LINER AND ANGULAR MEASUREMENTS

NEW METHODS OF OBJECTIVELY EVALUATING THE QUALITY OF ASSEMBLY OF BLOCKS OF END GAGES FOR LENGTH MEASUREMENT

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This article examines new methods of objectively evaluating the quality of assembly of blocks of gages. Use of the methods significantly improves the accuracy of the assembled blocks and eliminates hidden errors.

Most measurements of the linear parameters of precision parts are made by the method of comparison with blocks of plane-parallel end length gages (ELGs) of the appropriate length. The blocks are usually not checked for accuracy after assembly (since the buyers do not usually have "Kesters" interference comparators and special standard gages with the corresponding nominal dimensions). Thus, the length of the block is determined by calculation: by addition of the certified lengths of the gages lapped into the block. However, the actual value for the block differs from the calculated value.

The accuracy of the assembly of a block of end gages depends on the adhesive interaction of the gages and the accuracy of their lapping. The adhesive interaction is in turn affected by the quality of the surfaces of the gages and the parameters and distribution of the lubricant between those surfaces. The lubricant can be applied either in a very thin layer or in the form of fine drops.

The Scientific Research Institute of Measurement has observed and studied a phenomenon involving a reduction in pressure between the surfaces of ELGs separated by a fraction of a micron and the discharge of ultrafine drops of lubricant from the microstructure of the surfaces of the gages [1]. It is indeed this phenomenon that is characteristic of the ELG lapping operation, when the gages are gradually brought closer to one another over the entire measurement surface.

It has been established that when ELGs are brought closer together with an intervening gap on the order of 0.1-0.3 μm, there is a sharp increase in adhesive interaction, and the mean free path of the gas molecules between the surfaces being lapped decreases to the critical value. This in turn leads to a drop in pressure in the gap between the surfaces, resulting in the discharge of ultrafine drops of lubricant from the microstructure of the surfaces. The lubricant had previously accumulated in those surfaces. It was observed experimentally that a similar discharge is seen when the gages are placed in a vacuum chamber with a substantial vacuum.

The discharge of drops of lubricant during lapping facilitates adhesive interaction of the gages and makes it possible to evaluate the microstructure of their surfaces and the accumulation of lubricant. These observations can be made on a microscope through a quartz plate lapped to the end gage. The lapping operation is evaluated visually from the interference pattern formed in the lapping zone.

Measurements made on an MII-4 micro-interferometer showed that the thickness of the drops on the surfaces of steel gages ≤0.03 μm and that the drops have overall dimensions of several microns. The drops discharged onto the surfaces of hard-alloy gages have significantly larger parameters, which can be attributed to the specific pore structure of the hard alloy.

The number and parameters of the drops discharged during the lapping of end gages depends appreciably on the metrological characteristics and service properties of ELG blocks. The presence of a large number of drops (10²-10³ drops) ensures uniform adhesive interaction and exact parallel location of the measurement surfaces being lapped, while simultaneously serving as an indication of a large reserve of accumulated lubricant.

However, in production it is common practice to use ELGs in which no drops of lubricant exude during lapping. This indicates an absence of accumulated lubricant in the microstructure of the measurement surface due to long service of the gages. In this case, the gages are lapped as a result of the presence of a very thin layer of lubricant on the measurement surfaces.

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Experience shows that the quality of the lapping of these ELGs is inferior in terms of accuracy, reliability, and adhesive interaction to a lapping operation done with an intermediate layer of lubricant in the form of very fine drops. The difference is due to the fact that a large number of exuding droplets levels the geometric surface of each gage and makes the actual contact area large, which in turn increases adhesive interaction (i.e., the adhesive force between the gages) and the accuracy of the mutual positioning of the lapped surfaces. Thus, the proper assembly of ELG blocks requires the use of gages on which drops of lubricant exude during lapping. It is known that the lapping of ELGs by the operator of the unit is a very complex and "individual" process, since the operator is guided only by his or her senses while attempting to obtain good adhesion between the gages. It must be taken into account that ELGs are lapped as part of the certification of standard gages, instrument calibration, and the measurement of precision parts. Such a wide range of application of lapping necessitates thorough study and detailed description of the lapping process itself.

As a rule, ELGs are lapped to one another or to a transparent quartz plate. Lapping the gages to a quartz plate makes it possible to study this process on the basis of the interference pattern formed in the region of contact of the surfaces. First the operator places the gage on the plate in the free state, with the gage only being under its own weight. It is usually assumed that the planar finished surface of the gage coincides exactly with the finished surface of the plate. However, the gage surface is not entirely coincident and is always positioned with a slight slope. The slope is evaluated by means of the interference pattern: after the number of interference fringes is reduced, the fringes are replaced by an interference spot. This ensures parallel positioning of the measurement surfaces of the gage and the plate. The final lapping operation is then performed. During this operation, adhesive interaction is maximized, the surfaces being lapped are brought closer together, and the interference coloration and hues are replaced by a "metallic luster" in the region where the gage contacts the quartz plate.

Experience shows that, having achieved such high-quality lapping, the operator can estimate the mutual position of the lapped surfaces of the gage and the plate on the basis of the interference pattern formed on a "Kesters" interference comparator (IC), i.e., an accurate evaluation can be made to within 0.02-0.03 μm. Studies have shown that these values represent the maximum accuracy that can be attained in lapping ELGs of the "0" class to a quartz plate. This lapping is the "ideal" for controlled lapping with feedback, when the operator evaluates the mutual position of the surfaces of the measure and the plate during the operation by looking at the interference pattern.

It is obviously impossible to monitor the quality of the lapping operation from an interference pattern when metal gages are being lapped to one another (the lapping is uncontrolled). We conducted special studies to evaluate the operation in this instance and compare it with controlled lapping. Gages were lapped to a quartz plate, but the operator did not monitor the position of the gage being lapped by looking at the interference pattern. Instead, the monitoring was done on the basis of the operator’s sense of the adhesive force between the plate and the gage. The lapping operation was ended only when the operator sensed that this force was maximal. Only after the end of the operation was the interference pattern corresponding to the contact between the lapped surfaces used to evaluate the position of the lapped surface of the gage. Thus, the uncontrolled and controlled lappings were evaluated with the same degree of accuracy on the basis of interference patterns. This made it possible to objectively compare their accuracy. The data that were obtained showed that the precision achieved in the controlled lapping was several times greater than the precision attained in the uncontrolled lapping.

However, the lapping of ELGs to one another cannot be evaluated based on the interference pattern of the contact. Uncontrolled ELG lapping thus predominates under production conditions, and the fact that its accuracy is an order lower than controlled lapping significantly lowers the accuracy of the control that can be maintained over precision parts.

Many years of studies at the Scientific Research Institute of Measurement have made it possible to develop and make broad use of a contact resistance \( R_{\text{tac}} \) to monitor and check the accuracy of the lapping of ELGs under laboratory and industrial conditions. With respect to sensitivity and the level of accuracy, the estimates made of the contact of lapped surfaces \( R_{\text{tac}} \) are commensurate with the estimates obtained using interference patterns. Use of the resistance makes it possible to evaluate the lapping of gages from the very beginning of the operation. The value of \( R_{\text{tac}} \) may range over several ohms. The value of \( R_{\text{tac}} \) decreases as the gages approach one another during their lapping, this decrease indicating a gradual increase in the area of contact of the gages. The operator continuously obtains information on the mutual position of the gages through \( R_{\text{tac}} \), and this makes it possible to monitor the course of the process.

Studies showed that \( R_{\text{tac}} \leq 2 \cdot 10^{-3} \Omega \) in the high-precision lapping of ELGs of classes "0" and "1." This corresponds to the accuracy with which gages are lapped to a quartz plate with a "metallic luster." Thus, controlled lapping of ELGs, with evaluation of the process on the basis of \( R_{\text{tac}} \), provides the same level of accuracy as the controlled lapping of gages to a quartz plate — when the process is monitored on the basis of an interference pattern. As a result, \( R_{\text{tac}} \) and interference fringes are equivalent parameters for evaluating the quality and accuracy of the lapping of gages. It is this fact that makes it possible to