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Optimum Heat Treatment Conditions for C45 Steel in Fine Blanking Process *

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Abstract

The objective of this research is to investigate the optimum heat treatment condition for the fine blanking process in order to avoid fracture surface on the blank. The optimum condition will result in higher elongation while having small decrease in tensile strength. The circular workpiece of 16 mm. in diameter and 2 mm. thickness was chosen. The material is JIS: S45C which contains 0.45 percent carbon. Unlike the conventional blanking process, the fine blanking process yields the blank surface that is smooth and perpendicular to the top surface. However, there are certain factors, such as low elongation and irregular distribution of microstructure, which prohibit some materials from achieving the mentioned quality. Therefore, the proper heat treatment process of the materials becomes necessary. In this work, the S45C was chosen because of its availability and widely use. The experiment results showed that the optimum heat treatment will be the one that changes the microstructure of the material to spherroidite. The recommended heat treatment condition is that the workpiece is heat at 700°C for 10 hours. However, the above condition will result in decrease of yield stress approximately 20.57 percent compared to that value of the material before having heat treated.

Keywords : Fine Blanking, Fracture Surface, Heat Treatment, Spherroidite

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Introduction

Fine blanking is a high precision process and worldwide in several countries. This is due to workpiece does not occur fracture on the cutting edge, otherwise; it usually occur fracture for conventional blanking as shown in figure1. Thus, it is not necessary to decorate again in the finishing process for the fine blanking which can be reduced some operation step. For example, if chain wheel of motorcycle is produced by conventional blanking, then it need to nine operations. But if it produced by fine blanking, it requires only three operations. With these reasons, fine blanking is bloom for the metal forming industry in Thailand.

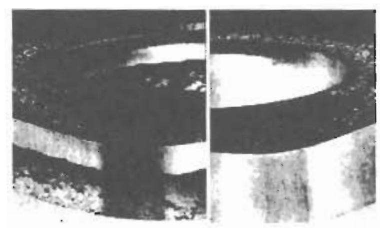


Figure 1 *Workpiece the two different processes (a) conventional Blanking (b) Fine Blanking [Birzer, F., 1997]*

Due to some mechanical property for some kind of metal e.g., low elongation or imperfect microstructure etc., it can not cut by using fine blanking directly. Although, punch and die mold are perfectly designed, the fracture on cutting edge is still occur. The cross – section picture of this material are shown in figure2.

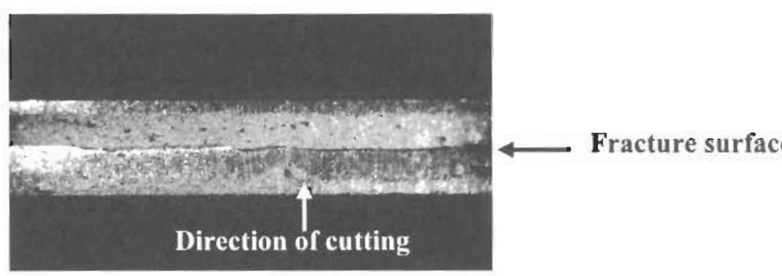


Figure 2 *The fracture surface of cutting edge.*

Several researches emphasize on a specific variable or a condition of fine blanking e.g., effect of distance between V-ring [Birzer. 1997, Murakawa, Kaewtatip, Jin and Koga and Sre-ngam-pong, 1998]. A few researches study the improvement of property of material for fine blanking. Bizer [1] proposes microstructure and mechanical property of carbon steel which able to cut by fine blanking but detail of heat treatment of workpiece for converting microstructure to the proper structure that ready for cutting is not clear. The propose of this research is to investigate the optimum heat treatment condition for fine blanking without fracture surface of carbon steel 0.45. The temperature and time of heat treatment are varied for studying trend of decreasing of fracture surface after cutting by using fine blanking. In addition, the microstructure of workpiece after passing heat treatment is also analyzed.

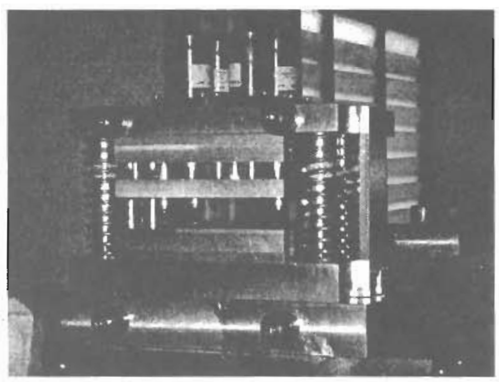
Materials and Methods

Workpiece preparation

The experimental material is 0.45% carbon steel and 2 mm thickness. A workpiece is prepared 50x50 mm square shape by fine blanking and another prepare for testing tension with size according to JIS : Z2201 No13.B.

Punch and die materials

Material that used for making a mold follows JIS SKD 11 standard and treat the hardness to the level of HRC 63. Distance between punch and die is fixed at 0.5% of thickness of workpiece. Distance between V-ring and V-ring height are 1.4 and 0.4 mm respectively. Lubricant ISOLUBE 4686 is used during cutting. The position of punch, die, V-ring and shear resist punch are shown in figure 3.



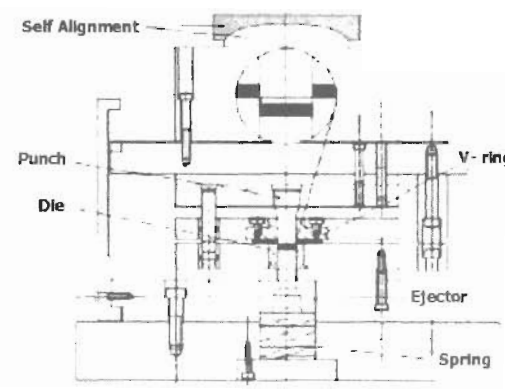


Figure 3 *Section view for the position of Punch, Die, V-ring, Ejector, Spring and Self alignment*

Heat treatment process

Heat treatment processes are totally eleven different conditions as follow:

1. Workpiece named N 700, N800, N850 and N900 are annealed at the temperature of 700,800,850 and 900 °C for 1 hr and then cool down in the normal atmosphere, respectively.
2. Workpiece named S2, S5, S10, S15 and S20 are annealed at the temperature of 700°C for2,5,10,15 and 20 hr and then cool down in the normal atmosphere, respectively.
3. Workpiece named SF and SC are annealed at the temperature of 830 °C for 1 hr and rapidly cool. After that they are annealed at lower temperature of 620 and 715°C for 3 and 4 hr and then cool down in the normal atmosphere, respectively [Lemmon and Sherby. 1969].

The hydraulic press is single action in size of 150 Tons. The nitrogen gas spring is used for supporting force on V-ring. Displacement data are transmitted through load cell and linear variable differential transformer (LVDT) and then are converted to force and displacement distance by DASY lab software.

Results and Discussion

Effect of temperature for heat treatment

Relationships between cutting surface and burr with heat treatment temperature are shown in figure 5. From experimental result, it showed that workpiece through heat treatment at the temperature of 700, 800, 850 and 900 °C result in the increasing of overall shear surface and the decreasing of fracture surface when compared with no heat treatment due to no appearance of strain hardening. When the temperature increases, fracture surface is slightly differ. It can be explained by the fact that the microstructure after heat treatment at 700, 800, 850 and 900 °C as shown in figure 6, 7, 8 and 9 which contained pearlite and ferrite grain are not different in size. At the temperature of 700°C, the fracture surface is at smallest because microstructure after heat treatment converts pearlite to spherroidite grain as shown in figure 6.

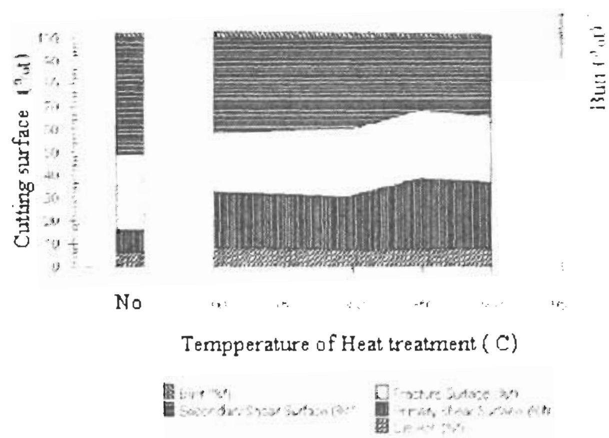


Figure 5 *Cutting edge of workpieces with temperatures used in the annealing for material JIS : $S_{45}C$*

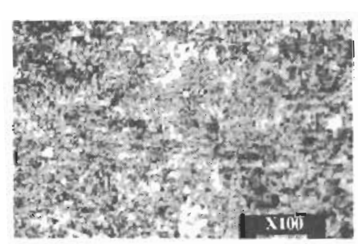


Figure 6 *Microstructure of workpieces with passed the N700 (S1)*

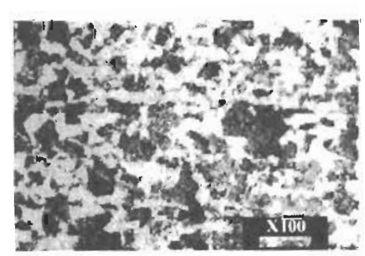


Figure 7. Microstructure of workpieces with passed the N800

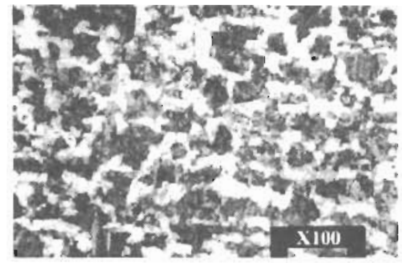


Figure 8 *Microstructure of workpieces with passed the N850*

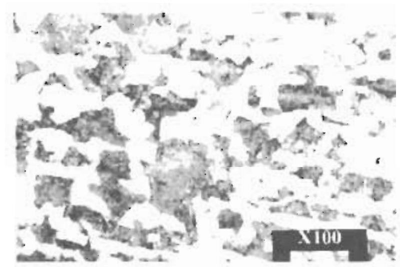


Figure 9 *Microstructure of workpieces with passed the N900*

It is well known that quality of workpiece from fine blanking is related to mechanical property [Birzer.1997]. The mechanical properties such as ultimate tensile strength and elongation are plotted with temperature of heat treatment as illustrated in figure10. The results in figure10 are consistent with each part of cutting surface in figure 5. Workpiece after heat treatment, the elongation is increased while ultimate tensile and yield strengths are decreased. At the temperature of 700 °C, the elongation is at highest value but ultimate tensile and yield strengths are at lowest values. For the other temperatures of heat treatment, elongation, ultimate tensile and yield strengths are almost at the same valve.

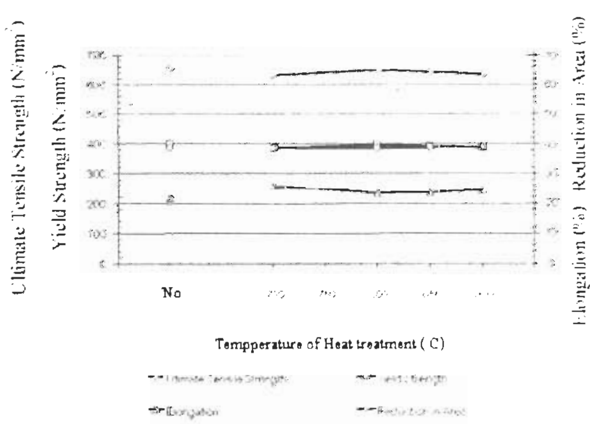


Figure 10 *The mechanical properties of the annealed workpiece with pass different temperature*

To consider the operating cost of the heat treatment processes, the power consumption and cutting force is evaluated with temperature as shown in figure11. The power consumption is linearly increased with the increasing of temperature while cutting force is increased and then decreased at temperature over 850°C. The highest cutting force is corresponded to ultimate tensile strength according to the theoretical calculation [Birzer. 1997 and Murakawa, Kaewtatip, Jin and Koga]. The power consumption at 700°C is 34.67 % saver than that at 900°C.

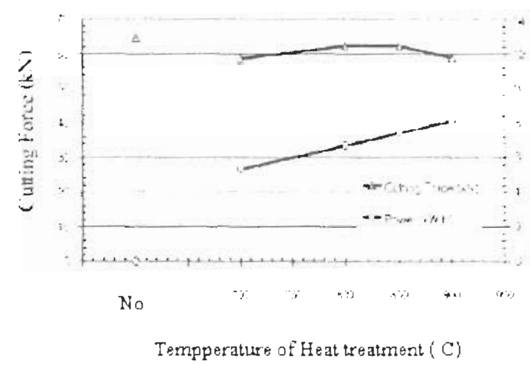


Figure 11 *Electric energy with use annealed and cutting force of material JIS : S45C, with pass different temperature*

As previously discussion, it can be concluded that the temperature of 700°C provides the best quality of cut profile, among 800, 850 and 900 °C. This is due to microstructure is almost spherroidite which is similar to Birzer report [Birzer. 1997]. Consequently, this temperature is selected to investigate the optimum period of time of heat treatment in the next section.

Effect of time for heat treatment

Figure 12 is a graph of the cutting surface and burr against time for heat treatment. It reveals that the overall shear surface after heat treatment in the first 10 hours is increased, otherwise; the fracture surface decreases. When heat treatment is over 10 hours, the fracture surface disappears from the cutting surface. Because microstructures during 10 to 20 hours are almost spherroidite as depicted in figures 15, 16 and 17, respectively. On the other hand, microstructures for the first 10 hours are significantly remained pearlite inside structure as shown in figures 6, 13 and 14, respectively.

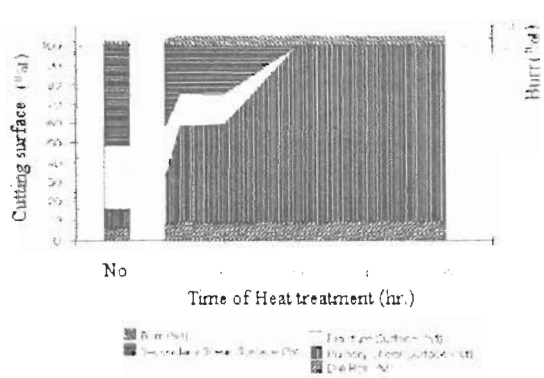


Figure 12 *Cutting edge of workpieces with times used in the annealing for material JIS :S45C*

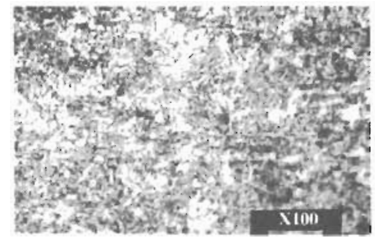


Figure 13 *Microstructure of workpieces with passed the S2*

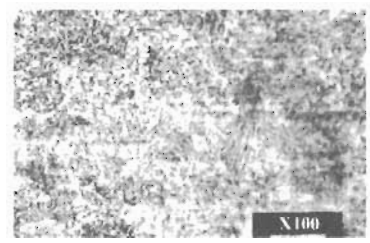


Figure 14 *Microstructure of workpieces with passed the S5*

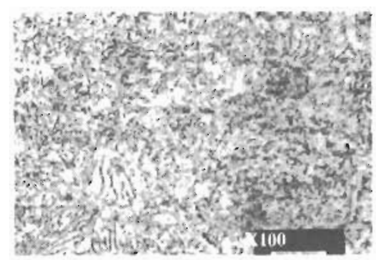


Figure 15 *Microstructure of workpieces with passed the S10*

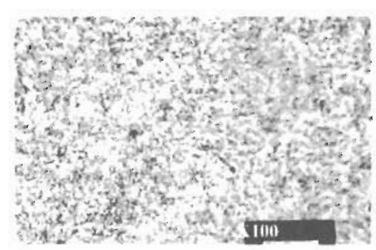


Figure 16. Microstructure of workpieces with passed the S15

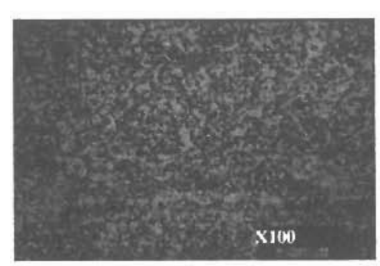


Figure 17 *Microstructure of workpieces with passed the S20*

Relationship of mechanical properties before and after heat treatment against annealing time is shown in figure 18. The elongation is exponentially increased while ultimate tensile and yield strengths are exponentially decreased. After 20 hours of heat treatment, the increasing of elongation is approximately 59.7% but the reduction of ultimate tensile and yield strengths is about 27.43 and 25.27%, respectively when compared with no heat treatment. Comparative operating cost for each time of heat treatment in term of power consumption is reported in figure 19. The power consumption is linearly increased with time, otherwise; the cutting force is linearly decreased. The changes of cutting force are corresponded to the changes of ultimate tensile strength. From microstructure pictures as shown in figures 15-17, microstructures after heat treatment are spherroidite, therefore; fracture surface disappears when workpiece passes the fine blanking process. To insist the spherroidite formation during heat treatment process as reported by Lemmon [Lemmon and Sherby. 1969], the next section will be discussed.

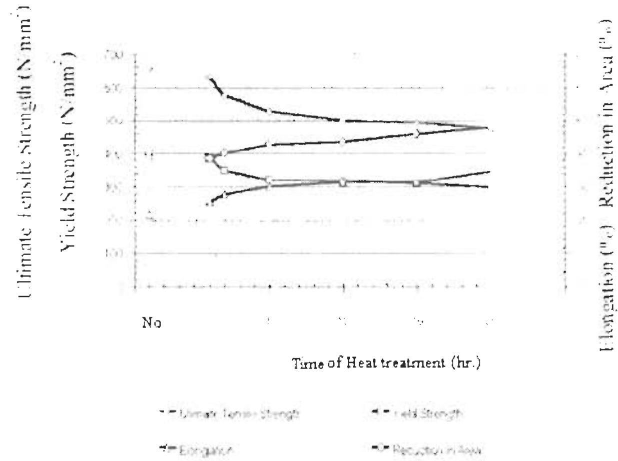


Figure 18 *The mechanical properties of the annealed workpiece with pass different time annealed*

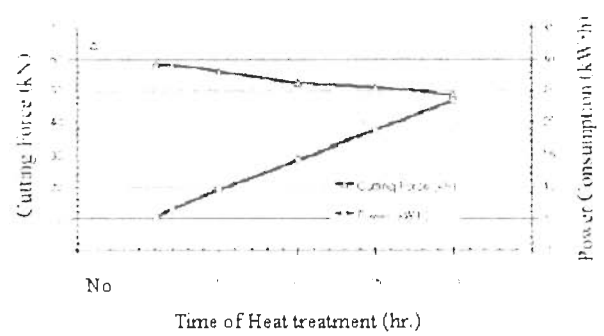


Figure 19 *Electric energy with use annealed and cutting force of material JIS : S45C, with pass different time annealed*

Annealing for increasing spherroidite formation

Annealing for increasing spherroidite formation is shown in figure 20. The overall shear surface and fracture surface after treated with condition SF are 82.87 and 8.47% of thickness of workpiece. In contrast, the fracture surface does not exist on the cutting surface when treated with condition SC. Annealing with condition SF still remains fracture surface because spherroidite microstructure is aggregated to a lump as seen in figure 21. On the other hand, spherroidite microstructure is uniformly distributed as seen in figure 22 when annealed with condition SC, therefore; cutting surface is without fracture.

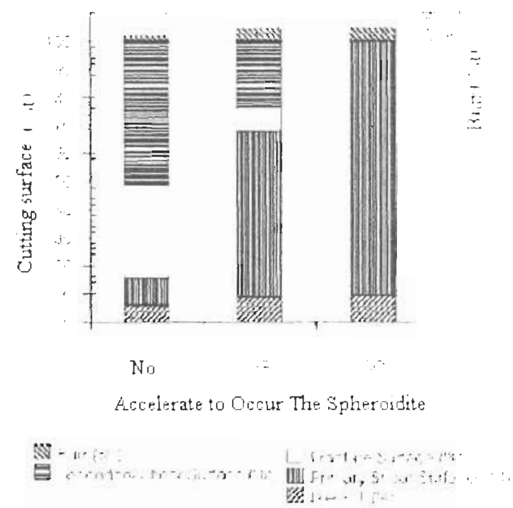


Figure 20 *Cutting edge of workpieces with passed SC, SF and No annealing*

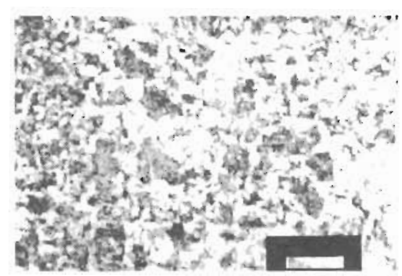


Figure 21 *Microstructure of workpieces with passed the SF*

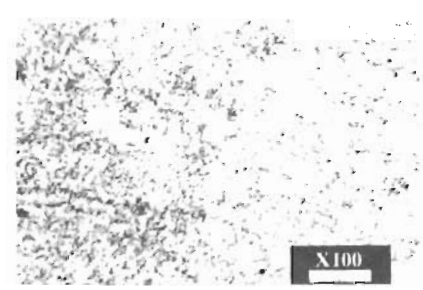


Figure 22 *Microstructure of workpieces with passed the SC*

The results from tensile test after annealed with conditions of SF and SC is shown in figure 23. It was found that the elongation and reduction of area are increased while the ultimate tensile and yield strengths are decreased when compared to no annealing.

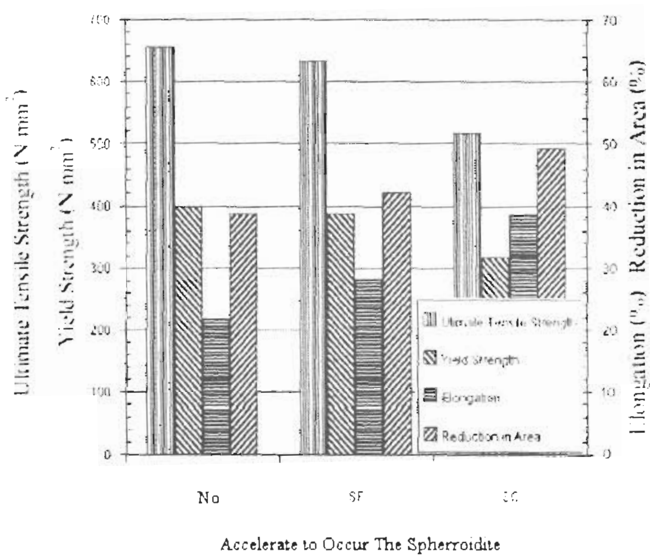


Figure 23 *The mechanical properties of the annealed workpiece with passed SF, SC and no annealing*

For power consumption as shown in figure 24, it is revealed that annealing for increased spherroidite formation consumes the energy higher than the normal annealing because it is necessary to anneal workpiece in two times. Besides, the highest cutting force varies with ultimate strength, corresponding to the above mentions.

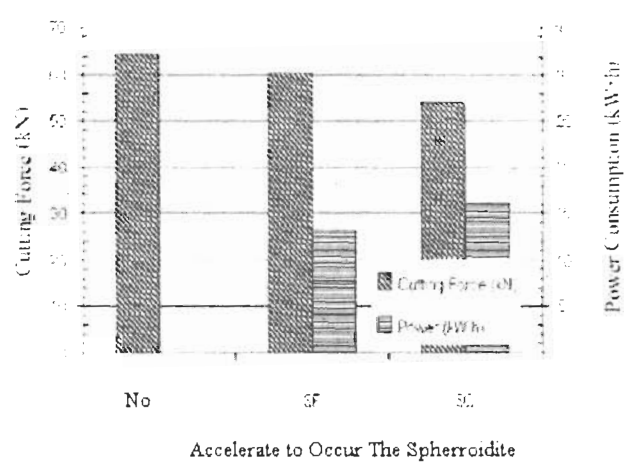


Figure 24 *Electric energy with use annealed and cutting force of material JIS : S45C, with pass SF, SC and no annealed*

Analysis for finding the optimum heat treatment process without fracture

The heat treatment process of workpiece made of S45C material without fracture on cutting surface is annealed with conditions S10, S15, S20, and SC. To optimize heat treatment process, the annealing cost and mechanical properties of workpiece after annealing are used for analyzing as shown in figure 25. It showed that annealing with condition S10 is the optimum heat treatment process due to the following reasons: 1.) The change of yield strength is lowest decreased approximate 19.63%, comparing with initial workpiece. The yield strength indicates the ultimate strength which able to resist plastic deformation. 2.) Annealing cost is the most save and cutting force has no difference when compared to the other conditions.

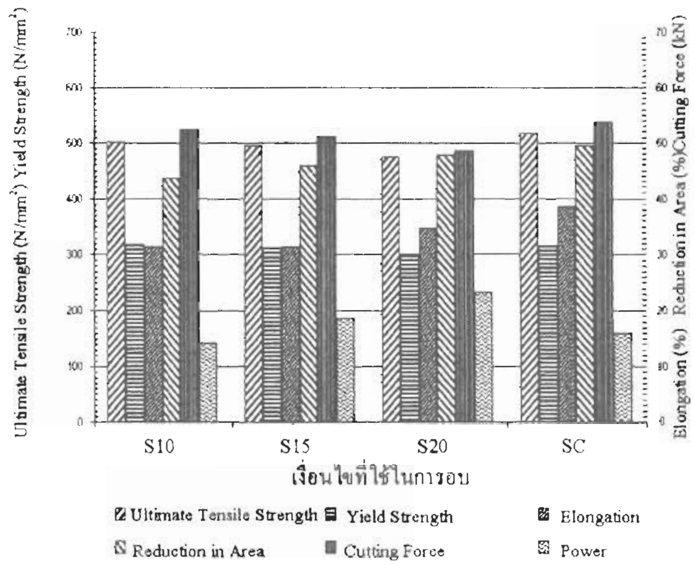


Figure 25 *Compare with the ultimate tensile strength, yield strength, Elongation, Area of reduction, Cutting force and Electric energy with use annealing of workpieces with passed fine blanking, these had not fracture surface.*

Summary

The changes of temperature of annealed process for carbon steel 0.45 insignificantly affect on the overall shear and fracture surface and yield strength, however; factor of temperature of annealed process is considerably differed between before and after heat treatment.

The changes of time of annealed process remarkably affect on the overall shear and fracture surface and yield strength

Annealing for increasing spherroidite formation without fracture which saved the cost of annealing and provided a little change of yield strength obtain from heat treatment with condition S10.

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