High Temperature Test Device for Targeted Lubricant, Coating and Work Roll Material Evaluation Applied in Hot Rolling – Tribotherm

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In hot rolling of steel the applied tools face a continuous wear due to thermal and mechanical work load. Depending on the addressed product (strip or profile) and deformation step in the process line (roughing or finishing stands) this load varies in contact time and material flow due to reduction rates and elongation. During the last decades different work roll materials were developed to fulfill these demands. Additionally, lubricants and wear protective coatings contribute to this task in order to decrease production costs and increase product quality. BFI has developed a high temperature testing device, Tribotherm, to enable a targeted pre-selection of potential work roll material, lubricant or wear protective coating. This test plant rotates two cylinders independently against each other with defined and adjustable slip, rolling speed and pressure. One cylinder, representing the product material, can be inductively heated until 1000 °C, while lubricant and cooling can be applied as well. Wear rates (wear profile, gravimetric), topography and torque can be controlled and evaluated. The main aim is to evaluate promising tools to be implemented in the industrial process. A qualitative comparison of different techniques allows to identify the most effective combinations. The Tribotherm plant has been continuously improved in several research projects and first results have been already transferred successfully into industrial practice.

Keywords: *hot rolling, lubricant, coating, wear, friction, cooling.*

1. INTRODUCTION AND MAIN AIMS

The demands for tools applied in hot rolling or hot deformation are high. The operating conditions due to thermal and mechanical stress during deformation operation cause material destruction. To guarantee the requested product surface quality rolls have to be exchanged and overworked regularly. Even smaller cracks in the surface are leading to undesired surface imprints, affecting surface quality aspects. If cracks become bigger, a complete fracture of the roll might occur. Plant downtime and complete replacement of rolls is resulting. During the last decades, especially improved material grades for hot flat rolling have been developed. Latest milestone was the introduction of high chrome and high speed steels (HSS) [1,2]. Besides that, lubricants were applied to decrease wear rates, to contribute to the process abatement and to reduce the rolling force [3,4]. To decrease the thermal impact and establishing optimal thermal crown, intensive and targeted work roll cooling is applied [5]. Additionally, different type of wear protective coatings have been developed and tested to increase service capability and reduce tool costs [6]. Coatings can be applied on a cheaper basis casting grades to reduce the tool costs in general.

To reduce the risk and costs for development and first industrial application most accurate and representative tests procedures and devices are requested to enable a pre-testing and pre-selection of most suitable and promising technologies. Especially in hot deformation, there is a lack of available test devices for screening of new materials, lubricants, coatings under varying process conditions. Therefore BFI has developed a variable test plant – Tribotherm, for the targeted examination of promising products and materials to close this gap.

2. TRIBOTHERM TEST DEVICE DEVELOPMENT AND PRACTICAL TESTING

A first approach of the hot test plant was generated in 2010. One drive with torque measurement was used for the rotation of bottom and top cylinder which were connected with cogged wheel to generate a fixed defined slip (Fig. 1).

After a certain running time wear occurred on the teeth, which leads to inaccuracies in slip and vibrations, affecting the torque measurement. Therefore a new improved setup was planned and realized within the last year (Fig. 2).

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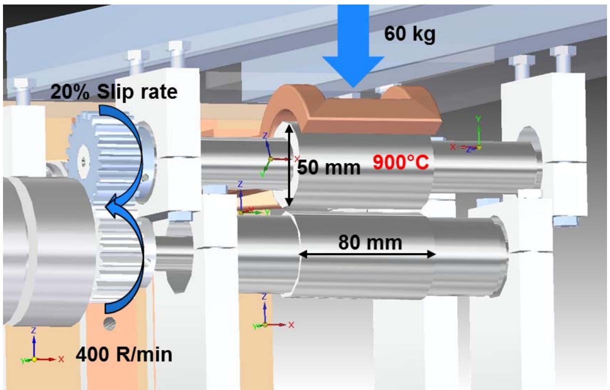

Figure 1. Original Tribotherm test plant setup

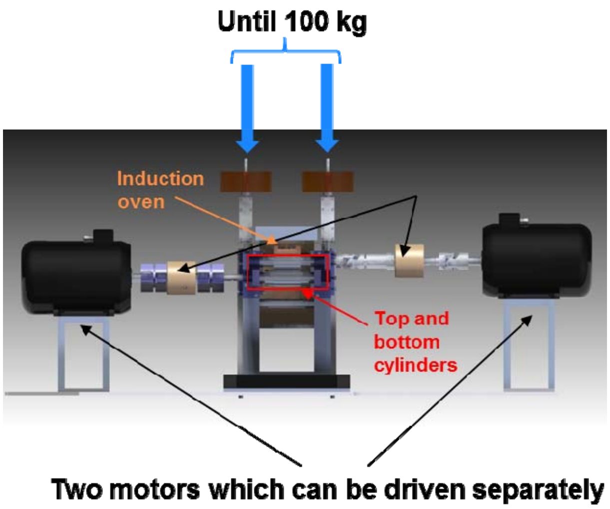

Figure 2. Revised Tribotherm test plant

Two independent drives and torque measurements for bottom and top cylinder were the main change regarding the former construction. Additionally, varying force to increase the Hertzian pressure up to 100 kg can be realized.

Improved housing and cooling of shaft drives and measurement units contributes to save and reliable experimental conditions for several hours. The capacity of the inductive unit was improved reaching a temperature level of heated cylinder up to max 1000 °C (Fig. 3).

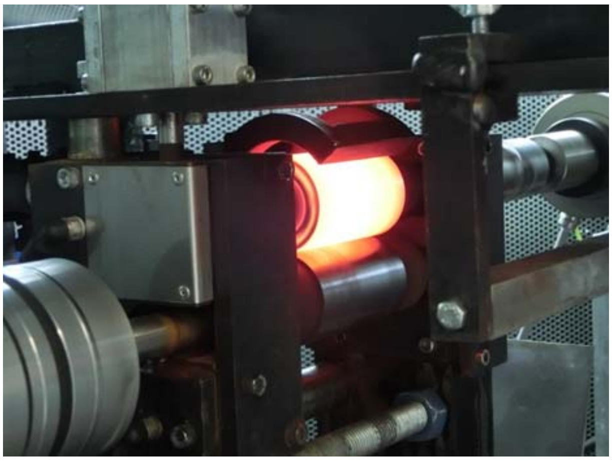

Figure 3. Revised Tribotherm test plant

After the setup, first calibration experiments have been performed to adjust and improve the control of the independent drives to generate stable and flexible slip. The slip represents relative speed between material and tool during deformation, which leads to mechanical wear between the contact partners. Furthermore, thermal effects, cooling and logging of relevant data had to be studied and used for establishing representative and reliable conditions. In Figure 4, the effect a water injection into the roll bite at 300 rounds per minute (rpm), without slip and 900 °C (900 °C maximum and 820 °C during spraying due to a cooling effect) can be seen.

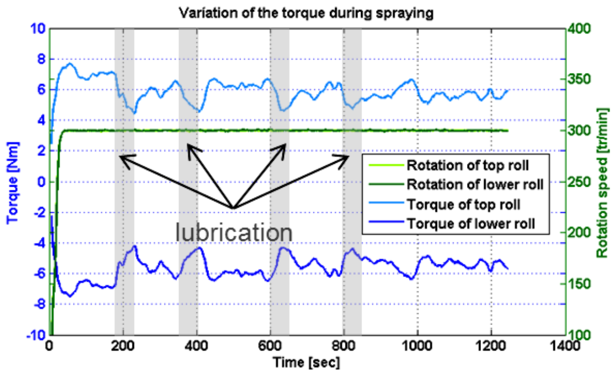

Figure 4. Torque measurements during application of water (indicated in grey as lubrication)

After reaching stable conditions water injection was switched on and generated a water film between the rotating cylinders. The result is a decrease of torque of 20 – 30 %. As the rotation is opposed, also the measured torques values are mirror-inverted. The behavior is equal, with slightly decreasing tendency of torque which could be connected to the heating effect on the torques measurement unit or due to scale on the roll surface which is removed during the test.

Following experiments were focused on the effect generated by the application of lubricants as oil in water emulsion (o/w-emulsion) of about 2 %. At 300 rpm and without slip initial torque values are higher due to the fact of increased surface roughness of applied cylinder (Fig. 5) as the cylinder already being applied in the former experiments. The lubrication effect can be seen clearly by the significant torque reduction. Almost 50 % torque reduction was generated in this experimental campaign. Again the decrease of general torque level was observed during the experimental campaign.

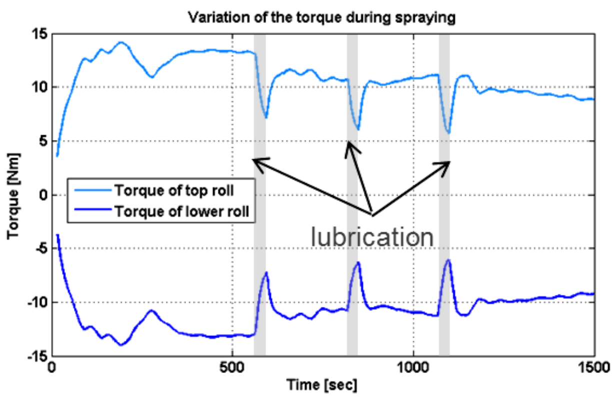

Figure 5. Torque measurements during application of o/w-emulsion

Temperature effects cannot be fully excluded but intensified cooling of bearings and the shaft softens this torque measurement disturbance. Additionally, this temperature effect is logged as well and temperature compensation can be calculated.

Finally, the introduction of defined slip was tested. In Figure 6 the difference of roll speed is indicated by the green lines.

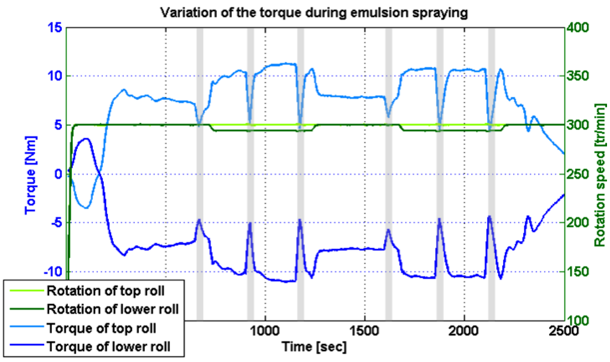

Figure 6. Torque measurements for lubricant application (grey) and 2 % slip

The decrease of the lower cylinder speed of about 2 % from 300 to 294 rpm leads to an increase of torque on both cylinders.

After activation of lubrication a significant torque drop over 50 % can be observed. After switching off lubrication and slip, former torque level has been reached and the next experiment with 2 % slip and lubrication starts.

The plant delivers representative values within one campaign to compare different effects.

The plant is now in the conditions for representative experiments to test lubricants, coatings or wear resistant materials.

3. SELECTED RESULTS

In different ongoing research projects the targeted evaluation of lubricants und coatings have been performed to contribute to the pre-choice of most promising products and techniques for industrial trials. Two examples for the test procedure performed with the Tribotherm test plant to describe the way of pre-evaluation will be given in the following.

In Figure 7 the screening of lubrication effect for different concentrations at constant flow rate is shown. Mean values have been generated from the complete campaign and compared with a second campaign (1st and 2nd) pass.

A higher fluctuation was observed for the tests without slip but with increasing slip the stability increases. It can be stated that torque decrease is higher for increasing slip and that higher concentration leads to lower friction as well. Saturation can be assumed as the difference between 1 and 2 % is not as high as it was expected. Anyway, the reproducibility is, for a tribological test, already high and allows the fixing of suitable concentration levels for selected material combination (work roll and product material). Furthermore, the qualitative comparison of lubricants against each other by targeted variation of concentration, application (roll, roll bite, hot cylinder) and process parameters (speed, Hertzian pressure, slip) is possible. Best configurations and lubricants can be pre-selected and used for industrial testing. The transferability of these results to industrial reality has been proven with the original Tribotherm test plant by pilot hot rolling and industrial trials.

Another example is the testing of wear protective coating on chosen substrates. Applied unheated cylinder is drilled and polished to the desired surface state and coated with the selected coating. In this case a chemical dispersion layer was examined on spheroidal cast and tool steel 1.2343 compared to the uncoated cylinders (Fig. 8). The experimental setup parameters were at 300 rpm, 20 % slip, 860 – 930 °C and 60 kg total load at 4 h trial duration under continuous cooling of coated cylinders.

Only the gravimetric loss of material was examined compared to an uncoated reference cylinder. It can be clearly seen that the effect on the tool steel with coating showed a decreased wear rate of 80 %. For the cast sample the wear tendency is already significantly lower but for coated roll still 25 % less wear was observed. Additionally, surface examination and cross-section analyses are possible to give detailed information about the surface state, roughness increase and remaining coating behavior. In this selected case wear rates were significantly decreased by the coating, while thickness of the coating layer was reduced but still intact.

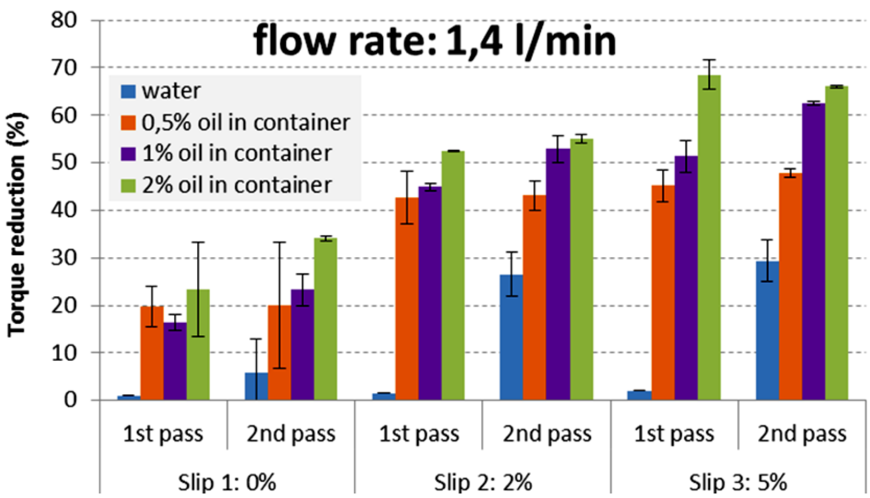

Figure 7. Torque reduction measurements for constant flow rate of different concentration of the oil in the emulsion applied in hot rolling

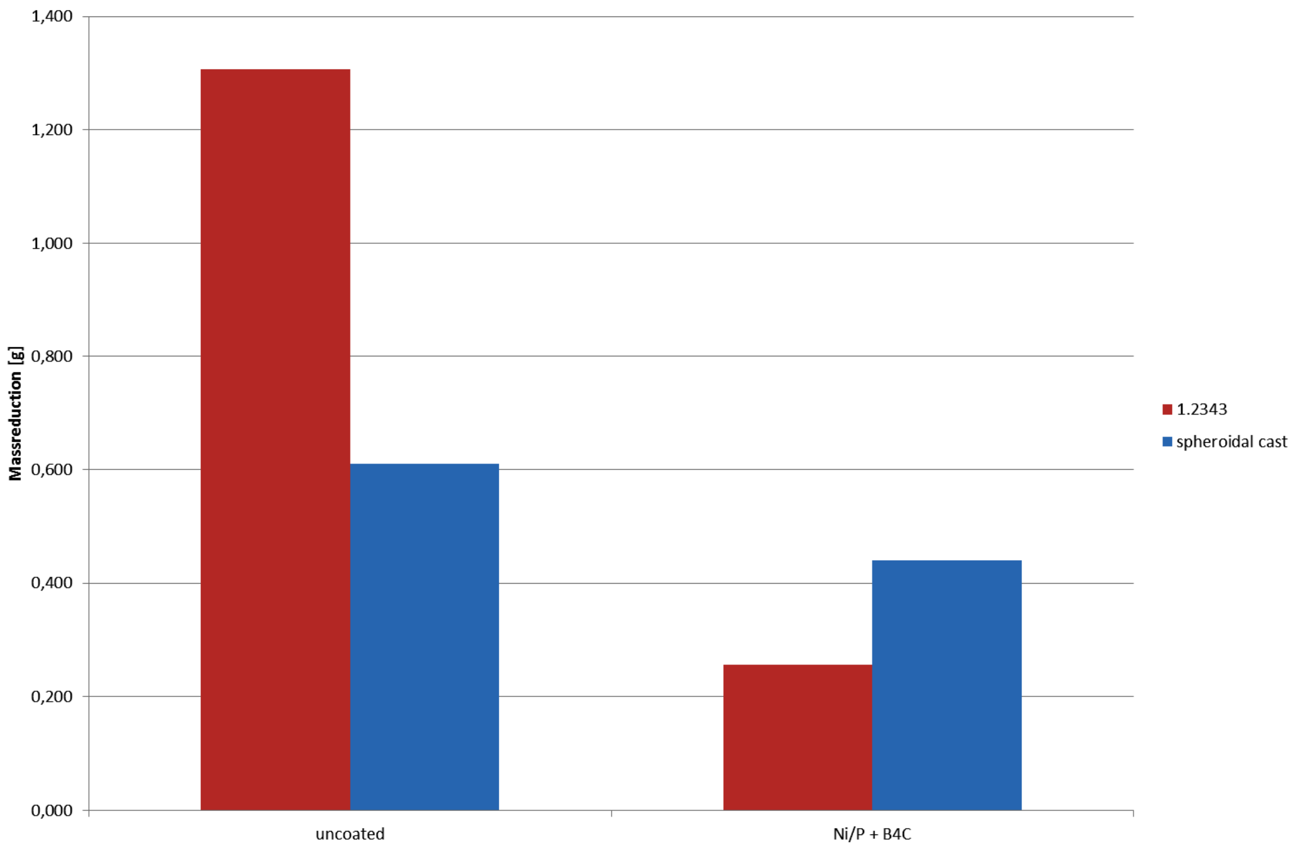

Figure 8. Mass loss uncoated tool and spheroidal cast steel and coated with chemical dispersion layer

For the wear protective coatings the transferability to the industrial process has also been proved in selected pilot and industrial trials.

4. CONCLUSION

From the described examples it can be stated that the Tribotherm test plant is running on stable and representative conditions, which allows the targeted comparison of different settings (rolling speed, Hertzian pressure, temperature, slip, lubricant application, selected material pairs) for lubricants, coating and roll materials. Most promising setups and techniques can be pre-selected to minimize total amount of industrial trials and risk of failures.

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ТЕСТ УРЕЂАЈ ЗА ИСПИТИВАЊЕ НА ВИСОКИМ ТЕМПЕРАТУРАМА МАЗИВА, ПРЕВЛАКА И МАТЕРИЈАЛА ВАЉАКА КОЈИ СЕ ПРИМЕЊУЈУ КОД ОБРАДЕ ТОПЛИМ ВАЉАЊЕМ - *TRIBOTHERM*

Тило Рајхард, Делфине Рехе, Миријам Зартор

Алати који се примењују при топлом ваљању челика су константно изложени хабању услед присутних термичких и механичких оптерећења. Ова оптерећења варирају у зависности од времена трајања обраде, односно степена деформације материјала обрадка, а на њих утичу облик крајњег производа (трака или профил) и корак у обрадном процесу (груба или завршна обрада). Да би се смањила оштећења услед хабања, током последњих деценија су развијени различити материјали за израду ваљака. На смањење ових оштећења, а самим тим и на смањење трошкова производње и повећање квалитета производа, утичу и примена одговарајућих мазива, односно заштитних превлака на ваљцима. Компанија *BFI* је развила тест уређај за испитивање на високим температурама „Tribotherm“ помоћу кога је могућ избор одговарајућих материјала за израду ваљака, односно заштитних превлака на ваљцима и мазива. Принцип рада се састоји од два независно покретана ротирајућа цилиндра у контакту, којима је могуће да се дефинише и подешава степен проклизавања, брзина ротирања и контактно оптерећење. Један од цилиндара представља материјал обрадка и он може индукционо да се загрева до 1000 °C, уз могућност подмазивања и хлађења. Интензитет хабања (мерен преко промене профила похабане површине или преко промене масе), топографија и обртни момент могу да се прате и одређују. Главни циљ овог рада је приказ могућности уређаја у циљу његове имплементације у индустријску производњу. Квалитативним поређењем различитих решења је могуће да се одреди најефикаснија комбинација материјала и радних услова. Сам уређај „Tribotherm“ је континуирано побољшаван кроз неколико истраживачких пројеката, а први резултати су већ успешно примењени у индустријској пракси.