ОБЩИЕ ВОПРОСЫ АВТОМОБИЛЬНОГО ТРАНСПОРТА

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INCREASING STAMPING FORMABILITY OF LOW-CARBON COLD ROLLED THIN STEEL SHEETS

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Abstract. *The use of surfactant (épila) was studied as a method for improving the cold-formability of steel sheets. The factors of the resulting effect were analyzed. Application of épila significantly reduces the surface roughness and decreases the stress concentrates. Epilam fills pores and microcracks, displaces moisture and gases, thereby reducing metal embrittlement. The application of épila provides the highest category of drawing the low carbon sheet steel 08kp.*

Key words: *epilam, defects healing, cold rolled sheet, stamping of sheets, stamping formability, drawing, hole-expansion test, drawability, roughness, surface profile.*

ПОВЫШЕНИЕ ШТАМПУЕМОСТИ НИЗКОУГЛЕРОДИСТОЙ ХОЛОДНОКАТАНОЙ ТОНКОЛИСТОВОЙ СТАЛИ

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Аннотация. *С целью повышения технологической пластичности холоднокатаной листовой стали впервые предложена поверхностная обработка – эпиламирование. В результате в холоднокатаной тонколистовой стали 08кп была достигнута высшая категория штампуемости (ВОСВ). Эффект достигается за счет залечивания поверхностных дефектов и уменьшения концентраторов напряжений.*

Ключевые слова: *сталь, холоднокатаный лист, технологическая пластичность, штампуемость, вытяжка, испытание на выдавливание.*

ПІДВИЩЕННЯ ЗДАТНОСТІ ДО ШТАМПУВАННЯ НИЗЬКОВУГЛЕЦЕВОЇ ХОЛОДНОКАТАНОЇ ТОНКОЛИСТОВОЇ СТАЛІ

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Анотація. *З метою підвищення технологічної пластичності холоднокатаної листової сталі вперше запропонована поверхнева обробка – епіламування. У результаті у холоднокатаній тонколистовій сталі 08 кп була досягнута найвища категорія здатності до штампування (ВОСВ). Ефект досягається за рахунок заліковування поверхневих дефектів та зменшення концентраторів напружень.*

Ключові слова: *сталь, холоднокатаний лист, технологічна пластичність, здатність до штампування, витягування, випробування на видавлювання.*

Introduction

One of the most popular types of steel products is cold rolled sheet which is widely used in all areas of industry. Total volume of thin rolled sheet in developed countries is around 50% and its production tends to grow.

Despite the increasing new structural materials applying the leading role in the automobile and tractor manufacturing, as well as in road-building machines production, still belongs to cold rolled steel sheets.

About 60% of automobiles parts and 40% of tractors parts various by purposes, shapes and sizes (body parts, frames, cases, covers, disks, flat levers, headlights etc.) are made from low-carbon sheet steels by cold stamping.

This method is widely used in civil engineering, power generation, railway and agricultural engineering, domestic appliance.

Taking into account the high usage of cold stamping the increase of thin steel sheet engineering ductility is a present-day issue. Insufficient stamping formability reduces cold stamping efficiency.

State of art

Cold stamping of sheet steels has a number of advantages. This rather simple method is practically unwasted, allows producing interchangeable parts with high accuracy of dimensions and shapes. This is especially important for assembling items (machines) on the conveyer [1, 2]. This method also has high productivity and low labor intensity.

Two basic requirements are placed upon cold rolled thin sheet – good drawability and high surface quality of product for following painting or coating [3].

In the cold stamping shops the workpieces from low-carbon cold rolled sheet steels (08kp, 08ps, 08Al) constitute about 90% of total production. These steels are widely used in the automotive industry and are known as automotive sheet steels.

The drawability of cold-rolled products (strips, sheets) is determined by hole-expansion test (*Erichsen* test) and is estimated by maximum depth of an expanded hole without crack [4].

In accordance with the regulations [5] the thin (thickness up to 2 mm) steel cold rolled sheet is divided into 4 groups: VPDD (very particularly difficult drawing), PDD (particularly difficult drawing), CD (complex drawing), VDD (very deep drawing). Requirements for VPDD, PDD and CD are applied for steel 08Al which contains aluminum to reduce the oxygen content. This helps to improve stamping formability. Steel 08kp which is more widely used provides only as VDD.
However, the difficulties often occur at the plants during stamping process because of steel poor stamping formability and insufficient drawability. This leads to defects occurrence, increasing material consumption and therefore decreasing the economic efficiency of production.

Previously we have proposed a method of increasing thin steel sheet engineering ductility, stamping formability and drawability using ion bombardment [6], but it requires special equipment and professional service.

The purpose and the problem formulation

The purpose of the paper is to propose a more simple surface treatment which does not need special equipment for increasing engineering ductility and stamping formability of finished thin cold rolled sheet. The proposed method must lead to defects healing what will result in improving stamping formability.

The material and research techniques

Flat samples from steel 20 (100×20×1,2 mm) and sheet samples from cold-rolled steel 08kp (90×50×0,5 mm) were treated with Epilam. Epilam is a solution of fluorine surface-active agents in a highly volatile halocarbon compounds. After evaporation of halocarbon compound, the monomolecular film forms on the surface. The procedure of Epilam applying consists of the following steps: degreasing and surface cleaning – Epilam applying – heat setting.

Samples were treated with Epilam SFK-05 (Specs. 2412-002-13868195-2012) by dipping in a hot bath at a temperature about 55°C with the holding time about 15 minutes. The heat setting of the film was carried out at the temperature of 110°C for 50 minutes.

The roughness and the surface profile were defined on surface analyzer TR-200. Sensor sensitivity of the surface analyzer was 0,002 μm. This allows estimating the surface topography from 0,005 μm. Measurement range was from 0,01 to 160 μm. Measurement error did not exceed 10 % of the *Ra*.

Tensile tests were carried out on the testing machine UIT-STM-50 according to the standard [7]. The drawability of cold rolled sheet workpieces was determined by hole-expansion test [4]. The depth of expanded spherical holes characterizes the category of flat products and its stamping formability in a cold condition.

The results

Experiments have shown that after Epilam applying the surface roughness *Ra* was significantly reduced (from 1,6 μm to 0,21 μm), see. Fig. 1. Epilams have very low surface tension and a high penetrating ability to fill pores, cracks, scratches. This leads to profile smoothing and improving surface quality. In addition, Epilam filling the pores and microcracks, displaces gas (hydrogen, carbon dioxide) and moisture, what in its turn reduces metal embrittlement.

Tensile tests of flat samples made from steel 20 (table 1) showed that Epilam applying results in substantial increasing of ductility characteristics (the percent elongation and the reduction in area increases by 44 % and 55 % respectively). This is accompanied by relatively small reduction of accompanied by relatively small reduction of strength characteristics (σ_u, by 4 %, $\sigma_{0,2}$ by 9 %). At the same time, the actual fracture stress due to essential rise of ductility increases by 12%.

Substantial ductility increasing should affect the drawability of steel. To confirm this assumption the cold-rolled steel sheet made from steel 08kp was subjected to Epilam treating. Then this sheet was tested by hole-expansion test (*Erichsen* test). The results are shown in table 2.

As it could be seen from table 2, Epilam applying significantly improves engineering ductility and stamping formability. As a result the highest category of drawing (VPDD) was obtained in cold-rolled thin sheet of steel 08 kp. It also should be noted that achieved depth of the expanded hole (11,7–11,85 mm) is far above the requirements of the standard for VPDD (9,7 mm).

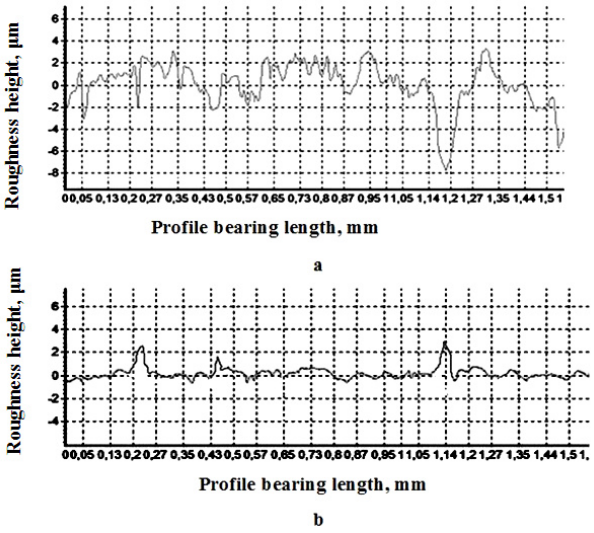

Fig. 1. The surface profiles of steel 20 samples before (a) and after (b) applying Epilam

Table 1 The mechanical characteristics of samples made from steel 20 before and after applying Epilam

The state	σ_u, MPa	$\sigma_{0,2}$, MPa	$S_к$, MPa	δ, %	ψ, %
Before Epilam applying	375	290	480	25	21
After Epilam applying	360	265	540	36	33

Table 2 The results of hole-expansion test of sheet steel 08kp

The state	The depth of expanded hole, mm	The category of drawing
Before Epilam applying	9,05	VDD
After Epilam applying	11,7–11,85	VPDD

It should be emphasized that despite a slight decreasing of strength characteristics after Epilam applying their values correspond to the standard for VPDD (thickness of sheet less than 0,7 mm) [5].

Conclusions

Epilam applying heals surface defects what results in substantial increasing the ductility characteristics of cold rolled low-carbon sheet steel. In addition this treatment improves sheets surface quality.

Exclusively high ductility characteristics cause the unusual increase of stamping formability: steel sheet obtains the highest category of drawing – VPDD. For this particular purpose Epilam is used for the first time.

The obtained results allow to recommend this method for improving the drawability of sheet steel workpieces directly on the consumer plants. It also could be used in plants that produce thin sheet steels.

Epilam applying is a simple method that does not require any special equipment and provides significant economic benefits due to reducing workloads and increasing tool durability, increasing productivity and product quality, reducing the number of transitions during cold stamping. The recommended method is protected by the patent.

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