APPLICATION OF ACOUSTIC EMISSION FOR MEASURING OF CONTACT FATIGUE OF AXIAL BEARING

Filip Hort, Pavel Mazal*

This paper describes some results of an experiment aimed at monitoring of contact fatigue during the axial bearings tests. The needful of AE set-up for measuring of signal and Axmat stand for testing is presented here. The measuring of some kind of bearings required the creation of new clamping elements (Segment and Bearing bush) to the existing key point of Axmat stand. The results in this paper show records in the time domain mainly for counts and events. These events are filtered by maximal amplitude for better response on signal changes during the lifetime record. For these evaluated records there are shown the final failures of tested bearings and possible causes of failures beginning.

Keywords: *acoustic emission, axial bearings, contact fatigue, time domain, maximal amplitude*

1. Introduction

The acoustic emission (AE) is one of the several NDT (Non-Destructive Testing) defectoscopy methods which can disclose an initial stadium of contact fatigue, the leakages of fluid from pipeline, the defects at pressure vessels, the corrosion and other failures. In the industry, mainly in energy, there are applicable diagnosis methods as ultrasound, vibrations and AE methods to the rotary machineries. The one of these important fields is diagnosis of contact fatigue from the slide or ball bearings. Then the maintenance operation is limited only for scheduled outage or in some cases developed damage [1, 2].

The global scale of intensity AE signal could be a various kind of signal modification. The most used type of AE signal intensity is counts – the excess of set energy levels. The parameter RMS (Root Mean Square) is often used for good evaluation, too. A closely description of initial stadium of the contact fatigue could give the AE events and their filtrating according to the specific parameters. Among these parameters rise time, duration of event or maximal amplitude belong to [3, 4].

The evaluation methods are still in the development and the new techniques are accessible. The one of these new techniques is method of full sampling rate where the results have been described in some papers published recently. This new technique requires the efficient computer technique but it is very conductive to identify the initial stadium of contact fatigue [4, 5].

* Ing. F. Hort, doc. Ing. P. Mazal, CSc., Institute of Machine and Industrial Design, Brno University of Technology, Technická 2, 616 69 Brno

2. Experimental set-up

The Axmat stands were used for testing stations of contact fatigue. These stands have been described in some last paper [2] and the overview is in the figure 1. Their using is very simple but effective. The main parts are: the frame, the rotary base with electromotor and the loading mechanism with defined weight. The main analyser for measuring was XEDO with 4 channels from Dakel Company. Which can record many parameters of AE, the main are Counts, Events, Trends, and which is able to evaluate the samples of AE events in the frequency domain, too. Sensors are from the same company as the analyser. Axmat stands have integrated the vibration sensors whereby the stands are stopped. There is possible to set the level of vibrations but this setting is not so much sensitive as can be AE method.

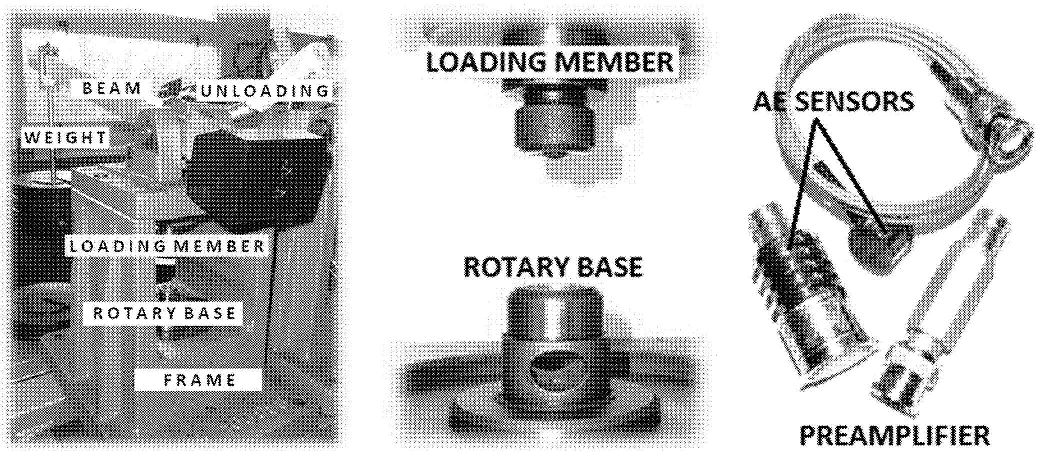

Fig.1: Axmat stands in laboratory, kea point of Axmat stand and AE sensors [2]

3. Pre-experiment

Axmat stands were created and still they are used for measurement of contact fatigue. These stands were used mainly for circle specimen of various kinds of material. The material of specimens can be for example bearing steels, cast-iron or plastics. In this experiment it was necessary to create the new clamping elements to the key point of Axmat stand. These

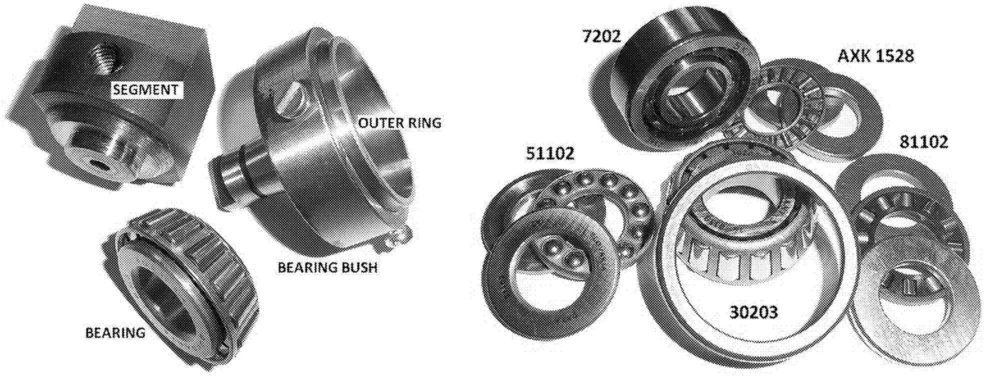

Fig.2: One of new clamping elements and tested bearings

new elements allow to measure the chosen types of bearings not only axial bearings with loading in axial direction. Figure 2 shows one of new clamping elements and used tested bearings.

The segment (Fig. 2) has several important parts. The first of them is section for connection one of the bearing ring, generally the inner ring. There is the friction force and thus the ring does not rotate. The segment has two ground surfaces on the both sides, these surfaces serve for the AE sensors. In the third section are tapped holes, the first is for vibration sensor and the second is for supporting bar. This is the main description of segment and the second element was named as bearing bush. The bearing bush has two main sections. The first of them is taper seat which transfer the rotary motion from the rotary base. The second one serves for mouthing one of the bearing ring and it is fixed by three screws.

4. Experiment

In this experiment the five types of bearings (Fig. 2) under the similar conditions of measuring were tested together. The measurement obtains the characteristics like the loading, lubrication, lifetime of bearing and finally the failures. The results of these measurements are shown in the following graphs. These graphs show the process of measurement in time domain, it means parameters Counts – count is the exceeding of the set thresholds and Events – number of record events. The events could be described by length of duration event, rise time or maximal amplitude of event. In this paper there are not shown the individual samples of events in the frequency domain. This problem is solved in other papers which are going to be published this year. There was tested mostly the five number of bearings from each type and following results are shown as representative samples of this provided experiment.

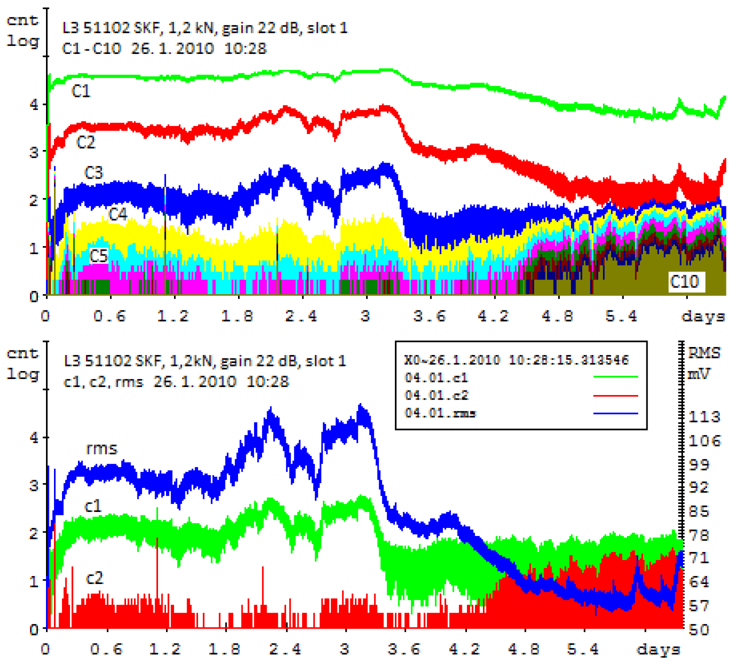

Fig.3: Counts 16 and count 1, 2 for running state of tested bearing

4.1. Bearing 51102

The first of results is shown in the figure 3 where two graphs display the same tested bearing. The tested bearing was lubricated and it was loaded by 2 kN in axial direction. The lifetime of bearing was approximately 552 hours. The measurement of this bearing was divided to several parts and the first part (running state) is shown in figure 3. The analyser XEDO can record up to 16 levels of signal intensity. The evaluation from these graphs is quite complicated because a huge amount of data is obtained there. Besides of it the analyser XEDO can also record not so much complicated data. The lower graph in the same figure shows only two counts but adds the RMS value. The comparison of these two graphs points to the trend of both graphs is similar. For routine evaluation there is suitable graph containing cout1, count 2 and RMS parameter then. Only for detailed inspection the using count with 16 energy levels is better.

The record from figure 3 shows the after running state almost in the linear increase of signal at the time 4.4 day. Figure 4 shows another section of measurement where disabled state about 0.8 day is caused by short time disconnection of the analyzer. The intensity of signal was almost steady from 6 day (Fig. 3) up to 3.2 day (Fig. 4). After 3.2 day the signal began steeply increasing mainly for RMS parameter. This increasing could be indication of developing contact fatigue.

Figure 5 shows the last part of tested lifetime of bearing. This graph is continuing from graph in Fig. 4. In the first area of figure 5 there are very apparent peaks up to 0.7 day. These peaks are very often and they have the great amplitude of signal. In considering the final failures these peaks could detect the chipping of material from upper layer of surface. The

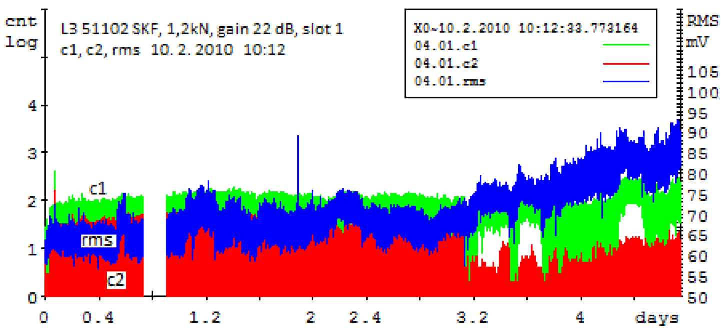

Fig.4: Record the count of third section of bearing lifetime

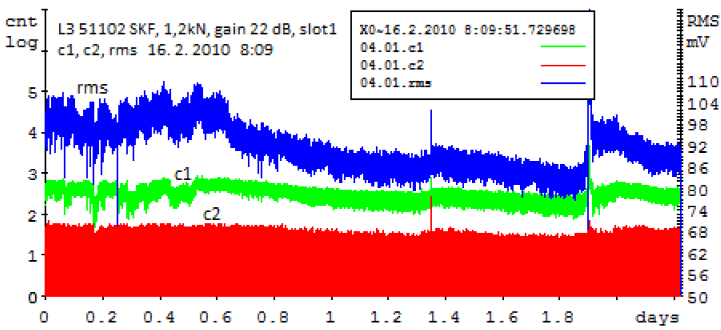

Fig.5: Record the count of last section of bearing lifetime

second area shows a slow falling in the signal which could be caused by surface smoothing. After 1.9 day there is a new speed of signal increase and then there is a falling how it has been described in the second area.

As mentioned above the analyser XEDO can record and evaluate also events of AE. These events are possible to filter according to event duration, rise time or maximal amplitude. Figure 6 shows the two graphs of AE events from the third section of measurement. The difference between these two graphs is only in the value of maximal amplitude. The first of them shows the amplitude from 0 to 500 and the second graph shows the amplitude from 500 to MAX value. The important point is at the time of 3.2 day.

At the analysis of events for duration and rise time there was found that at the time of 3.2 day the third section of measurement the events with small duration and rise time were increasing, too. Against to with, the long events were taken away. This investigation confirms also the graphs in the Fig. 6. The comparison of the Fig. 6 with previous Fig. 4 growth of AE right in small events with small amplitude is clear. The development of AE events in the last section is conformable to the record of counts and RMS (Fig. 5).

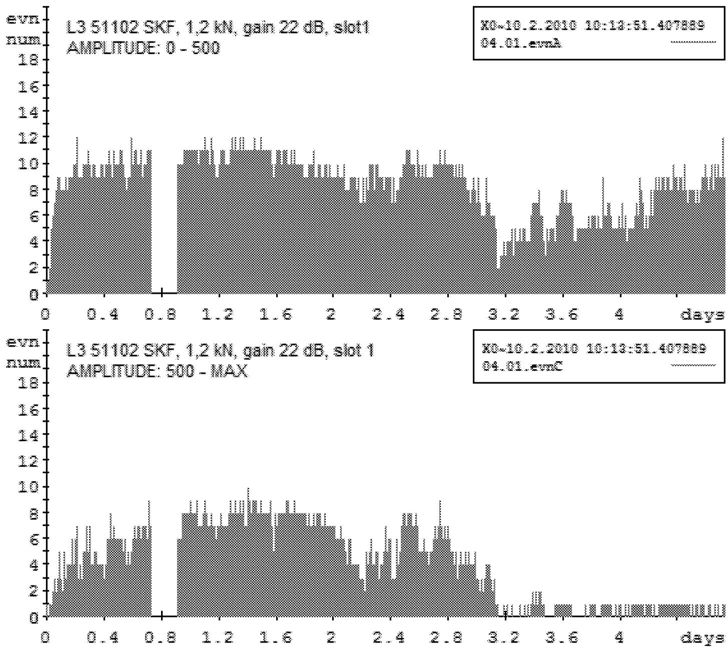

Fig.6: Lay-out of maximal amplitude from the third section of bearing lifetime

4.2. Damage of bearing 51102

The final damage of bearing is shown in the photos in Fig. 7. The bearing was the eight periodic failures in the one of bearing rings (left photo). The right photo shows failure in detail with magnitude 101×. These eight failures are corresponding with number of balls in this bearing. Therefore there is hypothesis that the connection between number of balls and failures is not random. These points with failure could have caused in the long storage when the balls are in the same position for a long time. There could be a beginning of failures called as fretting corrosion and these points were, with incipient failures, probably next developed to the actual size and form.

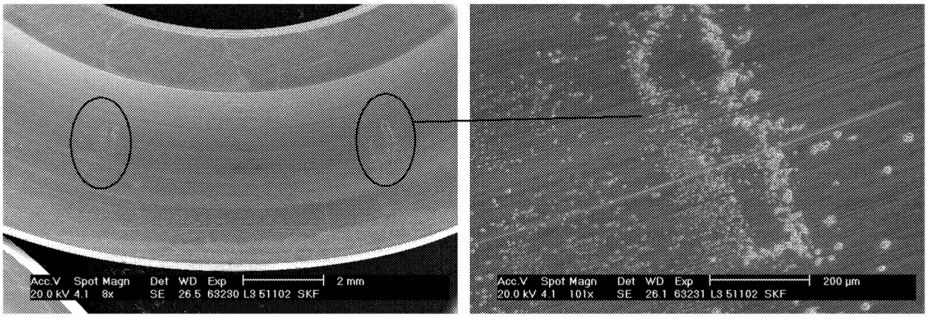

Fig.7: The final damage of tested bearing 51102

4.3. Bearing 30203

Bearing 30203 was investigated under specific condition. In this case there was not the bearing lubricated because it had a big layer of conservative oil. Then we can say that the bearing was tested without lubrication. After then we should not be surprised by such short lifetime of the tested bearing as it is shown in the figure 8. In this testing the monitoring of temperature was very important. For this test there were used a resistance thermometer and a laser thermometer, too. The temperature did not exceed value about 45 °C for all time of testing. This graph, in Fig. 8, is the record of Counts with 16 energy levels how it was described earlier. There was the loading 0.6 kN and lifetime was in sum of 586 minutes.

The record from graph in Fig. 8 does not show the classical evaluation of tested bearing. There is a very small running state and the intensity of signal is a steady during of testing.

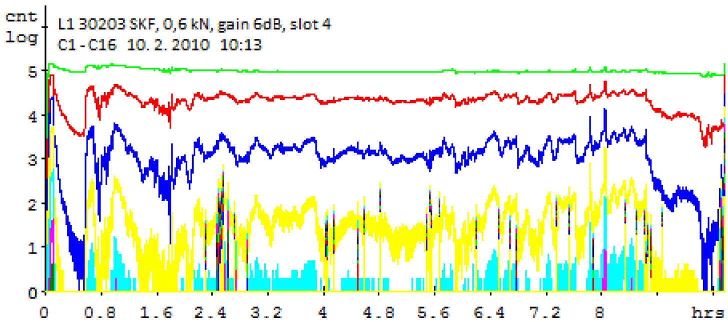

Fig.8: The record of Counts for all bearing lifetime 30203

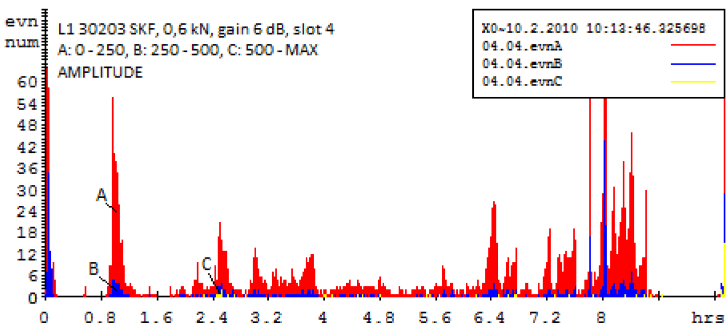

Fig.9: The record of AE events for all bearing lifetime 30203

So in Fig. 8 there is not so much information about tested bearing. The decrease of signal in time 8.8 hour is very interesting and after 9 hour there is a strong increase of signal and at this time the stand was stopped by vibration sensor.

If you can see in figure 9 the lay-out of AE event filtered by value of amplitude is more predicated about signal. The record includes several peaks, the first strong is about 0.9 hour then there is a group by a few peaks from 2 hour to 4 hour. Again, at the time of 8 hour there are many peaks of signal intensity but still with the quite small amplitude.

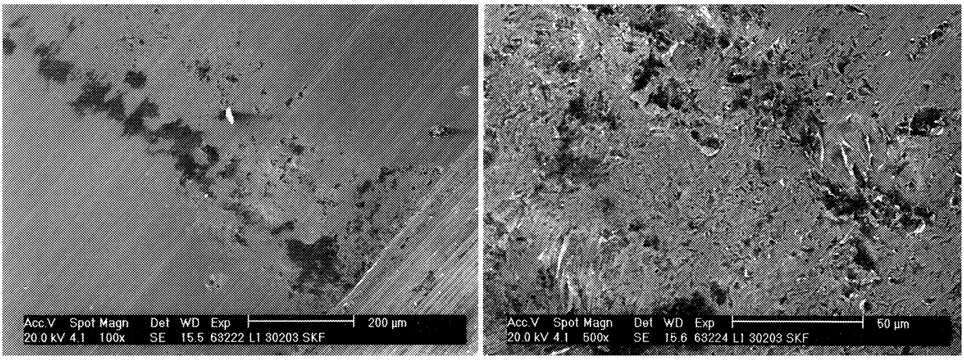

Fig.10: The final damage of tested bearing 30203

Final failure was discovered as the transverse seam in the race of inner ring. Figure 10 shows this seam with magnitude 100× in the left photo and the detail in the right photo. This failure looks like a damage from manufacture and the black places in the photos belong to residual oil.

4.4. Bearing 7202

The bearing 7202 is named as the Single row angular contact ball bearing which was loading by 2 kN in axial direction and it was quite a lot lubricated. The length of measurement of this bearing was approximately 1 213 hours and this measurement was stopped by maintenance. There was no evidence of some rough damage from signal but there was repeated increase and decrease of the signal intensity. And this repeated form is the guideline

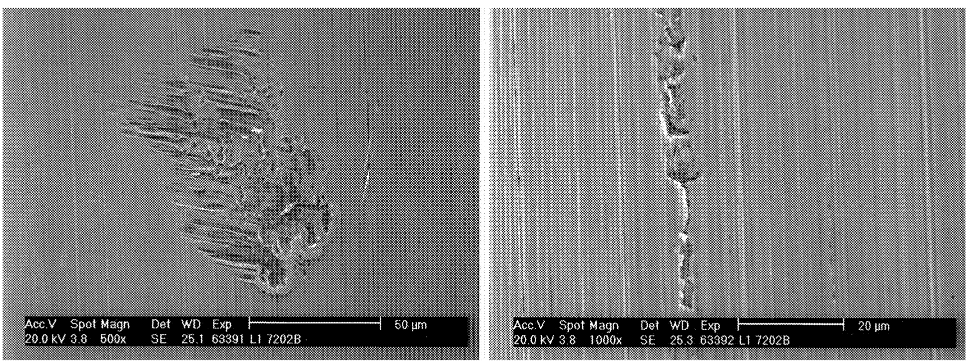

Fig.11: The final damage of tested bearing 7202

for some failures in the tested bearing. This testing was very curious, such a great lifetime for such a strong loaded bearing is surprising at least. After the bearing removal from the stand and cutting there were found only small failures shown in figure 11. The failure in the left photo shows the biggest damage from outer ring of bearing. The direction of damage is across the race way and this is in the same axial direction as the loading. The second smaller failure is shown in the right photo but there is much smaller damage here and the direction is longitudinal with raceway direction.

4.5. Bearing AXK 1528 and 81102

These axial bearings were tested in the same way as ball bearings but the construction of these bearings is different. The rings haven't got a guide way, for example in the elliptic shape such the ball bearing has. Then there is a problem with setting the snap-ring to the right location. The first ring of bearing is embedded to guidance of bearing bush and it is fixed by three screws. The second ring is mounted on the segment which centres the axial position. The main problem is snap-ring which is not the strong guided or fixed.

From tests there are these results; the lifetime of bearings AXK 1528 was around 210 up to 330 hours for the axial loading 0.6 kN. The bearings were lubricated by quality grease. The final failures of these bearings were the damage of needles in the snap-ring where there were the small longitudinal grooves mainly in the middle of needles. The inspection and evaluation of this needle is very complicated but there was nothing found what could be shown for contact fatigue. No pitting was found on the rings, too. There were only the similar grooves as with needles.

The testing of bearing 81102 shows some problems in compare to needle roller bearings. The tested bearing has a plastic snap-ring which causes much more heat. That means there is not appropriate the rising of loading to the reduction of time measurement then. The next restriction was much higher cost of this bearing against the needle bearing.

5. Conclusion

The comparison of tested bearings shows the same differences between suitability of testing and the gained results. The axial ball bearings 51102 were surely the best for the testing in every tested type of bearing. The presentation of the results in this paper describes almost all lifetime of bearing and detected final failures in the one of bearing ring. The final failures are not typically damage which is rising mostly in one or two points of raceway but these results of tested bearing were chosen for its unusual periodical damage. The interesting view to detect of incipient contact fatigue shows the record of AE events mainly for used suitable filter. The typical failures of contact fatigue from this series of measuring will be shown in paper created for 29th European Conference on Acoustic emission Testing from 8th to 10th of September 2010 in AUSTRIA.

The failure mode for several tested bearings can be markedly different and then the character of signal is so different mainly for AE events. The AE events are almost filtered by value of maximal amplitude and this is interesting because the lay-out of amplitude in signal is so different for lifetime of bearing. These differences are shown in comparison of Fig. 4 and Fig. 6. From made tests the maximal amplitude is providing more response in signal than rise-time or duration of AE events.

Tapered roller bearings and mainly angular contact ball bearing have some disadvantages for testing. The main disadvantage is that the bearings are not simply to disassembly. The disassembly, inspection of damage and continuing in tests is not possible for that closed bearings. In this regard, the classical axial bearing testing is the best. In the case of testing the needle rolling thrust bearing without a centring spigot was the damage of tested bearings only by groves as in the snap-ring as in the both rings, too. At these bearings there was not found, the contact fatigue against the axial ball bearings. The results containing the frequency analysis will be presented at the paper of 29$^{\text{th}}$ European Conference on Acoustic emission Testing.

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