The effect of composite microalloying on the performance of hot press forming B-pillars

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This article investigates the effect of niobium-vanadium composite microalloying on the performance of hot press forming B-pillars. Three-point bending experiments and trolley collision performance experiments on B-pillars were conducted. The results showed that during the three-point bending experiment on the B-pillar, the critical fracture strain increased from 0.537 of 22MnB5 to 0.857 of 22MnB5NbV; When the B-pillar fracture occurred, the displacement of the press head increased from 65mm to 82mm. During the trolley collision, the intrusion amount in the three key parts of the dummy's chest, abdom, and public corresponding to the B-pillar is significantly decreased. The HESI (hydrogen embrittlement sensitivity index) was measured by sampling from three locations of the B-pillar, and 22MnB5NbV showed a significant decrease compared to 22MnB5. Composite microalloying effectively improves the safety of hot press forming B-pillars in the using, protects passenger space, and extending the service life of the B-pillar.

Keywords: Niobium-vanadium composite microalloying; Hot press forming B-pillar; Three-point bending; Trolley collision; Hydrogen embrittlement sensitivity index.

1. Introduction

The B-pillar is the most important safety component in body in white, and it is closely related to the safety during the side collisions of the car [1], The B-pillars is made in materials with high strength and toughness [2]. In some literature, the application of high-strength and toughness materials to made in B-pillars has been a focus of research [3] [4]. It has been shown that niobium-vanadium composite microalloying can effectively improve the strength and toughness of hot press forming steel 22MnB5 and hydrogen embrittlement resistance [5]. However, in reference [6], it has been emphasized that material properties are different from the performance of components. Therefore, the purpose of this study is to use niobium-vanadium composite microalloyed hot press forming steel 22MnB5NbV to make B-pillars, and to compare their performances with those made of the original hot press forming steel 22MnB5 under the same conditions, in order to check the effect of composite microalloying on the performance of B-pillars.

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2. Materials and method used in the experiment

The materials used in the experiment are 22MnB5NbV and 22MnB5, which composition can be found in reference [5]. Using these two steel sheets to make the same B-pillar, the thickness of the component B-pillar is 1.5mm. According to the formal hot stamping process, a hot formed B-pillar is produced, as shown in Fig. 1. After hardness sampling, its Vickers hardness value is greater than HV450. Then, a three-point bending experiment of the B-pillar is carried out. When conducting this experiment, the sample is first installed on a special three-point bending fixture, as shown in Fig. 2. The critical fracture strain value and the corresponding position of the press head when micro cracks occur (i.e. the bending stroke of the press head) are measured. The B-pillar was installed on the wall barrier by using of a special fixture in order to carry out the trolley collision experiment of the B-pillar. After collision of the special trolley with a weight of 900kg and a speed of 20km/h, the deformation values of three locations, including the RIB of the B-pillar (corresponding to the ribs of the human body) ABDOM (corresponding to the human abdomen) PUBLIC (corresponding to the human pelvis) are measured. A schematic diagram of a trolley collision is shown in Fig. 3, Diagram 4 shows the installation of B-pillar on the wall barrier. The experimental method for physical hydrogen embrittlement is to take samples from the B-pillar and measure the changes in elongation of two steel grades before and after hydrogen charging.

Fig. 1. Physical photo of B-pillar.

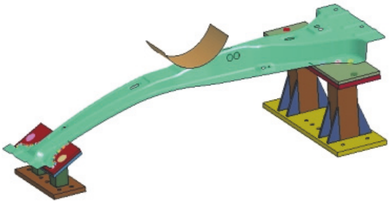


Fig. 2. Fixture and support for B-pillar under the three static point pressure.

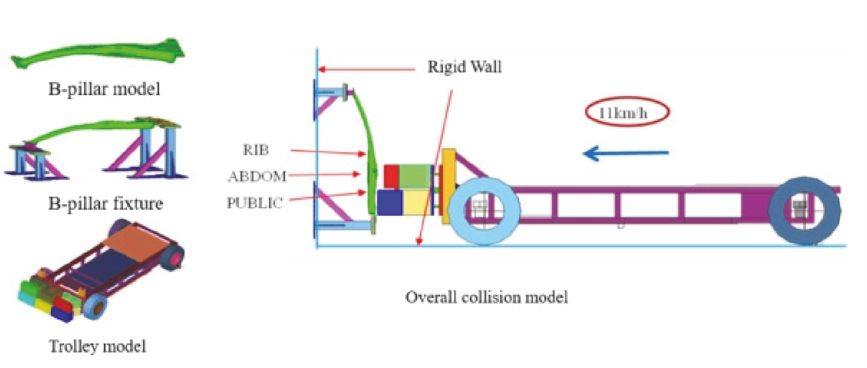


Fig. 3. Schematic diagram of trolley collision.

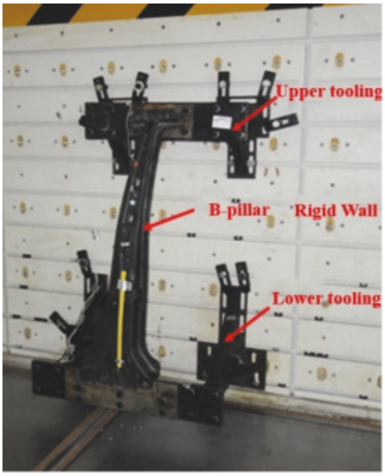


Fig. 4. Schematic diagram of B-pillar installed on a wall barrier.

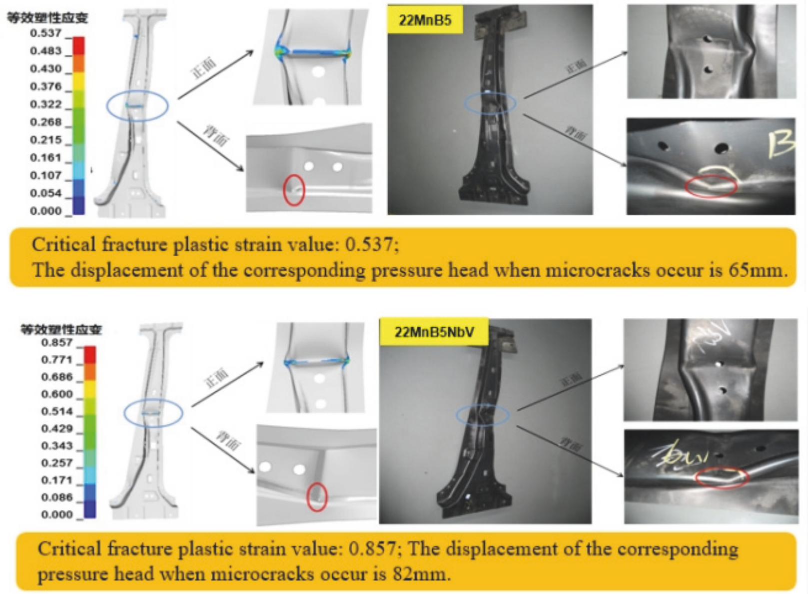
3. Experiment results and analysis

3.1. *Three-point static press bending experiment of B-pillar*

The peak load value and deformation distance of the press head at the peak load during the three-point static press bending of the B-pillar are listed in Table 1. From the results in Table 1, it can be seen that the peak load of the B-pillar during static pressure collapse is increased by 9.7% due to the niobium-vanadium composite microalloying. This indicates that the B-pillar has a stronger compressive collapse ability. The deformation distance of the press head at the peak load is decreased by 13.6%. This indicates that the B-pillar made from 22MnB5NbV, under the same structure, behave higher compressive collapse and protect passenger space ability due to the niobium-vanadium composite microalloying. At the same time, we can see that from Fig.5, the critical fracture plastic strain and corresponding the displacement of press head when microcracks occur are 0.537 and 65mm respectively for 22MnB5 increased to 0.857 and 82mm respectively for 22MnB5NbV. The B-pillar made from 22MnB5NbV has a better ability to protect passenger space under static pressure collapse conditions, which is related to the refinement of the material's grain through composite microalloying, an increase in work hardening rate and strength during deformation. This indicates also from Fig.5 that the B-pillars made from composite microalloyed steel has a higher ability to withstand deformation without cracking under static pressure. The displacement of the corresponding press head when microcracks occur increased from 65mm of 22MnB5 to 82mm for 22MnB5NbV, which is an increase of 26.2%. This indicates that the composite microalloyed B-pillar can withstand greater deformation without cracking during static pressure collapse, which is beneficial for improving the safety of the B-pillar.

Table 1. Peak load and corresponding head stroke for peak load during static pressure of B-pillar.

Test parts	Peak value load （KN）	The deformation distance of the press head at the peak load of static pressure（mm）
22MnB5 B-pillar	21.4	57.5
22MnB5 B-pillar	21.8	55.1
22MnB5NbV B-pillar	23.5	50.0
22MnB5NbV B-pillar	23.9	48.6



Critical fracture plastic strain value: 0.537;
The displacement of the corresponding pressure head when microcracks occur is 65mm.

Critical fracture plastic strain value: 0.857; The displacement of the corresponding pressure head when microcracks occur is 82mm.

Fig. 5. Critical fracture plastic strain and corresponding head displacement when microcracks occur in B-pillar under three-point static pressure.

3.2. *Result of trolley collision*

When a trolley collides, the deformation of the B-pillar under the same conditions can be divided into three regions, which correspond to the peak of the dummy's chest intrusion, the peak of abdominal intrusion, and the peak of pelvic intrusion. The experimental results are shown in Table 2. It can be seen that from the data in Table 2 the deformation value at three positions of the B-pillar made in 22MnB5NbV all have been reduced, with reductions of 8.6, 5.4, and 4.7mm respectively when impacted by the trolley. The decrease in amount of invasion into the human body during the trolley collision means that the B-pillar will provide passengers with greater living space under collision conditions. That is to say, the hot press forming B-pillar with 22MnB5NbV can improve passenger safety during collisions.

Table 2. Experimental results of B-pillar trolley collision.

Measure Item	Experimental measurement values		Variation
	22MnB5	22MnB5NbV	
Peak intrusion of dummy's chest corresponding to B-pillar（mm）	74.9	67.3	-7.6
Peak value of abdominal intrusion corresponding to dummy on B-pillar（mm）	82.1	76.7	-5.4
Peak value of pelvic intrusion corresponding to dummy on B-pillar（mm）	85.0	80.3	-4.7

3.3. *Improvement of hydrogen embrittlement resistance of parts*

The tensile sample is cut from the selected region marked by the red circle on the B-pillar, as shown in Fig. 6. The non-standard sample with a gauge size 10 x 25mm is processed, and the processing sample is stretched before hydrogen charging to measure the total elongation of the sample. The other sample was saturated with hydrogen and then stretched to measure the change in elongation.

Fig. 6. Schematic diagram of tensile specimen taken from B-pillar.

The relevant results are listed in Table 3. The data in the table indicates that hydrogen charging of the sample can lead to a decrease in elongation after stretching. The hydrogen brittleness sensitivity index (HBSI) used as a characterization parameter for hydrogen embrittlement sensitivity it can be calculated by equation (A before - A after hydrogen charging)/A before hydrogen charging; A is the elongation after fracture/%.

Table 3. Hydrogen embrittlement sensitivity index measured by sampling on B-pillar.

The name of a shop	Number	$A_{uncharged}$ (%)	$A_{charged}$ (%)	HBSI (%)
22MnB5	1#	6.8	5.0	26.5
	2#	7.0	2.0	71.4
	3#	6.4	1.3	79.7
22MnB5NbV	1#	7.9	6.2	21.5
	2#	7.7	3.0	62.0
	3#	8.0	2.2	72.5

As a characterization parameter of hydrogen embrittlement sensitivity, the HBSI of 22MnB5NbV samples at three sampling positions is lower than that of 22MnB5, indicating that the hydrogen induced delayed fracture resistance of 22MnB5 in niobium-vanadium composite microalloying is better than that of 22MnB5, or that the sensitivity of

22MnB5NbV to hydrogen embrittlement is lower than that of 22MnB5. The different hydrogen embrittlement sensitivity indices at the three positions may be related to the different microstructures at the three positions of the B-pillar after hot forming.

4. Conclusion

The three-point bending performance and trolley collision performance of B-pillars made of 22MnB5 and 22MnB5NbV were measured using three-point bending experiments and trolley collision experiments. The changes in elongation of tensile samples before and after hydrogen charging were measured from specific zone of the B-pillar to compare the hydrogen embrittlement sensitivity index. The experimental results show that the B-pillar made of 22MnB5NbV has higher peak load and critical fracture strain under three-point bending static pressure compared to 22MnB5, as well as higher press head displacement corresponding to the occurrence of cracks. Under trolley collision conditions, The intrusion value of the three human body parts corresponding to the B-pillar has decreased, indicating that the 22MnB5 B-pillar with niobium-vanadium composite microalloying has better resistance to plastic deformation and cracking under static pressure collapse and trolley collision conditions, which can better protect passenger safety. It also has better performance in protecting passenger space during collisions, all of which improve the safety of the B-pillar. The sensitivity index of hydrogen embrittlement was measured by cutting a sample from the B-pillar, and the HBSI of 22MnB5NbV was lower than that of 22MnB5, indicating that the hot press forming steel with niobium-vanadium composite microalloying has better resistance to hydrogen damage. The application of niobium-vanadium composite microalloying 22MnB5 in automotive hot press forming of B-pillars can effectively improve the safety and sensitivity to hydrogen embrittlement of B-pillars.

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