Demofilo MALDONADO CORTÉS*, Luz A. TREJO MONTEMAYOR*, José A. TREVIÑO CASTÁN *, D. MOLINA VARGAS*, R. BERLANGA ZAMARRÓN**

METHODOLOGY FOR LUBRICANT SELECTION IN DEEP DRAWING STEEL PROCESS FOR THE AUTOMOTIVE INDUSTRY, A NEW DEVELOPMENT AND VALIDATION

METODA DOBORU ŚRODKA SMAROWEGO DO PROCESU GŁĘBOKIEGO TŁOCZENIA BLACH STALOWYCH W PRZEMYŚLE MOTORYZACYJNYM, NOWE ROZWIĄZANIE I JEGO WERYFIKACJA

Key words

tribology, steel, automotive, parameters, lubricant, coatings, wear

Słowa kluczowe:

tribologia, stal, przemysł samochodowy, środki smarowe, powłoki, zużywanie

* University of Monterrey, (UDEM), Engineering Department, San Pedro Garza García N.L., México, demofilo.maldonado@udem.edu.mx.

** METALSA, Innovation in Forming Processes, Apodaca N.L, México, rodrigo.berlanga@metalsa.com.mx.

Summary

The following research presents the evaluation of lubricants currently used by the company METALSA and some proposed by the University of Monterrey to be used in the process of chassis manufacturing.

METALSA provides a series of lubricants whose use depends on the process that is going to make. Annually, its suppliers will recommend new lubricants to return more efficient procedures.

However, for the company, it is difficult to evaluate those products in the factory. If the evaluation is not the quality that they need, it can affect both the tooling and products. In addition, such an assessment would be a loss of time on the production line and would have to assume the expenditure involved in the possibility of ruining a batch of up to one thousand pieces or one expensive tool.

Based on the foregoing, our research has developed and validated a methodology for testing the lubricants used in mechanical processes of sheet automotive steel so that one can select the lubricant of better quality without losing time dedicated to production or risk parts or machinery. The methodology consists of choosing tests designed to make use of T-02 four-ball and T-05 block-on-ring tribotesters.

The tribotesters provide certain results, but it is necessary to understand the data. The tribotester T-05, for example, indicates the traces of wear, the friction coefficient, and the volume worn. Those results serve to help make the decision of choosing a lubricant for the studied process.

INTRODUCTION

METALSA is a company dedicated to the steel industry in processes such as stamping, embossing and bending, among others. The continuous use of dies causes deterioration that subsequently affects the quality of the product (**Figure 1**); therefore, METALSA is constantly looking for ways to reduced this deterioration through the use of lubricants with good antiwear properties.

On the other hand, the regulations on Corporate Average Fuel Economy (CAFE) in the United States, are asking for a dramatic increase in the efficiency of fuel use with a view to 2020 (**Figure 2**). All of the above, makes the big manufacturers exert strong pressure on their suppliers to achieve these values. In the case of the chassises, the option is to make them lighter without compromising its resistance.

Fig. 1. Chassis section of car type "Pickup" [L. 1]
Rys. 1. Wygląd podwozia samochodowego typu „Pickup" **[L. 1]**

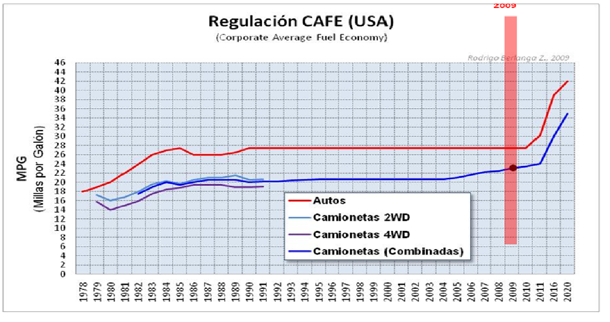

Fig. 2. CAFE Regulations CAFE [L. 1]
Rys. 2. Wymogi CAFE **[L. 1]**

Using steels of ultra high resistance allows the use thinner steel sheet in the chassises. These steels are evolving at a speed much faster than the manufacturers of chassises can react to modify the materials of their tools, since these steels inevitably produce high wear in the steel tooling (**Figure 3**).

Fig. 3. Damaged tool by wear [L. 1]
Rys. 3. Narzędzie uszkodzone w wyniku nadmiernego zużycia **[L. 1]**

On the other hand, Tribology is a science that studies the friction between two bodies in movement and wear as natural effect of friction and lubrication as option to prevent wear. These three factors are analysed in a tribological system.

A tribological system is a natural structure or artificial integrated system of surfaces of three or more components that interact in dynamic contact between them and their environment.

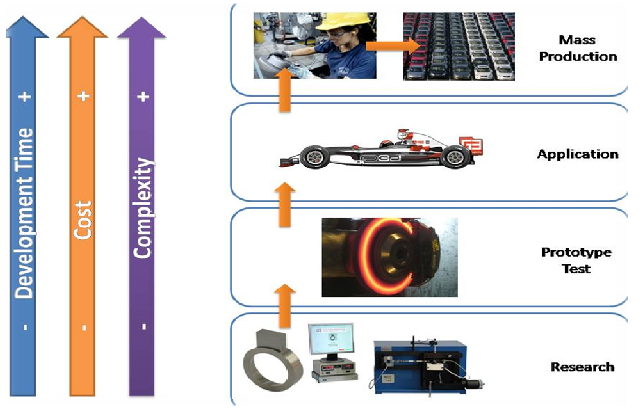

Fig. 4. Outline of the importance of tribology [L. 2]
Rys. 4. Stopnie przybliżenia badań w tribologii **[L. 2]**

Figure 4 shows the importance of the tribological investigations for the industry.

In the schema are four areas: research, test prototype implementation, and mass production.

The tribological tests reduce costs by generating a certainty in the choice of lubricant to use; therefore, it allows strong investment designed to change tooling with a minimum of risk.

EXPERIMENTATION: EQUIPMENT AND TEST METHOD

Tribotester T-02 four-ball test.

The machine T-02 (**Figure 5**) is used to determine the properties of lubricants, oils or greases, at extreme pressure and their properties of antiwear.

The tribological system is formed by three stationary balls secured by a holder and a fourth ball that applies pressure with a load *P* on the three fixed balls. The ball above is seated in a holder and rotates with a speed defined as *n*.

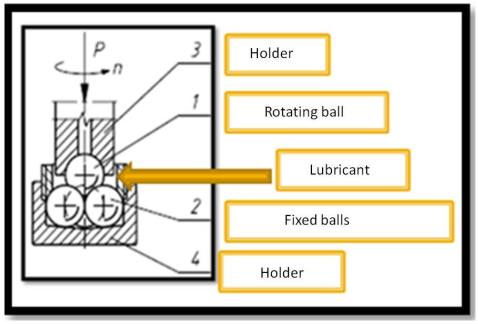

Fig. 5. Four balls tribotester [L. 3]
Rys. 5. Aparat czterokulowy **[L. 3]**

During the test, the friction torque, the applied load, and the temperature of the lubricant are measured.

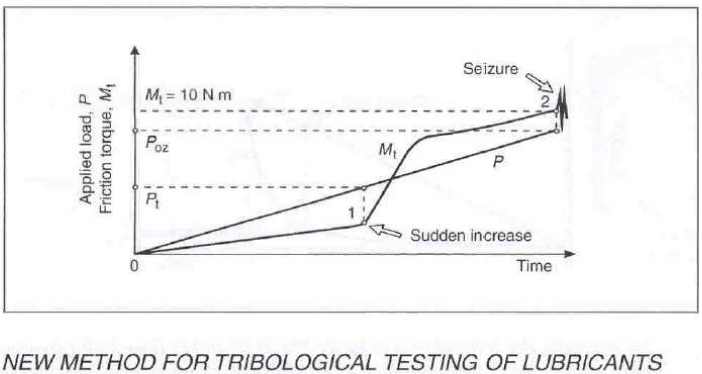

Fig. 6. Graph deployed in the software of T-02 to the *scuffing* test [L. 3, 5]
Rys. 6. Przebieg momentu tarcia w teście zacierania – tester T-02 **[L. 3, 5]**

Software that is designed for the T-02 displays a graph similar to that shown in Figure 6, where it is possible to identify the properties of the lubricant to be tested. The relevant indicators in this graph are the beginning of the friction and wear (scuffing initiation) identified with the load *Pt*. The schema also allows one to identify the time of the wear and fretting corrosion due to the loss of the film of lubricant (seizure), directly related to the load *Poz*.

The polish method or (scuffing test) uses an indicator calculated called *Poz* (pressure loss limit of film of lubricant) to quickly compare the lubricants and the average diameter of wear in cubic millimetres of the three stationary balls. It is obtained with the following formula:

$$p_{oz} = 0{,}52\frac{P_{oz}}{d^2}$$

The lubricant with the greater *Poz* is the one with the greatest properties anti wear and a low coefficient of friction.

Tribotester T-05: block on ring

The tribotester T-05 (**Figure 7**) is designed to identify and prevent wear thanks to the properties of the solids and films in the lubricants, greases, and the materials used in the system that you want to study.

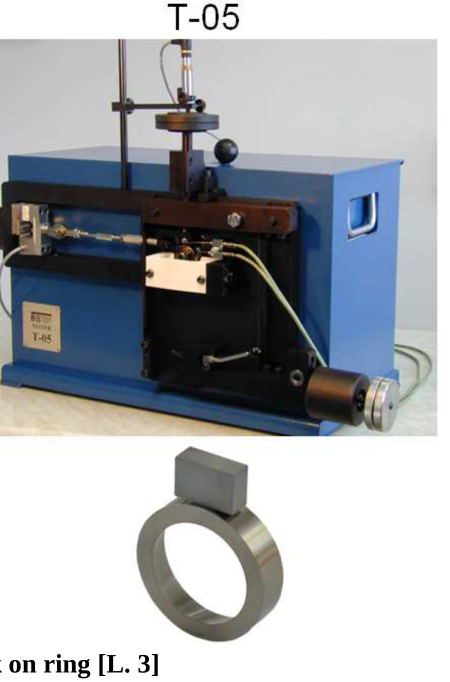

Fig. 7. Tribotester block on ring [L. 3]
Rys. 7. Stanowisko rolka klocek T-05 **[L. 3]**

In this case, the tribological system consist of a stationary block of the material to be tested and applies pressure with a load P against the ring, which turns at a defined speed or fluctuates from the frequency and amplitude determined by the investigator.

In this test, it is necessary to consider the conditions of actual operation of the process that one is attempting to duplicate to yield more accurate and pertinent results.

The test may be performed with two different forms of test-pieces, linear or, in accordance with the surface, one that modifies the contact between probe test and counter probe test (**Figure 8**).

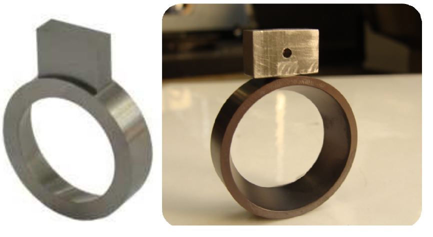

Fig. 8. Probe test and counter probe test under the surface and linear contact [L. 4]
Rys. 8. Próbka i przeciwpróbka w styku rozłożonym i skoncentrowanym **[L. 4]**

Having selected which of the two pairs of friction is optimal for the experiment, it is mounted in the machine where it is heated to raise the temperature of the lubricating fluid to the desired level (**Figure 9**). The temperature of the block is measured thanks to a thermocouple that is inserted into the hole in the block.

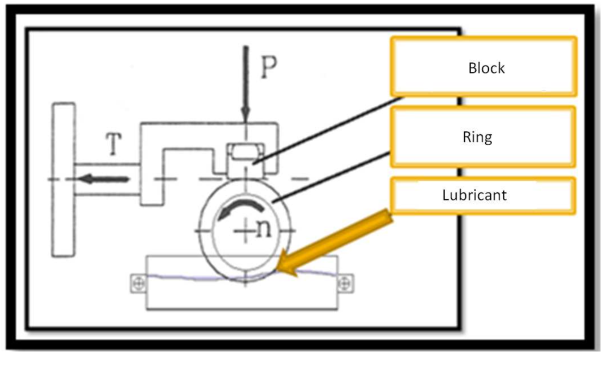

Fig. 9. Tribotester scheme: block on ring [L. 4]
Rys. 9. Schemat pary trącej testera rolka–klocek **[L. 4]**

During the experiment, the force of friction is measured, the linear wear of the whole tribosystem, the temperature of the block and lubricant, and the speed of rotation and the time or number of revolutions of the ring.

The test will stop automatically when the time runs out or the designated number of rotations has been reached.

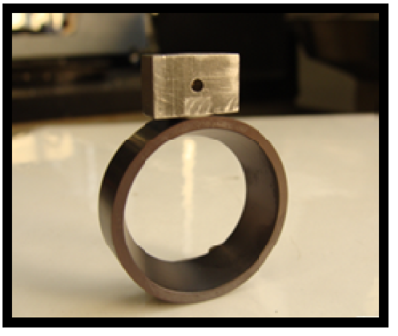

Fig. 10. Probe test with adaptation of the material of the chassis and against the ring [L. 4]

Rys. 10. Próbka testowa z testowanym materiałem stosowanym na podwozie samochodowe i rolka **[L. 4]**

Figure 10 presents the block and ring with the adapted insert of the material of the chassis. The chassis was produced only in sheet metal, which is too thin for the necessary dimensions to the block.

There is two ways of analysing the results:

- By means of graphs which are provided by the software on the T-05 (displacement and frictional force), and
- Measuring the actual wear on the block.

Figure 11 illustrates the three types of graphs that the T-05 provides.

The first shows the friction force that is taking place in the tribological system with which you can calculate the coefficient of friction. To analyse this data, it is advisable to average three points. It is known that the greater the friction force, the greater the wear.

The second graph provides vertical displacement of the tread depth. You need to take two reference points, the first is where it starts to stabilise the displacement, and the second is the greater value indicated on the graph. If there is a peak when the displacement is stabilised, it must be ignored, because it probably was due to an external abnormality and should not influence the test results.

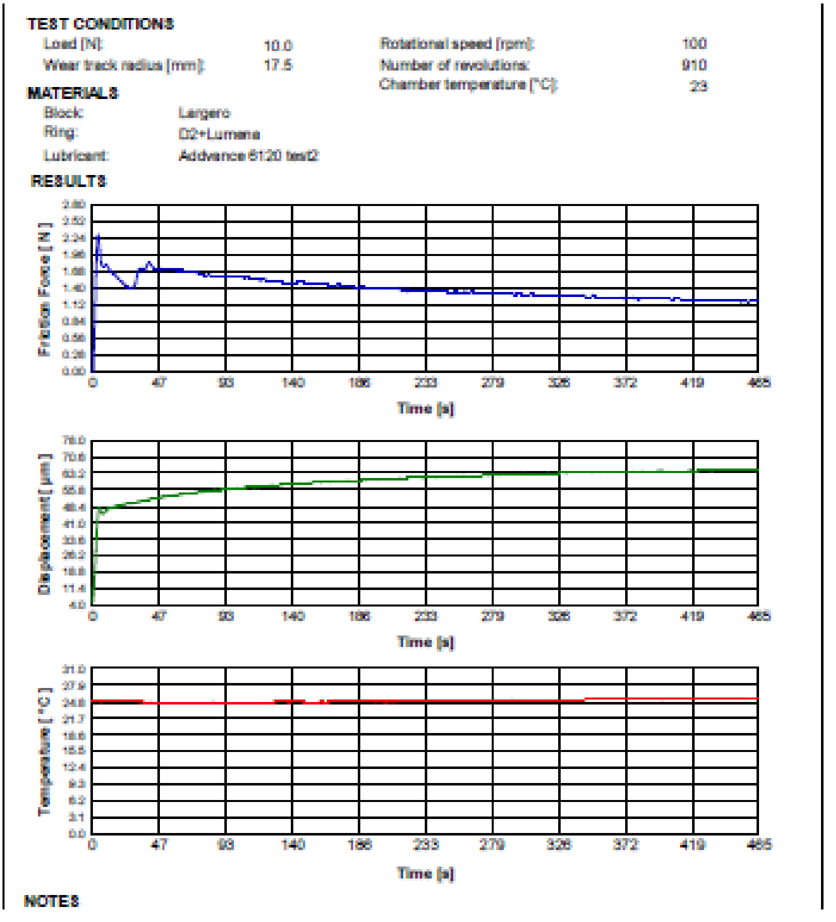

Fig. 11. Graphic provided by the T-05 tribotester [L. 4]
Rys. 11. Wykresy uzyskiwane za pomocą testera T-05 **[L. 4]**

The last graph indicates the value of the temperature of the block, which only indicates the stability of it. If the temperature is increasing, it is because it has begun to show wear and lubricant film has begun to fail. This graph is not necessary for the calculation of wear.

The "footprints" in the blocks are another factor to be considered in analysing wear. Since the trace is not completely uniform, it is necessary to refer to three or more distances with which an average is calculated for the approximate value as shown in **Figure 12.**

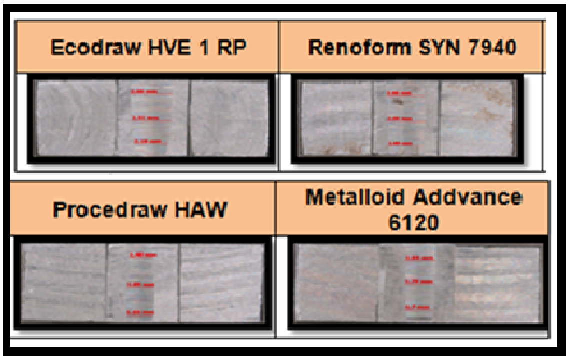

Fig. 12. Traces of wear on the blocks for different lubricants used [L. 4]
Rys. 12. Ślady tarcia na klocku uzyskane dla różnych środków smarowych **[L. 4]**

METHODOLOGY

The following steps are necessary to reach a valid suggestion to change the current tribological METALSA tool system:

a) Set the test parameters to equalise pressure in the tribotester T-05.
b) Identify the materials to test.
c) Define the lubricants to be investigated.
d) Filter the top three lubricants and add the current one used with the T-02 tribotester.
e) Test the two proposed coatings and make all possible combinations in the T-05 machine and the filter made in the previous step.
f) Analyse the results and make proposals for change.

For each combination at least three repeats was made until the test of Dixon gave reliable values.

RESULTS

Substantial improvements were achieved in reducing the coefficient of friction and wear of the tribological system against the current one.

Figure 13 and **Figure 14** show reductions in both parameters taking into account the currently used lubricant METALSA Ecodraw, and three others, Renoform, Procedraw and Addvanced-6120, proposed by the University of Monterrey.

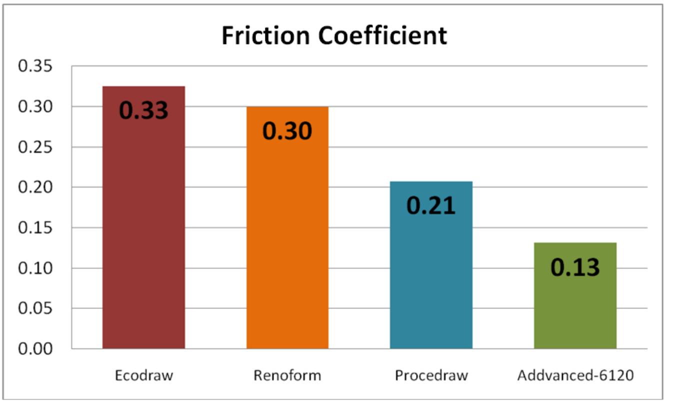

Fig. 13. Coefficient of Friction Results [L. 4]
Rys. 13. Wyniki współczynnika tarcia **[L. 4]**

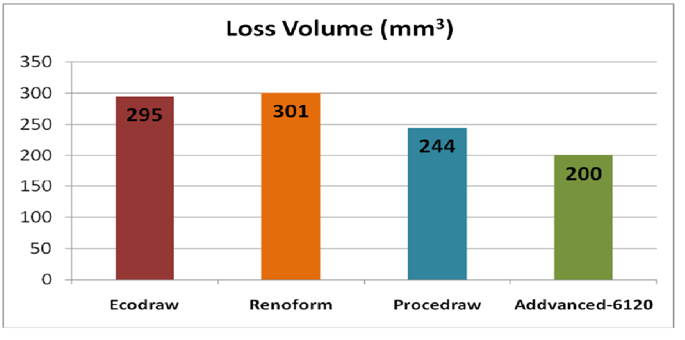

Fig. 14. Wear results [L. 4]
Rys. 14. Wyniki zużycia **[L. 4]**

In the case of the coefficient of friction, the reduction was 61% and in the case of wear was reduced by 32% over the currently used lubricant.

CONCLUSION

Using the proposed methodology is a reliable way to help reduce costs and METALSA stoppages in the production line to test new lubricants, since it is simpler and does not run the risk of damaging the tooling and production parts.

Using this methodology, we were able to find a lubricant with better performance than currently used. Evaluations made using the T-02 machine were fast and helped to determine the best lubricants proposed by METALSA and the University of Monterrey.

The T-05 machine helped to simulate the folding process of METALSA, taking into account the operating conditions. This process concluded that the results of the T-02 were consistent with those produced by the T-05.

It was found that the best lubricant was Addvanced-6120 with a 32 percent reduction of attrition as compared to the current lubricant and also showed a decrease of 61 percent in the coefficient of friction. This reduction means lower energy consumption in the process and creates a smaller carbon footprint, which benefits the environment.

RECOMMENDATIONS

We suggest periodical evaluation of the lubricants currently used in other METALSA processes and future proposals following this methodology.

There should also be pilot testing where a proposed lubricant is applied to test results.

It is also recommended to determine if the cost-benefit of the Addvanced-6120 lubricant is suitable for stamping processes of the company.

Invitation to assess the lubricant Addvanced-6120 is environmentally friendly allowing greater environmental responsibility.

REFERENCES

1. AERI Metalsa-UDEM, 2010
2. D. Maldonado, Influence of Test Equipment and Working Conditions on the Coefficient of Friction Values, Cracow University of Technology, PHd, Thesis June 2010.
3. Szczerek, Marian, Metodologiczne Problemy Systematyzacji Eksperymentalnych Bandán Tribologicznych; ITeE, 1997, pp. 10.
4. D. Maldonado, L, Trejo, D. Molina, J. Treviño, PPD UDEM Otoño 2010.
5. Remigiusz Michalczewski, Witold Piekoszewski, Waldemar Tuszynski, Marian Szczerek and Jan Wulczynski, TRIBOLOGY – LUBRICANTS AND LUBRICATION, Chapter 13.

Reviewer:
Marian SZCZEREK

Streszczenie

Przedstawiono wyniki badań tribologicznych środków smarowych obecnie stosowanych w firmie METALSA i zaproponowanych do stosowania przez Uniwersytet w Monterrey. Środki te wykorzystywane sa w procesie wytwarzania podwozi samochodowych.

W firmie METALSA obecnie stosuje się wiele środków smarowych w zależności od prowadzonego procesu wytwórczego. Ponadto dostawcy corocznie polecają wiele nowych substancji smarowych mających zwiększyć wydajność.

Niestety u wytwórcy jest wręcz niemożliwe zbadanie jakości nowego produktu. Jeśli jakość produktu jest poniżej potrzeb, może to wpływać negatywnie na trwałość narzędzi i jakość wytwarzanych detali. Może to także skutkować wydłużeniem czasu produkcji i spowodować straty sięgające tysięcy niezdatnych detali i spowodować uszkodzenie drogiego narzędzia.

Bazując na powyższych przesłankach, opracowano i zweryfikowano metodę testowania środków smarowych wykorzystywanych w obróbce mechanicznej arkuszy blach stalowych. Dzięi opracowanej metodzie możliwy jest wybór wysokiej jakości środka smarowego bez przerw w produkcji i ryzyka związanego z wybrakowaniem wytwarzanych detali bądź stosowanych narzędzi. Metoda realizowana jest z wykorzystaniem stanowisk badawczych: czterokulowego o symbolu T-02 i rolka–klocek oznaczonego T-05.

Z wykorzystywaniem stanowisk badawczych uzyskuje się wyniki, które następnie podlegają wyjaśnianiu. Dla przykładu, z wykorzystaniem stanowiska T-05 uzyskuje się wyniki w postaci śladu tarcia, współczynnika tarcia i zużycia objętościowego. Wyniki te są pomocne przy podejmowaniu decyzji o wyborze środka smarowego do dalszych badań.