An Infrared local heat-treatment method to improve local formability of forming and trimming processes

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Abstract. This paper presents a local heat-treatment method to improve the local formability for stamping and trimming processes by using focused infrared (IR) rays. Although the demand of ultra-high strength steel (UHSS) has been increasing in order to reduce car weights, the low formability of the UHSS has been a limitation. In order to resolve the formability problem, heat treatment methods have been often studied, and the authors also have developed a local heat treatment method by using focused infrared (IR) rays for a decade. The difference of this method from the author’s previous works is that the new heat treatment is completed by the supplier. The supplier of the materials completes the local heat treatment on target areas of blanks where to improve the local formability, then stamping companies can conduct cold forming and trimming. The target material of this paper is a 1.5GPa steel, CR1480M steel supplied by POSCO. This paper discusses the local formability change caused by the presented IR heat treatment.

1. Introduction
Since the environmental problem is becoming an important issue, auto companies have tried to improve energy efficiency and reduce vehicle’s weight. As part of the efforts, the automotive industry has increased the use of ultra-high strength steel (UHSS) which has a higher strength with a thinner thickness. The use of UHSS can lead to reduction of the weight of a car with maintaining the strength to improve the fuel efficiency. However, the low formability problem of the UHSS has become a limitation to expansion of the application of the UHSS. Specially, martensitic steel, consisting of martensite microstructure, has a very low formability. Consequently, roll forming process is a widely used for forming of martensitic steel since the roll forming process makes incremental forming at each stage. However, in auto industries, stamping process is popular because it can make complex shape parts under the mass production condition. For application of stamping process, martensitic steel needs to improve formability for stamping and trimming processes. Many studies have been conducted to improve formability of UHSS material by using hot press forming (HPF) and warm-forming [1-8]. The HPF is appropriate to form quenchable materials, such as boron alloyed steel sheet, and the process guarantees the hardness of the material by quenching after forming. While forming under the elevated temperature conditions drastically reduces springback, trimming of UHSS has become another issue, because the
quenching process during the HPF increases the strength of the blank. The increased strength of the material results in damage of the trimming tools. A widely used solution in industry is laser trimming without trimming tools. But the laser trimming method leads to a sharp drop in productivity and the investment of the laser equipment is very high.

This paper presents a local heat-treatment process for martensitic steel in order to improve the formability of the steel for the purpose of the stamping process in the auto industry. The difference of this method from the author’s previous works [9-11] is that the new heat treatment is completed by the supplier. The supplier of the materials completes the local heat treatment on target areas of blanks where to improve the local formability for stamping and trimming processes. Then, stamping companies can conduct cold forming and trimming while the previous methods conducted warm forming under the elevated temperature conditions. The target material of this paper is a 1.5GPa steel, CR 1480M steel supplied by POSCO. In this paper, V-bending and trimming tests are presented to validate the formability improvement. Microstructure change caused by the heat treatment was also observed. This study shows that this heat-treatment method has a potential to be used for stamping process of the martensitic steel.

2. Local heat treatment
This work uses the infrared (IR) local heater for the heat treatment. The heater consisted of an IR lamp and elliptical reflector. Figure 1 shows the IR local heater, and details of the IR heater is explained in the previous works [12-13]. The heater can heat a narrow heat affected zone (HAZ). The narrow HAZ effectively reduces the decrease of the whole structural stiffness and strength decrease by the heat treatment. Figure 2 shows the performance of the IR heater. The temperature profile history was collected with K-type thermocouples inserted in drilled holes of the specimen. Since the geometry of the specimen and the heater is symmetry, as shown in Figure 2(b), the thermocouples were located in 10 points on the right half of the specimen (0, 5, 10, 15, 20, 25, 30, 40, 50, and 60 mm from the symmetric axis). As observed in the Figure 2(b), temperature distribution was successfully controlled by gathering IR thermal flux at the center of the specimen. The temperature curves at 200°C, 400°C, 600°C and 800°C presents that the central temperature is the highest, and it decreases as the distance from the center increases. The reflector effectively concentrates the IR rays on the target HAZ where to improve the formability.

![Elliptical reflector and IR lamp](image1.png)

**Figure 1. IR Local heater[14]**
Figure 2. Temperature profile of local heating: (a) K-type thermal couple and (b) temperature profile along the longitudinal direction

The effect of the heat treatment on the microstructure was observed, as shown in figure 3. The specimen was obtained from the heated specimen after cooling to room temperature. Figures 3(a-b) shows optical micrograph images of as-received and 600°C heat-treated specimens, respectively. Figure 3(a) presents the material consists of almost all martensite. However, the martensite was tempered after the-heat treatment, as shown in figure 3(b). This microstructural change improves the formability.

Figure 3. Local heating effect on phase transformation: (a) as-received and (b) heat-treated specimen under 600°C condition

3. Experimental Setting

The V-bending experiment was conducted and repeated three times for five heat treatment conditions (as-received, 200°C, 400°C, 600°C, and 800°C). The center of the HAZ is the reference point of the heating condition. After the central temperature reached the target temperature, each specimen was cooled in room temperature. The dimensions of the V-bending specimen were 180mm × 20mm × 1.5mm. The center line of the HAZ on the specimen was aligned along the rounded edge part of the 2mm punch with 90° angle. The punch speed was 5mm/s. With the same temperature conditions, a trimming test was conducted for three times on each condition. The clearance of the trimming blade and die was 0.12mm (8% of the thickness of the specimen) and the dimensions of the specimen were the same to the V-bending case. The trimming die was attached on 10 ton UTS, so that the maximum punch force at the trimming process could be measured. Figure 4(a-b) presents experimental settings of the V-bending and trimming, respectively.
4. Experimental results and Discussion

4.1. V-bending

Figure 5. V-bending experiment result: (a) as-received specimen and (b) heat-treated specimen under 600°C condition

Figure 5(a-b) shows outer surfaces of the bent specimens of as-received and 600°C heat-treated, respectively. As shown in figure 5, the as-received material resulted in crack on the center of the bending zone because of the low formability. On the other hand, the heat-treated specimen had no crack in the same forming condition. This can be explained through the improved formability caused by decomposition of martensite. This comparison shows that the IR local heat treatment could improve the formability of CR1480 M. It is well reported that the 600°C condition can reduce springback and improve the formability by decreasing flow stress of advanced high-strength steels [9-10].
4.2. Trimming

Figure 6. Trimming experiment result of representative case

During the trimming process, punch force was measured as shown in Figure 6. Figure 6 shows decrease of the maximum punch force with respect to the heat-treatment temperature condition. Note that Figure 6 shows the force per width to remove the effect of geometry. While the maximum punch force of the as-received material is 1233N/mm, those of the 600°C heat-treated and the 800°C heat-treated are 948N/mm and 861N/mm, respectively; 23% and 30% of force reduction. As discussed above, generally 600°C condition reduce flow stress of advanced high-strength steels [9-10], it causes the decrease of the trimming force. This can match the trimming force of CP1180 material which is used in cold trimming process in mass production processes.

5. Conclusion

This paper studies forming and trimming process of 1.5GPa steel, CR 1480M supplied by POSCO. The IR local heat treatment can improve the formability of the CR 1480M material in bending and trimming process. Details are below:

1. The IR heat-treatment can improve the formability of the martensitic steel.
2. This improvement of the formability can avoid the fracture in the V-bending process.
3. Approximately, 23% of punch load decrease was observed when trimming was conducted with the 600°C heat-treated material.
4. Trimming force reduction can match the trimming force of CP1180 material which is used in cold trimming in mass production.
5. The bending and trimming processes were conducted with the specimens which were cooled after the heat treatment. That means the stamping companies can conduct cold stamping and trimming processes after the heat-treatment was completed by the supplier.
6. The effect of the local heat treatment on the trimmed edge condition will be studied in a future work.

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