SHEETS WITH SURFACE COATING OF Zn/Mg/Al FOR ADHESIVE BONDING APPLICATION IN THE AUTOMOTIVE INDUSTRY - COMPARISON OF PRODUCERS

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Abstract

The paper deals with the evaluation of sheets with surface coating on the basis of Zn/Mg/Al and their application possibilities in the automotive industry. Evaluation is carried out by determination adhesive joints strength acc. to ISO 11339 for three sheet producers from many who supply sheets for car-body parts production. Utilization of new types of materials means also necessity to test individual bonded car-body parts utility properties, mainly at peel test under certain temperature conditions simultaneously in dependence on type of adhesives and lubricants which are used in the drawing technological process. Results give sheet processors information about properties of sheets with these surface coatings from individual producers, behavior of bonded joints strength properties together with failure mode as a criterion for propriety selection to apply new types of coating on the basis of Zn/Mg/Al.

Keywords: Adhesive, Car Body, Coating Zn/Mg/Al, T- peel test

1. INTRODUCTION

Nowadays automotive industry belongs among the greatest consumers and processors of thin sheets so thus its requirements on the delivered material are still increasing. Thus as producer of thin sheets would be successful among difficult competition from other producers, it has to still improve producing assortment and to cooperate on problems with materials processing as can be e.g. drawing of difficult stampings as car-body stamping truly are. These parts are subsequently completed and here the adhesive bonding technology is very often the only one technique to joint materials which do not damage adherends surfaces. Adhesive bonding makes possible to joint also different materials - beside steel sheets also materials as e.g. glass, plastics or aluminium which are thus quite easily and safely combine and to obtain such shapes and properties which would be very difficult to obtain by other technologies. As a presumption for good strength and sufficient capacity of adhesive joint there is mainly proper joint design [1]. Determination of used materials utility properties for car-body design is so integral part of R&D of sheets producers and processors.

2. COATED SHEETS FOR PRODUCTION CAR-BODY PANELS

On sheet as a construction material are these days posing still new claims. Standard low-carbon steel sheets are for production car-body panels used in much more lower portion than before several years. Nowadays trend for these parts is production and processing of sheets with different types of coatings which effectively prevent from corrosion thus to improve utility properties of total car-body. In the automotive industry (mainly in Europe) are mostly used sheets with coating based on zinc. Zinc is suitable especially because of relatively low price and very good corrosion resistance.

Another level in the development of hot dip galvanized (HDG) coating with improves anti-corrosion properties and metal coatings based on zinc, magnesium and aluminium. Their development was specifically focused to improve protection of sheet surface mainly to improve corrosion resistance in lap joints, hems or blasting car-body zones. Further the car-body lower part (doors, fenders, side sills) are mainly during winter time almost immediately in contact with corrosion environment. Thickness of metal layer in comparison to common zinc coatings can be slightly thinner upon maintaining the utility properties of the coating [2].

2.1. Sheets producers

Sheets producers are still finding new methods hot to improve coating - types, properties also methods of their preparation. Usage of new coating means also necessity to test utility properties. So great attention is focused on determination the loss of properties of new coatings and their damage at own sheet forming. Sheets stampings as partial car-body part are produced by drawing and usage of coatings means some complications connected with technologies for their processing and subsequent completion. It is necessary to test utility properties of individual bonded parts. Among such testing methods belong also so-called T-peel test in dependence on adhesive and lubricant that is used during drawing technology. To obtain information about coatings properties in common production in press-shop is difficult and that is why there are carried out model tests in laboratories.

Tests were carried out to determine adhesive joint strength properties in comparison to randomly chosen thin sheets producers and their coating for application in the automotive industry.

Every producer has its own metallurgical procedure and method to produce not only workpiece itself (sheet) but also coating with surface layer(s) which represent object of company secret. For comparison suitability for sheets applications at car-body parts adhesive bonding process there were chosen three producers A, B and C which provide coated thin sheets with surface layer Zn/Mg/Al for car-body parts production.

Producer A - HDG - ZM 90 [3,4]

Surface composition of basic elements: Zn 93.3/ Mg 3.0/ Al 3.7 [wt.%]

There is multi-phase, non-homogenous composition of coating which creates zinc dendrites (grains) in lamellar eutectic matrix (Zn-Mg-Al).

In **Fig. 1** is EDS surface analysis by method of Zinc-Magnesium layers.

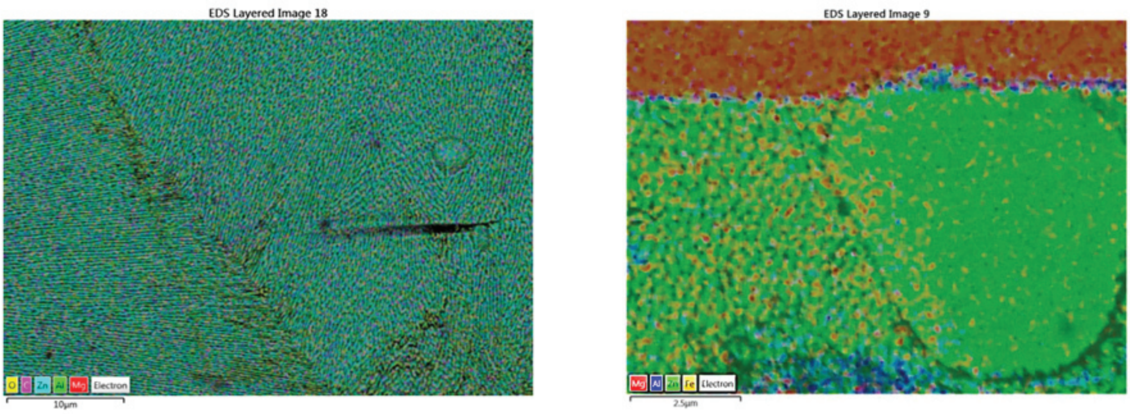


Fig. 1 Surface layer ZM 90 (left) and its section - producer A [3, 4]

Producer B - HDG - ZM 90 [3, 4]

Surface composition of basic elements: Zn 96.0 /Mg 1.5 / Al 2.5 [wt.%]

There is multi-phase, non-homogenous composition of coating which creates zinc dendrites (grains) in lamellar eutectic matrix (Zn-Mg-Al).

In **Fig. 2** is EDS surface analysis by method of zinc-magnesium layers.

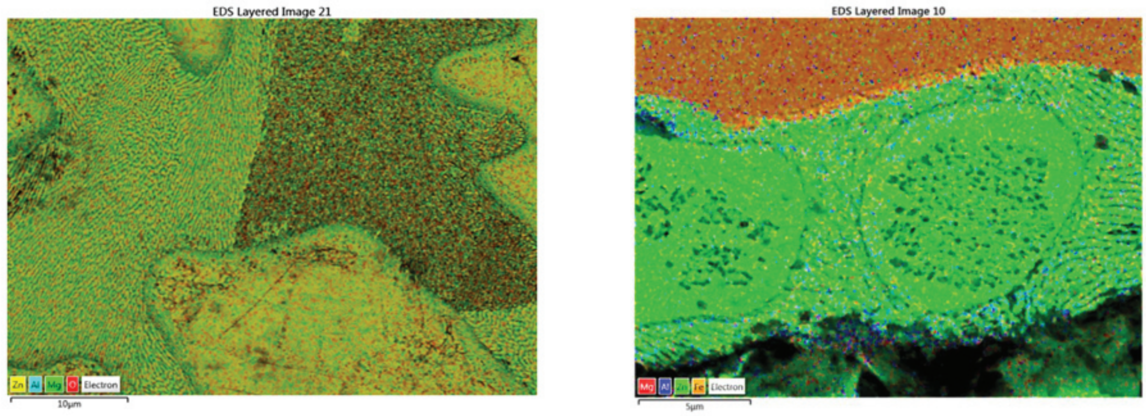


Fig. 2 Surface layer ZM 90 (left) and its section - producer B [3, 4]

Producer C - HDG - ZM 90 [5, 6]

In **Fig. 3** is shown sheet surface with section through surface layer ZM 90 producer C

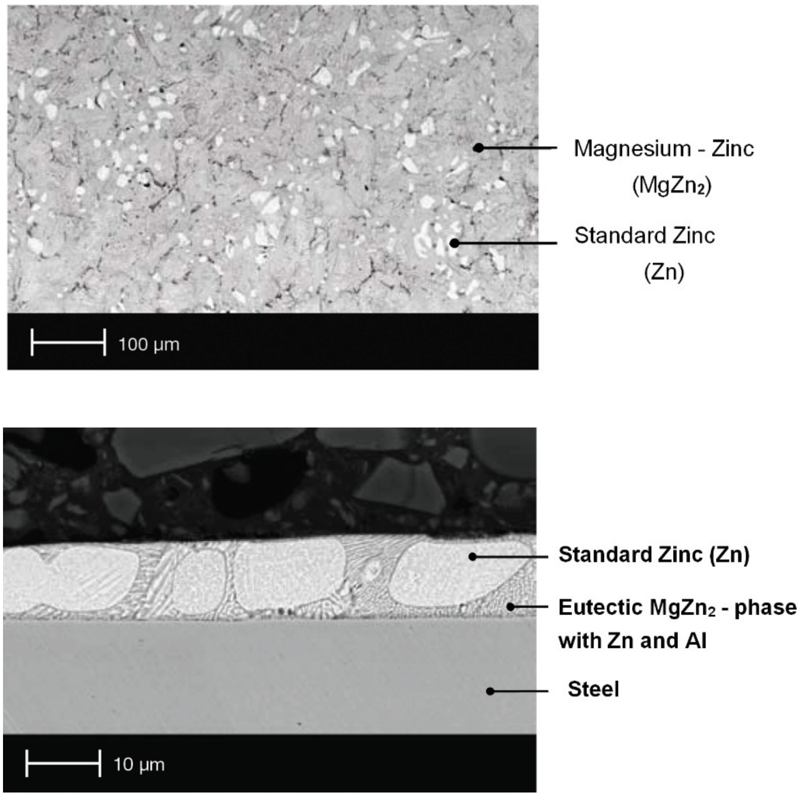


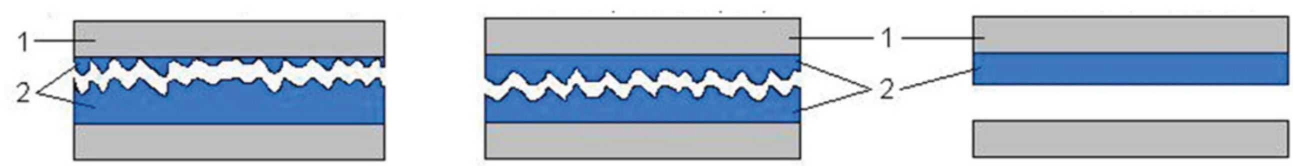
Fig. 3 Sheet surface and section through surface layer ZM 90 producer C [5, 6]

3. EVALUATION OF COATINGS - ADHESIVE BONDING

Within the evaluation of individual producers and their coatings there was carried out so-called strength peel test acc. to standard ISO 11339 [7].

3.1. Evaluation of adhesive joints failure patterns

For evaluation the adhesive joint quality there is as another criterion evaluation of adhesive joint failure patterns acc. to ČSN ISO 10365. Basic types of failure patterns are shown in **Fig. 4**, SCF - particular cohesive failure, CF - cohesive failure, AF - adhesive failure, symbols: 1 - adherend, 2 - adhesive [8].



SCF CF AF

Fig. 4 Failure patterns acc. to ČSN ISO 10365 [8]

3.2. Conditions of experiment [9, 10]

- Substrate: ZM 90 - dipping coating, Zn/Mg amount: 45/45 [g/m^2] producers A, B, C
- Lubricant: Prelube oil - amount 3 [g/m^2]
- Adhesive: /1/ Higher-strength rubber, /2/ Elastic - rubber
- Curing: without ageing (temperature +180 °C /time 20 min)
- T-peel test at temperatures: RT (+23 °C), +80 °C, -35 °C

Results of experiments - peel strength for coatings at temperatures: RT, +80 °C, -35 °C [9, 10].

Table 1 Results of coating A: T-peel tests for Adhesive 1 and 2

Peel strength **Ps [N/mm]**	ISO 11339 at temperatures: RT, +80 °C, -35 °C							
	Without ageing 180 °C / 20min							
	Coating ZM 90 - A							
Temperature	**/1/ Adhesive** Higher-strength rubber	Failure pattern CSN ISO 10365			**/2/ Adhesive** Elastic-rubber	Failure pattern CSN ISO 10365		
		CF	SCF	AF		CF	SCF	AF
RT	3.15 ± 0.10	85	10	5	2.88 ± 0.07	100		
+80 °C	-			100	1.08 ± 0.04	85	5	10
-35 °C	0.35 ± 0,31		10	90	3.93 ± 0.30	100		

Table 2 Results of coating B: T-peel tests for Adhesive 1 and 2

Peel strength **Ps [N/mm]**	ISO 11339 at temperatures: RT, +80 °C, -35 °C							
	Without ageing 180 °C / 20min							
	Coating ZM 90 - B							
Temperature	**/1/ Adhesive** Higher-strength rubber	Failure pattern CSN ISO 10365			**/2/ Adhesive** Elastic-rubber	Failure pattern CSN ISO 10365		
		CF	SCF	AF		CF	SCF	AF
RT	3.15 ± 0.11	85	10	5	3.75 ± 0.20	100		
+80 °C	0.68 ± 0.09			100	1.27 ± 0.07	95	5	
-35 °C	0.59 ± 0.06	70	20	10	4.55 ± 0.46	100		

Table 3 Results of coating C: T-peel tests for Adhesive 1 and 2

Peel strength **Ps [N/mm]**	ISO 11339 at temperatures: RT, +80 ºC, -35 ºC							
	Without ageing 180 ºC / 20min							
	Coating ZM 90 - C							
Temperature	**/1/ Adhesive** Higher-strength rubber	Failure pattern CSN ISO 10365			**/2/ Adhesive** Elastic-rubber	Failure pattern CSN ISO 10365		
		CF	SCF	AF		CF	SCF	AF
RT	1.87 ± 0.46	60	15	25	3.79 ± 0.11	100		
+80 ºC	0.37± 0.25			100	1.27 ± 0.03	100		
-35 ºC	-			100	5.14 ± 0.85	100		

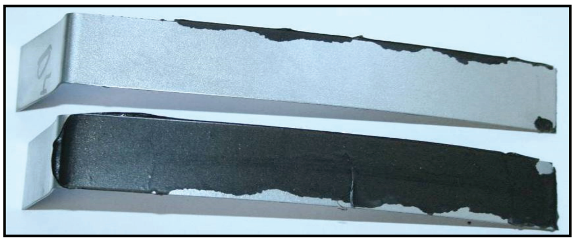


Fig. 5 Coating A, AF 100 %, Adhesive 1,+80 °C [9]

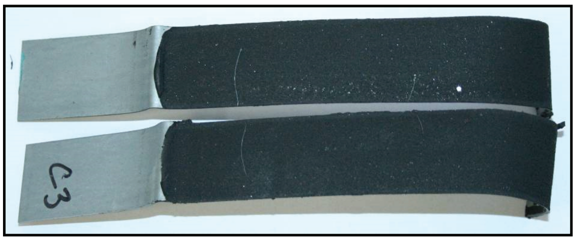


Fig. 6 Coating C, CF 100 %, Adhesive 2, -35 °C [10]

4. CONCLUSION

Sheets producers react on nowadays claims from sheets processors that are offering new sheets resp. different types of coatings which would fulfill requirements not only at production and also in cars running. At car-body production is important, beside minimization of negative influences at drawing (e.g. lowering friction and elimination galling), to also ensure functional properties at subsequent completion of parts at adhesive bonding technology.

For individual coatings from three producers there were evaluated utility properties regarding adhesive joints strength. Samples from sheets were tested by T-peel test acc. to ISO 11339. Peel is the most difficult type of loading for adhesion. For complex adhesive joint quality evaluation there are beside evaluation strength properties also visual evaluation of adhesive joint failure patterns acc. to CSN ISO 10365. Thus there were also evaluated individual failure patterns types after destruction of samples by delamination.

Determination of strength properties of coated sheets with respect to car running was carried out by tests under different temperature modes - i.e. under temperatures: RT (+23 ºC), +80 ºC and -35 ºC.

Results from individual adhesive joints strength tests and failure patterns are shown in **Tables 1 - 3**.

For the experimental part were used different types of adhesives, their strength properties cannot be mutually compared. Experimental laboratory tests for comparison coatings from individual producers revealed following facts:

At adhesive 1 for tests under RT was determined that coatings A and B have the same result of T-peel strength of 3.15 N/mm, coating C reveled T-peel strength of 1.87 N/mm that is 59.36 % from the strength of both previous coatings. At all three coating were observed all three failure patterns (CF, SCF, AF). Regarding adhesive joint quality is adhesive failure (AF) inadmissible. That is why there are results of evaluation failure patterns under temperature +80 °C unfavorable because at all three coatings were detected failure pattern AF 100%. In **Fig. 5** is shown the failure pattern AF 100 % for coating A and temperature +80 °C. As well also tests under temperature -35 °C revealed for all coatings AF failure pattern.

For adhesive 2 and tests under RT there were measured similar values of T-peel strength for coatings B (3.75 N/mm) and C (3.79 N/mm). Compared to that coating A had strength 2.87 N/mm which is 76.8 % resp. 75.98 % of previous coatings strength. Also under temperature +80 °C there were measured strength values of coating A lower (1.08 N/mm) that the other coatings (B and also C 1.27 N/mm), occurrence of AF 10 % failure patter proves fact of the lower strength.

Compared to that at tests under temperature -35°C was determined interesting fact that failure pattern for all three coatings is type of CF 100 %. In **Fig. 6** is shown failure pattern CF 100% for coating C and also temperature -35 °C. However strength values are different. Coating A (3.93 N/mm), coating B (4.55 N/mm) and the highest strength was measured for coating C (5.14 N/mm).

By laboratory tests were also determined interesting results on coating C - for all temperature modes was observed failure type CF 100%.

Submitted and discussed results revealed some facts that for application of individual coatings and it is not possible to unambiguously evaluate which coating is generally the most suitable for the application in automotive industry. Regarding fact that adhesive joint quality strongly depends on many factors as can be e.g. amount and type of used lubricant, type of used substrate and its surface morphology or surface treatment, thus own evaluation is very difficult. Great number of variable parameters makes problem of testing adhesive joints quality relatively difficult and requires further tests about individual factors influence.

For application of new surface coatings types in series production in the automotive industry there will be necessary to define specific surface properties regarding requirements for good formability at sheet processing but simultaneously also at adhesive joint quality. Great influence arises from increasing corrosion resistance. Processors thus have difficult task to select fine coating to be used in car-body series production.

ACKNOWLEDGEMENTS

This paper was supported by project Student Grant Contest from the TUL /SGS 21005/ with the cooperation of SKODA AUTO a.s. Mlada Boleslav, Czech Republic

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