# Division 3

## METHODS AND EQUIPMENT FOR CONTROL OF DEFECTIVENESS AND STRESSED STATE OF CONSTRUCTIONS («Diagnostics» Project)

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«Diagnostics» Experiment

## DEVELOPMENT OF METHODS AND COMPACT EQUIPMENT FOR CONTROL OF DEFECTS AND STRESSED STATE IN WELDED ELEMENTS OF STRUCTURES, WHICH OPERATE UNDER THE SPACE CONDITIONS

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Large-sized thin-walled welded structures, which should meet the requirements of high reliability and performance, are widely used now in construction of aerospace engineering systems.

Application of welding and brazing for repair and assembly of thin-walled elements of orbital stations has attracted increasing interest over the last years. In this connection intensive studies are carried out for development of effective methods of quality control and determination of residual stresses in welded joints of structures used under the space conditions.

The investigation methods should meet a number of requirements such as the possibility of defect visualization, validity of results, high sensitivity, contactlessness and accuracy of measurements and compactness of equipment. Traditional methods and means of structure diagnostics do not satisfy the above-mentioned requirements and do not provide any data on the features of the stressed state and quality of thin-walled elements under examination. Eddy current method and holographic interferometry — a new method of examination, meet these requirements.

The non-destructive testing method of holographic interferometry allows direct generation of the qualitative pattern of deformation distribution over the entire surface of an object to which certain forces are applied, without making any measurements of the interferogram being formed. Even without further analysis, this pattern provides very useful information for control purposes, thus permitting various defects to be detected easily.

The advantages of the new method are as follows: contactlessness of measurements; absence of harmful effect on the environment and attending personnel (ecologically clean method); feasibility of a simple visual observation of the interference fringe pattern over the whole field; applicability to examination of intricate objects; absence of special requirements to preparation of the surface of the objects to be examined; accurate quantitative determination of small values of the space vector of displacement over the surface of the object to be examined; simplicity

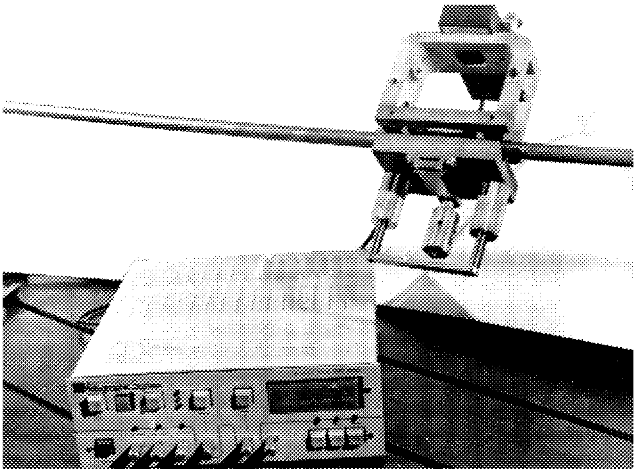

Fig. 6. General view of the mock-ups of holographic devices used for quality control of tubular elements

of interpretation of interference fringe patterns during quality control; absence of the effect of magnetic and electric fields on the accuracy of measurements; safety in operation; possibility of automation, etc.

The information on the quality of elements being examined was recorded by a developed compact thermoplastic recording camera, thus permitting to avoid chemical developing. This significantly increased the speed of information acquisition and shortened the time of hologram recording to 5-10 s.

The use of light guides in holographic quality control of the structural welded elements allows compact holographic instruments and devices to be developed, which are suitable for non-destructive examination in space.

In addition, the optical light guides can be sufficiently long for arranging the laser sources at a large distance from the holographic instrument.

On the basis of the developed procedures, operating mock-ups of holographic devices have been created for their testing, allowing evaluation of the possibility to perform non-destructive holographic control. Figure 6 presents general views of the operating mock-ups of holographic devices for quality control of tubular elements.

The interference fringe patterns, which characterize the quality of tubular specimens, are given in Figure 7.

Fast analysis of the quality of welded tubular specimens showed the feasibility of applying the holographic method for non-destructive control of welds of thin-walled tubes used as technological piping at the orbital space station. In our opinion,

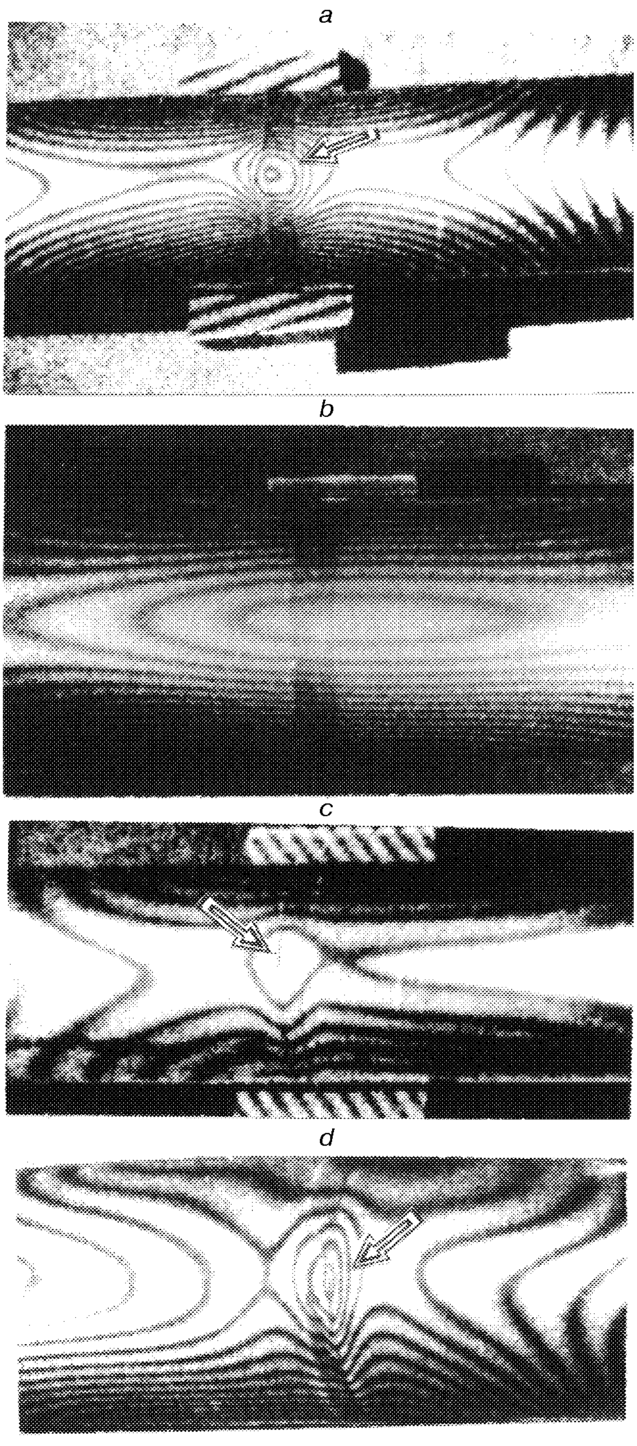


Fig. 7. Interference fringe patterns, which characterize the quality of tubular specimens

one of the advantages of the method is visualization of control results, availability of photos, which are a document of the interference pattern that charac-

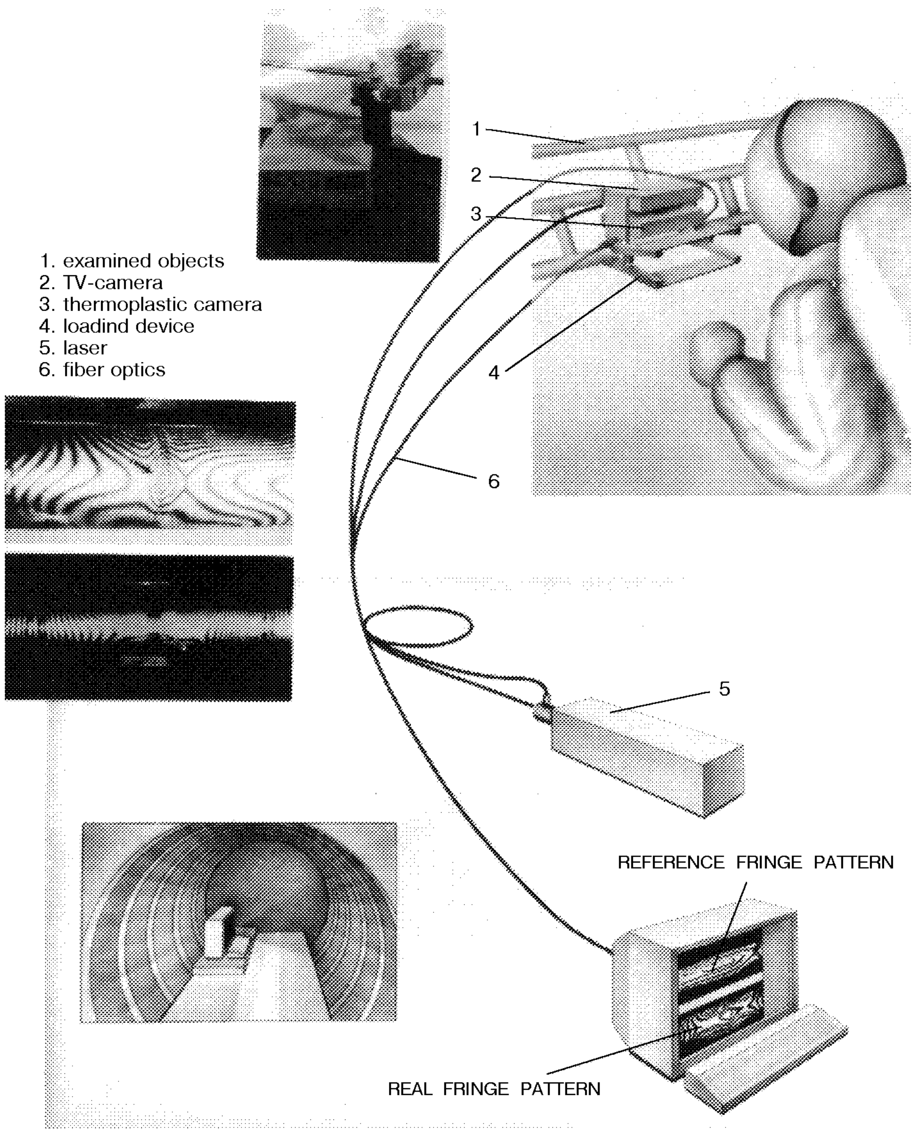


Fig. 8. Schematic of non-destructive quality control of structural elements under the space conditions.

terizes the quality of the object being examined. To identify all possible defects and causes of their initiation, it is necessary to obtain the reference fringe patterns, generated by a crack, lack of penetration, burn-through, changing of mechanical properties, etc.

Application of holographic non-destructive quality control of welded piping in vacuum, for example, in space, is most promising. The experiment on quality control in this case is performed in the following sequence.

After tube welding the astronaut takes a small-sized holographic device for quality control and mounts it on the tube in the weld zone being examined with the help of a simple clamp-holder (Figure 8). The small-sized laser source is located onboard the space station or in the casing of the holographic device. With the help of light guides the laser light is transmitted to a weld zone being examined. The weld interferogram is recorded and the image is transferred to the on-board computer monitor, which has a reference of the interference fringe pattern of a tubular sample stored in its memory. The computer compares the reference with

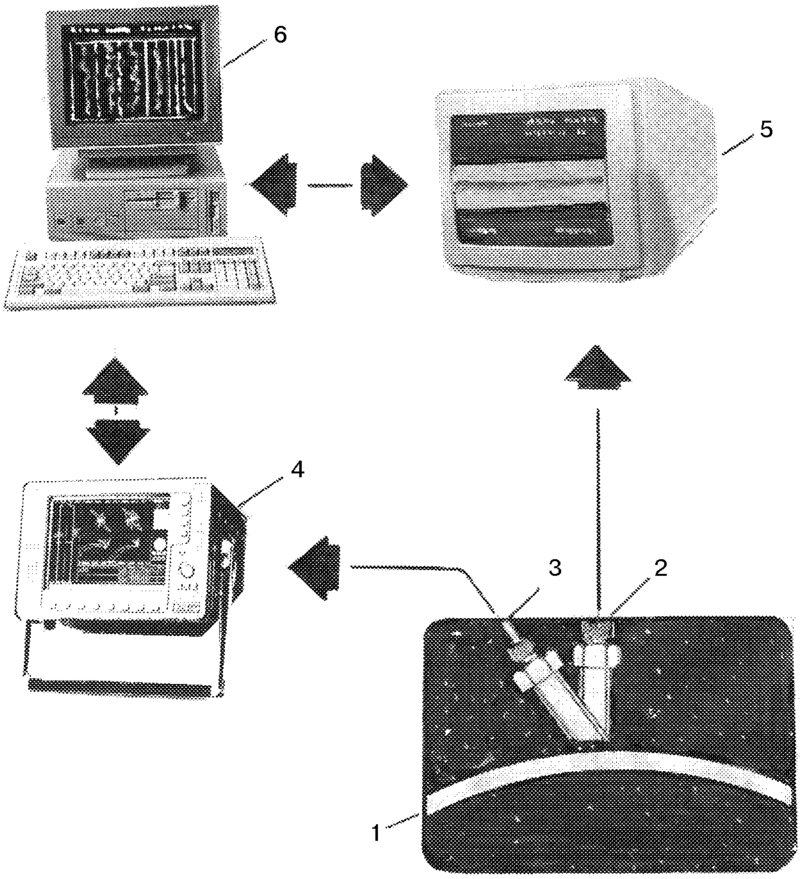


Fig. 9. Block-diagram of examination of welds in space using visual and eddy-current methods.

the interference pattern of the weld being examined. In case of a defect the computer sends a command about the weld being defective, or confirms its quality. In addition, the generated information can also be sent to Earth.

The version of visual comparison of the reference on the monitor with the interferogram of the examined weld by the operator is also possible. This can be done without using the computer. It should be noted that there is no need in any special complicated training of the operators.

Preliminary experiments on non-destructive contactless holographic control of the quality of thin-walled welded structural elements demonstrated its high efficiency and reliability.

Visual and eddy-current methods can also be used for non-destructive control of orbital station elements in space.

The first method provides information about the appearance of the welded joint, while the second (eddy-current) method — about its internal structure.

The block diagram of control of welds for space vehicles is given in Figure 9.

A combined scanning sensor (2, 3) which includes optical 2 and eddy-current 3 transducers moves along the weld and near-weld zone. Information from this sensor is transmitted to the space vehicle cabin where eddy-current flaw detector 4, video camera 5 and computer 6 are located. After scanning along the weld, the information stored in the memory is visualized and analyzed in the space vehicle cabin. Each of these methods (visual and eddy-current) can be also used independently, but their combination provides more valid information on the quality of the metal structure. The information entered for processing allows determination of the size of the defect, its location and evaluation of the probable hazard. Control is performed in real time. The most hazardous defects are marked by sound or light signals and are to be subjected to more careful examination with a repeated scanning of the hazardous zone.

The eddy-current flaw detector, in addition to a linear scanning image on the screen, provides the mode of a two-dimensional imaging of defective regions. In this mode, the point on the screen, which represents the end of a vector of a complex output voltage of the transducer, describes complex closed trajectories during the transducer movement with respect to the object of examination. The trajectory is memorized for a time required for analysis, which is set by the operator. The phase characteristics of the signal are determined from the trajectory position in a complex plane, while the defect can be identified from the trajectory.

The computer memory stores coded information on the typical internal and external defects that allows the classification analysis of defects to be made from the recorded scanning signals.

«Transformable Shells» Experiment

## WELDED METAL TRANSFORMABLE SHELLS

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Progress in space science and technology, practical exploration of space, which has been started in the 60s of the XX century, opened for the scientists and engineers the complicated, but challenging prospects of study and exploration of near-earth space and the nearest planets. Stations, which are equipped for an integrated study of the natural conditions, will enable the use of the resources of these planets for the benefit of mankind. The presence of scientific expeditions on the planets implies provision of comfortable conditions for work and rest of the crew. For this purpose, it is necessary to create living quarters, laboratories and production shops, stores, shelters, etc. Such constructions naturally have large volumes and their transportation from the Earth will be problematic, as there are contradictions between the required dimensions of structures and limited sizes of transport containers of rocket carriers.

Engineering thought has produced a number of approaches to overcome this contradiction, for example, folding of structures made from air-tight fabric and films, modular assembly, etc. The many-year practice showed that the use of metals is the most rational way to create space objects, but transformation of the overall constructions into compact packs is extremely difficult, the more so since

a b c

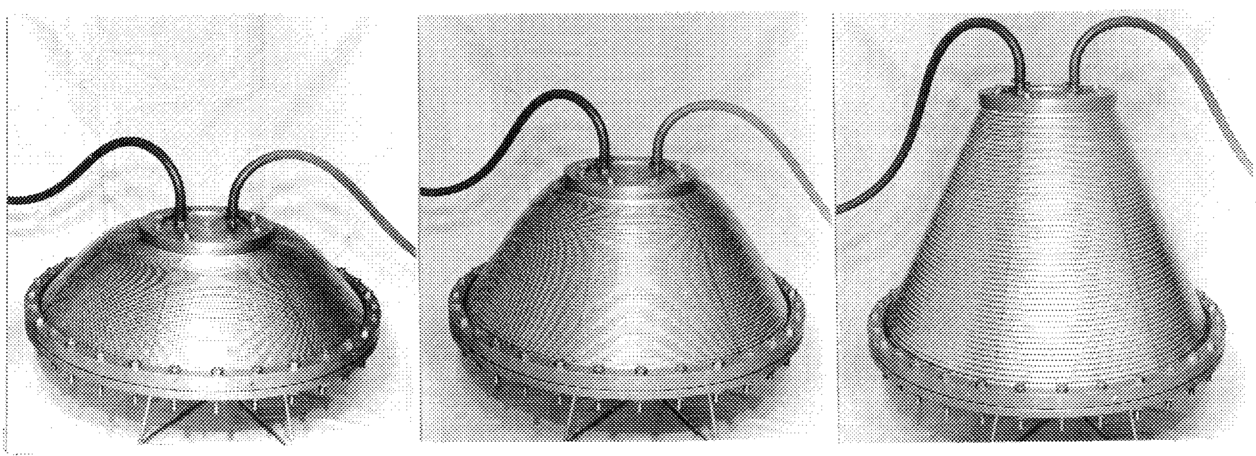

Fig. 10. Transformation of a corrugated disk into a conical shell at the initial (a), intermediate (b) and final (c) phases