4	3.00	2.30	0.34	0.07	0.02	0.69	
5	2.92	2.32	0.35	0.07	0.03	0.92	
6	2.94	2.61	0.34	0.06	0.02	0.90	
7	2.70	2.70	0.33	0.06	0.02	1.42	
8	3.20	2.70	0.52	0.07	0.02	1.43	

First, carbon content was controlled by the addition of electrolytic iron, Second, silicon content was adjusted by Fe-Si(6mesh). While temperature of melts was held at 1450 C, Cu and Fe-Si (12mesh) were added into melt. Specimens were prepared by casting into green sand mould which has 25 mm diameter and 160 mm length.

Specimens collected by cutting at the position of 20mm from the base after solidification. Specimens for tensile test are shown in Fig. 1. Tensile strength was measured by the universal tensile tester. Hardness was measured by Rockwell Hardness Tester using B scale . Specimens for microscopic structure were prepared by cutting at the position of 30mm from the base.



mm

Specimen's Type	P	D	R
8 - B	≒ 12.5	≒ 12.5	25

Fig1. Shape and dimmension of the specimen for tensile test

3 . Experimental Results & Discussion

3.1. Effects by amount of Cu addition

3.1.1. Microstructure and form of graphite

Fig.2 shows the change in microstructure of cast iron by various amount of Cu addition. The amount of pearlite increased with increasing Cu addition and decreased when

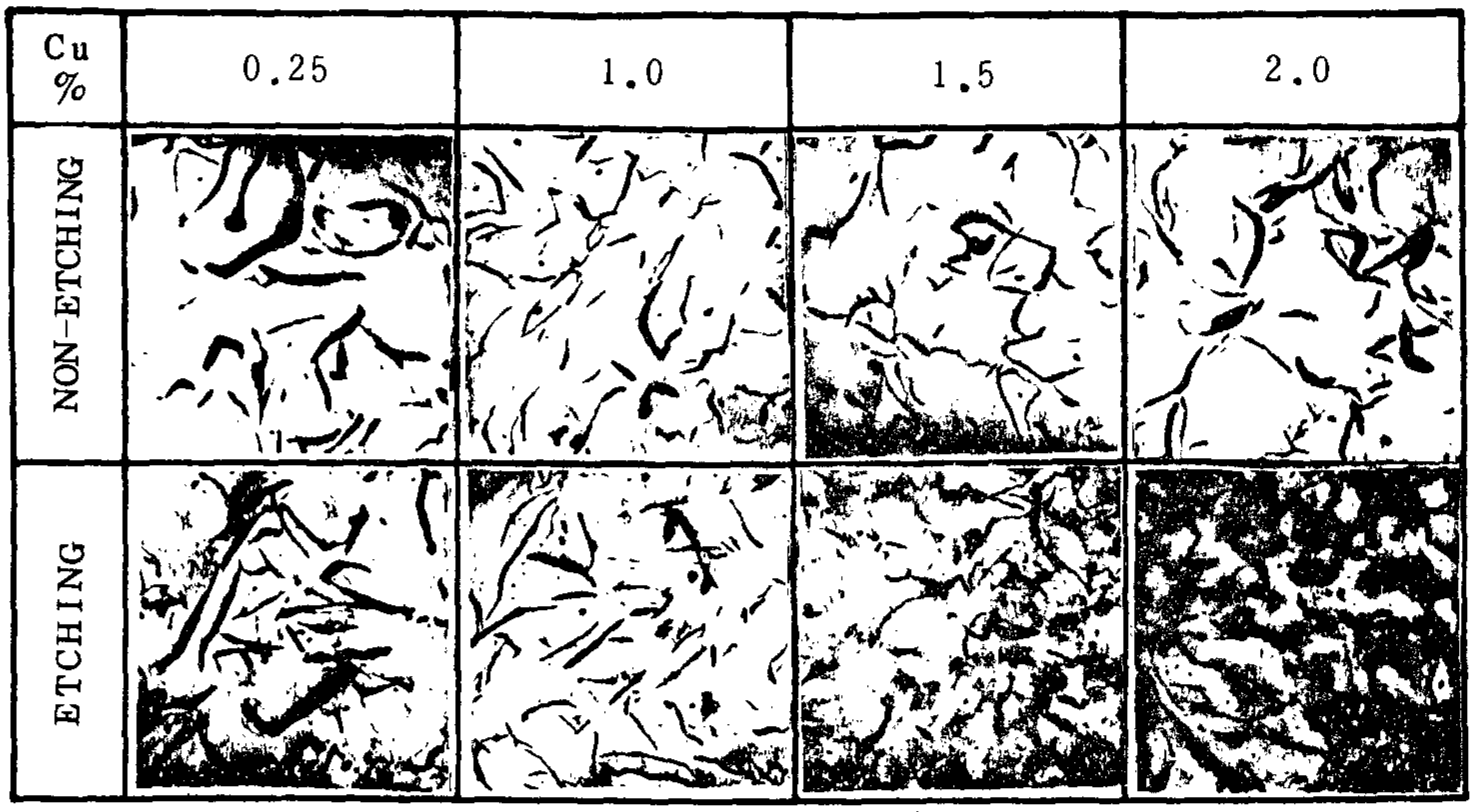


Fig 2 Microstructures change of Cast Iron by various addition of Cu
(Si : 1.6 % C : 2.8 %) (×100)

Cu addition was more than 1.0 %.

That is, copper is a stabilization element of pearlite when copper addition was 1.0 %. Most of the structure was pearlite as shown in Fig. 2. But graphite was coarse in shape and ferrite appeared to be increased by Cu addition. Therefore it is not desirable to add more than 1.0 % Cu when silicon content is 1.6 %. In thsecase of 2.8 % carbon and 3.1 % silicon contents, graphite' form was C type of ASTM and irregular as shown in Fig.3. The size of graphite was severely changed and partially altered into kish graphite.

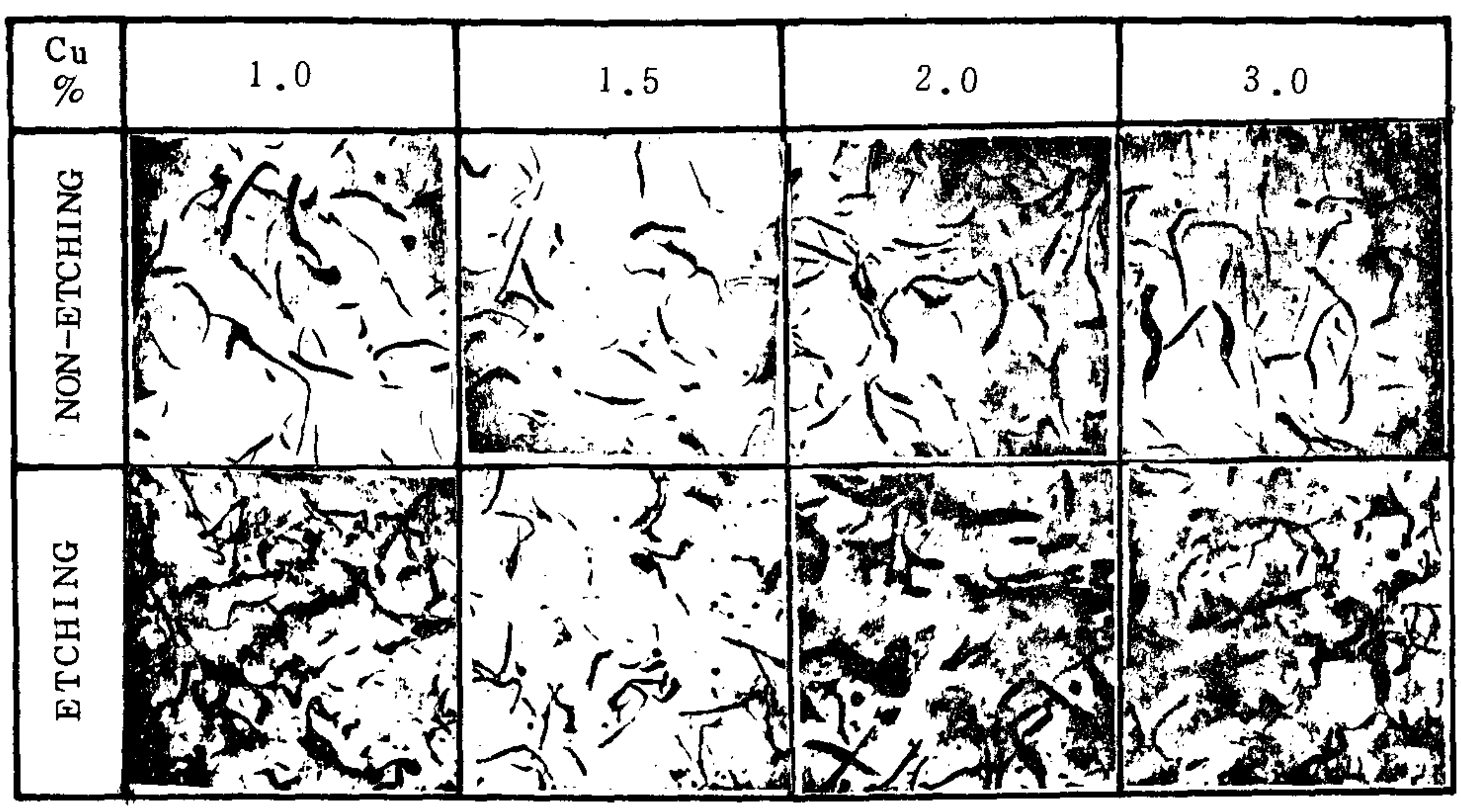


Fig 3 Microstructures change of Cast Iron by various addition of Cu
(Si : 3.1% C : 2.8 %) (×100)

Microstructure appeared to be coarse as shown in Fig. 3. Pearlitization was formed with 1.5 % Cu addition, but more Cu addition induced ferrite to form around graphite.

3.1.2 The effect on mechanical property

Fig.4 shows the change in tensile strength of alloy with 2.8 % carbon and 1.6 % silicon contents. In this figure, maximum tensile strength was obtained when Cu addition was 0.75 %, and increase in Cu addition induced pearlitizing. The maximum tensile strength was increased by 30 % compared to that without Cu addition. Thus, Copper showed to stabilize the pearlite matrix at small amount of addition, but a large amount of copper addition caused graphite to be coarse and ferrite to form.

Fig.5 shows the change in tensile strength of alloy with 2.8 % carbon and 3.1 % silicon contents. As in Fig. 5 tensile strength increased with increasing Cu addition. Increasing rate was lower than when alloy had 1.6 % silicon content. Tensile strength was maximum when 1.5 % copper was added. Tensile strength is maximum in 1.5 % copper addition which is more addition than 1.6 % silicon contents. In Maurer diagram, increase of

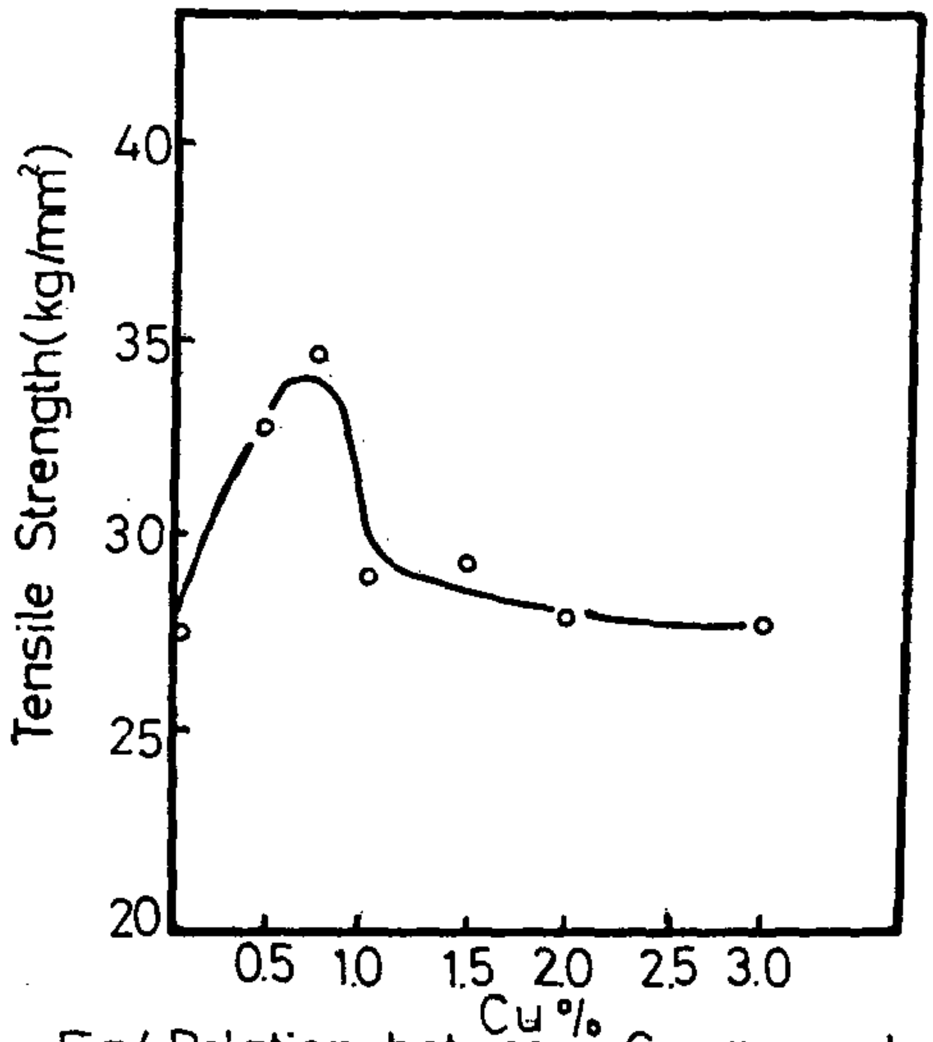


Fig4 Relation between Cu amount and Tensile Strength (Si:1.6%, C:2.8%)

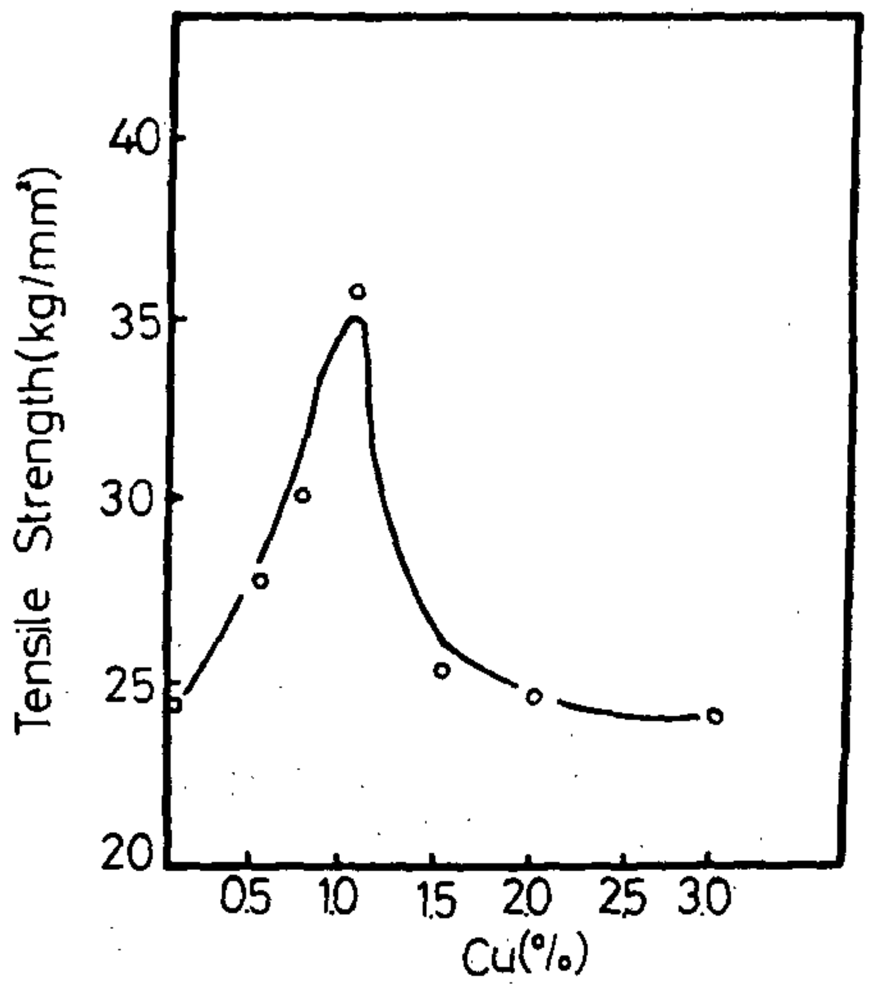


Fig.5 Relation between Cu amount and Tensile Strength (Si:3.1, C:2.8)

silicon contents transformed matrix structure from pearlite range to ferrite range.

Fig. 6 shows the change in hardness at 2.8 % carbon and 1.6 % silicon contents. This figure shows that the maximum tensile strength and hardness were obtained when 0.75 % copper was added and more addition showed increase in hardness.

This is probably due to fusion limit.

Fig. 7 shows the change in hardness at 2.8 % carbon and 3.1 % silicon contents. 1.5 % copper addition yielded maximum hardness and tensile strength and more addition showed similar hardness. It is thought that the reason for this would be the same as explained above.

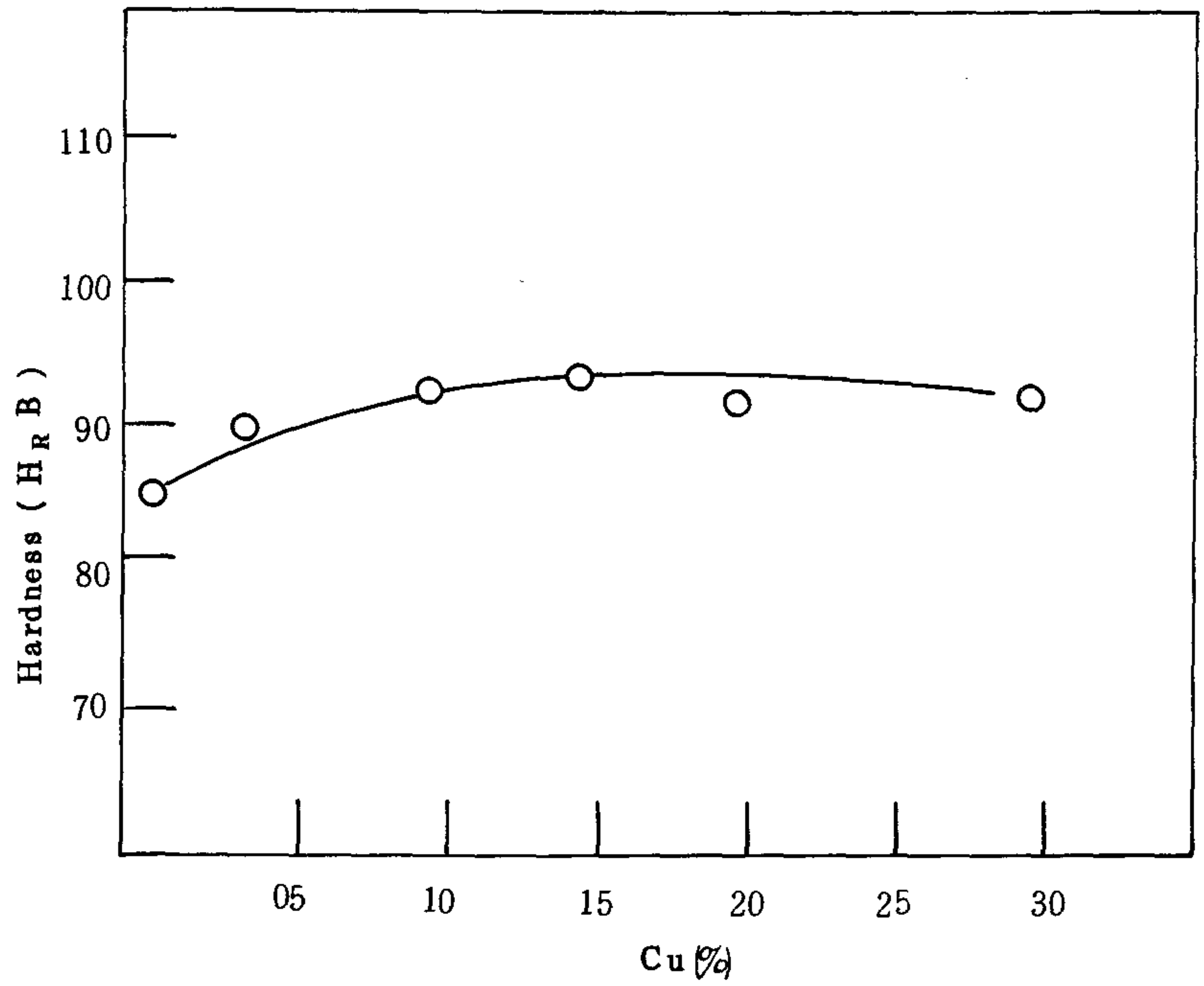


Fig.6 Relation between Cu amount and Hardness
(Si : 1.6 C : 2.8)

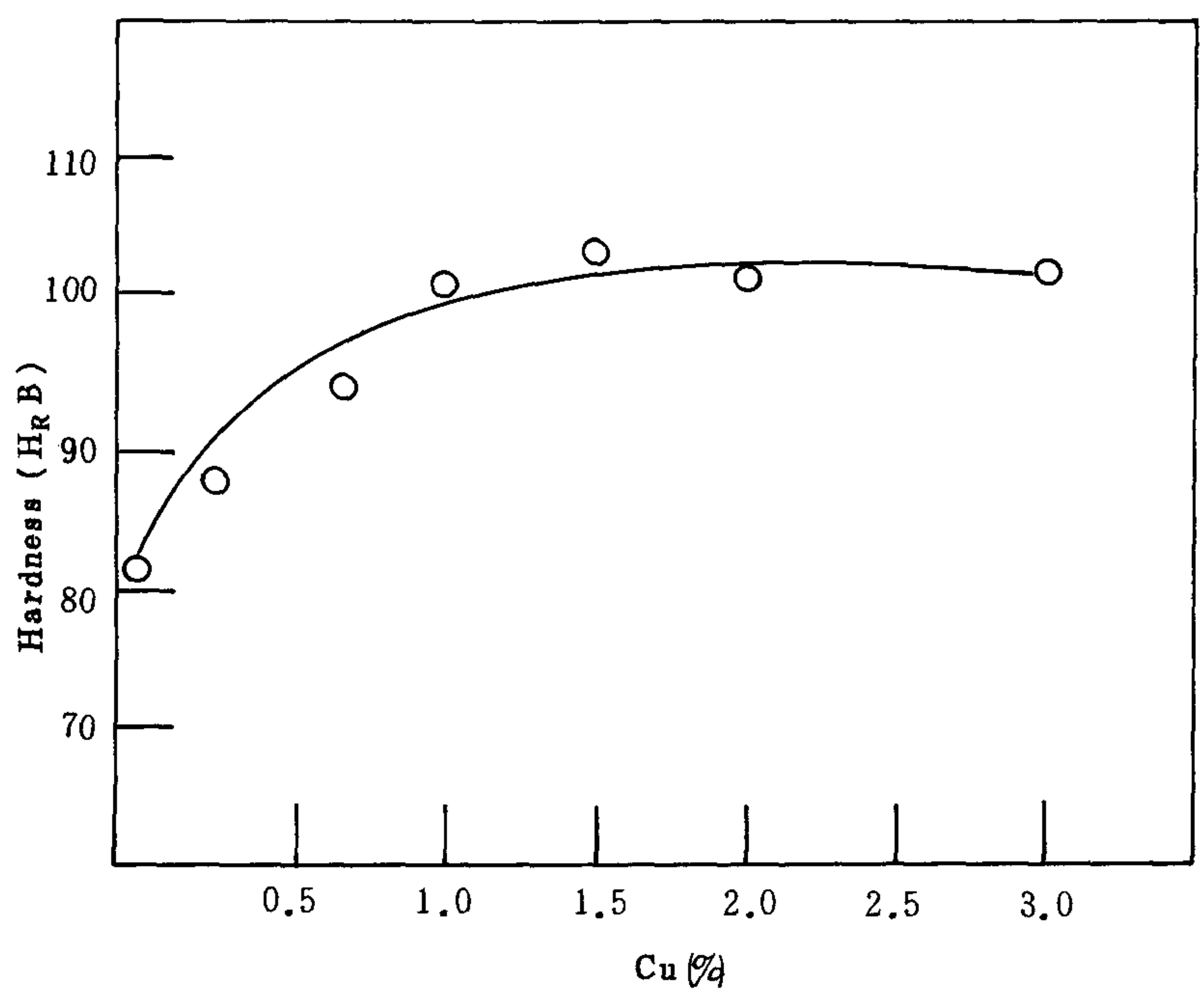


Fig.7 Relation between Cu amount and Hardness
(Si : 3.1 % C : 2.8 %)

3.2 Effects by the change of carbon content

3.2.1 Structure change

Fig. 8 shows the change in structure in the case of 1.0% Cu addition with various carbon content. This figure shows that as the carbon content increased, the graphite form more coarse, the amount of pearlite was decreased, and the amount of ferrite was increased. As the carbon content increased, the graphite grew in size, kish graphite formed, and the degree of pearlite stabilization lowered in the matrix structure.

3.2.2 Hardness change

Fig. 9 shows the change in hardness at 2.8% silicon content with rarious carbon contents. As the carbon content increased, hardness decreased in all cases. It is considered that the result was not related to Cu addition, but as the amount of Cu addition increased, graphite's form grew bigger and the amount of ferrite was increased.

Fig. 10 shows the change in hardness by varying carbon content at 3.1% silicon content. In comparison with Fig. 9 hardness was generally decreased. The change in hardness with increasing carbon content was significant, because more silicon content promoted graphitizing in the matrix, and graphite grew in size.

3.2.3 Tensile strength change

Fig. 11 shows the change in tensile strength by varying carbon contents. As the graphite content increased, tensile strength increased and increasing rates were high. This seems to be due to the same reason as mentioned previously.

Though silicon content was fixed, increasing carbon content changed the matrix into the ferrite rgnge and tensile strength also changed.

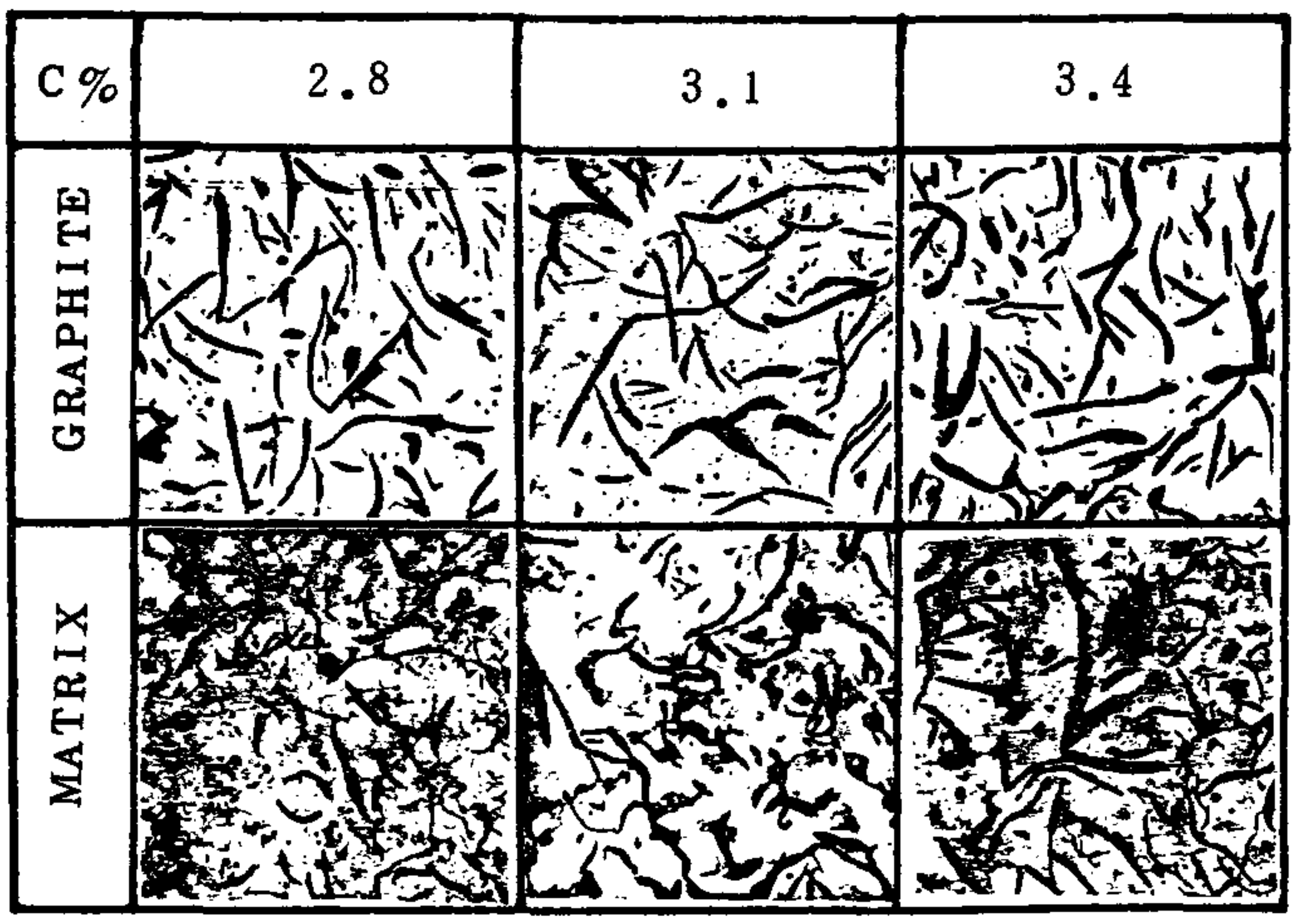


Fig8 Microstructres change of Cast Iron by various adding C.(×100) (Si:2.4%) (Cu: 1.0%)

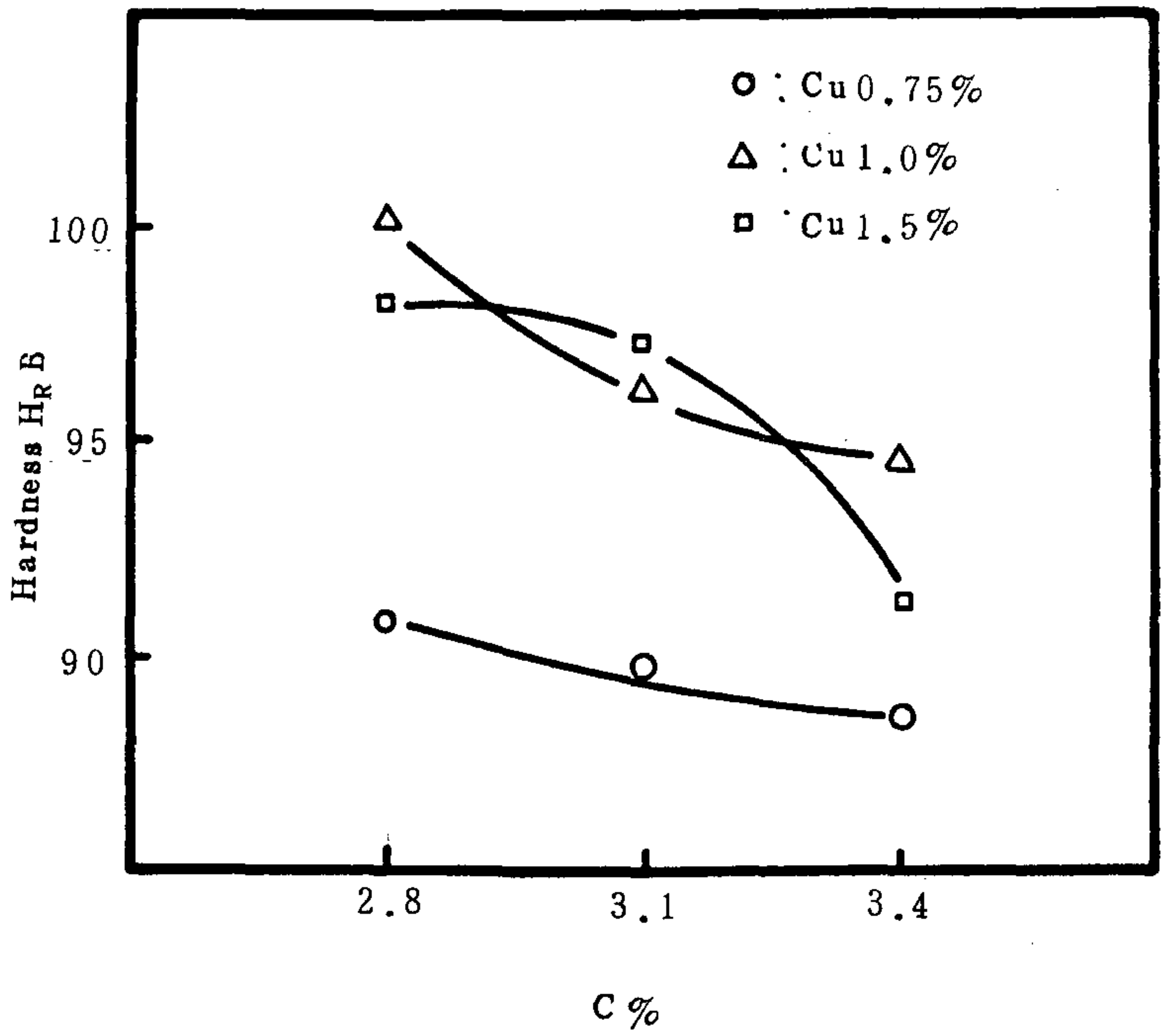


Fig 9 Relation between C amount and Hardness (Si : 2.8 %)

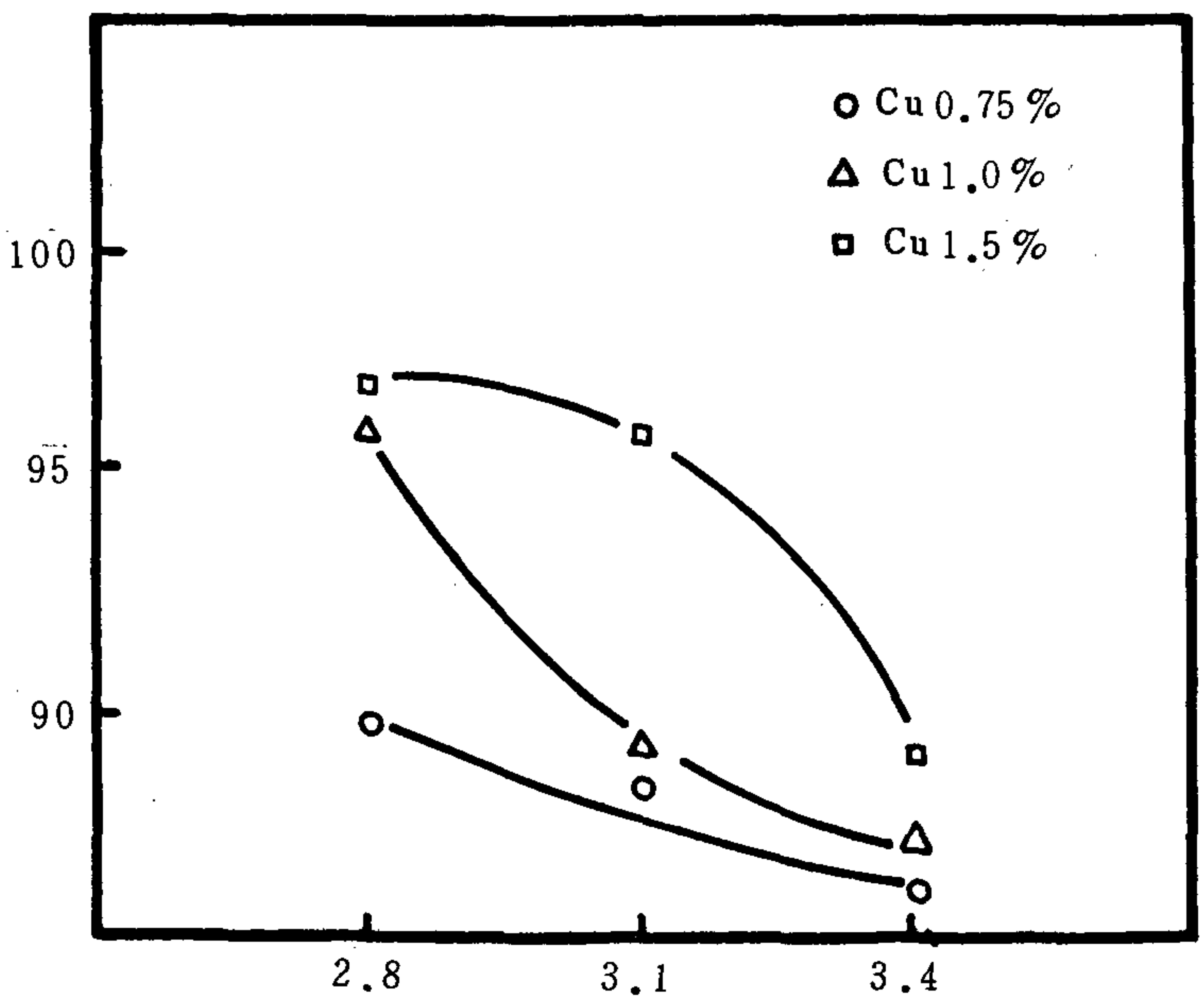


Fig 10. Relation between C amount and hardness (Si 3.1 %)

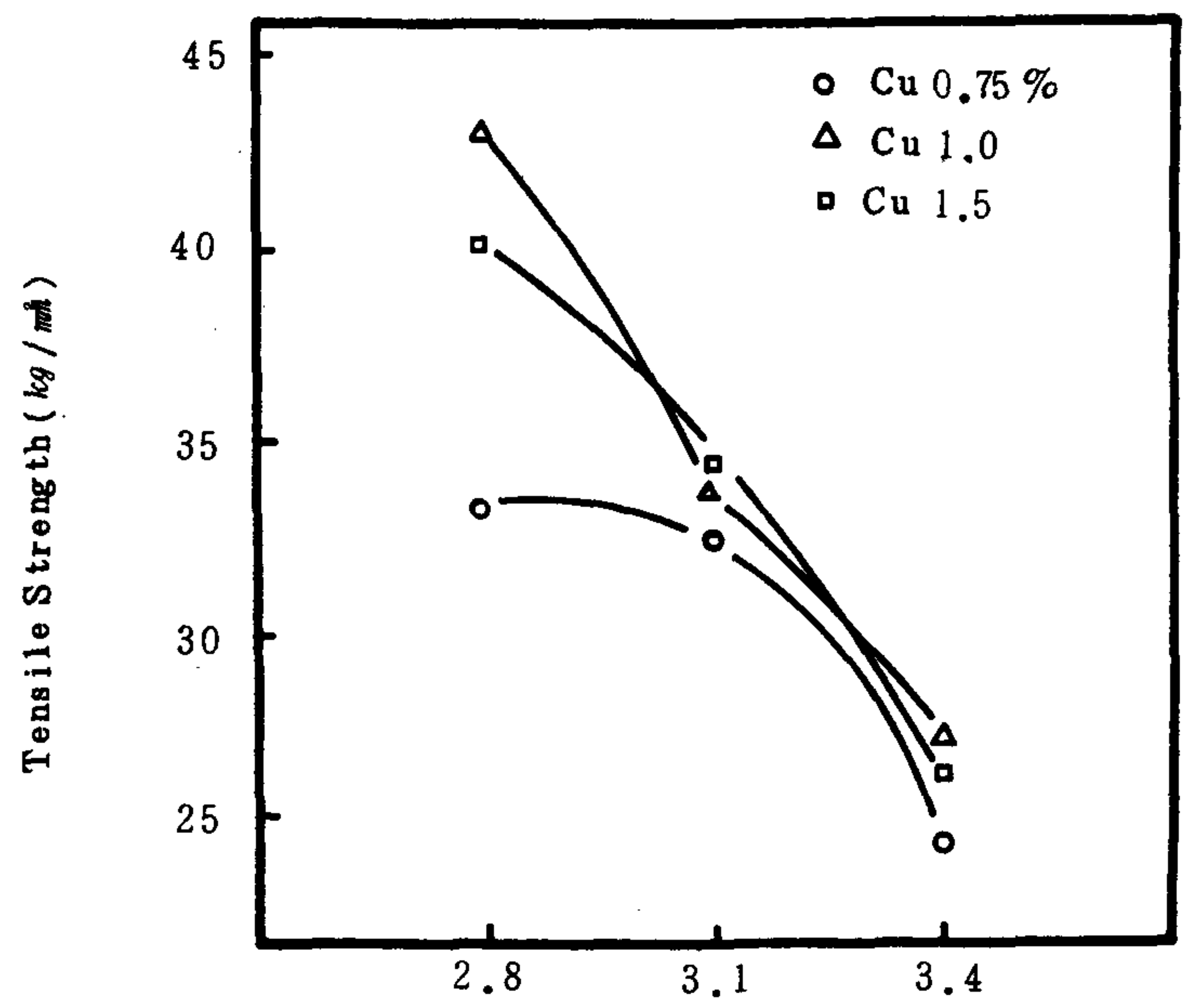


Fig11. Relation between amount and Tensile Strength (Si : 3.1 %)

3.3 The effect by change of silicon content

3.3.1 Tensile strength change

As seen in Fig. 12, when Cu addition was 0.5 % or 0.75 %, the smaller the silicon content was, the higher the tensile strength was.

But in the case of 1.0 % or 1.5 % Cu addition, higher silicon content yielded higher tensile strength. Namely, as Cu addition was increased from 0.5 % to 1.5 %, tensile strength decreased at first but gradually increased.

While Cu was added more than 1.5 % at 2.4 % silicon contents, tensile strength decreased. It is probably due to high silicon content. Excessive Cu addition, which is a graphitizing element, produced ferrite and kish graphite.

3.3.2 Hardness change

Fig. 13 shows the change in hardness by varying silicon content. Up to 2.8 % silicon content, hardness increased.

More silicon content caused the structure to deviate from the ferrite range in Maurer diagram because pearlitization was weakened in the matrix structure.

3.4 C.E. change

3.4.1 Structure change

Fig. 14 shows the change in structure by C.E. at 1.5 % Cu content. As C.E. was increased, graphite showed a tendency to be coarse and the amount of pearlite decreased.

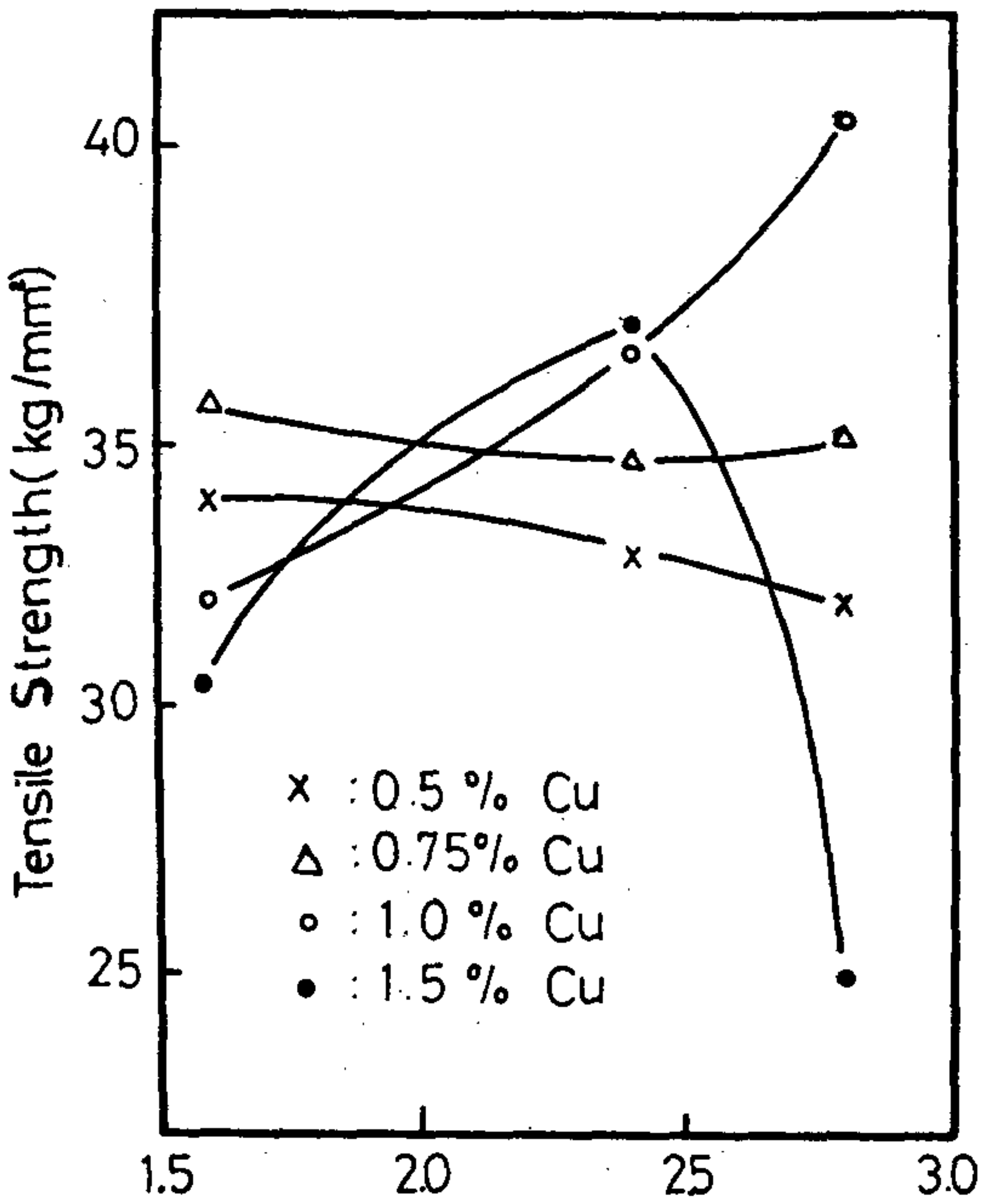


Fig12 Relation between Si amount and Tensile strength

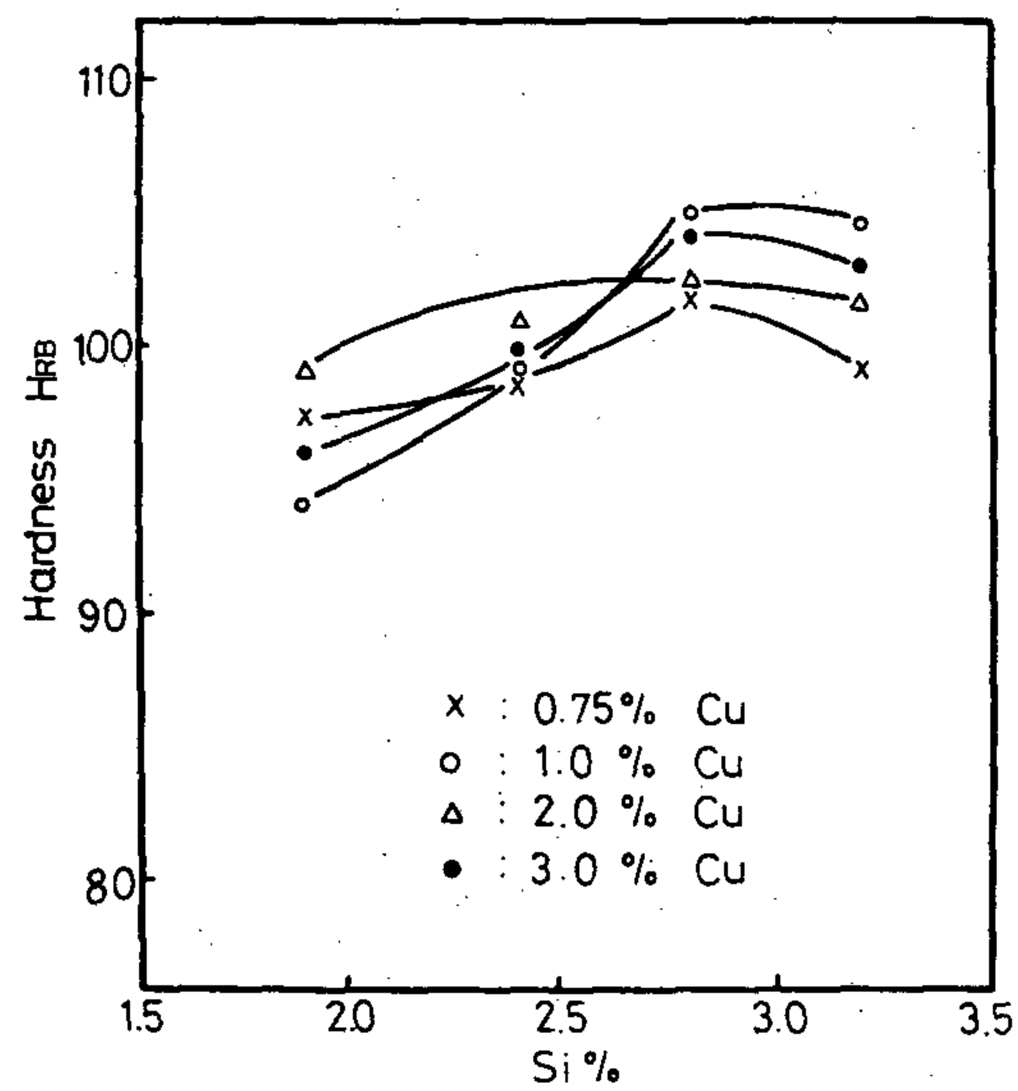


Fig13 Relation between Si amount and Hardness

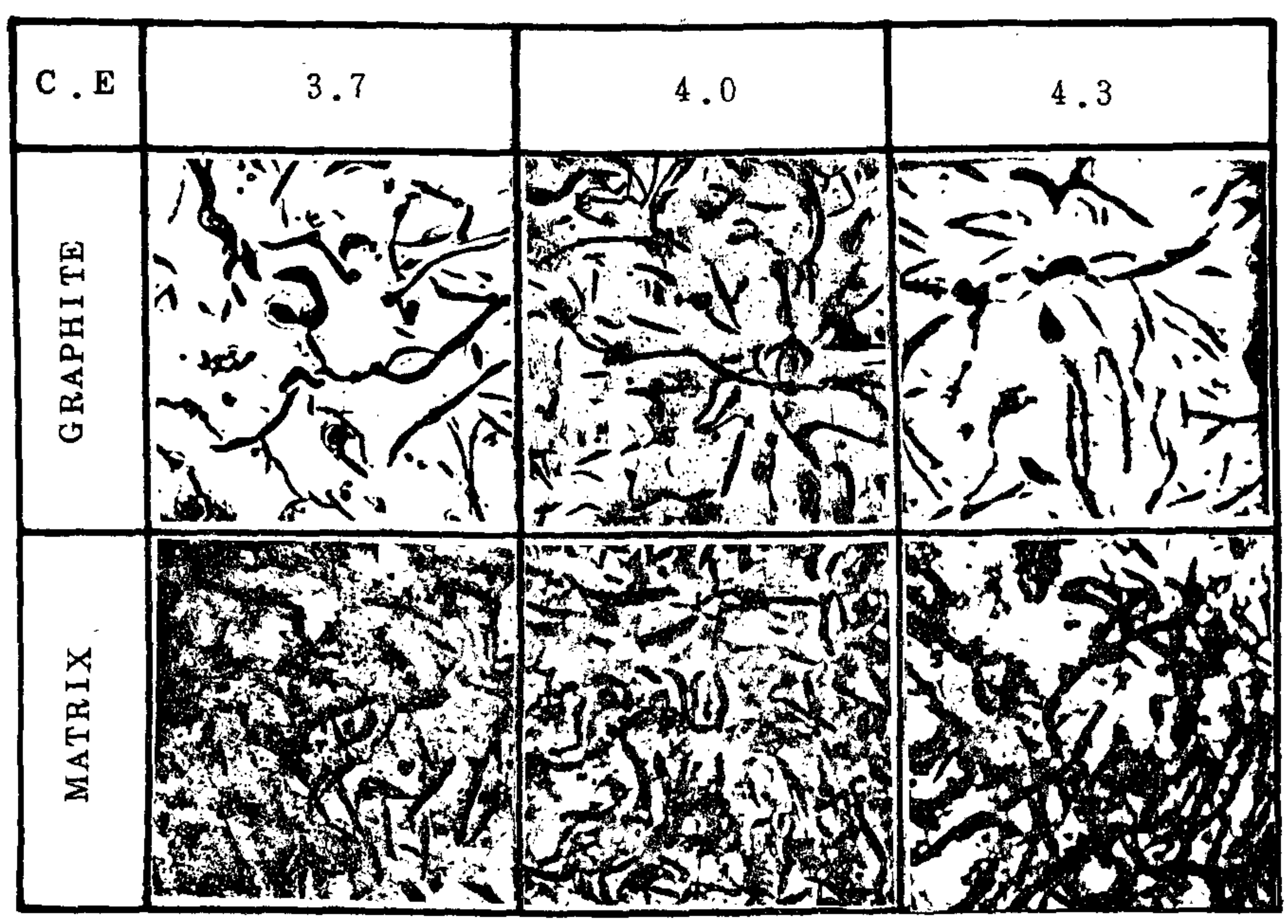


Fig 14 Microstructures Change of Cast Iron by various of C.E.(× 100)(Cu : 1.5 %)

3.4.2 Tensile strength change

Fig. 15 shows the change in tensile strength by C.E. when Cu addition was less than 1.0 %. The change in tensile strength was similar to that when Cu addition was 0.5 % and 0.75 %.

The reason why the same result was obtained as in the previous case, that is, is the case of 0.5 % and 0.75 % Cu addition is probably due to copper which acted as a graphitizing and pearlitizing element. Therefore, it is desirable to add Cu less than 1.0 % to popular grey cast iron.

Fig. 16 shows the change in tensile strength of the alloy with Cu content ranging from 1.0% to 3.0%. In all three cases, that is, 1.5 %, 2.0 %, 3.0 % addition of Cu, similar mechanical property was obtained and maximum value was obtained at 3.6 C.E.

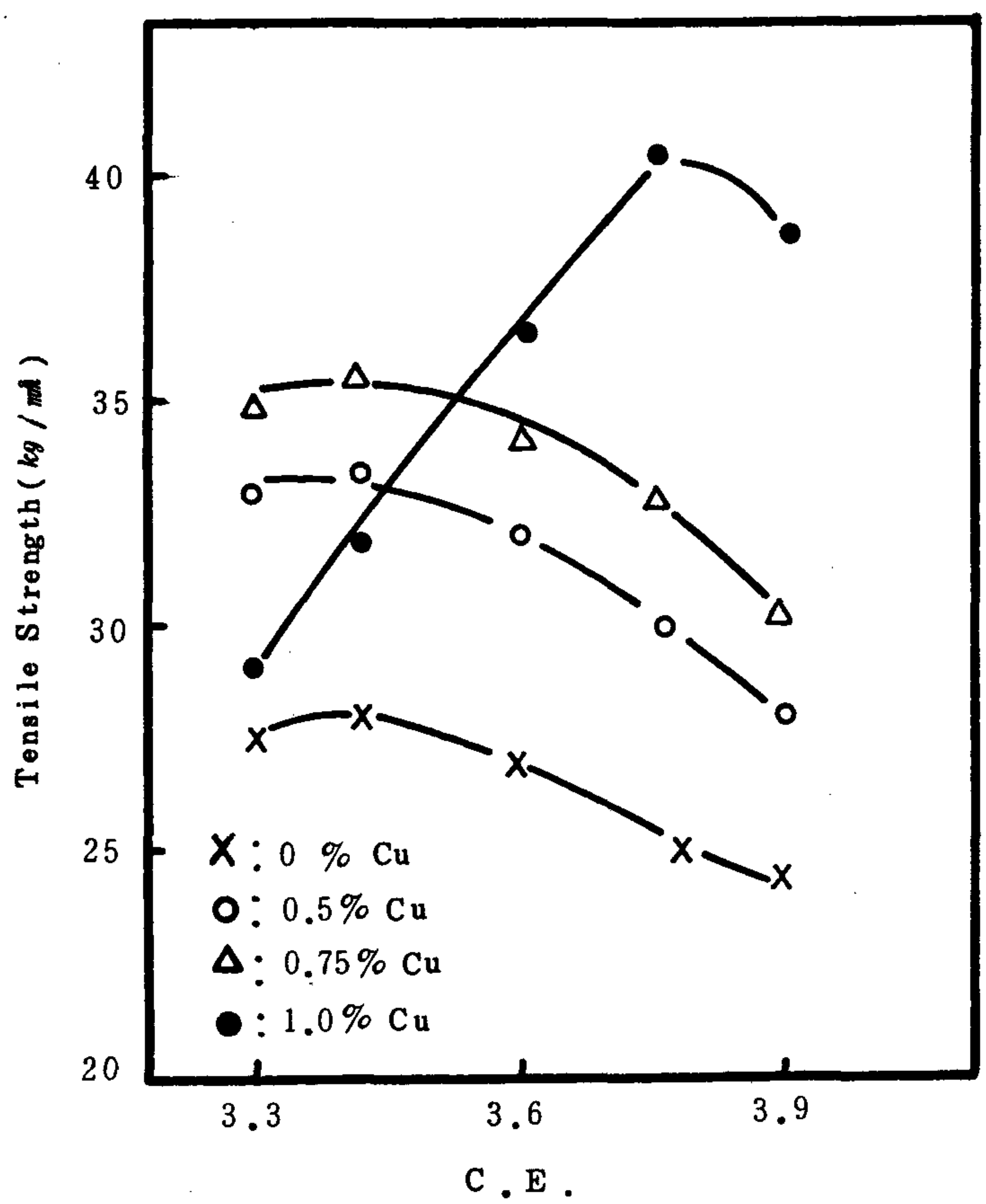


Fig 15 Relation between C.E and Tensile Strength (CU: 1.0% MAX)

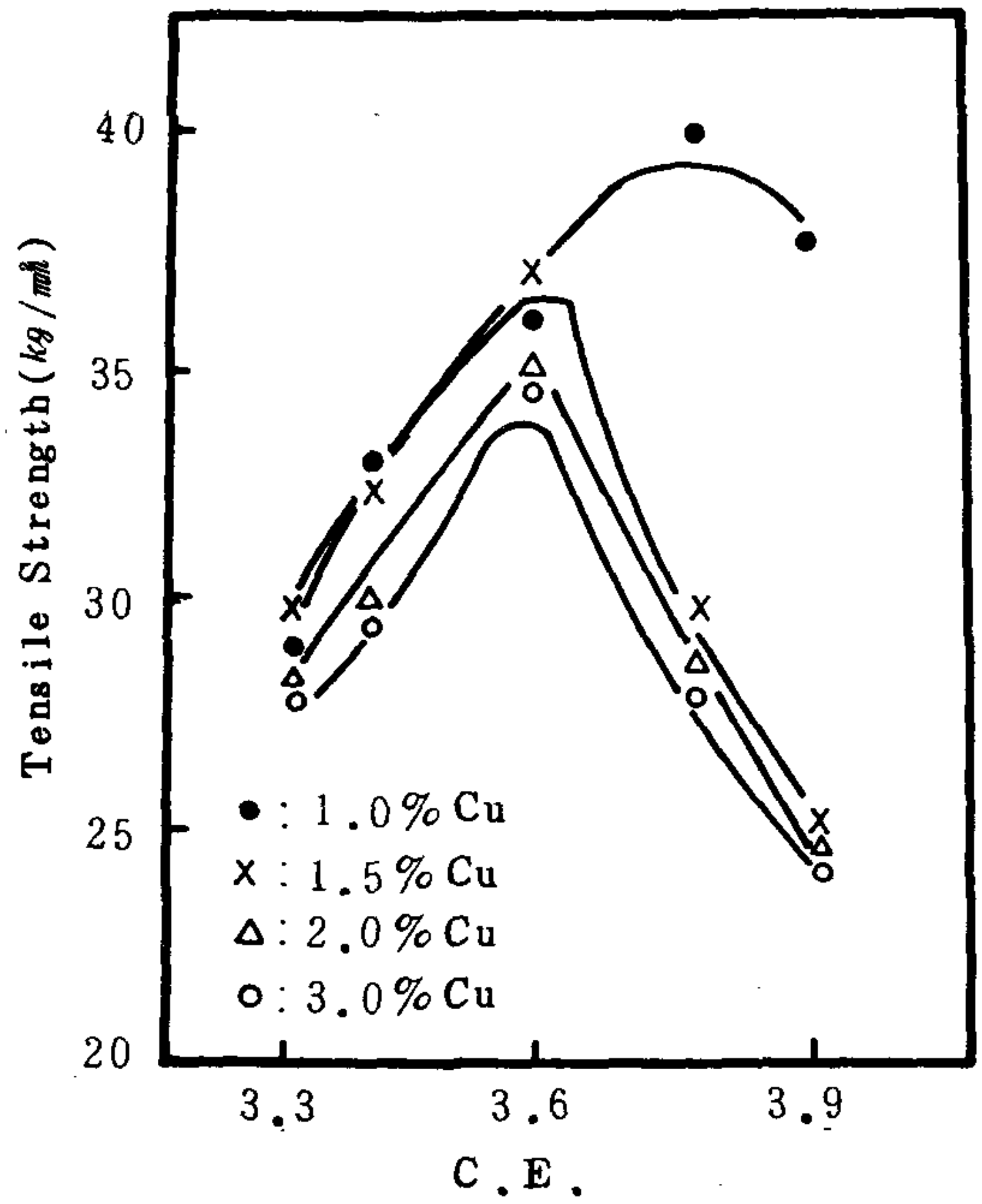


Fig16 Relation between C.E. and Tensile Strength(Cu1.0%MIN)

4. Conclusion

The important results obtained in this study are as follows;

(1) Addition of small amount of copper to the cast iron increased tensile strength and hardness. In comparison with those without addition, alloy with 1.6% silicon content showed 30% more increase in tensile strength and 14% more in hardness.

(2) When carbon content was constant at 2.8%, increase in silicon content showed an increase in tensile strength up to 1.5% Cu addition, while Cu was added more than 1.5% the tensile strength decreased.

(3) Tensile strength increased notably as copper content increased, while the same effect was not found in case of Al addition.

(4) Hardness increased as the amount of copper addition increased up to a certain value beyong which hardness decreased.

5. Reference

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