Anticorit Prelube oils for sheet metal forming

Lubricity joined to corrosion protection for steel mill and automotive press shop application

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SUMMARY

The pressing of car body parts is one of the most important sheet metal drawing processes. The corrosion protection oil applied by the steel mills plays a part in every sheet metal forming operation and also makes up the largest proportion of lubricants used. The idea to combine the corrosion protection properties of a corrosion preventive oil with the lubricity of a drawing oil lead to the development of the Anticorit prelubes. Applied at the finishing lines of the steel mills, they finally serve as lubricant in the press shops. A prerequisite for the suitability of a prelube-type oil is the absolute compatibility with all single processes from the coil to the Body in White. The use of prelubes in steel mills reduces the number and quantity of spot lubricants for additional press shop oiling dramatically. But their true benefits can only be fully achieved if the compatibility principle is applied throughout the manufacturing chain. Therefore, modern prelubes systems are modular, even different viscosities can be part of the same concept. This results in a far-reaching multi-functionality of the Anticorit prelube system for all applications.

1. INTRODUCTION

Although prelubes have existed in America for more than 20 years, they were only introduced in Europe in the early 90's. Meanwhile, they have been adapted to European requirements. Due to their excellent performance in lubricity and corrosion protection, prelubes are fully established in the European market. Car makers appreciate in particular the compatibility with the entire manufacturing process.

2. FROM SHEET METAL TO BODY-IN-WHITE

The typical part transfer sequence from the sheet metal to the body-in-white is described in fig. 2.1. At every stage where oil is applied to the metal surface a full compatibility with up-stream and down-stream processes is necessary for a high production reliability at minimum overall costs. The single steps of production are discussed in the special chapters below.

All relevant requirements of a mill-applied lubricant are described in the standard VDA 230-201 "Prelubes" of the Association of German Automobile Manufacturers (VDA) [2]. Important properties are defined, the test procedures are reported on. The results – with exception of lubricity – are compared with the standard corrosion preventive oil Anticorit RP 4107 S. According to these VDA requirements a Prelube needs to be thixotropic for a reduced run-off and is applicable by electrostatic spraying. Of course it should protect the sheet metal against corrosion as effective as the standard oil. Precipitation or other chemical reactions must not occur

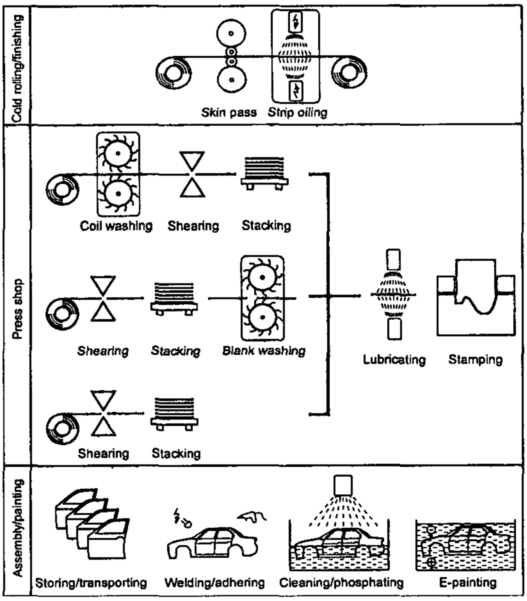

Fig. 2.1: Process line [1]

when mixed with the standard oil. Furthermore, the Prelube should be compatible with cataphoretic paint and adhesives used in the assembly line. Eventually, the Prelube has to be easily removable with industrial cleaners in the pre-conditioning zone prior to phosphating and e-painting [3].

3. SKIN PASSING

To achieve the desired quality, the final surface finish of sheet steel is often rolled-on wet. Water-based solutions are normally used for plain cold rolled steel but low-viscosity oils are used for zinc-coated sheet, electro-galvanized or hot dip galvanized. As a result of the increasing use of coated sheet steel in recent years, the compatibility of skin-pass oils is becoming an increasingly important factor.

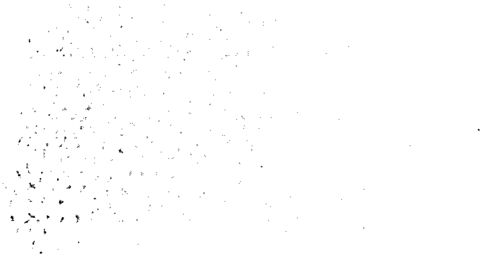

Fig. 3.1: Non-compatible skin-pass/mill oil system

If the skin-pass and the subsequently-applied corrosion protection oil or Prelube are not compatible, the oil film can rapidly separate in spite of having been evenly applied. Fig. 3.1 illustrates this phenomenon with two uncompatible oils whereby the higher-viscosity corrosion preventive or Prelube was sprayed on top of the skin-pass oil wetted surface. The formation of dry islands is detrimental to the tribological system and can cause tearing or oil dents.

4. COIL OILING

A prerequisite for the oil being used by steel mills, is that it can be applied easily. The most common method these days is electrostatic spraying. The optimum spraying temperature has been shown to be 50 - 60 °C while the voltage, depending on the equipment itself, is between 80 and 120 kV. Oils with a viscosity of 30 - 60 mm^2/s at 40 °C spray easily. The full solubility of the thixotropic agents at the spray temperature is a prerequisite for an optimum spray pattern and a low film thickness. On the other hand, the oil may have to be very finely filtered to remove any impurities in return circuits.

5. TRANSPORT AND STORAGE

The principal objective of oiling coils and stacks in steel mills is, similarly to that of Prelubes, to reliably protect against corrosion during transport and storage. Fundamentally, temporary corrosion preventives combine a barrier effect with specific inhibitors. The specific adsorption layer is extremely thin. The effect of inhibitors diminishes rapidly the further they are away from the metal surface. On the other hand, the barrier effect of the oil depends largely on the thickness of the film. Thixotropic oils counter the loss of barrier protection by retarding run-off. The stable film helps maintain the original level of protection. As this level of protection cannot be achieved with conventional formulations, all of today's Prelubes are thixotropic. The retarded run-off characteristics also prevent the soiling of press shop floors with oil as well as build-up of oil in swage beads and cavities which may cause problems with adhesive bondings or paint blisters during curing.

6. WASHING OF STEEL STRIPS AND BLANKS

Automobile outer body panels often have to be washed because of cleanliness requirements. Advantages, however, are uniform oil film thickness, less die contamination and therefore low die wear. As washing, particularly stack washing, does not generate high costs when compared to the overall manufacturing process, it is economically acceptable.

Compared to plants in the Far East where solvent-based systems are often used, European plants mostly use low-viscosity oils. Washing machines do not fully remove the oil from the panels. About half of the oil is washed-off and this is squeezed off with rubber rollers. The amount of oil remaining on the metal is primarily influenced by the viscosity of the oil and plant-specific parameters such as feed velocity and the number, diameter, material and pressure of the rollers. The residual oil film thickness after blank washing operation with various fluid systems is shown in fig. 6.1. The oil film after squeezing by the fleece rollers increases as the oil viscosity rises. Systems of lower lubricity might require additional drawing oils. [4]

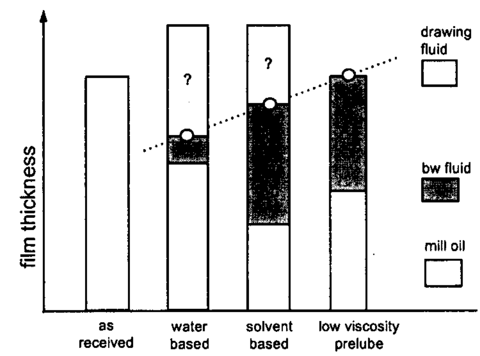

Fig. 6.1: Residual oil film after blank wash

As the mill oil removed from the coil surface mixes up with the washing oil and influences its properties increasingly, the washing oil has to be monitored: More than 50% of dragged-in mill oil can be found after several months of the washer's operating time (fig. 6.2). It is, therefore, advantageous to choose prelube-type mill oils for outer skin car body parts even if the panels are to be washed prior to stamping.

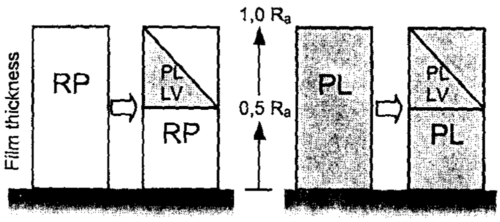

Fig. 6.2: Washing of strips with rust preventive oil (RP) and prelube (PL) in comparison

Washing oils have to fulfill similar requirements to the mill-applied Prelubes because they are viewed as lubricants by the press shops. Apart from offering adequate pressing lubrication, they should be easy to remove, compatible with adhesives and paints and supplement the corrosion protection offered by the underlying oil. As all washing oils obviously settle on top of the mill applied oil layer and are thus relatively far from the metal surface, they endanger to run off extensively. For these oils to have thixotropic properties is therefore a significant advantage.

7. ADDITIONAL LUBRICATION

The higher viscosity drawing lubricants applied in press shops lose out when Prelubes are applied Ultimately, they will become unnecessary if the lubricity of the mill applied oil on the panels is adequate. In fact, some enormous savings could be realized. Long-term plant trials which were exactly documented were evaluated. The savings resulting from the elimination of the drawing lubricant itself were only a part of the overall savings potential. The bottom line is improved by additional effects such as lower disposal costs and more stable manufacturing parameters. If, in spite of the Prelube, difficult deep drawing still requires the use of additional spot lubricants at critical points, these must be process-compatible. As such spot lubricants are again applied on top of the other oil layers, a thixotropic formulation is also advisable to avoid run-off.

8. PRESSING

The central manufacturing process is that which occurs during pressing. The extremely high investment and running costs of advanced, multistage presses make it essential that the pressing operation is consistent and reliable. Rejects caused by tears, dents or poor dimensional conformity, but also die cleaning, grinding or setting time can soon generate high costs. The large performance reserves offered by Prelubes and the Prelube-compatible washing oils used for outer skin panels can provide decisive benefits.

Various methods are used to evaluate the deep drawing performance of lubricants. The most common is the strip drawing test which is performed with and without deflection. This method simulates the conditions found under the blank holder and during the flow of material into the die. Fig. 8.1 illustrates the principle. A strip of metal is drawn between two flat dies. The drawing force required is measured against the normal force to determine the coefficient of friction. In addition, the time is also recorded. The most important measuring parameters are tool and material dimensions, drawing speed and the maximum drawing force applicable. Apart from the coefficient of friction, the uniformity of the force-time frame is an important criteria for evaluating the tribosystem. Ideally, the material flow between the tool is uniform and free of stick-slip. Finally, the maximum normal force possible until the strip jams is a measure of a lubricant's ability to separate the sheet and the tool under pressure. Evaluation of such data allows lubricants to be developed which are ideal for metal forming operations. Fig. 8.1 shows the strip testing equipment used by the Institute for Production and Forming Technology of the University of Darmstadt/ Germany which allowed tribological systems to be examined with large tool dimensions, variable drawing speeds and very high normal contact pressures. The various stations are de-coiling, cleaning and oiling and tools with sensors to measure forces. Finally, the strip metal is coiled again.

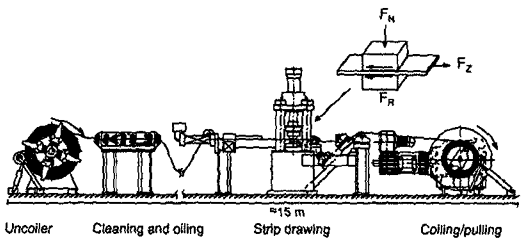

Fig. 8.1: Strip-drawing tester and tools [5], [6]

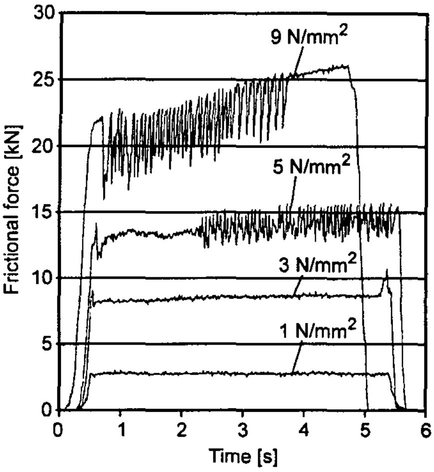

Fig. 8.2: Frictional force vs. time with load as parameter, mill oil/uncoated sheet metal/50 mm/s

Fig. 8.2 shows the results obtained from uncoated cold-rolled steel. The strip drawing test without deflection is reported on at all times. The lubricant is a mill-applied corrosion prevention oil. The forces measured are recorded against time. According to the friction law the frictional force increases with higher loads. From 5 N/mm² onwards stick-slip occurs. The coefficient of friction as a function of the load is outlined in fig. 8.3 where the drawing speed is varied. The coefficient of friction falls with increasing speed. The begin of stick-slip is marked. The curves end with the maximum load, when the strip jams and further drawing would cause the metal to tear.

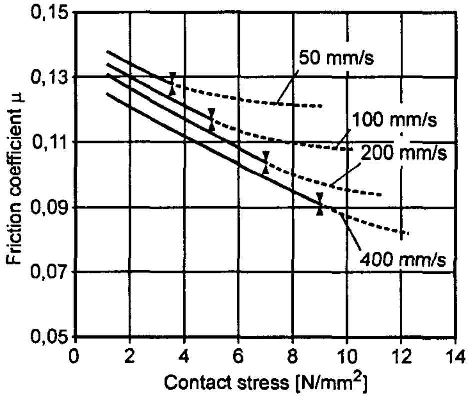

Fig. 8.3: Friction coefficient vs. load with sliding velocity as parameter, mill oil/uncoated sheet metal

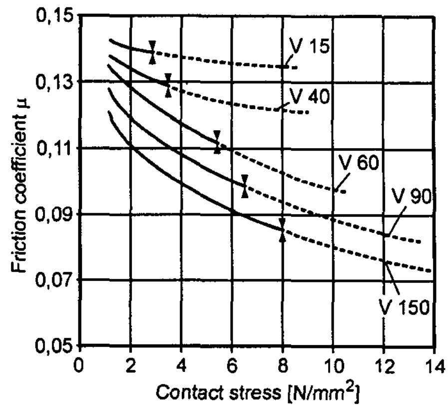

Fig. 8.4: Friction coefficient vs. load with oil viscosity as parameter, mill oil/uncoated sheet metal/50 mm/s

As a rule lubricants with a higher viscosity have a better lubricity. To distinguish the effect due to pure rheology from that caused by additives some lubricants with identical formula but with differing viscosities are tested. The result is shown in fig. 8.4 with a corrosion preventive oil as example. The viscosity is chosen between 15 and 150 mm²/s at 40°C to cover the most common applications from blank washing to drawing oils applied by spraying.

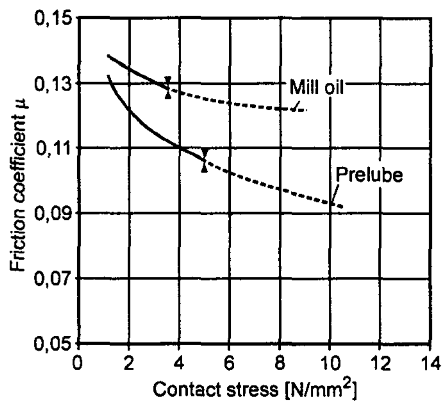

Fig. 8.5: Friction coefficient vs. load with type of oil as parameter, uncoated sheet metal/ 50 mm/s

Fig. 8.5 illustrates the advantage of a Prelube-type oil in comparison to a corrosion preventive mill oil on uncoated steel strip. Considerably lower friction combined with a smooth flow of material up to higher loads is achieved when the Prelube is applied. Since cold rolled steel strip for car bodies is to an increasing extent zinc-coated, the Prelube needs to be as versatile as possible with regard to various metal coatings such as electro-galvanized, hot-dip galvanized, galvannealed or pre-phosphated sheet metal surface. Different lubricants do not necessarily display similar behaviour on all coatings.

An example is given in fig. 8.6 where two Prelubes are compared on different substrates. While the performance of both lubricants on uncoated sheet metal is quite similar, the coefficients of friction differ dramatically on zinc-plated steel.

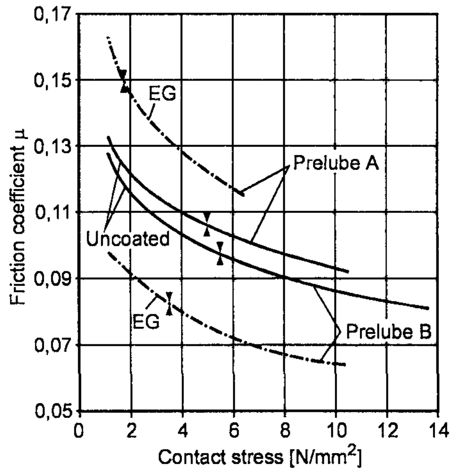

Fig. 8.6: Friction coefficient vs. load with type of Prelube and surface coating as parameter, 50 mm/s

9. TRANSPORT AND STORAGE OF PRESSED PARTS

As a rule, pressed panels do not enter the manufacturing process immediately but are stored for a period of time. In-house storage does not pose any particular demands on the corrosion protection oil used. However, if the pressed panels have to be transported to other plants, overseas, through or into tropical regions, particularly high performance concepts have to be used. A high-performance, thixotropic Prelube can make special transport protection oils unnecessary if it is combined with an intelligent packing concept and vapour phase inhibitors (VCI) [7]. The use of run-off-retarding products throughout the manufacturing process is especially worthwhile in the post-pressing stages because oil no longer runs-off during transport and storage. This feature is emphasized by the lower film thicknesses of Prelubes and Prelube-type low-viscosity washing oils.

10. WELDING AND BONDING

Welding is not influenced by today's corrosion protection oils and pressing lubricants and therefore poses no particular requirements. However, this does not apply to the bonding processes used in body building because of the substitution of an increasing number of spot welds by adhesives and the increasing demands on the durability of such bonded joints. Of importance is the strength of the joint - up to its breaking point - but also its corrosion protection and its sealing properties. As oiled panels are bonded, the type and quantity of the oil, physical surface characteristics of the metal and naturally, the type and thickness of the adhesive effect the bonding result. As the automobile manufacturers use a number of different adhesives in their plants for different purposes and all combinations of metals, adhesives and application methods have to be compatible, the corresponding testing procedures are enormous. The formulation of a mill-applied Prelube which has displayed optimum compatibility cannot be constantly adjusted to suit new adhesives, not least because it may be used by a large number of companies. As described, non-thixotropic or extremely over-applied oils can run-off pressed panels and collect in beads and swages. In spite of originally positive compatibility tests, this can lead to poor bonding if the oil bead is too thick. Here again, the specification of run-off-retarding Prelubes but also thixotropic washing and drawing oils can eliminate such problems.

11. CLEANING AND PHOSPHATING

Oil which is trapped in cavities is difficult to remove with the normal treatment processes. Usually, the cleaner spray does not reach these points. Dip cleaners offer better performance with regard to removing oil from these inaccessible points but they foam excessively when sprayed. In spite of the use of spray and sprayed dip cleaners, components must be degreasable by simple dipping to remove the oil trapped in cavities. The oil must be easily removed from all surface qualities even after long-term storage or temperature induced ageing during the pre-curing of body adhesives.

12. CATAPHORETIC PAINTING

Even though Prelubes offer outstanding removability, the drag-in of small quantities into the electrophoretic paint bath is unavoidable. The potential harm caused by such contamination can be lessened to a certain extent by special additives in the paint tank. The danger of serious, i.e. visible markings in top coats is best minimized by the use of the most compatible oils. A wide variety of contamination tests are performed to establish an oil's compatibility with electro-deposited paints.. Small quantities of oil are usually emulsified in a paint bath. After drying, the size and number of craters in the cured paint film are evaluated. Excessive quantities of oil in beads, swages and other cavities resulting from run-off can also be expelled when trapped water and cleaners are boiled off in paint drying ovens. If the oil-water mixture is spat onto wet and sensitive paint, serious paint irregularities can occur. In the laboratory, this effect is simulated by the oil spray or Blow-out test. As opposed to the contamination tests, the results however cannot be quantified with figures but only by a relative evaluation.

13. SAVINGS POTENTIAL AND OUTLOOK

The use of Prelubes in steel mills reduces the number and quantity of spot lubricants required for pressing operations. The savings potential of Prelubes is not just the result of one less lubricant required. The true benefits are only available if the compatibility principle is applied throughout the manufacturing chain, beginning in the steel mill and up to the paint shop. It is therefore hardly worthwhile using a highly specialized product for every application at the cost of subsequent manufacturing stages. It is much more important to optimize all the manufacturing stages together. A suitable Prelube offers the potential, but the biggest savings result from a more rational overall manufacturing concept. This would result in a far-reaching multifunctionality for the corrosion preventives and lubricants used for different applications, i.e. specific characteristics under the umbrella of overall compatibility. Anticorit prelubes from Fuchs are therefore modular so that even different viscosities can be part of the same concept.

Since their introduction, thixotropic, run-off retarding oils have outperformed conventional oils. It remains to be seen if Dry Film Lubricants offer additional advantages.

Further detailed reading in [8].

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