NON-SUITABLE DEVICE TECHNICAL STATE REPLACEMENT RESULTS MAINTENANCE APPROACH

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Abstract

Paper presents the methodology of maintaining dependability of devices used in process with use particular scheduled methods of maintenance. Presented in paper methods are dedicated for particular area and included there machines, devices, auxiliary system or tools. Presented in paper selected method and area are connected and have influence for each other. Methods are combination of operators experience, recommendation of production line supplier and engineers approach. Selected areas enfold both, operating and maintenance issues. From production process point of view, operating area which is mostly focused on steering of the process and maintenance area which is mostly focused on maintaining dependability of included into process machines and devices on satisfy level, should be treated with the same importance. Situation whit taking care about operational issues and forgetting about maintenance issues can work out only for very short time. Opposite situation is not possible to imagine. Operational area and maintenance area are interconnected and can be beneficial only in cooperation. Another problem connected with that is peoples' understanding, they have to accept that their jobs in their areas can be profitable with strongly and proper cooperation with jobs and positive attitude of people from other area. Production process consist from operation and maintenance area as well and only with this approach can be profitable for owners and all employees. Presented in paper methods touches both operational and maintenance areas as well. Paper is summarizing by results of experiment coming from practice.

Keywords: *dependability, safety, monitoring, availability, production process, synergy effect*

1. Introduction

Problems in production enterprises are very various. Companies have different resources and meet every day different situations. These situations can be a reason of problems or opportunities. One of the most expensive problems is low productive time due to unexpected delays. In addition, unexpected delays appearing usually due to failures of tools and devices included into production process. Very often it happens because of low level of dependability of particular part. How to keep dependability of devices and tools included into production process on requested level? Good question from financial department to process engineers. Process engineers use their knowledge and experience to not only keep these values on requested level, but also for improving key performance indicators, achieve better results and increase value of dependability of whole process.

This paper presents activities helpful in maintain level of selected devices and tools on satisfy level. Described procedures concern one particular production process, but proposed approach is universal and should be implemented in others kinds of industry and transportation systems as well.

The dependability of devices under operation has been discussed in several publications, for example [6-8, 10, 11]. Paper presents the methodology of maintain dependability of devices used in process with special dedicated methods. Presented methods base on professional experience and were proven many times in real life during production time.

2. Dependability of devices and tools included into production process

Maintaining dependability of devices on requested level in production process is very complex. Usually production process is complex and complicated itself. Covers number of operations simultaneously perform on many devices in the same time. To achieve satisfy level of dependability in process apprehension operators must take care about every single device with special attention. This approach is based on real state of the devices and represents preventive maintenance and will be presented on the example.

Production process of wire rod seems to be very good to present some methods of proper behavior both in maintenance and operational areas. Final linear speed of rolling Ø 5.5 [mm] rod is about 100 [m/s], what for better understanding is equal 360 [km/h]. This speed we can meet in formula 1 race, we can imagine that to provide proper dependability of devices in this rolling process, all involved people must take care about their duties as well as mechanics in pit stop during the F1 Grand Prix race.

Process dependability can be presented as the set of dependability of particular devices involved into production. In this set we can find number of different devices, auxiliary systems and tool's state. From obvious reasons not all of them can be presented. For this paper were selected five groups of activities:

- control of clearance, provided for pinions shafts of rolling stands and pinch rolls,
- control of vibrations, provided for mill sections, gear boxes, switch boxes, laying heads and motors,
- control of surface and geometry, provided for tapered sleeves,
- control of surface and geometry, provided for Tungsten Carbide rings,
- control of assembly and work environment, provided for rolling guides.

2.1. Control of clearance

In nowadays fast rolling process we can find different configurations of devices. Configurations are projected and implemented according client's needs. Details depends on requested assortment of production, from both diameters and grades points of view. But beside these differences some behaviours and instructions must be common. To keep dependability of process on satisfy level, majority of maintenance jobs must be done in the same or very similar way. Presented in this article examples are activities included in maintenance obligation every where we can find fast rolling process.

How important is control of clearance we can imagine if we recalculate linear speed for RPM (revolutions per minute), with 100 [m/s] linear speed and usual diameter of carbide ring we can achieve more than 12000 [RPM]. Method of measurement is not complicated; important is to do it always in the same way and to do it periodically. Only then we can see if measured values are changing in time and when there is the best moment to replace shaft and send them to renovation. All measured values should be kept in data base.

Description of method.

For every pinion shaft, operator does the same activity. Using dial gauge and torque wrench, operator measure axial play and radial play, beside visual state of seal and state of shaft's surface is controlled. During radial play measurement, lubrication must be switched off, to avoid oil between shaft and acetabulum, operator should use torque wrench three times. Of course force on wrench must be according suggestions of producer of installation. Beside this force, tolerances of plays must be according supplier recommendation. Example values (can be different according different installations):

- axial play – 0.00-0.08 [mm],
- radial play – 0.18-0.44 [mm],

- surface of shaft – 75-100 [%],
- seals – not leakage, not mechanical deformation or worn, and:

Frequency: every month; Tools: dial gauge, torque wrench

Figure 1 presents scheme of described methodology and Fig. 2 presents cassette during maintenance, preparation for clearance control.

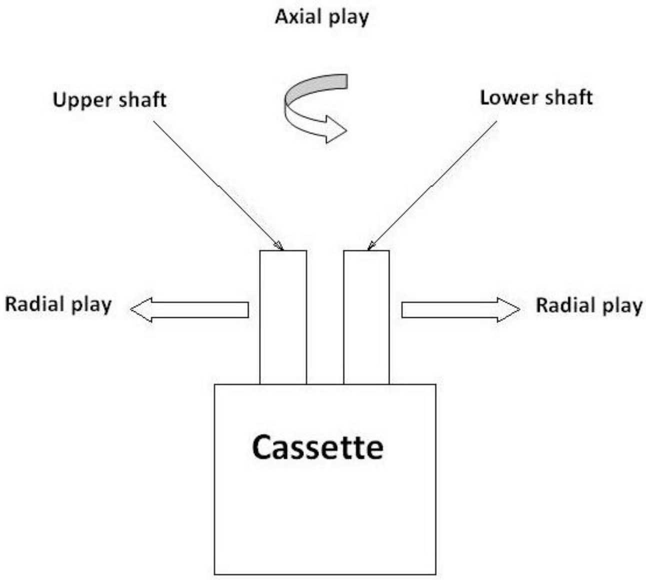

Fig. 1. Control of pinion shaft's clearance

Fig. 2. Cassette under maintenance

If operator observe that value of measurement is close to margin value it is the best moment to replace shaft and prepare for renovation. This is a good example of preventive maintenance: decision is taken according real technical state of device. After few months or years, data base can be beneficial and helpful during creating reasonable spare parts management. Storage built based on real demand is safe and not so expensive.

What problems can't be avoided in this approach? Lack of good maintaining can result in very serious failures of sprocket or broken teeth on shafts. Fig. 3 presents broken teeth on sprocket. What could be a reason of this serious failure? For sure too big clearance or too big vibrations could affect in that result.

Fig. 3. Broken teeth on the sprocket

2.2. Control of vibrations

Clearance is measured in static way, during downtime of production line. Another way of control technical state of working shafts, motors, gear boxes, switch boxes and rolling cassette is measurement of vibrations during normal operating time. That is dynamic way. Method is more complicated and usually includes cooperation of supplier. On some specific places of installation, supplier mount special sensors accelerometers, which measure vibrations. Operator uses special detector delivered by supplier of installation and according set sequence measure and record data. After that file with results of measurement is sent to supplier for analysis. Supplier is giving feedback as soon as possible with clear information about technical state of measured parts. Of course this activity is providing periodically, data base about results of each considered part is created and fulfilled. Analyzing of this data base is also very helpful in defining real technical state of devices. This kind of information is priceless during preparing schedule of maintenance's activities. If operators observe that vibrations are growing in particular area, can avoid very serious failure and replace crucial element before breakage.

The methodology of measurement provided by Siemens is presented on Fig. 4. This approach is a very good example of predictive and preventive maintenance of critical rolling mill components. How important is this approach we can understand if we see what kind of problems we can avoid. Fig. 5 presents destroyed transmission, what is a result of too big vibrations. Price of whole destroyed device is very big; also downtime due to not expected failure is difficult to estimate. In total, cost of lack of proper maintenance procedures is very serious and can be a reason of disadvantage on the market.

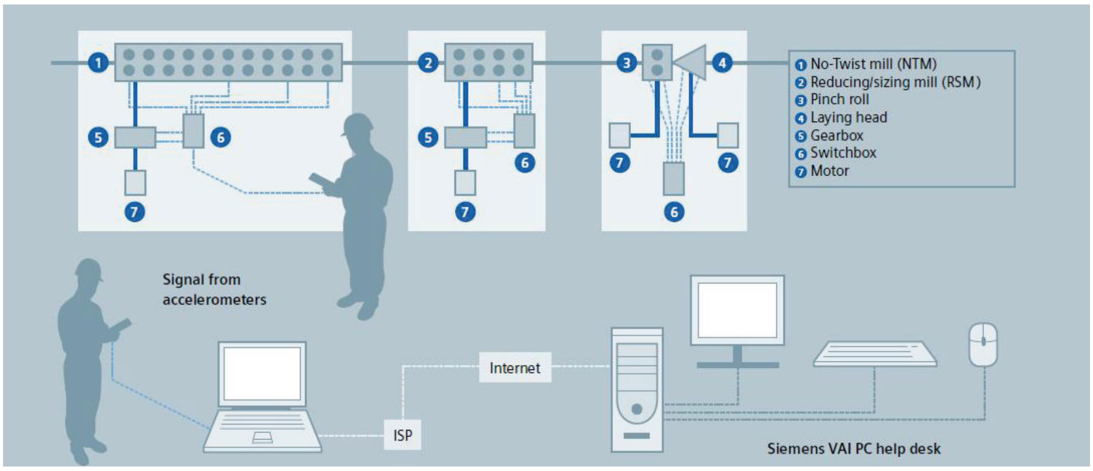

Fig. 4. Measurement of vibrations in Siemens approach [4]

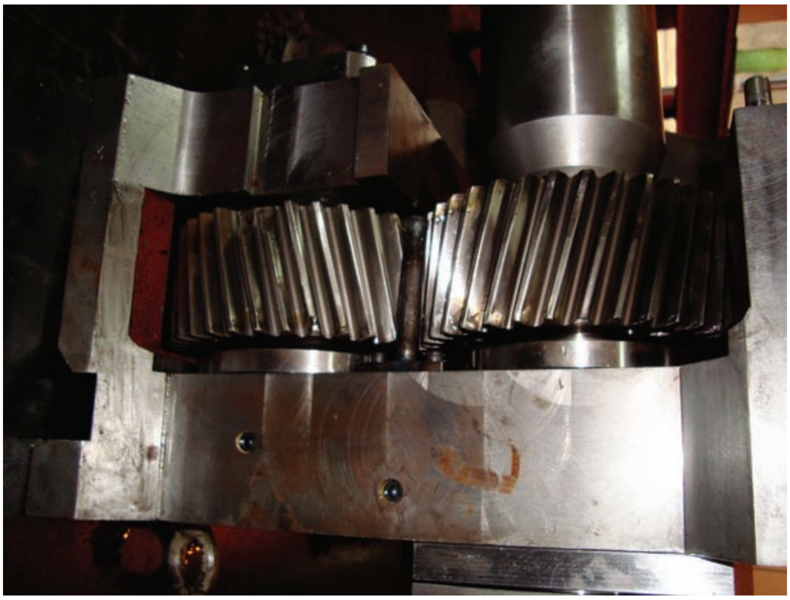

Fig. 5. Destroyed transmission

2.3. Control of surface and geometry, tapered sleeves

Rolling tools in fast rolling process are usually carbide rings. Preparing properly rings and tapered sleeves are very important in whole process. Tapered sleeve is a part connected rings with pinion shaft; usually process of assembling ring with tapered sleeve is done ahead mounting these parts on the shaft. Proper geometry of rings and tapered sleeves is very important, contact area between shaft and rolling tools depend on that. External surface of the shafts and internal surface of the tapered sleeve is conical. External surface of the tapered sleeve and internal surface of carbide ring is round. To mount ring with tapered sleeve on the shaft, operators uses special mounting device with set pressure. Only proper geometry and dimensions of shaft, tapered sleeve and carbide ring guaranty good result. All contact surfaces must be clean and contact area should be close to 100%. We can imagine that any aberration can negatively influence for whole process. Fig. 6 presents assembled parts and on Fig. 7 is presented how accurate is measure each tapered sleeve and how important is proper geometry for process of fast speed rolling.

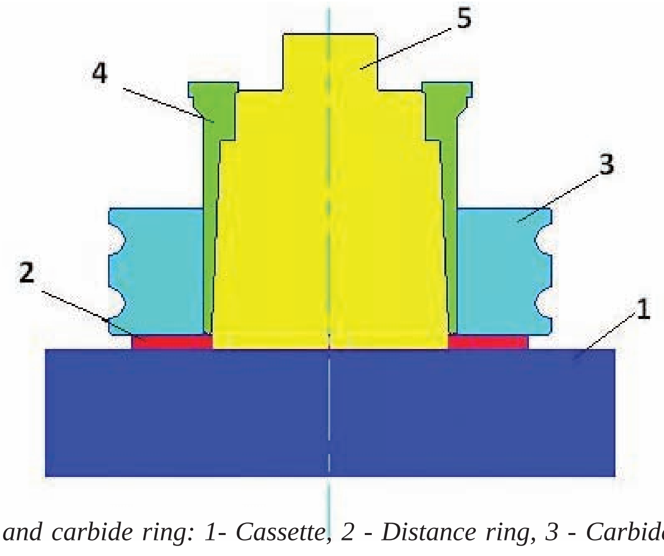

Fig. 6. Shaft, tapered sleeve and carbide ring: 1- Cassette, 2 - Distance ring, 3 - Carbide ring, 4 - Tapered sleeve, 5 - Roll pinion shaft

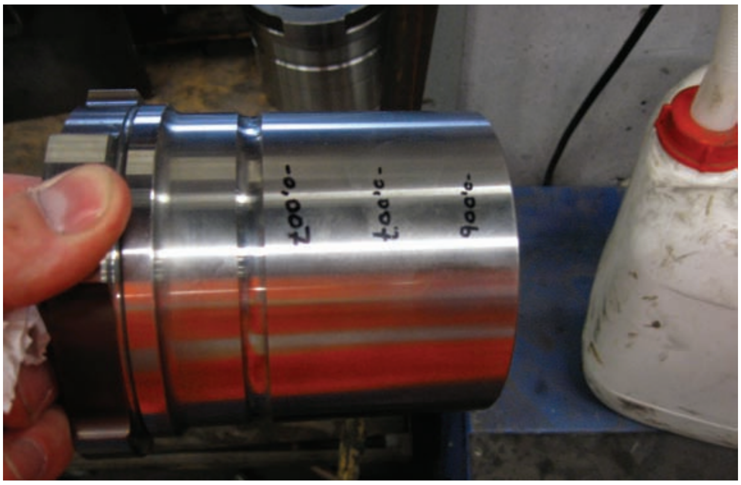

Fig. 7. Tolerances of tapered sleeve's diameter

Method of checking geometry of tapered sleeve is very simple. First of all visual inspection, if operator has any suspicion about geometry, there necessary is second step.

Using new (or like new) roll pinion shaft, free from wear and mount the used sleeve and ring using following procedure correlate with Fig. 8:

- blue (use ink) the internal surface of tapered sleeve,
- place the assembly plate on the base,
- install the ring on the plate,
- insert the tapered sleeve into the ring,
- press the tapered sleeve into the ring until it stops,
- remove the taper sleeve and ring from the assembly plate. Verify the bottom of sleeve is "x" mm from the bottom of the ring – based on applicable running arrangement. This will ensure the bottom of the ring makes appropriate contact with the flinger after the ring and sleeve are mounted on the pinion shaft,
- using the roll mounting tool mount the tapered sleeve and the ring on the new roll pinion shaft,
- remove ring and tapered sleeve,
- read the blue transfer.

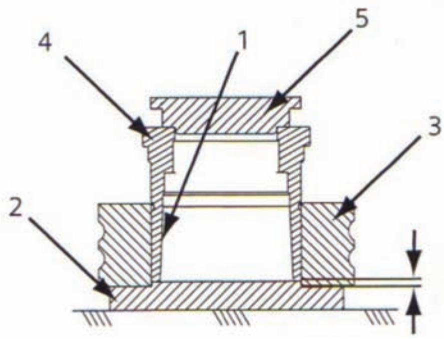

Fig. 8. Pre assembling the taper sleeve and the ring: 1- Surface to use blue ink, 2 - Assembly plate, 3 - Carbide ring, 4 - Tapered sleeve, 5 - Press side

If transfer is more than 80% of surface, test is acceptable. Less than 80% tells us that geometry of tapered sleeve is deformed and contact area cannot guarantee good cooperation between pinion shaft, tapered sleeve and carbide ring. Why tapered sleeve not ring or pinion shaft? Usually tapered sleeve are purposely made softer than the roll shaft and carbide rings so they are sacrificial. Of course tapered sleeves are much cheaper so it is better to replace them than rings or shafts. On this basis, some wear of taper sleeves can be expected, requiring that decision be made periodically on their continued usefulness.

2.4. Control of surface and geometry, Tungsten Carbide rings

Next also very important issue concerns carbide rings. Maintaining of fast rolling tools is crucial for proper providing whole production process. In general every single part removed from rolling line, must be inspected very carefully. Very important is visual inspection, which is usually first step. Unfortunately very often is not enough. For checking wearing it is useful to use special prepared templates, this activity we can see on Fig. 9.

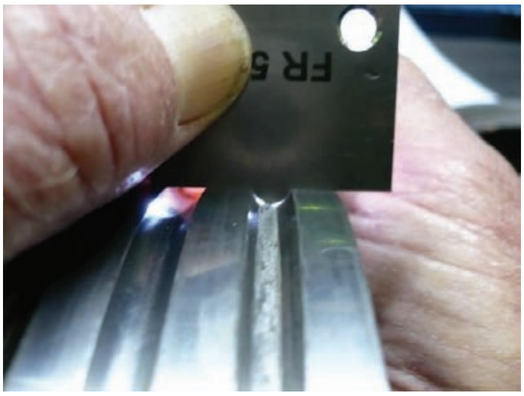

Fig. 9. Checking shape of groove by template

Most danger problems are micro cracks which cannot be visible by unaided eye. Very efficient solution in this issue is checking surface by special current method. The technique offers a cost effective method of surface inspection. Special electronically tester sending current into surface of ring and check if there is no any aberration in current flow. Current instruments specifically developed to test components for surface cracks, either prior to, or after, grinding, machining or other production sequences.

The principle of operation is based on the environmentally clean eddy current test method. Cracks as small as 0.05 [mm] in depth can be detected in components parts with predominately round finished surfaces. The signal amplitude varies according to the depth of the crack; however, the effects of alloying and surface conditions will determine crack detection ability. Fig. 10 presents one of available testers on the market. How dangerous can be micro cracks? Very much, on Fig. 11 we can see a real crack, which could be a result of not detected micro crack.

Fig. 10. Eddy current tester for cracks detection [3]

Fig. 11. Brocken carbide ring

Figure 12 present how micro crack looks in big zoom.

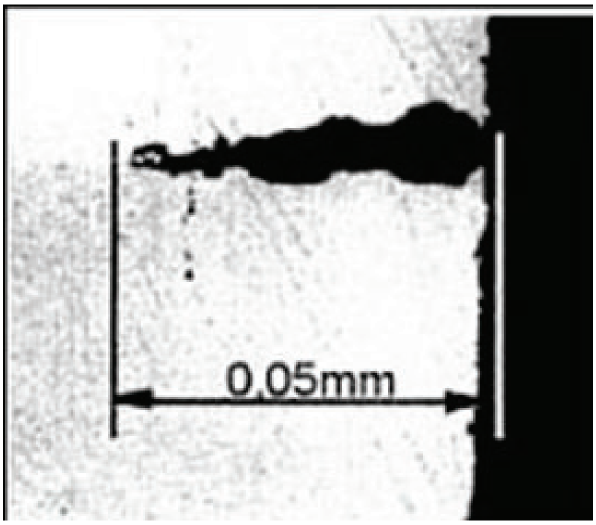

Fig. 12. Micro crack detected with method of eddy current [1]

Also proper renovation of carbide rings is very important. After each machining, operators are checking diameters, pulsation, and shape of grooves on machined ring. Every step of maintaining is as well quality inspection. Lack of attention in this activity can results in not stabile work of rolling unit or no proper tension between units. Both are very danger and always results in unexpected delays.

2.5. Control of assembly and work environment, rolling guides

Proper assembly of rolling equipment is very important for rolling process. Fig. 13 presents example of rolling guide dedicated for fast rolling and Fig. 14 presents sketch of example rolling guide. For proper preparation of rolling guides is used special equipment. Fig. 15 presents optical device.

Usual guide consists of: body, funnel, rollers, bushes, bearings, screws and nuts. All parts have to be inspected before use and if they are not worn then can be assembled. After assembly, operators with a help of optical device, get ready settings of guide. Rolling axis must be exactly in the middle of clearance between rollers. This is crucial and usually is done on the workshop to avoid loosing of time necessary for adjusting on the line.

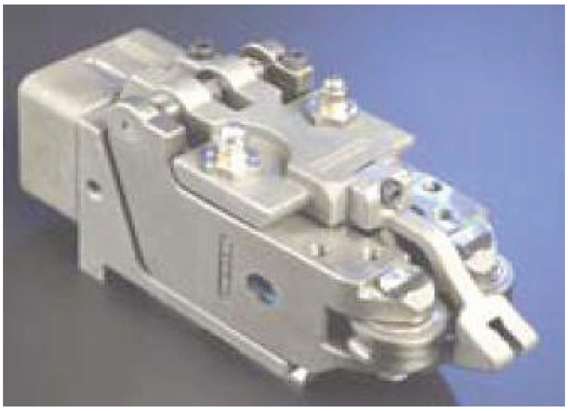

Fig. 13. Entry guide for fast rolling [1]

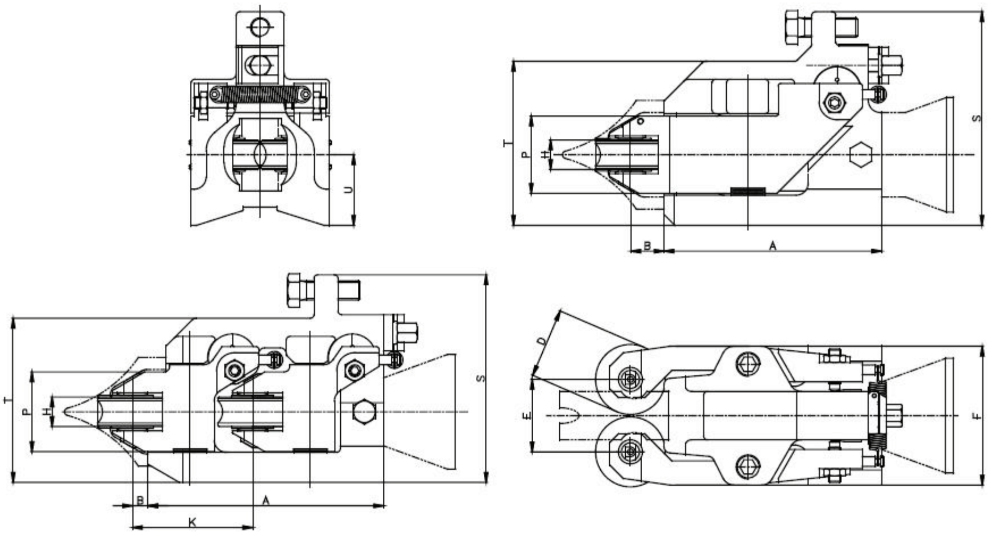

Fig. 14. Entry guide for fast rolling sketch [2]

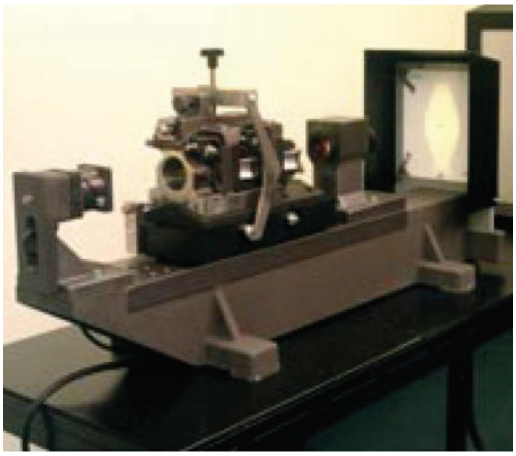

Fig. 15. Optical device for checking guide assembly [2]

Another important issue is an environment of work. Rolling guide in fast rolling process is working in very high temperature, about 900 [°C]. That is a reason that must be very intensively cool by water. Rollers in guide are touching rolled material; linear speed reaches 100m/s so they are spinning very fast. For proper work, bearings of these rollers have to be lubricate very efficient. In described process usually are used air-oil systems, which with high pressure bring lubrication through specials pipes and hoses into bearings. Lubrications systems must be efficient and work without any aberration. Control of these systems is crucial, because lack of lubrication affects in seized bearing. Usual result of this is a cobble and unexpected delay.

How to control these kinds of systems? Constantly control of pressure, cycle of work, clearness of oil. Another important issue is checking content of water in oil. With this kind of process water always find a way to get inside an oil circuit. Acceptable content is up to 1 [%] of water inside oil. To avoid problem with water inside oil, on these kinds of installations are used dehydration stations. Fig. 16 presents example dehydration station. Obviously very important issue is cooling. Fig. 17 presents completed ready to roll fast roll stand, with carbide rings, rolling guides and with installed coolers.

Fig. 16. Dehydration station [5]

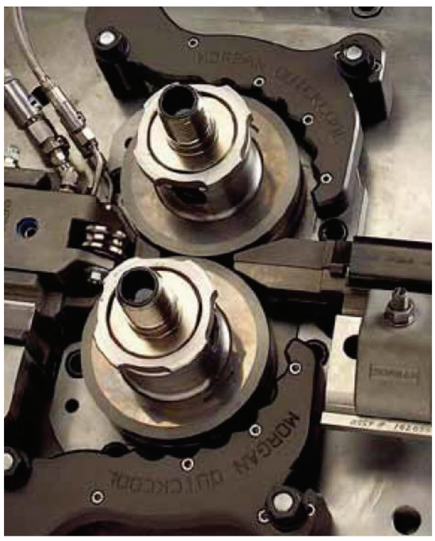

Fig. 17. Rolling stand ready to roll [4]

To protect tools and equipment in fast hot rolling process, special cooling systems deliver more than 5000 [l/min] for all units. To avoid problems with cooling, some parameters are controlled; flow of water, temperature and purity. Circulation is equipped in flow meters, thermometers and filters. In addition water is enriched in special chemical components; protect cooling system prior to biological life and lime scale.

3. Synergy effect, positive impact of described activities for other areas

Experience teaches us, that many times problem in one particular area especially on the beginning is affecting negatively much more in neighboring area. That’s why inexperienced operators make a lot of mistakes when something unusual appears. They start to look in wrong place.

Described above procedures and activities are good examples for achieve synergy effect in whole production process. For better understanding, in below hypothetical situations we will describe lack of proper maintenance procedures to show how negatively these abandonments affect for neighboring areas.

3.1. Control of pinion shafts’ clearance

Lack of proper procedures and maintenance schedule for clearance control can be very big problem for the rolling mill. For example if clearance on the pinion shaft is equal or bigger than accepted tolerance, in long term will destroy seals or even cassette, of course pinion shaft itself will be also worn. The question is what happen in short term? In short term we will observe problems with stability of process after unit with suspicious pinion shaft. In linear view problems can appear far away from the real reason. Inexperienced operators will lose a lot of time for searching problem in area where it never been. Another negative impact is not proper control of rolling rings gap. Checking rings’ gap is always done with slow speed mode, but if process will roll on full speed and when material appears inside the rings, gap can be different. Result? Wire rod out of tolerance. How to found guilty? The answer is: proper maintenance procedures and wide look on whole process.

Proper clearance control affects positively not only for cassette itself but also for another areas and in fact for whole process.

3.2. Control of selected units’ vibrations

If vibrations are not controlled, effect can be very expensive and unexpected delay can last very long time. On the beginning of too big vibrations on gear box of rolling unit we can observe problem with tension control between particular unit and previous devices. Usual reason for that effect is not proper amount of material. Operators try to adjust gaps and tensions, but situation is constantly changing, so is not possible to stabilize this way. What to do without information about vibration report? Just guessing.

Proper vibration control program can avoid really serious problems with providing process.

3.3. Control of surface and geometry, tapered sleeves

If geometry of tapered sleeve is not proper we can observe that diameter of final product is out of tolerance. Usually operators suspect shape of groove on carbide ring. Solution what always help is changeover set of rings for new. Even for experienced operators this operation take about a 1 hour for unit. But problem was not found. Deformed sleeve will be send to the work shop and if again nobody checks it, problem will come back.

Correct geometry of tapered sleeves is one of the foundations of stabile rolling process.

3.4. Control of surface and geometry, carbide rings

Micro cracks can be a reason of destroying whole carbide ring. With fast speed rolling we can only imagine what happening inside the block during breakage. It is explosion. Of course reasons for that can be different. That’s why usually after breakage micro cracks cannot be detected. From other side, experience shows that after entering procedure of checking micro cracks, number of breakages was decrease.

Micro cracks if they are detected are very easy to erase by turning ring. Proper prepared rings can guarantee proper shape and diameter of final product in rolling process.

3.5. Control of assembly and work environment of rolling guides

Non-use optical device during preparing rolling guides for fast rolling process is very hazardous. If rolling axis is not exactly in the middle of rollers' clearance, one of rollers will wear much earlier. Then rolled material is providing not proper way and first negative effect can appear in product out of tolerance. Number of reasons can be guilty. Operators will lose a lot of time to find a real problem.

Another example: if oil circuit is not controlled for water content, we can very fast observe breakage of bearings, rollers and other elements lubricated by oil circuit.

Proper preparation and control of work environment of rolling guides is very important. Mistakes in these areas can affect in very long unexpected delays.

4. Summary

To keep dependability of production process on requested level, number of activities must be done. Most of them are included in preventive maintenance procedures and are scheduled in details. Production processes are usually very complex, what affects number of activities scheduled for the same time. To present example of these activities, five different areas were selected. In these areas presented five different scheduled activities.

Described activities are crucial in their areas but also in addition have very big positive influence for other areas of the production process. Thanks to that, effect of synergy was achieved. To emphasize synergy effect, in chapter 3 presented hypothetical situations describes lack of proper procedures and how negatively it influence for neighboring areas and in fact for whole process.

Acknowledgements

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