ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 4, October 2013

Study of Formability of Coated Sheets from the Plasma Chemical Pretreatment of Surfaces

Milan Dvorak, Emil Schwarzer

Abstract - Coated steel sheets with different paints and coatings extend to most industries and decide about the quality and functional reliability goods. Protective coatings have an irreplaceable role in a wide range in using of construction materials. For the area of testing and assessment of adhesion of protective coatings on sheets is characterized by a great diversity of methods and procedures. In addition to the testing procedures to test for adhesion of coatings include tear-off test, adhesion test, cupping test and technological tests by Erichsen device. For example at the Institute of Engineering Technology, BUT is graded bending product which has been designed allows the testing of coated sheets of thickness greater than currently recommended standard test preparations. [14] The application of multi-jet system used to test samples coated with the optimal parameter settings of nineteen flowing plasma jets are functional samples after bending.

Index Terms -**Metal sheet, aluminum coating, adhesion, bending, plasma.**

I. INTRODUCTION

Bending technology of surface finish sheets. When bending of coated metal coating is loaded differently depending on its position in JIG. [5] In case the plastic layer on the outer side, is stressed such stresses, due to which it is pressed against the base material. [16] If the plastic layer on the inner side is loaded by tensile stress, Fig.1. Magnification roughness functional parts of the tool causes higher friction on the contact surfaces, which can lead to damage of the surface layer. Foreign experience (company Umformtechnik Erfurt) that the minimum bend radius of the metal-coated plastic material of thickness greater than 150 μ m in the case of tensile stress in the coating same as the thickness of the base material. [1] If the coating thickness is less than 150 μ m, it is recommended to choose a larger bend radius to prevent the formation of cracks in the surface layer. [15]

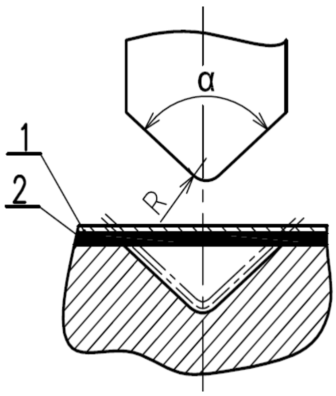

Fig.1 Scheme of bending sheet metal surface treated (bend to V) 1 - base material 2 - coat

II. THE PRINCIPLE OF HIGH-FREQUENCY HOLLOW CATHODE (13,56)

The basis of nozzles were used dielectric capillary tube made of quartz glass, which flows through argon, including any additions. The resulting plasma jets from the cavity and the mouth of the plasma jet to the external environment, where it acts on the coated samples of steel. Shock is the entire length of its plasma channel actively generated. Power absorbed by the plasma channel used multi-jet equipment was selected as the working conditions in the range of 102-103 $W.cm^{-2}$ Unlike the electron beam welding where the power density at the spot welding to 109 $W.cm^{-2}$. [1] The thermal effects on the surface of samples may range from 30 ° to 1600 ° C while maintaining substantially not-isometric character discharge (energy particles at a temperature of up to 10 000 K). Based on these properties may plasma jet system to provide a high reaction with high efficiency for both chemical and physical modification of the material surface. Appropriate grouping jets into linear or other departments allows cutting of larger areas of test samples respectively semi-finished steel in industrial practice [16].

III. DEFORMATION AT BENDING SHEET METAL

Bending deformation is generally surround the state of stress φ_r, φ_z, φ_t, whichever is tangential tensile strain on the outer side of the neutral surface and the pressure on the inside. Plastic deformation in radial direction φ_r causes decreasing thickness t of the stock at the bend. Deformation φ_z in tension and reduced in pressure extends transverse dimension b Both deformation φ_r and φ_z, in the case of bending wide strip neglect and the description of the deformation applies only tangential deformation φ_t. [12]

The intensity of deformation can then be expressed as:

$$\varphi_i = \ln(R_0 / R_n) = \ln(R_n / r_1)$$

Theoretical aspects of the bend Bending along a straight line is the most common procedure for forming the surface, but can be done in various ways, such as forming along the bending path in the die or by folding, crimping in special machines or plate through a radius in the die. The research sheet can be defined as a continuous mass. A very large amount of material is rolled, which is bend very progressive under shape of a cylinder. Functional bending is usually limited increase in strength and less formable sheet and more frequent cause unsatisfactory bending any lack of dimensional control in terms of springing and thinning of the material. [3], [4] If the line of bending curve, the contact sheet is usually

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 4, October 2013

deformed in the process and the sheet is either stretched, which can lead to division or compression with the possibility of ripple. There are special cases where the sheet can be bent along curved lines without stretching or ripples in adjacent areas, but they require special geometric design the outline of the bent parts. The following simple examples of bending along the lines are presented for elastic, elastic-plastic and plastic material condition.

IV. BASIC PRINCIPLES OF EXCAVATION BY ERICHSEN

This International Standard specifies a standard test method for determination of the metal sheet and strip, of a thickness of 0.1 mm to 2 mm and a width of 90 mm or more plastically deform when towing a semi-circular metal cupping questionnaire.

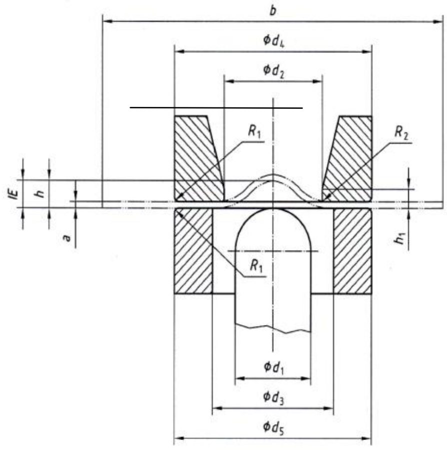

Fig.2 Test according to Erichsen, IE - index excavation, thickness (a) and width (b) sheet before the test

The test principle is based on questionnaires with ball end that pushes into the specimen holder and clamped between dies and creates a deeper until a continuous cracks. Measured depth deepening the test result, based on a straightforward path questionnaires with half-ball finish, Fig.2. For an examination is needed device equipped median, questionnaires and retainer specimen. Test procedure is monitored from the outside in order to determine the moment when appears interconnecting crack. At the end of the test is subjected to the test protocol. [2] Great attention should be paid to selecting lubricants should not contain corrosive substances, grit resin, wax and fillers. [6], [11]

V. EXPERIMENTS WITH MULTI- JET PLASMA SYSTEMS (MPS)

Experiments with MPS have been carried out in collaboration with MU Brno multi-jet plasma system with a width of 100 mm with nineteen nozzles providing a low-no-isometric discharge at atmospheric pressure. The physical nature of the phenomenon in multi-jet plasma system is to generate plasmas at atmospheric pressure. For example at the Institute of Engineering Technology, BUT product is graded bending in Fig.6, which by its design allows testing of coated sheets of thickness greater than the current recommended standard test preparations. [14] Delivered plate was delivered by engineered company that produces heavy construction equipment. Delivered sheets with a confirmed certificate and chemical composition have been previously degreased and then scrubbed with a special deburring machine. Grid tests and applied coatings also performed in engineered company. The base layer (KTL), where the temperature is in the range 160-180 ° C was applied electrophoresis method. The thickness of paint depends primarily on the size of the voltage normally varies between 15 and 30 microns.

Fig.3 Sample sheet steel (90x90mm) with a basic coating (KTL)

On Fig. 3 is a test excavation by Erichsen. The test was conducted on a sample which is identified in the table as a sample steel plate (90x90mm) with a varnish (CDP) and the value of the IE 6.85 coatings ruptured, as shown in the accompanying photographs. This sample is regarded only as a reference without further treatment degreasing and application of plasma using multi-jet system. In the factory, these samples should last for IE punching depth of 4mm. From the viewpoint of coating thickness and coating quality is the reference sample in order. On the other experiments that were performed, the samples were divided into the following categories and sets. (Table-1)

SET	26-30	31-35	36-40	1-5	6-10	11-15	21-25	16-20
THE PROCEDURE APPLICATION OF COATINGS AND MULTI-JET PLASMA SYSTEM	BP	BP	BP	Z	Z	Z	TC	TC
	PL	PL	x	x	PL	PL	PL	x
	Z	Z	x	x	TC	TC	x	x

Table-1 BP – without coating, PL - plasma, Z basis, TC - top coat

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 4, October 2013

FINISHING SURFACE OF STEEL SAMPLES WITH VARIOUS SURFACE TREATMENTS OF PLASMA NOZZLES

NUMBER OF EXPER.	SAMPLE NUMBER	POWER [W]	FLOW Ar [l/min]	FLOW N_2 [l/min]	FLOW O_2 [l/min]	FLOW $Ar+H_2O$ [l/min]	FLOW CO_2 [l/min]	FEED [m/min]	Number of passes
1	A-30+35* B-15+10* C-25	550	50	-	-	-	-	3	2x
2	A-34+29* B-14*+6 C-24	600	50	0,2	-	-	-		
3	A-33+28* B-13*+8 C-23	550	50	-	0,2	-	-		
4	A-27*+32 B-12+7* C-22	600	40	-	-	13	-		
5	A-31*+26 B-11*+6 C-21	600	50	-	-	-	0,2		

A - clean metal surface (laser brush - degreasing)
B - with basic coating
C - with basic coating + final coating
A, B, C - before applying plasma degreased with alcohol

* - Label samples that were plasma treated only one side (with slot)

Rf - generator (13.56 MHz), atmospheric pressure - free atmosphere.

Table-2 Working surface of steel samples with various surface finishes by plasma jets I.

FINISHING SURFACE OF STEEL SAMPLES WITH VARIOUS SURFACE TREATMENTS OF PLASMA NOZZLES

NUMBER OF EXPERIMENT	SAMPLE NUMBER	POWER P / [W]	FLOW Ar [l/min]	FLOW O_2 [l/min]	FLOW N_2 [l/min]	FLOW CO_2 [l/min]	FLOW $Ar+H_2O$ [l/min]	FEED [m/min]	NUMBER OF PASSES
REF	Z 1-3, 20* BP 1-3, 20* TC 1-3, 20*	-	-	-	-	-	-	-	-
1	Z 4-6, 19* BP 4-6, 19* TC 4-6, 19*	550	50	-	-	-	-	3	2x
2	Z 7-9 BP 7-9 TC 7-9	600	50	0,2	-	-	-		
3	Z 10-12 BP 10-12 TC 10-12	550	50	-	0,2	-	-		
4	Z 13-15 BP 13-15 TC 13-15	600	40	-	-	0,2	-		
5	Z 16-18 BP 16-18 TC 16-18	600	50	-	-	-	13		

Z - Sample sheet steel (90x90 mm) with a basic coating
BP - Sample sheet steel (90x90 mm) without coating, with an oil finish surface (preservation)
TC - Sample sheet steel (90x90 mm) with a basic coating + finish coating

* - Label samples that were plasma treated only one side (with slot)

Rf - generator (13.56 MHz), atmospheric pressure - free atmosphere.

Table-3 working surface of steel samples with various surface finishes by plasma jets II.

Samples 1-3 are reference, not-scoured. Valid for samples of BP, Z, TC. These samples were toured multi-jet plasma system. For other samples of 4-19 samples were toured multi-jet plasma system as a starting gas was chosen media: Argon, oxygen, nitrogen, carbon dioxide, argon + WATER. As seen from Table-2, three of these samples was altered performance. Constant flow has a value of 0.2 l / min, feed 2m/min and the number of passes the second according Table-3, sheets were evaluated according to the deep-Erichsen, the following samples:

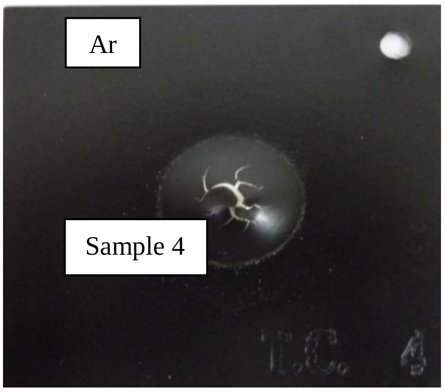

Fig.4 Samples of sheet steel (90x90x1 mm)

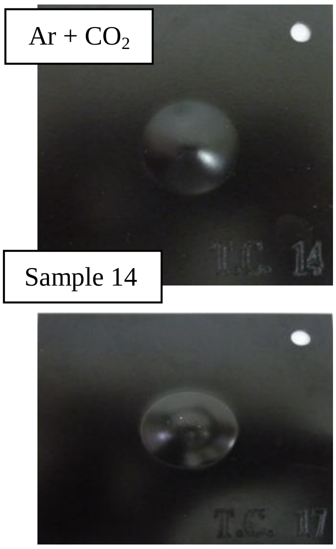

Fig.5 Samples of sheet steel (90x90x1 mm)

The sample of Fig.4 and Fig.5 was MPS used in the following sequence: On the raw sheet was applied basis, then chemically treated MPS and finally deposited TOP COAT (top coat). in a sample of 4 was used where argon was damaging the coating before the border IE 4 mm. Sample 14 with medium Ar + CO2 behaved a little better. An indication of damage is manifested in the value 3.7 IE, with fewer cracks on the outer coating. Sample 17 with medium Ar + H2O was rated as the best specimen of this series of tests according to Erichsen. The value of the damage was to the IE 7.5. Further experiments were performed on the samples mentioned in Table-4.

Table-4 Measured values IE by Erichsen Sample size 90x90x1mm

SAMPLE	BP4	BP5	BP6	Z1	Z2	Z3	TC1	TC2	TC3
DEEPENING IE [mm]	9,75	4	6	6,85	4	7,1	2,89	3,27	11,6
FUNCTIONAL	x	x	x	x	x	x	-	-	x
NON FUNCTIONAL	-	-	-	-	-	-	x	x	-

Samples of Z1, Z2, Z3, TC1, TC2, TC3, were degreased and not toured plasma. For samples BP4, BP5, BP6 test was performed as follows: On a steel base (BP) was used multi-jet plasma system and subsequently applied primer (KTL). For a sample BP5 we value IE stopped at 4 mm. The sample was no apparent damage to the primer coat. For a sample BP6 we stopped at the value of IE 6 mm. The sample was also no damage to the primer coat. The table does not include samples Z20, TC20. These samples were degreased, without passing through the plasma. Z20 - damage to the value of IE 7.5 mm. TC20 - damage to the value of IE 8.5 mm. For further experiments will use the

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 4, October 2013

new tiered bending tool, Fig.6 developed at the Institute of Engineering Technology in Brno. The new product is graded bending its design allows testing of coated sheets of greater thickness than the current test devices recommended standard DIN EN ISO 1519. [12] The product allows simultaneous bending the five samples in the interval of angles up to 180 ° using pulleys through cylindrical segments. This may be made of "U" bends to the inner radius R11, R17, R23, R29 and R35 mm. Cylindrical segments can be easily exchanged for another radius. The bent specimen is in the case of clear coating damage assessed visually, and if there is no apparent damage to the coating using all segments otherwise followed closer examination of the functionality of the coating on the micro-cracks under the microscope. The aim of the experiment is to test the new graduated bending test of adhesion of selected steel samples.

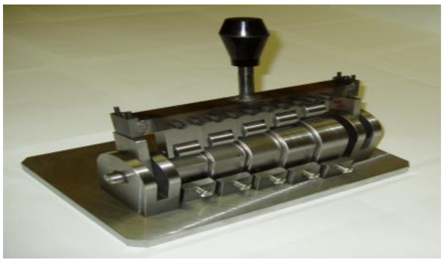

Fig. 6 Photo phased bending of the rollers

VI. CONCLUSION

This article covers the basic theoretical background to the formability of sheet metal drawing and bending of coated respectively organic coatings in one or more layers in the interaction with the metal base. The outcome of planned experiments in the dissertation would be to increase adhesion of the coating respectively coating to the metal substrate under uniaxial stress state respectively biaxial stress state off questionnaires at Erichsen test. The main benefit of experiments will obtain functional moldings with the possibility of greater deepening of the coated sheets pulling off, respectively bending. For this purpose in the experimental section optimized composition of the input components of plasma, which generally leads to higher compressibility of the sheet and it is reflected in the achievement of higher levels of excavation. The steel sheet coated with a primer or a topcoat can be considered as a system. When technology is shaping operations for these units to distortions common bonds. Disruption of these relationships can result in disruption of the integrity of the coating and its subsequent peeling. In the engineering sector in these modern times applied paints and varnishes mainly electrophoresis method. [10] Cataphoresis is one of the most advanced production technologies application of basic colors with a high degree of corrosion protection of metals. Method cataphoresis painting are among the most advanced technology surface treatment of metal products. Currently no cataphoresis in numerous areas of comparable competitors. The largest contribution to the development of technology has cataphoresis automotive industry, where corrosion resistant chassis and other components is crucial for most manufacturers. High quality finishes, along with the benefits of economic and ecological allow this technology to use in other fields of engineering and consumer goods industries. Distortion between the steel base material and the coating causing defects occurring in sheet forming (waviness of the plate surface, shape deformation, breakage, metal release, inadequate structure of the surface), or a combination of poor choice of base material and coating. Current requirements for coating technologies are to maintain the integrity of the surface layer and of the links between the surface and the base material after the drawing respectively bending. [7], [13]. Functional extrusion coated to achieve optimization of selected technological parameters of the process that will be part of the doctoral dissertation. [8], [9]

Note:
The article is supported by the grant project, BUT FME Brno – BD 1393016 from 2009.

REFERENCES

[1] DVORAK, Milan. et al., “Technology II,” Academic Publishing CERM, Ltd., Brno, 2001. 238 p. ISBN 80-214-2032-4.

[2] BLANKS, Taylor. “*Metals Handbook: Mechanical testing*, American Society for Metals”, 1985. 837 p. ISBN 0-87170-007-1.

[3] CADA, Radek. “Surface formability of metallic materials,” Ostrava-Poruba: Technical University of Ostrava, 1998. 90 p. ISBN 80-7078-557-8.

[4] FOREJT, Milan; PISKA, Miroslav, “Theory of machining, molding and tool,” Brno: CERM Academic Publishing, Ltd., 2006. 225 p. ISBN 80-214-2374-9.

[5] KRAUS, Vaclav. “Surface modification,” Plzeň: University of West Bohemia, 2000. 218 p. ISBN 80-7082-568-1

[6] KREIBICH, Viktor. “Theory and Technology of Surface Treatment,” Publishing House of CVUT, Prague, 1996. 89 p. ISBN 80-01-01472-X.

[7] KREJCIK, Vladimir.” Surface Treatment of Metals II,” Publishing House of Technical Literature, Prague, 1988.

[8] HERMANN, Frantisek, SCHILLER, Marek. “Testing of paints and protective coatings,” Pardubice - Green suburb: SYNPO a.s, 2007.

[9] SAMEK, Radko. “Analysis of limit state plasticity and formability technology,” Brno: Brno Military Academy, 230 p. ISBN 2-128-63057-0. 1988.

[10] Test of resistance of coatings, ProInex Instruments, Ltd. Ostrava: Measuring equipment, thickness, hardness, gloss meters, thermometers. [cit. 2010-01-04], 2004.

[11] CSN EN ISO 1519, “Paints Substance—Bend Test (Cylindrical Mandrel),” Czech Standards Institute, 2002.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 4, October 2013

[12] CSN EN ISO 7438, "Metallic Materials Bend Test," Czech Standards Institute, 2005.

[13] CSN ISO 24213, "Metallic Materials—Sheets and Belt: Evaluation Method of Suspension for Flexural Bending," Czech Standards Institute, 2009.

[14] CSN EN ISO 20482, "Metallic Materials-Sheet and Belts—Bulge Tests According to Erichsen," Czech Standards Institute, Prague, 2004.

[15] CSN EN 13144, "Metallic and Other Inorganic Coatings: Method for Quantitative Measurement of Adhesion for Tensile Test," Czech Standards Institute, 2003.

[16] Patent EP 1077021, US 6,525,481, "Method of Making a Physically and Chemically active Environment by Means of a Plasma jet and the Related Plasma Jet," Brno : Masaryk University, 2005.

AUTHOR'S PROFILE

MSc. Emil Schwarzer, 2004 - Technical University Ostrava, Faculty of Mechanical Engineering, Main field(s) of study for qualification: Design Operation and Maintenance of Vehicles
Field: Dynamic of Road Transport, Road Vehicles, Vehicles Maintenance
Diploma thesis: Optimal Variants of an Ecological Processing of Layed-up Tyres
Present
Brno University of Technology, *Faculty of Mechanical Engineering, IMT, Technical 2896/2, 619 69 Brno.*
Research work
Study of formability of coated sheets with plasma-chemical pretreatment of surface.
Employment
MUBEA Stabilizer Bar Systems, Czech Republic
e-mail: emil.schwarzer@mubea.com

Assoc.Prof.MSc.Milan Dvorak, Ph.D.
Present
Institute of Manufacturing Technology, Dept. of Metal Forming and Plastics
Faculty of Mechanical Engineering, Brno University of Technology
Education and academic qualification
1975, MSc., Faculty of Mechanical Engineering, Brno University of Technology
1989, Ph.D., University of Defence
2000, docent., University of Defence
Publication
DVORAK, Milan; SCHWARZER, Emil; "New Methods Testing of Adhesion of the Coating to Sheet Metal by Bending," *Journal of Surface Engineered Materials and Advanced Technology*, Vol. 2 No. 2, 2012, pp. 61-64. doi: 10.4236/jsemat.2012.22011.
DVORAK, Milan; SCHWARZER, Emil; KLIMA, Milos. New trends in the bending of coated sheet metal. *Journal for technology of plasticity*, 2012, vol. 37, no. 2, p. 111-119. ISSN: 0354- 3870.
CISAROVÁ, Michaela.; DVORAK, Milan. The influence of bending angle of the Zn metal sheet coated on surface morphology. *Journal for technology of plasticity*, 2012, vol. 37, no. 2, p. 189-194. ISSN: 0354-3870.
Research work
Study of formability of coated sheets with plasma-chemical pretreatment of surface.
e-mail: dvorak.m@fme.vutbr.cz