

Suitable Compositions for Efficient Deep Stamping Lubricants

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The aim of the present study is to emphasize the influence of chemical composition of deep stamping lubricants on their efficiency, in specific application of automotive industry. In this respect, two different types of lubricants were realized and tested: a usual lubricant, paste type, based on sodium soap chemical formula and a new composition, oil type, based on complex formulation of sulphur, calcium sulfonate and polymethacrylate additives and suitable base oils. The evaluation of these lubricants was realized by typical laboratory tests, but also by specific procedure of automotive equipment manufacturers, on factory stands. The experimental results proved that the combination of the additives, studied for the new type of deep stamping lubricants, significantly enhance their performance and implicitly extend the range of applications, making possible the stamping of the steel – sheets characterised by 3.5-4mm thickness, instead of 1,2-1,5mm thickness specific for sodium soap paste lubricant.

Keywords: deep stamping, lubricant, extreme pressure additive

The automotive manufacture industry includes a large category of processes, from the production of the simple parts and equipment, to the modern body car shaping and the car onboard computer production. These manufacture processes suppose high tech knowledge and methods as well as special materials and components.

Considering the component parts of the cars, most of them are realized by casting, cutting and welding working processes. Some of these components like oil baths, fuel tanks, bumpers etc, can be only made by deep stamping.

Stamping is the process of metal sheet casting into a net shape, by using a machine press or stamping press, and includes a variety of sheet-metal forming manufacturing processes, like blanking, punching, bending, embossing, flanging and coining. This procedure involves a wide range of the metallic sheet thickness, various shapes and depths of the profiles, high working pressure for the forming of the steel sheet [1].

For an adequate stamping process of the metallic components, there are necessary efficient lubricants that are laid on the metallic sheets or on the dies, ensuring a smooth and uniform aspect of the profile surface, preventing rips, tears or wrinkles, as well as the steel-sheet seizure or breaking [2-4].

There is a variety of lubricants recommended for stamping process. They include soap based, vegetable and mineral oil based, animal fat based, graphite composition based, etc

The common category of lubricants used for metallic sheet stamping, is the lubricating paste, based on sodium soap chemical formula. This type of lubricant has the advantage of a low cost, but is limited as applicability: can be used for maximum 120 – 150 daN stamping pressure, and maximum 1.2 – 1.2 mm steel sheet thickness. There are also some difficulties considering the spreading on the steel sheet as well as the removing from the metallic surfaces. The typical characteristics of this kind of lubricants are presented in the table 1.

The more exigent requirements of equipment construction industry, considering the thickness, the loading pressure, the corrosion protection of the manufactured metal sheets, lead to important changes of deep stamping lubricants formulation. In this respect, special characteristics, like extreme pressure resistance, antiwear and anticorrosion properties, very good adherence to metal sheets, easy spreading and removing from the metallic surfaces, have to be accomplished.

The specific characteristics trends, that are considered for the deep stamping lubricants, are presented in the table 2, as a synthesis of automotive manufacturer's new requirements [5-8].

The aim of the work paper is to emphasize the efficiency of a new composition of deep stamping lubricant, oil type, developed by experimental study for heavy duty stamping process, in comparison with a traditional paste type lubricant.

Characteristics	Requirements of cars manufacturer	ASTM test methods
Appearance	paste	-
Density at 20°C, max	1.2 – 1.3	D 941
Saponification value, mgKOH/g, min	16	D 1962
Corrosion resistance	pass	D 4627
4 Ball test- weld load, daN, min	150	D 2783

Table 1
TYPICAL CHARACTERISTIC OF DEEP STAMPING LUBRICATING PASTE TYPE

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Characteristics	New requirements	ASTM test methods
Density at 20°C	report	D 941
Viscosity at 40°C, cSt	250 - 450	D 445
Flash point, °C, min.	230	D 92
Pour point, °C, max	-15	D 97
Copper corrosion (3h, 100°C), max	2c	D 130
4 Ball machine: weld load, daN, min.	400	D 2783

Table 2
TRENDS OF NEW DEEP STAMPING
LUBRICANTS CHARACTERISTICS

Experimental part

Considering all the aspects presented above and the state of art, the present study had as the main objective the elaboration of a new lubricant composition for deep stamping processes, liquid type, in accordance with the actual requirements of the automotive manufacturers and the evaluation of this new lubricant in comparison with the usual one, paste type lubricant.

The new composition was based on high viscosity mineral base oils and performing additives like extreme pressure and antiwear additives, corrosion inhibitors, detergent-dispersant additives and depressant components [9].

The first stage of the study was the characterisation of the selected base oils and specific additives, as well as the testing of the new lubricant compositions realized by these components. In order to obtain efficient composition of deep stamping oils, many types of base oils and different additives for each functional category were tested.

The evaluation of the characteristics, at laboratory scale, was in accordance with specific ASTM testing methods [10].

Characterisation of the base oil

Considering the referential viscosity of the deep stamping oils (table 2), the base oil used in the formulation had a high level of viscosity, in the range of ISO-VG 220 to ISO-VG 460 class. In the table 3 are presented the typical characteristics of the base oils selected for the experimental study.

Characterisation of specific additives

The additives are very important in ensuring different functions of lubricant oils; these specific functions could

not be provided by the base oils as such. The selected additives used in the formulation of the new deep stamping oil, are further presented.

Extreme pressure additive is used for ensuring the oil high pressure capacity. Usually these additives contain in their chemical structure sulphur and phosphorus compounds that form a resistant film on the steel sheet surface, by the chemisorption process. The surface layer is an alloy whose melting point is low enough to provide lubrication below the softening point of the base metal [9-12].

In this way, the lubricating film efficiently takes the pressure stress and protects the metallic surface against wrinkles, distortions or galling.

There were several types of extreme pressure additive tested for the lubricating composition formulation, but the most suitable one chosen for, was a sulfurized isobutylene additive type, that has the following characteristics (table 4).

Detergent-dispersant additive was introduced in the lubricating formulation in order to boost the efficiency of the extreme pressure additive and to improve the corrosion resistance.

The chosen additive is a calcium sulfonate type, with detergent-dispersant properties and additional antirust, anticorrosion properties. The mechanism for the film formation is similar with those of extreme pressure additive; chemical action with the metal surfaces resulting in the production of chemical compounds that increase the metal protection [15, 16].

The typical characteristics of the selected additive are presented below (table .5).

Table 3
TYPICAL CHARACTERISTICS OF THE
SELECTED BASE OILS

Characteristics	Values	ASTM test methods
Density at 20°C	0,906	D 941
Viscosity at 40°C, cSt	445	D 445
Flash point, °C	242	D 92
Pour point, °C	- 8	D 97

Table 4
SPECIFIC CHARACTERISTICS OF EXTREME
PRESSURE ADDITIVE [9]

Characteristics	Specific values	ASTM test method
Density at 20°C	1.0734	D 941
Viscosity at 40°C, cSt	140	D2270
Flash point	150	D 92
Sulfur, % wt	38	D 2622

Table 5
CHARACTERISTICS OF DETERGENT
DISPERSANT ADDITIVES [14]

Characteristics	Specific values	ASTM test method
Density at 15°C	1.015	D 941
Viscosity at 100°C, cSt	65	D2270
Flash point	130	D 92
Total Base Number, mgKOH/g	38	D 2622

Characteristics	Average values	Requirements	ASTM test methods
Density at 20°C	0,909	report	D 941
Viscosity at 40°C, cSt	442	250 - 450	D 445
Flash point, °C	241	Min.230	D 92
Pour point, °C	- 20	Max -15	D 97
Copper corrosion (3h,100°C), class	2b	Max.2c	D 130
4 ball test machine, weld load, daN	430	Min.400	D 2783

Table 6
SPECIFIC CHARACTERISTICS OF
SELECTED DEEP STAMPING OIL
FORMULATIONS

Depressant additive is a polymethacrilate soluble in mineral oil and compatible with the other additives used in lubricants formulations. This additive has the function of lubricant pour point decreasing and also ensures an effective thickness of lubricating composition.

Formulation of new deep stamping lubricants

These all components presented before, were used in different combinations and dosages for the optimum deep stamping oil formulation. Several compositions were tested in order to evaluate the correlation between their specific characteristics and the requirements of automotive manufacturers.

The most efficient deep stamping oil composition had the following formulation:

- Base oil, % wt	91
- Extreme pressure additive, % wt	5
- Detergent-dispersant additive, % wt	3
- Depressant additive, % wt	1

In the table 6 are presented the average values of characteristics, representative for the selected deep stamping oil formulations presented above, in accordance with automotive manufacturers requirements.

Evaluation of the testing results, obtained at laboratory level for the selected formulations of deep stamping oil, emphasized that the specific values of the characteristics were correlated with the automotive manufacturer new requirements.

Considering this good correlation, the next step of the study was the testing of the formulated deep stamping oils in working conditions.

Experimentation of deep stamping lubricants in simulated service conditions

The most edifying proof of the formulated lubricants efficiency is their behaviour in real conditions of working. This is the most concluding test that can confirm, or not, the sustainability of the lubricant formulation concept. But the testing in real conditions of application is also expensive and quite risky, so an intermediate stage of testing, between laboratory and real work conditions, is required: the testing on the special factory stands that actually simulate the real conditions of work.

Therefore, the new developed deep stamping oils were tested in one of the well known automotive equipment factory in Romania, in conformity with the automotive manufacturer testing procedure.

In order to make more evident the quality of the new developed lubricant, the tests were realized in parallel with an usual lubricating paste.

In this respect, the two types of lubricants were prepared in laboratory for the experimentation purpose. The encoding of these lubricants was: DS Paste - for deep stamping lubricant paste type and DS Oil - for deep stamping lubricant oil type.

The specific characteristics of these lubricants are presented in table 7.

Characteristics	DS Paste	DS Oil	ASTM test methods
Density at 20°C.	1.217	0,925	D 941
Viscosity at 40°C, cSt.	-	438	D 445
Flash point, °C.	-	240	D 92
Pour point, °C.	-	- 18	D 97
Saponification value, mgKOH/g	18	-	D 1962
Sulfur, % wt	=	1.94	D 2622
Copper corrosion (3h,100°C)	2a	2c	D 130
4 ball test machine, weld load, daN	150	420	D 2783

Table 7
CHARACTERISTICS OF PASTE TYPE
AND OIL TYPE DEEP STAMPING
LUBRICANTS

Seq	Metal sheets thickness, mm	Loading pressure, daN/m ²	Profile depth, mm	Aspect of the metal sheet	Noise occurred during the test	Test evaluation
1	0.5	100	20	Smooth and uniform	No noise	pass
2	1.0	100	20		pass	
3	1.5	150	20		Indefinite noise	pass
4	2.0	200	20	Visible stress traces	Specific breaking noise	failed

Table 8
STAND TESTING RESULTS OF THE PASTE DEEP
STAMPING LUBRICANT

Seq	Metal sheets thickness, mm	Loading pressure, daN	Profile depth, mm	Aspect of the metal sheet	Noise occurred during the test	Test evaluation
1	0.5	100	20	Smooth and uniform	No noise	pass
2	1.0	100	20			pass
3	1.5	150	20			pass
4	2.0	200	20			pass
5	2.5	250	20			pass
6	3.0	300	20			pass
7	3.5	350	20	Indefinite stress traces		pass
8	4.0	400	20	Indefinite stress traces	Indefinite noise	Not conclusive
9	4.5	450	20	Visible stress traces	Specific breaking noise	failed

Table 9
STAND TESTING RESULTS OF THE
OIL DEEP STAMPING LUBRICANT

The testing methodology on factory stands requires several sequences, differentiated by metal sheets thickness by shape and depth of the casting profile, by level of loading pressure and these parameters are correlated in between [1, 2]. The evaluation of the two formulated types of deep stamping lubricants was realized as follows:

- the samples of lubricants were laid over the metal sheets, in such a way as to form a uniform lubricant film, at quite the same thickness;

- the thickness of metal sheets was increased progressively, using 0.5; 1.0; 1.5; 2.0; 2.5; 3.0; 3.5; 4.0 and 4.5 mm of metal sheets thickness;

- the metal sheets were pressed on specific casting shapes and profiles of the testing stands, on loading pressure from 100 daN to 450 daN.

In the tables 8 and 9 are shown the main experimental results obtained on the special factory testing stands for the paste type lubricant and for the oil type lubricant; there are also presented the specific parameters of the testing methodology.

Results and discussions

The experimental results and the observations registered during the laboratory specific tests of the studied deep stamping lubricants and during the evaluation on special factory stands, highlighted the following aspects:

- the experimental deep stamping lubricants are in accordance with the general requirements of the automotive equipment manufacturers, but for different applications;

- the two experimental deep stamping lubricants had a different behaviour for superior values of thickness and pressures range;

- lybricant paste have clearly passed the test up to sequence 3 of the experiment, characterized by the metal sheet thickness of 1.5 mm and the loading pressure of 120 daN;

- lubricant oil have successfully passed the sequence 7 of the test and almost reached the exigencies of the sequence 8 of the experiment, characterized by the metal sheet thickness of 4.0 mm and the loading pressure of 400 daN;

- for both lubricants could be observed a good correlation between the specific welding load tested on 4 ball test machine and the pressure load of the last sequence that was passed on the factory stand, as following:

- the maximum welding load tested for paste lubricant, on 4 ball test machine, was 150 daN and the maximum pressure load on the factory stand, without visible stress traces, was also 150 daN;

- in the case of the new developed lubricant, oil type, the maximum welding load on 4 ball test machine was 420 daN and the maximum pressure load on the factory stand, without visible stress traces, was 400 daN.

Conclusions

The aim of experimental study was the evaluation of chemical composition influence on deep stamping lubricant efficiency. In this respect two types of lubricants were tested: a usual deep stamping lubricant - paste type and a new composition of deep stamping lubricant- oil type.

Paste type lubricant, based on sodium soap chemical formula, has a limited application on moderate pressure charge – 150 daN and medium metal sheet thickness - 1.5 mm .

The oil deep stamping lubricant based on high viscosity base oils and a combination of suitable additives, have an extended range of application, for a high pressure loading and large range of metal sheet thickness; this lubricant has successfully passed the testing on the factory stand up to 350 daN loading pressure and 3.5 mm metal sheet thickness and could be carefully used for 400 daN loading pressure and 4.0 mm metal sheet thickness.

This different behaviour of the two types of deep stamping lubricants could be explained by the influence of their composition, as following:

- sodium soap forms a protective layer but has a fibrous structure, not perfect adherent on the metal surface; therefore the paste lubricant is resistant to moderately high temperature and pressure loading;

- sulphur based additive that enhance the extreme pressure capacity of oil deep stamping lubricant is more efficient than the sodium soap additive that is component of paste type. The effectiveness of extreme pressure sulphur based additives is due to chemical action with the metal surfaces and forming of an alloy layer whose melting point is low enough to provide lubrication below the softening point of the base metal. In this way an efficient protection of the metallic surfaces is realized.

The base oil of this type of lubricant also confers a better efficiency because the film of the lubricant is more adherent on the metallic surface and, implicitly, more effective.

The experimental deep stamping lubricants, tested by specific laboratory methodology and also on specific factory stands, are in accordance with the general requirements of the automotive equipment manufacturers, but are recommended for different range of applications.

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