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## CONTACT FTIGUE OF HIGH-STRENGTH CAST IRON WITH SPHERICAL GRAPHITE: SHORTCUT TESTS

In the paper the techniques are approved and results of the shortcut tests for contact fatigue of high-strength VChTG cast iron with spherical graphite are presented for the first time. The application of given methods has allowed: 1) to define the limit of contact endurance of cast iron the numerical value of which is comparable with the one received at the construction of a curve for contact fatigue (variation is ~ 10 %); 2) to compare high-strength cast iron with spherical graphite and a high-strength steel on fatigue durability at contact load (there is no difference in bearing ability; the resource of cast iron is 2 % less, than of steel). The received results testify that VChTG cast iron can be applied in manufacturing tooth gears for PA «Gomselmash» (instead of high-strength steel).

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## PRINCIPLE AND APPLICATIONS OF PHOTOSTRESS® METHOD

The aim of this paper is to present optical method PhotoStress® and its use in experimental analysis of main relative deformations and main normal stresses on photoelastically coated structural elements and their systems. The method can also be applied in static and dynamic stress analyses of elements of mechanical systems of various shape and material.

In addition to basic theoretical aspects of the method, the paper presents its practical applications as well.

PhotoStress® method is an experimental method which is usually used for determination of strains and stresses on photoelastically coated, statically or dynamically loaded construction elements and their systems. On the basis of photoelastic phenomena that occur on applied photoelastic coating while component part is loaded, the PhotoStress® method enables to get quantitative information. Received information, after being mathematically evaluated or after further experimental measurements, allow us to determine strain constituents or stress constituents in particular point, line or on particular surface. This method was introduced by M. Mesnager at the beginning of 1930s. Photoelastic coating was made from glass, however, its high stiffness and low sensitivity to photoelastic phenomena did not enable its wider application. Other experiments that have been done on Bakelite coating gave more attractive results. Nevertheless, with respect to adhesives that were used and arising marginal effects, this technique did not bring wider application possibilities [1, 2]. Eventually, the application of epoxide photoelastic coatings and double-component adhesives has enabled wider use of the method. Remarkable development of PhotoStress® method came in the last years of the 20th century and the beginning of the 21st century. This development refers to development of experimental equipment, computer and digital technologies.

**The development of PhotoStress® method.** With PhotoStress® method, a special strain sensitive and optically sensitive photoelastic coating is bonded to the analysed surface of tested part. While the part with photoelastic coating is loaded and then illuminated with polarized light from a reflection polariscope and when viewed through polariscope, the coating displays the surface strains and stresses as colourful photoelastic strips. These strips reveal complete visual distribution of stresses and points of high stresses. Quantitative analysis can be done very simply and quickly by means of optical compensator which is bonded to the reflection polariscope.

With PhotoStress® method we can:

– immediately identify critical areas and highlight understressed or overstressed areas;

– measure principle strain directions and principle strain magnitudes or directions and magnitudes of principal normal stresses;

– accurately measure peak stresses and determine stress concentrations around holes, notches, fillets and other potential failure areas;

– optimize distribution of stresses in parts and systems for minimum weight and maximum reliability;

– repeatedly do measurement on one construction part under varying loads and without application of a new photoelastic coating;

– do measurements in laboratory or outdoor;
– identify and measure residual stresses.

In determination of principal strain direction parameters and principal strain magnitude parameters and principal normal stresses by means of PhotoStress® method we distinguish two types of photoelastic fringes:

– isoclinic fringes;
– isochromatic fringes.

**Isoclinic fringes** are geometrical areas of points along which the directions of principal normal stresses coincide. In linear polarized light isoclinics appear as black lines or areas. Each isoclinic is determined by the angle parameter α. In PhotoStress® method the angle parameter α is between $0° \leq \alpha \leq 90°$. The angle α is changing continuously, so that the following isoclinic fringes that appear one after another do not intersect. Only one isoclinic fringe can intersect the analyzed point on photoelastic coating. However, singular points count for an exception, since even a whole bunch of isoclinic fringes with arbitrary parameters can intersect it. Figure1 depicts isoclinic fringes of the angle parameter that were gained by means of reflection polariscope LF/Z-2 on a sample of eccentrically loaded split ring. Isoclinic fringes with angle parameter $\alpha = 0°$ and $\alpha = 90°$ are identical. Registration and subsequent drawing of isoclinic fringes is aimed to set up the system of isoclinic fringes belonging to schemes I and II and determining directions of principal normal stresses or stress paths. Registration and drawing of all isoclinic fringes along whole analyzed surface is not possible. In practical application it is sufficient to register and draw isoclinic fringes which were gained after the growth of 5° or 10° from 0° to 90°. The process of forming the system of isostatic fringes of schemes I and II from the system of isoclinic fringes is precisely described in literature [3, 4].

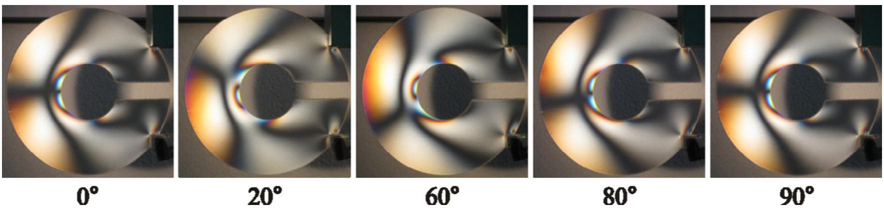
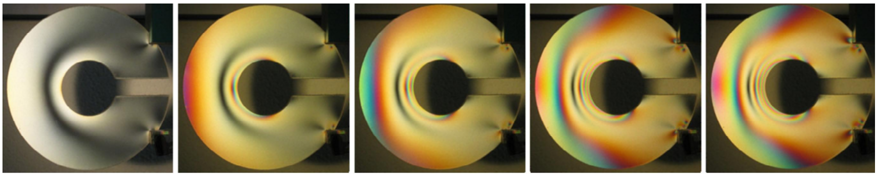



Figure 1 – Isoclinic fringes in a different angle parameter on an eccentrically loaded split ring

**Isochromatic fringes** are joining lines of points along which the difference of principal normal stresses $\sigma_1$-$\sigma_2$ is constant. On illuminated photoelastic coating isochromatic fringes appear as lines or areas with constant (iso) colour (chromos) and arise in circular polarised light. They appear on the surface of a photoelastically coated and loaded construction part which was subsequently illuminated by polarised light. These lines can be read as a topographic map that offers us visual representation of stress distribution on the whole analysed surface. When using a compensator, isochromatic fringes reveal quantitative information on magnitudes of principal normal stresses in chosen points.

When gradually loading some unloaded construction part, isochromatic fringes appear first in understressed areas. While loading is increasing, new stripes start appearing and the first isochromatic fringes are pressed closer to understressed areas. Increasing load gives rise to other stripes in overstressed areas which move to understressed areas or areas with zero stress until maximum load is reached. Isochromatic fringes are continuous; they never intersect nor join together. Each colourful isochromatic fringe stands for particular double refraction value which includes specific damage of tested construction part. The colour of every fringe represents a double refraction or fringe place value. The sequence of individual isochromatic fringes is stated in literature [5]. Figure 2 depicts isochromatic fringes which occur during gradual loading of a photoelastically coated and eccentrically loaded split ring.



Load 1 Load 2 Load 3 Load 4 Load 5

Figure 2 – Isochromatic fringes during gradual loading of an eccentrically loaded split ring

**Measurements of parameters of principal normal stress.**

Contactless measuring devices called reflection polariscopes are applied in order to visualise and measure the parameters of principal normal stress directions and principal normal stress magnitudes. The research workplace of the authors currently disposes of three reflection polariscopes: M030, M040 and LF/Z-2 (Figure 3).

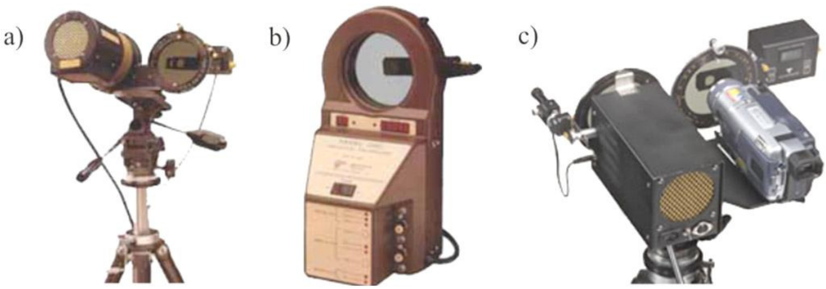


Figure 3 – Reflection polariscopes: a – M030; b – M040; c – LF/Z-2

Manual measurement process by means of reflection polariscopes includes four simple steps:

– determination of tested points on the surface of photoelastic coating;

– setting parameters of principal normal stress directions (Figure 4, *a*);

– setting magnitude parameters of the difference between principal normal stresses (Figure 4, *b*);

– value determination of particular principal normal stresses.

a) b)

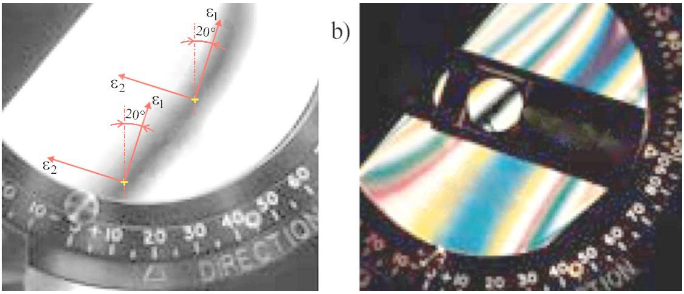



Figure 4 – Direction measuring of principal normal stresses (a) and magnitude measuring of principal normal stresses (b)

Manual measurement process with reflection polariscopes is relatively time consuming, mostly in determination of quantitative values of separate principal normal stresses in a number of points on photoelastic coating of a tested construction part. In order to speed up measurement process with reflection polariscopes M030, M040 and LF/Z-2, we use a newly developed software application PhotoStress (Figure 5) which in a simple way on photographic basis of colourful isochromatic fringes on photoelastic coating of loaded objects enables us to determine directions and magnitudes of separate values in relation to ratio strains or principal normal stresses in particular point, vector or curve [6]. For determination of the third parameter which is needed for determination of separate values of principal normal stresses uses the up-to-date application three separating methods – Slitting method, oblique illumination method and method of shear stress differences [5].

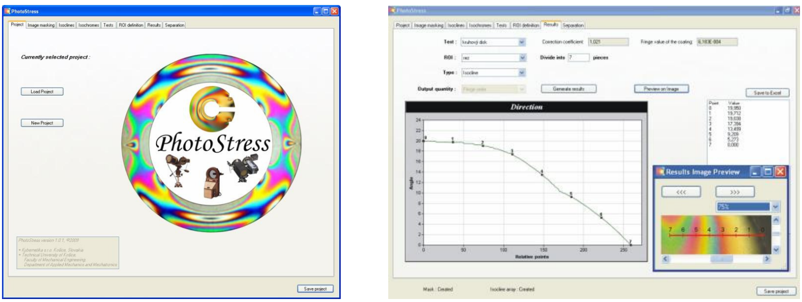



Figure 5 – The environment of software application PhotoStress

PhotoStress® method is successfully applied practically in every production and construction field, particularly in cases where stress analysis is needed, e.g. in automotive industry, biomechanics, agricultural machinery, aviation, astronautics; building of specific constructions, engines, pressure tanks, vessels, bridges, office equipment, appliances etc. There were number of practical utilisations of the method performed on our research workplace too. Figure 6 depicts practical application of PhotoStress® method in the analysis of stress tendency in case of an automobile steering knuckle [7].

Figure 6 – Analysis of stress tendency in an automobile steering knuckle

**Conclusion.** PhotoStress® method is one of optical methods. Nowadays, it is being applied in the field of experimental stress analysis of mechanical and mechatronic systems more frequently. Since new measurement systems and software applications that can assess analyzed values more precisely and in reasonably shorter period of time are being introduced, the development of the method in the above-mentioned field is even faster. The development of new software applications supports wider use of PhotoStress® method in stress analyses not only as regards engineering, but, at the same time, it offers the opportunity for the application of the method in other industrial sectors as well.

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## ПРИНЦИП И ПРИМЕНЕНИЕ МЕТОДА PHOTOSTRESS ®

Цель работы – ознакомление с оптическим методом PhotoStress® и его использованием при экспериментальном анализе главных относительных деформаций и главных напряжений с помощью покрытия фотоупругим слоем структурных элементов и их систем. Этот метод может быть также применен для анализа статических и динамических напряжений в деталях механических систем, имеющих различную форму и материал. В дополнение к основным теоретическим аспектам этого метода, в работе приведены также примеры практического применения.

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# PROBLEMS RELATED TO WELDED STEEL STRUCTURES IN CRANES

This paper deals with fundamental problems related to welded steel structures in cranes, and it is based on many years' experience of crane inspections and condition monitoring in Sweden. Considered diagnostic methods that reveal cracks occur and prevent the destruction of structures during their operation.

**1 Introduction.** Failures in steel structures and machines occur due to faulty designs, poor material quality, bad manufacturing processes, handling faults, and a defective maintenance. Welded joints, in particular, are very sensitive to fatigue loads, corrosion, low welding quality or a combination of these situations. This analysis shows that failures due to poor designs are most significant for highly fatigue-loaded structures.