UDC 621 . 98 : 621 . 89 : 669 . 146 . 97

Lubricative Coated Steel Sheets with Oil-free Formability

Yujiro MIYAUCHI*1
Taketoshi TAIRA*2
Ikuo KIKUCHI*4
Hiroshi KANAI*1
Toshiyuki KATSUMI*3

Abstract

With the recent heightening of awareness regarding environmental protection, the manufacturing industry has investigated actions to several problems. One of the problems is the discontinuing of the use ozone layer depleting substances. The press forming process needs the lubrication and cleaning of oil after forming. However, the 1,1,1-trichloroethane and designated chlorofluorocarbons are prohibited by law from 1996 because they are ozone layer depleting substances. For this reason, we developed the lubricative coated steel sheets which have excellent formability without using a lubrication oil. The lubricative coated steel sheets have self-lubricating ability in a dry press forming process without cleaning agents. In this paper, we introduce the performance of lubricative coated steel sheets.

1. Preface

Conventionally press forming of steel sheets required a lubricant such as a lubrication oil. The lubricant has to be removed by a degreasing process after the forming work and, in addition to the cost involved, it fouls the working environment. Cleaning agents such as fluoro-hydrocarbon, trichloroethane, etc. have been used for the degreasing, but the use and production of these products came to be restricted under the Montreal Protocol[1] in 1987 as ozone layer depleting substances. Thereafter, in accordance with the Amendment to the protocol at Copenhagen in 1992, production and importation of designated chlorofluorocarbons, trichloroethane, etc. came to be banned[2] in Japan from 1996.

In the above background, the industries which had been using these regulated solvents were forced to look for their substitutes. In this situation, lubricative coated steel sheets (hereinafter the "lubricative sheets") made the press forming work possible without using the lubrication oil. This fact brings about various advantages such as elimination of the oil application and the degreasing processes, making the clean work environment without the oil, etc. (See **Table 1**)

This paper describes properties and characteristics of the lubricative sheet product mainly referring to the type manufactured from electro-galvanized sheets.

Table 1 Oiling/degreasing methods in the press forming process, problems related thereto and advantages of the lubricative sheets

Product	Oiling	Press forming	Degreasing	Problems
Cold rolled sheets, plated sheets	Conventional stamping oil	Conventional	Trichloroethane, chlorofluorocarbon, etc.	Ozone layer depletion
Cold rolled sheets, plated sheets	Conventional stamping oil	Conventional	Inflammable solvent	Ventilation Fire protection
Cold rolled sheets, plated sheets	Conventional stamping oil	Conventional	Water	Waste water treatment
Cold rolled sheets, plated sheets	Volatile stamping Oil	Conventional	Unnecessary	Ventilation Formability
Lubricative sheets	Not used	Oil-free	Unnecessary	–

*1 Technical Development Bureau
*2 Kimitsu Works
*3 Niigata Sales Office
*4 Hirohata Works

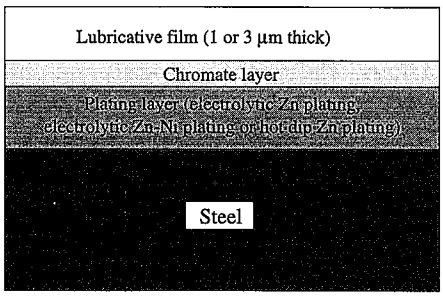

Fig.1 Coating layer model of the lubricant sheets

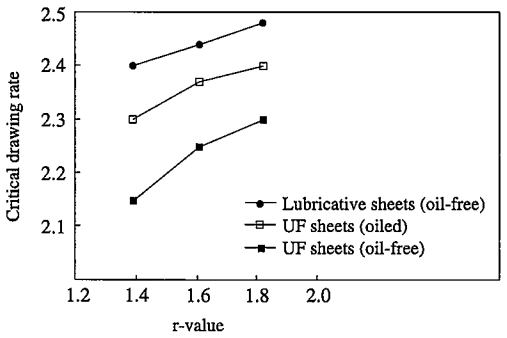

Fig.2 Effects of steel materials and kind of products on the critical drawing rate

2. Film Layer Structure of the Lubricative Sheets and Characteristics

As shown in **Fig.1**, the lubricative sheets consist of lubricant organic film coated electro-galvanized or hot dip galvanized steel sheets with a chromate film. These product is classified into two kinds depending on the thickness of the organic layer: one is the electrically conductive type (thin film type : 1μm) and the other is the deep-drawable and high corrosion-resistant type (thick film type : 3μm).

Lubrication property of the organic film, which affects the press formability, is the most important characteristic of the product. Lubricity of steel sheets with normal stamping oil is 0.10 - 0.15 in dynamic friction coefficient, and in the case of high lubricity oil it is approximately 0.06[3]. The organic film of the lubricative sheets has a lubricity equivalent to that of the high lubricity oil used for deep drawing work[4, 5].

3. Product Properties

3.1 Press formability

The most important characteristic required of the lubricative sheets is the press formability under no oil conditions. As shown in **Table 2**, the product has the lower dynamic friction coefficient than either corrosion-resistant chromate-coated sheets (hereinafter the "chromate-coated sheets") applied with lubricating oil or anti-fingerprint organic film-coated sheets (hereinafter the "UF sheets").

The excellent lubrication property affects deep-drawability of the press forming process. **Fig.2** shows a result of a comparative test of formability of the thick film type (3μm) lubricative sheets based on electro-galvanized sheets (coating weight: 20g/m^2) and the UF sheets of an equal film thickness. The specimens were drawn into 50 mmϕ cylindrical cups by an Erichsen cylindrical drawing tester and the critical drawing rate was investigated. The lubricative sheets (with no oil) showed superior critical drawing rate to the UF sheets with lubricating oil, demonstrating that the product can be deep-drawn without oil and has a very good press formability. Deep drawability is largely affected by mechanical properties of the material sheets, typically the r-value, but the lubricative sheets showed good deep-drawability with different r-values.

Table 2 Dynamic friction coefficients of surface-treated steel sheet products

Products	Film thickness (μm)	Oiling	Dynamic friction coefficient
Lubricative sheets	1	No oil	0.06
Lubricative sheets	3	No oil	0.06
UF sheets	1	No oil	0.19
UF sheets	1	Stamping oil	0.15
Chromate-coated sheets	-	No oil	0.48
Chromate-coated sheets	-	Stamping oil	0.15

Stamping oil: NIHON KOHSAKUYU Co. Ltd. #620

Dynamic friction coefficient:

Measuring device: Friction coefficient tester made by Kett

Condition: 10mmϕ stainless steel ball of JIS SUS 304
Load: 100gf
Sliding speed: 100mm/min

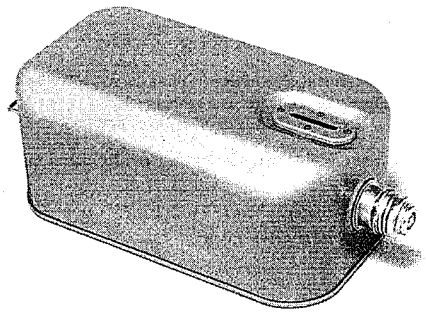

Photo 1 Detachable kerosene tank of oil heater (an example of press forming product of the lubricative sheets)

Due to the excellent press formability of the lubricative sheets without using the oil as described above, they have been used for various kinds of formed products such as kerosene tanks of oil room heaters (deep drawing), chassis of audio appliances (flanging), etc. **Photo 1** shows a detachable kerosene tank of oil room heater formed by continuous stamping. The product has good appearance without defects such as galling.

3.2 Continuous sliding property

Some of the VTR chassis parts and audio recorder parts are subject to repeated sliding movements between the steel sheets or the steel sheet and the tape cassette. The lubricative sheets can be satisfactorily applied to these parts.

The lubricative sheet product shows a very good continuous sliding property besides the press formability because of very low friction coefficient. **Fig.3** shows a result of a scratch resistance test by counting the number of continuous sliding movements till the organic film suffers any scratch. The number of sliding movements of the lubricative sheets is markedly higher than the chromate-coated sheets.

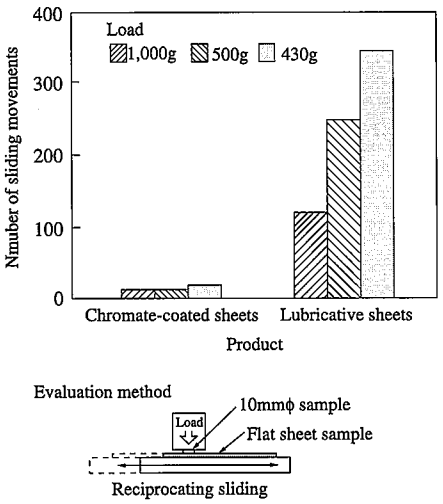

Fig.3 Continuous sliding behavior of the lubricant sheets

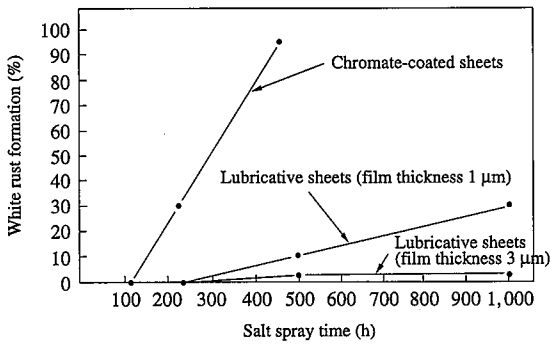

Fig.4 Corrosion resistance of the lubricative sheets

3.3 Corrosion resistance

Corrosion resistance of the lubricative sheets depends largely on the environment insulation effect of the organic film and thus the thick film type is superior in the corrosion resistance to the thin film type, which has yet a better corrosion resistance than the chromate-coated sheets in terms of white rust formation. **Fig.4** shows result of a salt spray test (JIS Z 2371) of lubricative sheets based on electro-galvanized sheets (coating weight: 20 g/m²) and the chromate-coated sheets. The thick film type lubricative sheets proved to be the most corrosion-resistant followed by the thin film type, then came the chromate-coated sheets. The result was altogether the same when the lubricative sheets based on hot dip galvanized sheets were tested[6]. Due to the excellent lubricity of the organic film, the lubricative sheets suffer little damage during forming work and the corrosion resistance of formed portion is excellent.

3.4 Paint adhesion and weldability

The lubricative sheet product was developed assuming that it would most commonly be used without painting but the possibility of painting after forming work could not be neglected. **Table 3** shows paint adhesion of melamin alkyd resin paint for common paint finishing and epoxy resin ink for silk screen printing on the lubricative sheets. Either the thick film type or the thin film type shows good adhesion for both the materials in direct applications. The paint adhesion is also good in the 4 mmϕ and 4T bend forming portions.

Although the lubricative sheets allow for oil-free forming work, volatile stamping oil is sometimes used when the forming is very intensive or for preventing peeling off of the film for avoiding dents caused by the film peel on the press die surface. It is necessary that the organic film is not affected by the solvent of the volatile oil. The film also has to be resistant to kerosene in consideration of applications like the detachable kerosene tank of oil heater as the product is used without painting. **Table 4** shows solvent resistance of the lubricative sheets tested by a rubbing tester. The lubricative sheets showed sufficient resistance against any of the three solvents used in the test.

Table 4 Solvent resistance of the lubricant sheets

Sample		Kerosene	Xylene	Benzine
Plating	Type			
Electrolytic Zn	Thin film	◎	○	◎
	Thick film	◎	○	◎
Electrolytic Zn-Ni	Thin film	◎	○	◎
	Thick film	◎	○	◎
Hot dip Zn	Thin film	◎	○	◎

Rating ◎: No marking, ○: Marked but no paint peeling, △: Partial paint peeling, ×: Total paint peeling

Test condition Rubbing tester
Load: 500 g/cm²
10 reciprocating cycles of 50 mm stroke
(50 cycles for kerosene)

Table 3 Evaluation of finishing paint adhesion

(Rating: poor 1 → good 10)

Sample			General painting (AMILAC No.3)				Silk screen painting (#1000)			
Product	Type	Plating	Checker	4 mmϕ	4T	Appearance	Checker	4 mmϕ	4T	Appearance
Lubricative sheet	Thin film	Electrolytic Zn	10	10	10	Good	10	10	10	Good
	Thick film	Electrolytic Zn-Ni	10	10	10	Good	10	10	10	Good
Chromate-coated		Electrolytic Zn	9	1-2	1	Good	10	7-10	2	Good

Paints for finishing and painting conditions

Paint name	Description	Maker	Thpe	Baking	Dry film thickness
AMILAC No.3	For general finishing Melamin alkyd resin	Kansai Paint	1 liquid	90°C, 20min	20μm
#1000	For silk screen painting Epoxy resin	Seiko Advance	2 liquid	120°C, 20min	10μm

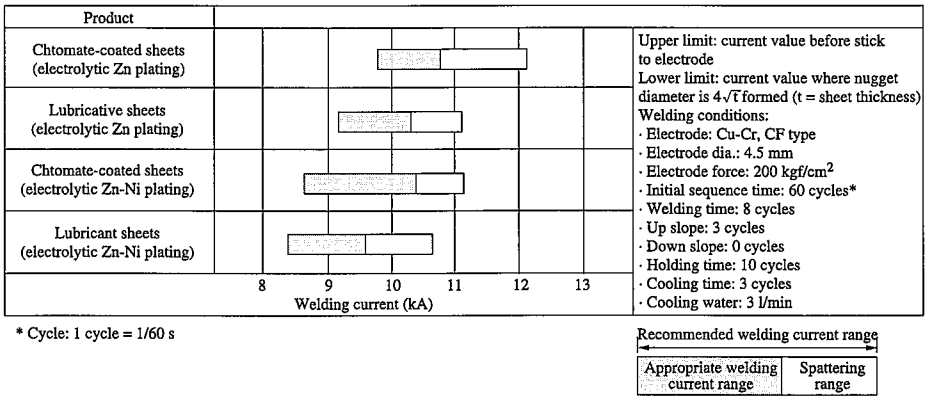

Fig.5 Appropriate welding current range for the lubricative sheets

3.5 Weldability

Resistance welding methods such as spot welding are commonly employed for welding steel sheets and many of the applications of the lubricative sheets require good weldability. Weldability is largely influenced by the organic film thickness. The thicker the film the larger the electro-resistivity and hence the thick film type with the film thickness of 3μm is not suitable for spot welding while the thin film type of 1 μm thickness does not present any problem. For joining the thick film type sheets, methods such as caulking and small bolts are commonly used in combination with adhesives when necessary.

Fig.5 shows a measurement result of appropriate welding current range for the thin film type lubricative sheets. The appropriate current range for the lubricative sheets shifts to the lower current side compared with the chromate-coated sheets without organic film, although the width of the current range is almost the same.

4. Conclusions

The lubricative sheets demonstrate excellent press formability equal to or better than the press lubrication oil to the highly lubricative organic film applied on the surface. Furthermore, the product has also very good performances in continuous sliding, corrosion resistance, paint adhesion, etc. and for these reasons it has expanded the applications in fields mainly of electric appliances and office automation facilities as shown in **Table 5**.

Use of the lubricative sheet product brings about various advantages such as elimination of oiling and degreasing processes contributing to decreasing the general environmental loads and enhancement of the working environment through the oil-free operations.

Table 5 Some applications of the lubricative sheets

Basic steel sheet	Applications
Electro-galvanizing	Chassis and parts of VTR, CD drive
	Detachable kerosene tanks of oil heater
	Tanks of stove
	Display shields
	Control panels of air conditioner
	Motor covers
	Refrigerator rear panels
	Side and rear panels of microwave oven
Hot dip galvanizing	Internal panels of air guider
	Magnetron cases
	Support trays of kerosene tank
	Air conditioner parts
	Washing machine parts

References

1) Sakurai,T.: Gekkan Chikyukankyo. 29 (7), 17 (1997)
2) Odagiri,T.: Senjo Sekkei. (75), 34 (1997)
3) Okumura,Y. et al.: J. Japanese Soc. Tribologists. (36), 764 (1991)
4) Taira,T.: Press Technology. 32 (6), 40 (1994)
5) Katsumi,T., et al.: Bulletin of The Iron and Steel Institute of Japan. 34 (6), 789 (1995)
6) Kanai,H. et al.: Press Technology. 33 (8), 34 (1995)