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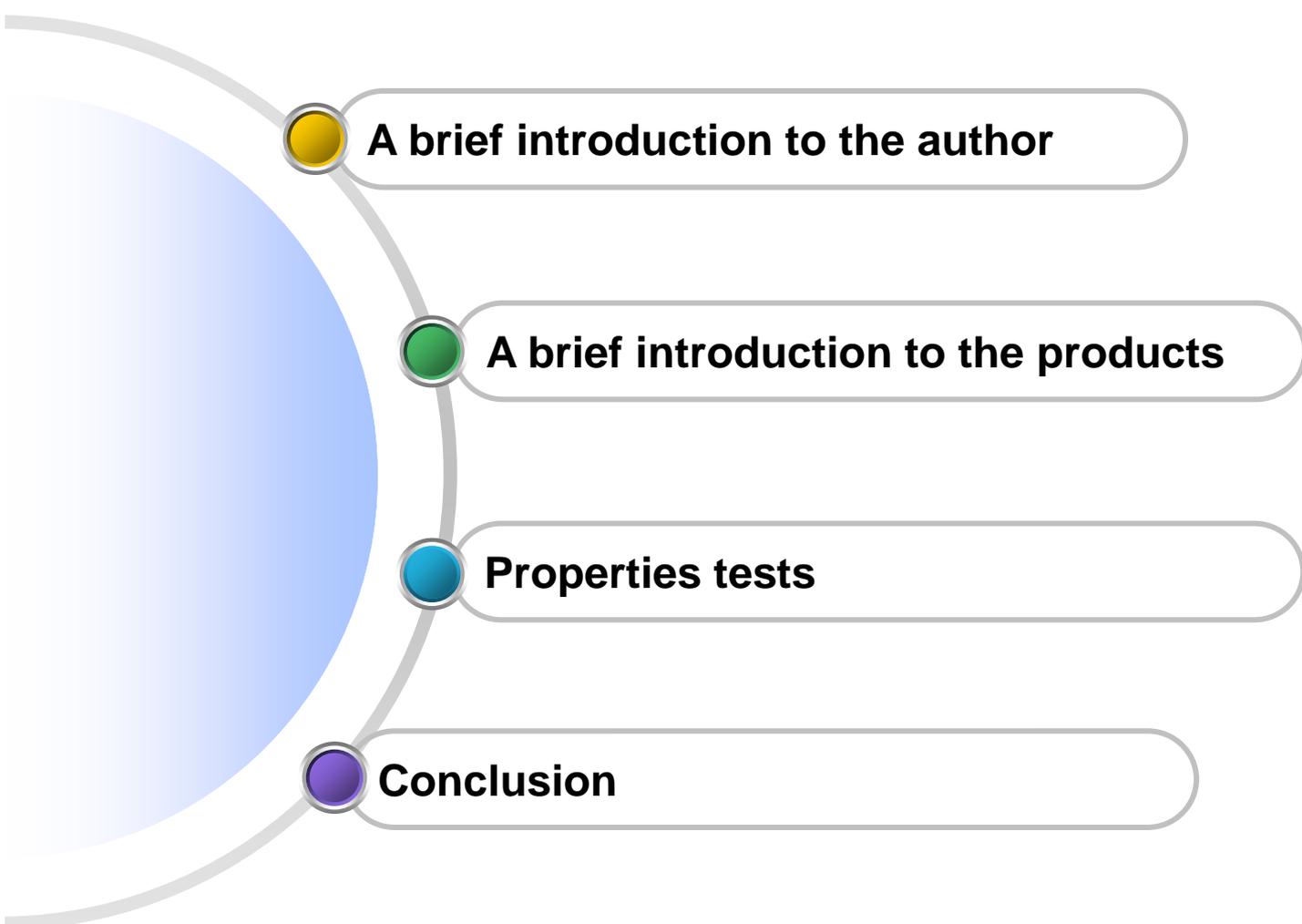
# **Hot formed Steel and its Properties Test**

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# Hot formed Steel and its Properties Test



**A brief introduction to the author**

**A brief introduction to the products**

**Properties tests**

**Conclusion**

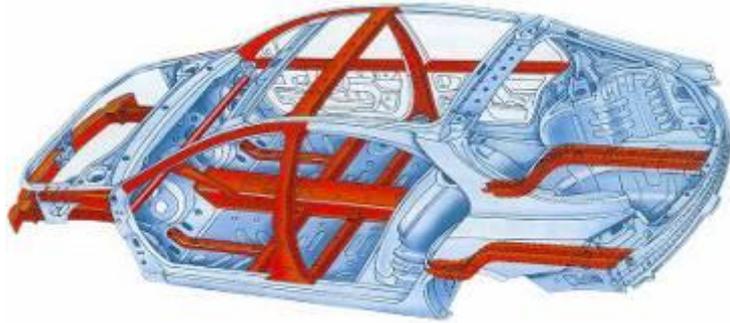
# A brief introduction to the author

## ❖ Technological innovation in the automotive sector

- Drafted automotive industry standard “passenger car door tube type beam technical conditions”
- Participated in the development of a mandatory national standard “car traction device technical conditions”
- Participated in the 7 series aluminum alloy material development, technology research and performance test
- Carried out the design and manufacturing research of hot forming’s prototype dies and mass production dies.
- Completed two patents application in 2013.

# A brief introduction to the products

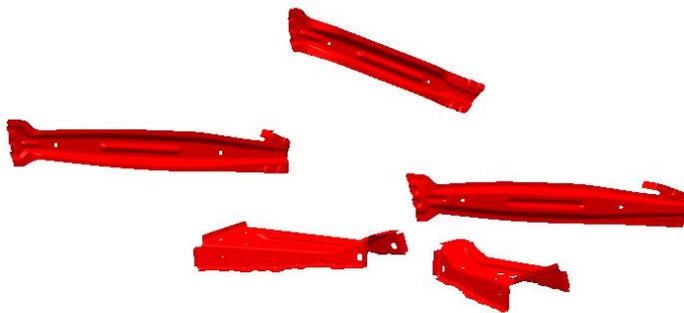
## ❖ Hot forming products



Structure of automotive



Hot forming line of lingyun



The hot forming parts Lingyun produce

# Properties test

- ❖ **Chemical composition test**
- ❖ **Tensile test**
- ❖ **Hardness test**
- ❖ **Metallographic structure test**
- ❖ **Decarburization layer test**
- ❖ **AlSi coating test**
- ❖ **Thinning rate test**
- ❖ **Test of car body safety component**

# Properties test

## ❖ Chemical composition test

- The boron steel is widely used in the hot forming products, which is a micro alloy carbon manganese boron steel sheet and adds a large amount of alloy elements, such as chromium, molybdenum, niobium, vanadium and boron.



Polishing



Instrument



Testing

**Table 1 Test Result of Main Chemical Composition (% Mass Fraction)**

**Test Result of Uncoated Steel Sheet**

C	Si	Mn	P	S	Al	B	Ti	Cr
0.23	0.21	1.22	0.013	0.0036	0.038	0.0021	0.022	0.24

**Test Result of AlSi Coated Steel Sheet**

C	Si	Mn	P	S	Al	B	Ti	Cr
0.21	0.27	1.25	00019	0.0037	0.032	0.004	0.025	0.19

# Properties test

## ❖ Tensile test

- The tensile test is one of the most common and important test methods to evaluate the material properties.
- The tensile test sample is usually cut by the wire cutting equipment, and the test sample shall meet the sampling requirement in GB/T 228 -2010 (Equivalent to ISO 6891-1:2009) .
- Special attention shall be paid to the poor surface roughness on the test sample.



**Sample position**



**Sample**



**Test facility**

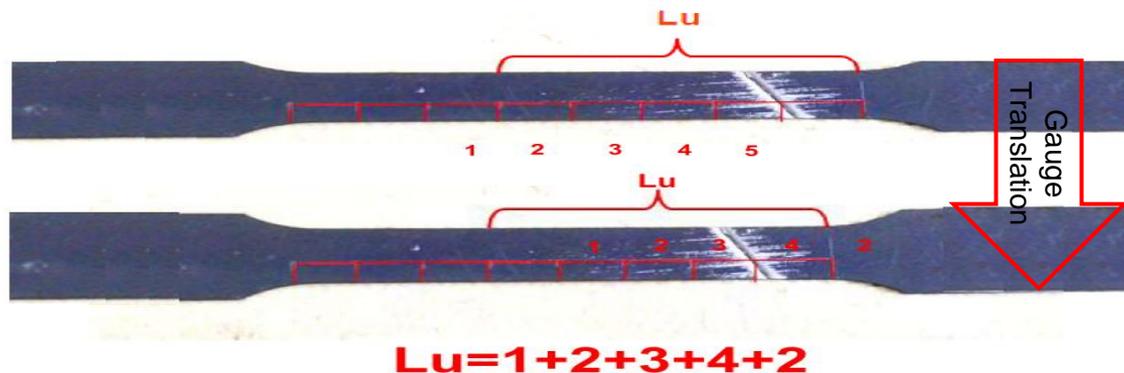
# Properties test

## ❖ Tensile test

**Table 2 Tensile Test Result of Hot-formed Steel Sheet**

Test Result of Uncoated Steel Sheet			
Test sample condition	Yield Strength Rp0.2 (MPa)	Tensile Strength Rm (MPa)	Elongation at Break A <sub>50mm</sub> (%)
Raw Material	333	505	25.0
After hot forming	1,161	1,608	7.5
Test Result of AlSi Coated Steel Sheet			
Test Sample condition	Yield Strength Rp0.2 (MPa)	Tensile Strength Rm (MPa)	Elongation at break A <sub>50mm</sub> (%)
After hot forming	1,147	1,597	6.5

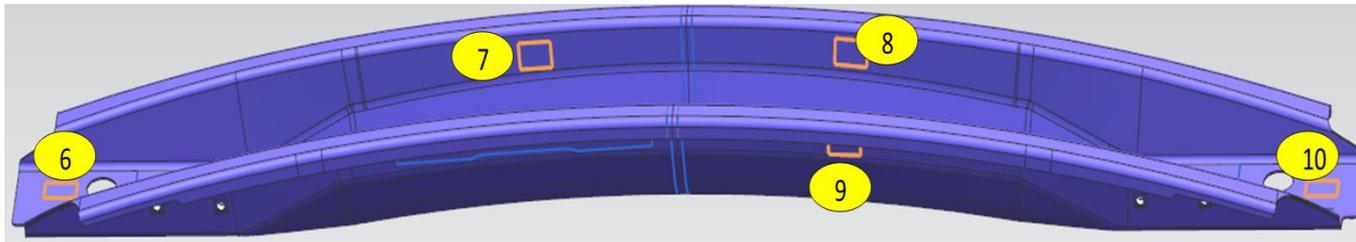
- For the measuring method when the distance from the fracture to the closest gauge is less than 1/3 of the original gauge, refer to Figure 1. The elongation at break is calculated by the gauge translation method.



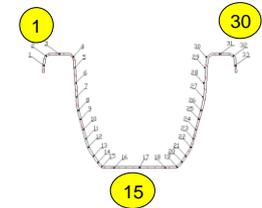
# Properties test

## ❖ Hardness test

- For the heating is affected by the temperature uniformity of the furnace and the die during the cooling of the hot forming parts and there is potential uneven strength in local area of parts, it is necessary to carry out the hardness test in several areas.
- The hardness test includes the surface Rockwell hardness test and the core Vickers hardness test.



HRC sample position



HV sample position



HRC hardness tester



HV hardness tester



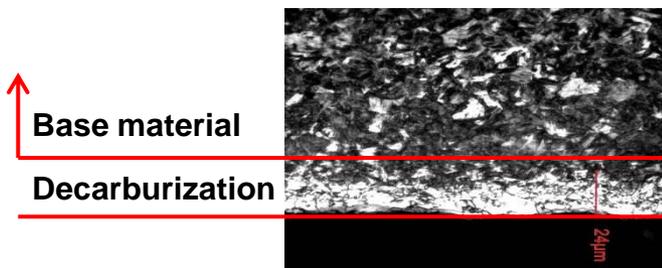
# Properties test

## ❖ Hardness test

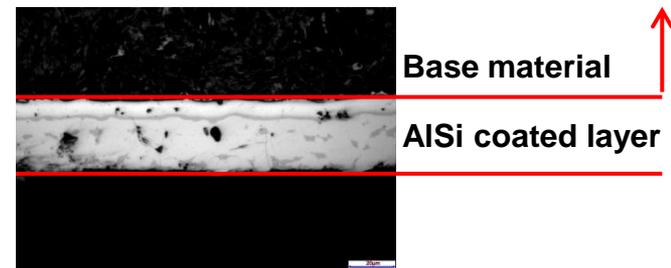
Table 3 Hardness Test Result

Test Location	Surface Rockwell Hardness (HRC)				Core Vickers Hardness (HV <sub>10</sub> ) (No.1 - 30)				
	Hardness 1	Hardness 2	Hardness 3	Average	493	483	493	493	488
Location 6	47.0	48.4	48.0	47.8	478	488	493	488	508
Location 7	48.5	48.0	47.7	48.1	483	498	478	493	483
Location 8	47.5	47.0	48.0	47.5	503	498	498	503	514
Location 9	48.2	48.4	48.4	48.3	493	491	498	516	498
Location 10	47.8	48.2	48.8	48.3	516	498	503	508	498

- For a decarburization layer for several micrometers will be produced at the surface of the uncoated steel sheet and the AISi coating of the AISi coated steel sheet will thicken after the hot forming, the hardness value at the edge shall be less than the hardness value in the middle. If the hardness test result is less, it is necessary to check whether the measuring location is at the edge of the blank.



Uncoated material



AISi coated material

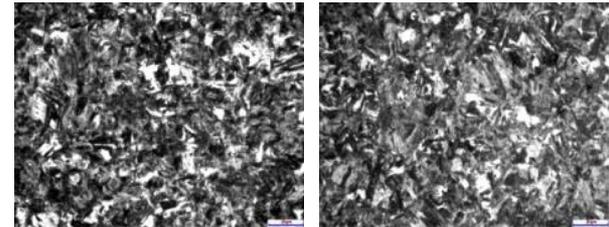
# Properties test

## ❖ Metallographic Structure Test

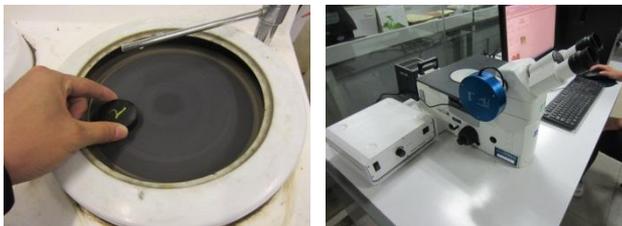
- The test sample of the hot formed parts is usually of the sheet material, which is not applicable for the grinding and polishing directly, so it is necessary to embed the test sample firstly. The heat embedding method is usually taken. Furthermore, the sample holder is needed to be used to ensure the embedded sheet material is in the vertical state.
- The embedded test sample shall be rough grinded, fine grinded and polished. The polished test sample shall be dipped into the nitric acid alcohol solution with the concentration 4% for several seconds, and rinsed by the water and alcohol, and dried by the dryer, then observed by the metallographic microscope.



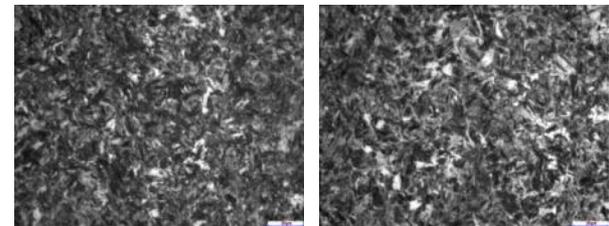
Embedded sample



Uncoated material structure



Test procedure



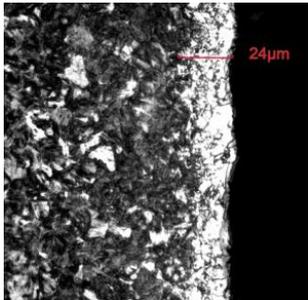
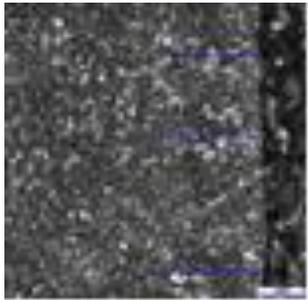
AISi coated material structure

# Properties test

## ❖ Decarburization Layer Test

- When the steel is heated at the high temperature, the carbon at the surface and the oxidizing gases in the furnace gas (such as  $O_2$ ,  $CO_2$  and  $H_2O$ ) and some reducing gases (such as  $H_2$ ) reacts with each other, the carbon content at the surface is reduced. This phenomena is referred to as the decarburization. The chemical equations are shown as follows:
  - $2Fe_3C + O_2 = 6Fe + 2CO$
  - $Fe_3C + 2H_2 = 3Fe + CH_4$
  - $Fe_3C + H_2O = 3Fe + CO + H_2$
  - $Fe_3C + CO_2 = 3Fe + 2CO$

**Table 4 Status of Decarburization Layer under Different Parameters**

Process Parameters	Test Result	Process Parameters	Test Result
Heating Temperature: 930°C		Heating Temperature: 910°C	
Heating time: 297s		Heating time: 297s	
Press Quenching time: 8s		Press Quenching time: 8s	

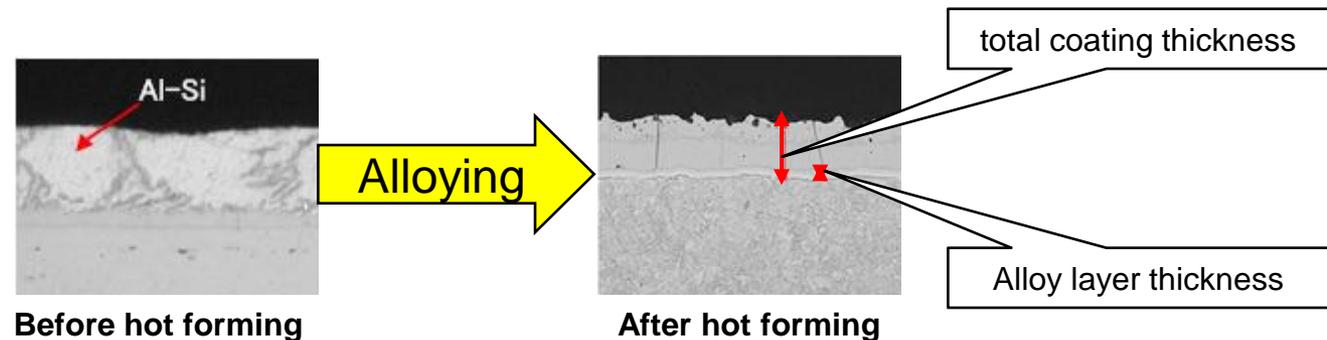
# Properties test

## ❖ Decarburization Layer Test

- Many factors influence the decarburization, such as the chemical composition of the steel material, heating temperature, press quenching time and heating atmosphere. The higher the carbon content, the easier the decarburization is. The higher the heating temperature, the quicker the diffusion of carbon is. The longer the heating time, the deeper the decarburization layer is.

## ❖ AISi coating Test

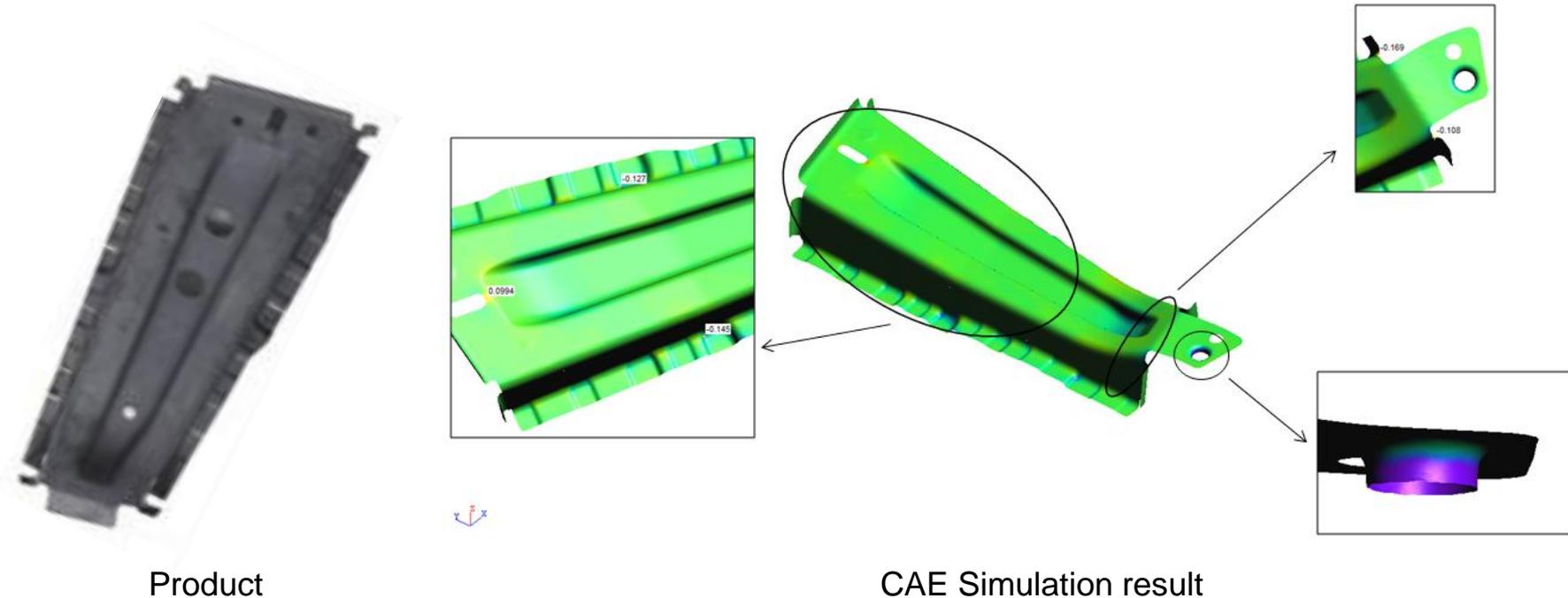
- The oxidation film will be formed quickly when the aluminum contacts the air under the condition of the hot formed steel austenitizing, which will prevent the surface oxidation and decarburization. so it is not necessary to be shot blasted for the AISi coated steel sheet after the hot forming.
- The alloy layer will be formed due to the diffusion of C and Fe after the heating. Hence, it is necessary to test two thicknesses, namely, the thickness of the alloy layer and the total coating thickness. The thickness of the alloy layer is relevant to the welding performance of the material. Hence, it shall be controlled specially



# Properties test

## ❖ Thinning Rate Test

- It is needed to carry out the CAE simulation analysis during the development of the hot forming component. On the one hand is to verify the structure of parts ,on the other hand is to predict the formability of parts, accordingly to judge whether there is any forming risk. In general, the thinning and the wrinkling shall be no more than 20% of the material thickness.



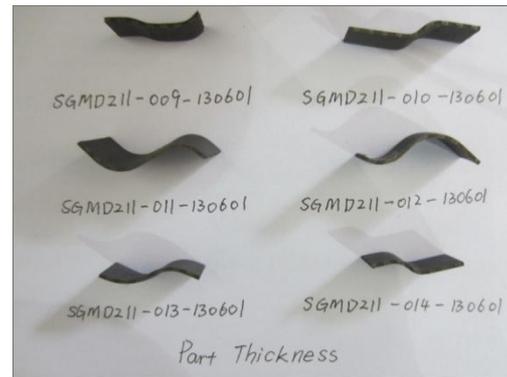
# Properties test

## ❖ Thinning Rate Test

- As shown in Table 5, the maximum thinning rate is 11.8% in the test result, and the maximum thickness reduction rate is consistent with the CAE analysis. For the situation that the analyzed thinning rate and the wrinkling rate are more than 20%, it is necessary to adjust the component structure and optimize the process scheme.



Sample position



Sample



Testing

**Table 5 Test Result of Thinning Rate**

SN	Test Value (mm)	Thinning Rate	SN	Test Value (mm)	Thinning Rate
1	0.97	11.8%	4	0.98	10.9%
2	1.03	6.4%	5	1.02	7.3%
3	1.02	7.3%	6	1.04	5.5%

# Properties test

## ❖ Test of Car Body Safety Component

- The car body safety component puts forward higher requirement for the strength. Such as Bumper , Door beam , B-pillar and so on.



B-pillar



Rear door beam



Front door beam

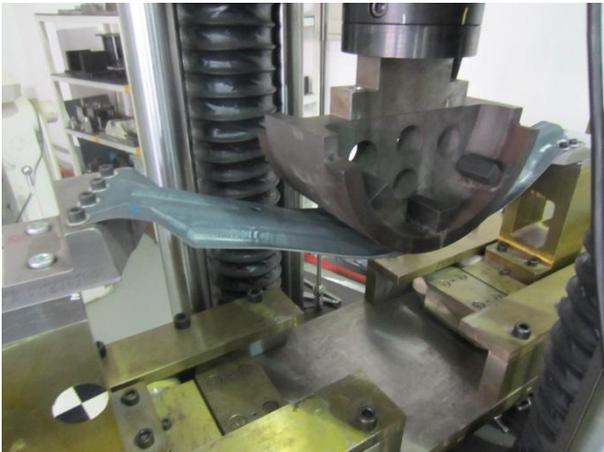


Bumper

# Properties test

## ❖ Test of Car Body Safety Component

- In addition to the routine properties test requirement, there are some more special properties test requirements, such as the three-point bending test and the bumper impact test etc..
- **Three-point Bending test of Door Beam.** The door beam test is mainly the three-point bending test of single piece which is improved on the basis of the static crushing strength standard. Table 6 is the three-point bending test result of the front door beam for some vehicle type.



Testing



After testing

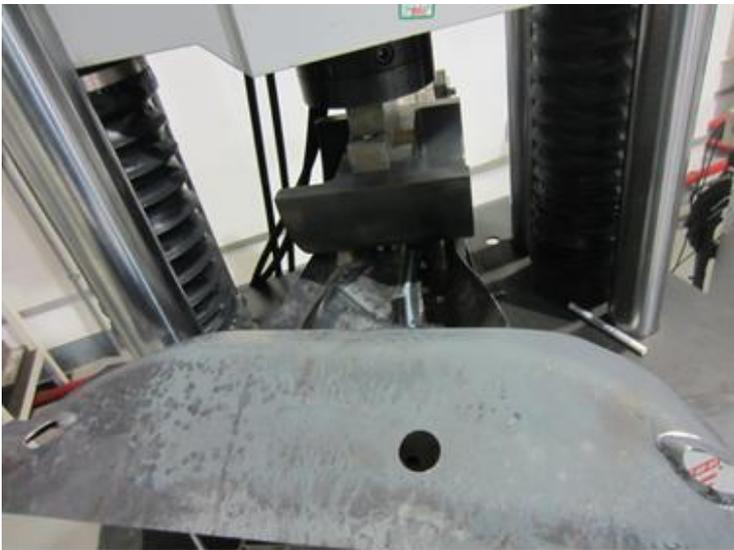
**Table 6 Evaluation Result of Three-point Bending Test**

Sample No.	Max. Force (KN)	Bending Energy (J)	Average Force (KN)
1	20.06	1,995.2	13.092
2	20.32	1,926.5	12.641

# Properties test

## ❖ Test of Car Body Safety Component

- **Three-point Bending Test of the B Pillar.** The three-point bending test of B pillar is one of the most important tests to assess the collision performance of the vehicle. Its theoretical basis is the deformation of the B pillar after the side collision of the whole vehicle.
- The three-point bending test requirement for the door beam and the B pillar is evolved from the crash regulation of the car body safety component, and the success in the single piece test can provide the crash test with enough data support and improve the success rate of the product development.



Testing



After testing



Auto crash test

# Conclusion

- **The properties test result of the hot formed product can provide the basis for the optimization of the process parameters.**
- **The hot forming process parameters have serious effect on the performance, and the reasonable setting of process parameters can obtain the product with the optimal performance.**
- **Make full use of the CAE simulation technology to optimize the process scheme and the parts structure.**

***Thank you for your attention!***