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MEASUREMENT OF THE SHRINKING FORCE OF CATHODE RAY TUBE'S SHRINK FIT RIM BAND

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Abstract – The paper describes some Cathode Ray Tubes (CRT) Implosion Protection Systems (IPS) and their possible control methods.

The implosion of CRT (tube) is prevented by using the Shrink Fit Rim Band (SFRB) reinforcing the edge of the tube so that it cannot bulge outwards. The main parameter of SFRB is the shrinking force. Measurement of such a shrinking force is a very important SFRB quality control method herewith of safe CRT. In this paper we consider several methods of shrinking force measurement:

- Magnetization method;
- Barkhausen's noise method;
- CRT imitator-measurer.

Magnetization method can be successfully used for the measurement of shrinking force. However, there have been found some regularities of this method, which partly limit its application in a number of cases. This method cannot be used when the shrinking force changes its direction. It is applicable only when controlled material is magnetized.

Barkhausen's noise method is rather effective in the control of shrinking force. However as the Barkhausen's noise depends not only upon stresses in material but also upon chemical and structural composition of material, there is a problem of calibration.

CRT imitator-measurer provides sufficient accuracy of measurement; therefore it can effectively measure the shrinking force. The device is successfully used in carrying out experiments in Ekranas Co.

Keywords: Force Measurement, Cathode Ray Tube.

1. INTRODUCTION

CRT is a vacuum device. When air is evacuated from the tube, the screen (front of tube), affected by the atmospheric pressure, sags (bends inwards). This situation causes very dangerous tensile (positive) stresses in glass, which is the main factor of the glass cracking. Such tension stresses practically prevail all over internal surface of the CRT, when the latter is without IPS.

The safety of CRT depends mainly on the envelope design and IPS. There have been known many different IPS, which are used to provide implosion protection of CRT. They may be divided into four basic systems:

1. Passive restraint systems
2. Sidewall expansion preventing systems
3. Prestressed banded systems
4. The shrink fit systems

The main purpose of all tubes IPS is to afford the user from flying glass slivers in case of implosion. Some of the systems are used for a passive protection of tubes, enclosing them into a TV set with a safe glass or plastic shield in front of the TV set (1st system). The second system worked by preventing sidewall expansion. If the sidewalls of the tube cannot expand easily, crack propagation into the tube sidewall is very slow, and the tube wills slowly devacuate instead of imploding.

However, IPS, based on the pressure of CRT's sidewalls (3rd and 4th systems), ensures the best implosion protection. The SFRB construction is the main system used for implosion protection at present.

At any case, an implosion or breakage of glass, which can occur, depends on material strength and on the possible stresses in the CRT glass. The strength of glass is largely determined by the surface conditions (micro-cracks). When glass is under tension the cracks increase and the strength of glass diminishes.

Thermal stresses, vacuum stresses, stresses resulting from the implosion protection system and stresses resulting from an impact can occur in the glass.

The compression of CRT circumference by SFRB increases the tube resistance to the atmospheric pressure and reduces the screen sagging, because SFRB causes compensatory compression (negative) stresses. Thus, the main task of IPS, based on pressure of CRT's sidewalls, is to reduce as much as possible or to remove totally all tensile stresses in tube glass and to develop compression stresses areas as large as possible.

The simulation of CRT by finite element method [1] confirm that:

- During the simulation it is very difficult to evaluate all parameters which have effect upon the safety of CRT;
- The most dangerous tensile stresses stimulating the breakage of glass occurs during pumping out air out of the tube, when the front side of CRT sags as a result of atmosphere pressure;
- Glass circumference compression by SFRB increases the resistance to atmospheric pressure and reduces sagging of the tube front side, because SFRB develop compensatory compression stresses.

The safety of the CRT depends upon many factors. The main factors, which have an effect upon tubes safety, in case of IPS based on pressure of CRT's sidewalls, are position of SFRB, shrinking force and stresses in glass. So that the checking of the shrinking force, sag of tube front surface or glass stresses is rather necessary to make sure that the implosion protection of CRT is reliable.

2. THE FACTORS EFFECTING THE QUALITY OF SHRINK FIT RIM BAND

The operation of SFRB is based upon the variation of mechanical steel band properties at stretching. The inside circumference of the manufactured SFRB must be less than outside circumference of CRT. Before setting to the tube, SFRB must be preheated so that it might expand until it achieves the dimensions necessary for begirding the tube. When cooling, SFRB shrinks till the predetermined size, and also compresses the tube with determined force. SFRB is stretched beyond its elastic area, into the plastic, where it provides uniform compressive forces over a large range of sizes.

The main task, which should be solved when SFRB is used for tubes implosion protection, is to keep the shrinking force stable.

The stability of the shrinking force depends on three main factors:

- Outside CRT circumference;
- Inside SFRB circumference;
- Mechanical properties of SFRB material [2].

However, the checking of these parameters is not always sufficient. It is very important to make the comparable measurements of such parameters (shrinking force, sag of tube front surface, glass stresses, etc) which effect the tube safety during the design of a new tube, testing new SFRB material, changing the setting technology of SFRB or in other cases.

3. THE MAIN MEASUREMENT METHODS

Control methods of SFRB shrinking may be conditionally divided into two groups:

1. Methods based on CRT parameters measurement.
2. Methods based on SFRB parameters measurement.

The first group includes the methods of stresses in glass measurement, methods of tensometric measurement of glass parts absolute deformation, etc.

The second group covers SFRB shrinking force measurements by mechanical, ultrasonic, magnetic, Barkhausens's noise methods, etc.

Some of the mentioned methods are applicable only when carrying out experiments: optical stresses in glass measurement methods, methods of tensometric measurement of glass parts absolute deformation, etc. Other methods are suitable for 100% production control: mechanical methods of screen deformation measurement, etc.

The measurements of glass stresses and tube front surface sag are most widely used in the world.

3.1. The measurement of glass stresses

For measurement of glass stresses there are mostly used optical methods based on the fundamental photo elastic concept [3, 4]. As a result of stresses, optically isotropic materials become optically anisotropic. When polarized light propagates through such anisotropic materials, the differences in the speed of light rays vibrating along the maximum and minimum principal stress introduce a relative retardation between these rays. This relative retardation is proportional to the measured stresses, and can be accurately determined.

The formed interference lines (fringes) carry information of uniform stress areas. Analysing them, it may be possible to recover the distribution of stresses and calculate values of the stresses.

This test method offers a direct and convenient way to non-destructively determine the residual state of stress on the surface and at the edge of glass.

As the optical methods of stresses in glass measurement are widely used, in the present paper we will not analyse them.

3.2. The measurement of tube front surface sag

As was mentioned, the SFRB reduces sag of the tube front surface. This deformation is proportional to the stresses, which appear in glass, the later in turn depend on stretching of SFRB.

However, the sags of tube front surfaces measured in different tubes are not the same. The reasons of such instability are: dispersion of tubes glass thickness, dispersion of tubes circumference, dispersion of mechanical SFRB properties, dispersion of geometrical SFRB dimensions, etc.

In order that the results of screen surface sag measurement might allow evaluating CRT implosion safety with sufficient accuracy, the reasons of instability must be to some degree reduced. Thus, the geometry of tube glass parts, residual stresses in glass, the mechanical properties of SFRB, geometry of SFRB and other parameters, which are not widely studied in this paper, must be controlled before using them for CRT manufacture. All mentioned here parameters must meet the requirements raised for them. Only then, controlling the difference of tube screen surface sag values before and after the SFRB setting operation, it becomes possible to make any conclusion about the CRT quality in respect to the implosion safety. There should also be evaluated the uncertainty of measurements.

The measurement of tube front surface sag allows evaluating the deformation of tube, but does not allow evaluating the shrinking force.

3.3. The measurement of shrinking force

As far as our knowledge goes, the measurement of shrinking force is used rather rarely. In this work we have investigated several methods of the shrinking force measurement experimentally.

3.3.1. Magnetization method

Magnetized materials demagnetize under influence of external mechanical forces. This effect can be successfully used in practice – in our case for measuring SFRB shrinking force. Fig. 1 shows a typical magnetization characteristic.

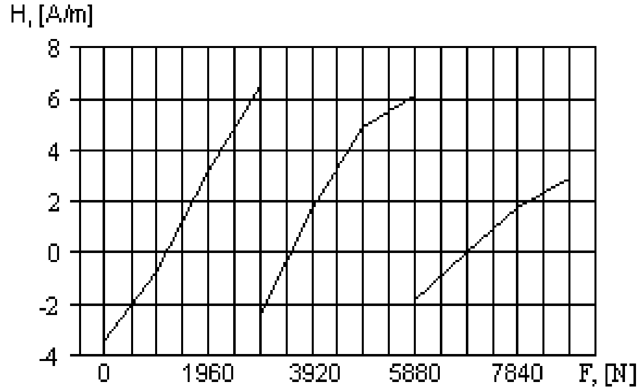

Fig. 1. Magnetization dependence upon SFRB tension force

Fig. 1 shows that the magnetization dependence in the tension area and in the yield area is different. This makes the application of magnetization method for measuring SFRB shrinking force more complicated as the SFRB works beyond the limit of yield point.

We have developed a device, which is made up of a measurement converter and an electronic unit. The output signal of the measurement converter is proportional to magnetic induction in the controlled SFRB. The electronic unit amplifies this signal, and then the latter is detected and fed into a digital meter.

With this device there have been carried out a number of experiments. In one of them, we have measured magnetic field strength and temperature of the SFRB (Fig. 2).

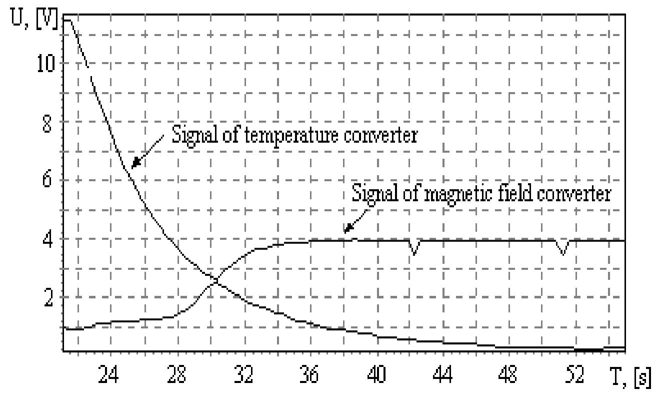

Fig. 2. Shrink fit rim band setting

It may be seen that until the SFRB is hot and its inside circumference is larger than the tube outside circumference the variations of SFRB magnetization are rather small. However, when the temperature of the SFRB decreases to such level that it inside circumference becomes almost equal to the tube outside circumference and its tension starts, then there are being observed rather great variations of the SFRB magnetization until it entirely demagnetizes.

Disadvantages of the magnetization method:

- Non-linear magnetization dependence upon force when material passes into a plastic deformation area;
- The method is applicable until the material under control is magnetized;
- The method cannot be used when the shrinking force changes its direction.

3.3.2. Barkhausen's noise method

Barkhausen's noise method was investigated by V.Augutis and Z.Nakutis [5]. This effect is observed by broadband fluctuations of magnetic field on the surface of ferromagnetic materials, when they are magnetized by external magnetic field. The intensity of Barkhausen's noise (Fig. 3) depends on microstructure and stresses of material [6].

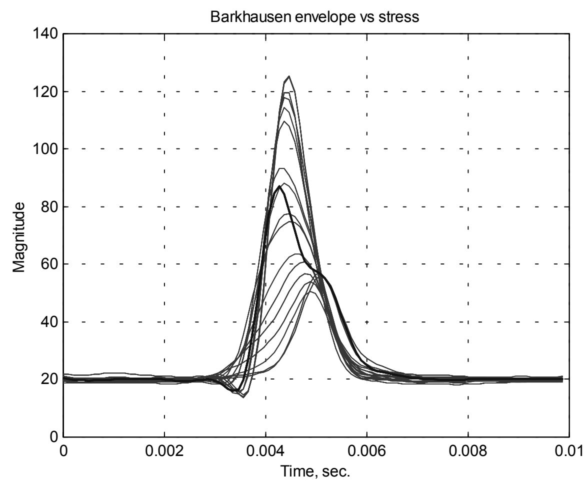

Fig. 3. Barkhausen envelope vs stress

There has been developed a device for Barkhausen's noise measurement in shrink bands. Experimental results carried out with this device exposed the following disadvantages of this method:

- Using Barkhauzen's noise method the stresses have been evaluated only on the surface of the investigated material, because high frequency Barkhauzen's noise magnetic field does not penetrate from the deeper layers of material;
- Barkhauzen's noise depends not only on the stresses in material but also on the chemical and structural composition of material, therefore the calibration of the device is associated with certain problems, and due to them there occur rather great measurement errors;
- Most suitable operation of the device is control by comparison method.

3.3.3. CRT imitator-measurer

CRT imitator-measurer is a meter simulating tube circumference and containing force sensors for the evaluation of SFRB shrinking force.

The imitator-measurer consists of a force unit and an electronics unit. An imitator force unit is illustrated in Fig. 4.

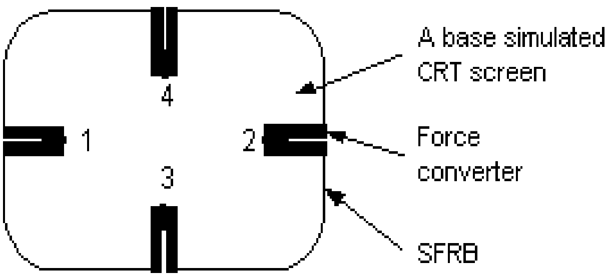

Fig. 4. CRT imitator-measurer

A schematic diagram of an imitator-measurer is shown in Fig. 5.

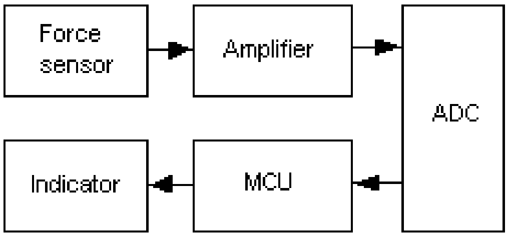

Fig. 5. Schematic diagram of imitator-measurer

The software used in this arrangement consists of two modules – calibration and data readout one. There are several operation modes: when measured force values are displayed on LCD, transferred to the computer, or data is recorded in to the device flash memory.

The main characteristics of the imitator-measurer are:

- Number of measuring channels 4;
- Maximum value of measuring force 16kN;
- Measuring error ±50N;
- Resolution 1N;
- The results are displayed on an imitator-measurer and can be sent to PC;

The imitator-measurer measures shrinking forces of cooling SFRB at four points and displays changes of these forces in respect to time (Fig. 6).

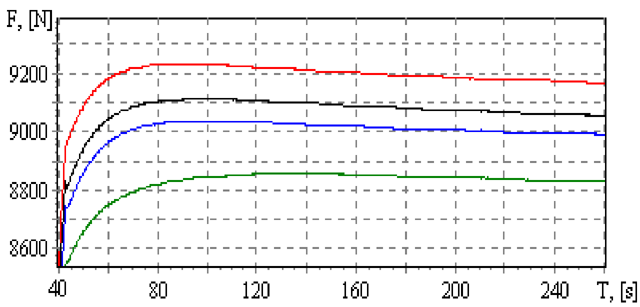

Fig. 6. The curves of shrinking forces, measured by imitator-measurer

The imitator-measurer was used in carrying out a great number of experiments, which with sufficient accuracy coincided with the calculated SFRB shrinking force results. Its calibrations and operation is rather simple.

The greatest disadvantage of the imitator is its limited application. It may be used only to control SFRB shrinking force designed only for a certain type on CRT. For tubes with smaller or larger outside circumferences there should be produced a corresponding imitator force unit.

4. CONCLUSIONS

The method of magnetization can be successfully used for the measurement of shrinking force. However there have been found some regularities, which partly limit its application in a number of cases. The method cannot be used if the force changes it direction. It is applicable only when controlled material is magnetized.

Barkhausen's noise method is effective when controlling the shrinking force of SFRB top layers. However as the Barkhausen's noise depends not only upon stresses in material but also upon chemical and structural composition of material, there is a problem of calibration.

Imitator-measurer provides sufficient accuracy of measurement; therefore it can effectively measure SFRB shrinking force.

All these investigated shrinking force measurement methods are successfully used in carrying out experiments in Ekranas Co.

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