Determination of heterogeneity of composite materials of shell structures by conductometric method

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Abstract

The paper proposes an approach to simulation modeling of the inhomogeneity of composite materials of shell structures based on the conductometric method. The object of research is the control of the inhomogeneity of composite materials used for the shell structures of mirror antennas by the conductometric method. The information and measuring system for determining the inhomogeneity of composite materials by the conductometric method is presented. Typical designs of devices for measuring the inhomogeneity of composite materials by the conductometric method are analyzed. The shell structure of mirror antennas (mirror reflector or aperture array) is used as a control object. For the actuators that ensure the operation of the system, a structural calculation and a description of the operating principle are given. A Petri net is presented to display the process of verification for the presence of composite inclusions and the probabilistic distribution of the time spent by the test material at the working positions P1, P2, P3, P4. The state of the working positions of the measuring unit during the control process and the computer program and results of visualization of the internal structure of the composite are presented. The errors of the measuring channels are analyzed and the permissible values of parameters and operating modes are selected. Assumptions about the development of the object of study in the search for optimal design characteristics of the device for analyzing and calculating the measurement and study of radio engineering characteristics of mirror antennas in the form of standing wave coefficient, gain, and radiation pattern at a constant frequency range are predicted.

Keywords

antenna mirror, electric arc spraying, composite materials, conductometric method

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1. Introduction

The development of measuring equipment aimed at providing solutions to the problem of automating the control of various processes (technological, testing, research, diagnostic, etc.) is accompanied by a rapid growth in the variety of types of measurements with a steady expansion of measurement ranges and an increase in speed and accuracy.

The main prerequisite for expanding the functionality and a fundamental feature of modern measuring equipment is the introduction of programmable computing power into the measuring chain, mainly in the form of a microprocessor device or computer.

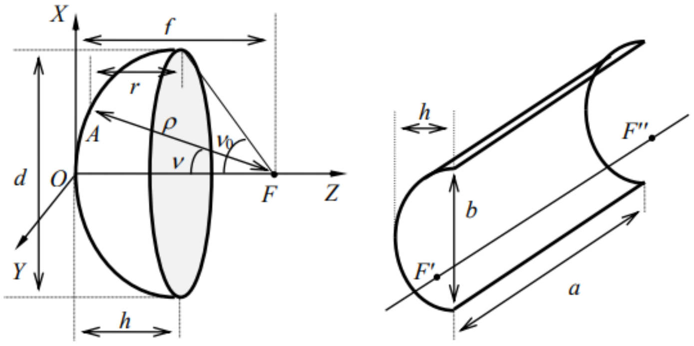
The transition from digital measuring instruments and devices to processor-based measuring instruments has led to the fact that the measuring device has two parts - hardware and software, since a significant part of the measuring procedure in them is realized in digital form, i.e., by means of measuring transformations of digital arrays. Measuring transducers, as measuring instruments designed to convert physical quantities into output signals convenient for measurement or further transformation, are becoming increasingly used both in measuring equipment and in automatic process control systems.

It should be noted that most test methods were developed long ago and over time, only the equipment for their implementation has improved. The conductometric method of measurement, which is often used to control composite materials to determine the inhomogeneities and depth of surface cracks, was used.

2. Analysis of available research

Manufacturing and calculation of mirror antennas on the initiative and direct participation of Professor Oleg Shabliy and Associate Professor Andriy Rudnyk began at Ivan Pului Technical University and continues to this day with the search for a technology for forming surfaces with specified geometric properties and increased accuracy of the shape of the reflective surface. In particular, as one of the options, the method of forming a reflective surface of a given profile by electric arc spraying was considered [1]. It was supposed to manufacture a reflective surface from a mesh material blank placed on a punch by applying an electric arc spray coating on it, which would reduce the overall dimensions of the shell in terms of thickness and weight. It should be noted that in order to maintain uniform application, it is important to correctly position the working unit in relation to the punch surface, i.e., to move it at a constant distance and orient it normally to each point on the surface.

Scientists from Ukraine and abroad have been involved in the design, production, and development of the mirror, which is reflected in [2, 3]. The mirror is intended to fully reflect the electromagnetic waves incident on it (Fig. 1). Therefore, its surface is made of highly conductive metals. The surfaces of hard metals are 2-3 times thicker than the thickness of the reflective layer δ and have the best reflectivity (the distance at which the amplitude of the electromagnetic field decreases several times). Solid reflectors are made in the form of metal sheets or films (foils) that are applied to a lightweight dielectric base of foam or fiberglass.



a) b)

Figure 1: Reflectors in the form of a paraboloid of rotation (a) and a parabolic cylinder (b): ρ - distance from the focus to the observation point; ν - is the angle between the reflector axis (FO) and the direction to the observation point.

To reduce weight and wind load, the reflective surface is sometimes made in the form of perforated sheets, one- or two-line mesh of round or rectangular wire. In the case of an inconsistent reflector, part of the electromagnetic energy leaks through it, creating unwanted back radiation and reducing the antenna gain. To reduce leakage, the characteristic holes should not exceed (0.1 ÷ 0.2)..λ, where λ is the radio wavelength [4].

Formation of shells by electric arc spraying and application of composite material. The formation of mirror antennas (aperture arrays) consists of several stages. The first stage is deformation of the two-dimensional mesh and fixing of the nodes by electric arc spraying with aluminum (Fig. 2). The second stage, after sputtering on the punch, is to obtain a surface with a high temperature and apply a composite material such as polystyrene. Polystyrene is a polymeric material used in the manufacture of various products due to its unique properties.

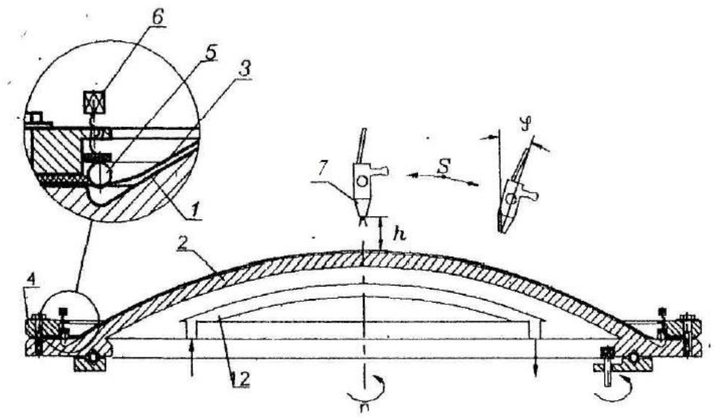


Figure 2: Electric arc spraying method for mesh material.

Depending on the complexity of the structure of the substance, the state in which it is located, and the corresponding level of technology [5, 6], the methods used to assess the composition and structure of composite materials are divided into:

- chemical;
- structural and mechanical;
- physical and chemical, including electrochemical (potentiometry, conductometry); thermoanalytical (differential thermal analysis, calorimetry; X-ray (X-ray diffraction and X-ray phase); spectral (molecular spectroscopy, photoelectric method, flame photometry, electron and nuclear magnetic resonance spectrophotometry, infrared and ultraviolet spectroscopy); optical (light microscopy, reflected light microscopy, refractometry, electron and scanning microscopy).

For our case, it is sufficient to use the conductometric measurement method, which is often used to control composite materials [7]. The conductometric method is a method for determining the electrical conductivity of electrolytes (systems with an ionic type of conductivity, which are represented by aqueous and non-aqueous solutions, colloidal systems, suspensions, pastes, and melts).

Conductometric analysis allows not only to determine the electrical conductivity of colloidal systems (e.g., binders, sludge glass), but can also be used to study the degree of saturation of capillary-porous bodies or the kinetics of hydrolysis, hydration, and dissolution processes that occur during the curing of binders. By measuring electrical conductivity, it is possible to control the processes of accelerated curing of building materials (for example, during steaming or autoclave processing).

3. Description of the created information system

Mathematical modeling of an information and measuring unit for controlling the internal structure of a composite. The control of the internal structure of a composite includes a number of methods and techniques for evaluating and analyzing its composition, size and organization of components. The main methods of controlling the internal structure of composites include:

Optical microscopy: It is used to study the structure at the micro level, to assess the size and shape of inclusions, and to evaluate the homogeneity of the material.

Electron microscopy: Includes scanning electron microscopy (SEM) and transmission electron microscopy (TEM), which provide high-resolution images for studying structure at the nanoscale.

X-ray diffraction: It is used to analyze the crystal structure of materials, to detect the presence of crystalline phases and determine their structure.

Thermal Analysis: Includes Differential Scanning Calorimetry (DSC) and Thermogravimetric Analysis (TGA) to study the thermal properties and changes in material structure when heated.

Nuclear magnetic resonance: Used to study the molecular and atomic structure of a material.

Ultrasonic inspection: Used to detect defects and assess material uniformity.

These methods help to study the structure of composites at different levels, from the nano- to the macro-level, which is important for understanding their properties and improving their production processes.

Inhomogeneities in composite materials in shell structures can be caused by various factors and have different characteristics. Some of the most common types of inhomogeneities in composites include:

Inclusions: Small particles or areas of other material that are embedded in the main matrix material. These inclusions can be random or regular in size and shape.

Porosity: The presence of pores beneath the surface of a composite that can occur during the manufacturing process or as a result of mechanical damage.

Manufacturing defects: Irregularities that occur during the manufacturing process, such as cracks, bubbles, wrinkles, etc.

Property variations: Material properties that do not match in different directions or in different parts of the structure.

Various methods can be used to model such inhomogeneities, including computational methods, finite element analysis, analytical models, and experimental methods. In addition, for each type of inhomogeneity, specific methods can be used to evaluate and predict their impact on the properties and behavior of composite materials in structures.

Conductometry is a technique that uses the measurement of a material's conductivity (or resistance) to determine its properties. To determine inhomogeneities in composite materials of shell structures, the conductometric method can be used to:

Pore Detection: Porosity in composites typically has a higher resistivity than the composite material itself, so measuring the resistivity can help detect the presence of pores.

Measurement of inclusion concentration: If inclusions have different electrical properties than the base material, their presence can affect the conductivity. Conductometry can help determine the concentration of such inclusions.

Detection of manufacturing defects: Cracks or other defects in a composite can alter its electrical conductivity, which can be detected by conductometry.

Assessment of material homogeneity: Different inhomogeneities in a composite can lead to changes in its conductivity. Conductometry can be used to evaluate material homogeneity.

To determine the inhomogeneities of composite materials in shell structures, the conductometric method requires careful analysis of the measurement results and may require specialized equipment and techniques.

Different approaches and methods can be used to mathematically model the information and measurement system for controlling the internal structure of a composite. Here are some possible stages of creating such a model:

Define composite parameters: Set parameters that characterize the internal structure of the composite, such as inclusion sizes, distribution, concentration, material type, etc.

Selecting the inspection method: Selection of internal structure inspection methods, such as radiography, ultrasonic inspection, thermal imaging inspection, acoustic inspection, etc. Each method may require appropriate mathematical models for data analysis and interpretation.

Development of a mathematical model of the control method: Create a mathematical model for the selected inspection method. For example, for ultrasonic inspection, a model of the propagation and reflection of ultrasonic waves in a composite can be created.

Simulation and analysis of results: Application of the created mathematical model to simulate the control of the internal structure of the composite and analysis of the results. This allows us to evaluate the effectiveness of the chosen method and optimize the control setup.

Model validation: Checking the developed mathematical model against experimental data to confirm its accuracy and correctness.

This approach makes it possible to systematically develop and improve the information and measuring equipment for controlling the internal structure of the composite.

The digitized data set on the structure of a composite may contain information on various parameters that characterize its internal structure. Here are some possible parameters and methods for digitizing them:

Inclusion sizes: The size of inclusions in a composite can be estimated by processing images from microscopes. The data can be digitized by measuring the area or diameter of the inclusion.

Inclusion distribution: A histogram can be used to evaluate the distribution of inclusions, where each column corresponds to the number of inclusions within a certain size range.

Component organization: You can use parameters such as component spacing, angular relationships, etc. to describe the organization of the composite components.

Material homogeneity assessment: To evaluate material homogeneity, indicators can be measured that indicate the degree of inclusion diversity in different areas of the composite.

Defects and damage: Assessment of defects and damage may include measurement of their dimension and distribution in the composite.

3.1. Petri net as a mathematical apparatus for studying information processes

To process the results of measuring the current strength using current electrodes, it is necessary to have its nominal static characteristic, on the basis of which the desired current strength can be calculated from the measured current value and the appropriate corrections made.

When analyzing measurement results, it is often necessary to find an analytical expression that relates some variables. Such an expression allows you to draw conclusions not only about the nature of the relationship between these factors, but also to quantify the value of one of them for a given value of another.

In some cases, the form of the relationship between variables may be known based on certain theoretical considerations.

However, there are often situations when the nature of the relationship between variables is not known in advance and it is necessary to find a mathematical expression of the relationship between them based on the experimental data.

If the nature of the relationship between the variables is known, the problem is reduced to determining the constant coefficients in the relationship equation using the least squares method.

A Petri net is a graphical and mathematical tool for modeling systems and processes. As a rule, Petri nets are used to model parallel (synchronous and asynchronous) systems and processes.

Originally proposed in Karl Petrie's doctoral dissertation, they were further developed in the works of such scholars as Tadao Murata, Kurt Jensen, Vitaly Kotov, and Anatoly Sleptsov [8, 9].

In recent years, an annual conference "Applications and Theory of Petri Nets" has been held, the Petri Net Newsletter is published in Bonn, several hundred modeling systems for various hardware and software platforms are known, and implementations of Petri net processors exist. Areas of application of Petri nets include the study of telecommunication networks, network protocols, computing systems and computing processes, production and organizational systems.

3.2. Petri nets as a means of modeling systems and processes

Petri nets are a structure defined by a set of input and output transactions. Modeling systems using Petri nets.

Simple Petri nets contain only three basic elements: nodes, transitions, and markers. Therefore, building models of complex dynamic systems with a large number of interacting parallel and asynchronous processes and many information and material flows becomes a rather complicated and cumbersome procedure.

This significantly narrows the class of system models that can be built on the basis of simple Petri nets. In such cases, extensions of simple Petri nets are used, which make it possible to significantly simplify the construction of complex models and their graphical representation.

Expanding the capabilities of nodes during modeling.

Further expansion of the capabilities of Petri nets for modeling tasks is associated with the transition from the use of nodes with markers and transitions to the use of data warehouses (a node with a certain data structure) and data streams [10, 11].

It was mentioned above that in a Petri net, all possible states of the model are indicated by nodes with markers. In general, nodes act as data stores of a given size, and transitions act as data flows.

The capabilities of Petri nodes can be greatly expanded by assigning different types of data to tokens, such as character strings, integers or real numbers, sets, structures, as is done in programming languages.

Display nodes with such markers, you need to specify the types of data and determine the maximum number of markers of each type that can be in a node. Another way to expand the functions of *mode of access* to tokens, i.e., to specify how tokens (data) are received by nodes and how they are removed from them.

This allows you to create token queues in nodes in a similar way to how requirements queues are created in the CMO.

The choice of queueing and token removal modes depends on the sequence in which you want to check tokens in nodes. Therefore, it is hardly possible to give general advice on which access modes to use.

In simple Petri nets, random access mode is automatically used (the order in which tokens are queued and the order in which they are removed does not matter to them).

Extending the capabilities of Petri nodes is a very convenient tool for modeling material and information flows in production systems.

Petri net rules and methods of description [12, 13].

Expanding the possibilities of transitions during modeling.

Transitions are active network elements that can be triggered in parallel. Whether a transition can be triggered in parallel or whether it will be triggered earlier than other transitions must be specified in the transition definition during the simulation.

The order in which transitions are triggered is determined by the simulation control program. In order to reproduce the dynamics of the system being modeled, transitions must be triggered at the appropriate moments in the simulation time.

A transition can only be excited if the excitation rules are met. To do this, the simulation control program searches for markers at the input nodes of each transition to check whether the rules defined by the input arcs are met.

If the required set of markers in the input nodes of a transition is found, it is triggered. A transition is triggered when all four conditions are met:

- the parallelism bandwidth is still not exhausted (i.e., how often a time-dependent transition can be triggered in parallel with itself);

- the input nodes of the transition contain a sufficient number of markers with the necessary attributes that correspond to the expressions of the input arcs;

- the logical conditions formulated for the attributes of node markers can be fulfilled;

- the throughput capacity of the output nodes of this transition is such that they are able to include as many tokens as can be specified by the numbers of the throughput capacity of the output arcs, i.e., the numbers that determine the number of tokens that will get to the output nodes.

Then, the simulation program checks the markers in the input nodes that are destroyed at the current moment of the model time (for input arcs, a later marker destruction time can be set), and the markers that will be created for the output nodes are generated after the transition time has expired (for output arcs, the time on the arc relative to the transition time can be set).

Consider the Petri net shown in Fig. 3 (black markers are marked with the symbol #). When viewing the set of markers in the left part of the network, the simulation control program checks the excitation rule of the *T1* junction. The transition can be triggered by removing three black tokens from the input node *P1*, generating one black token at the output node *P2,* and five black tokens at the output node *P3*. The next set of tokens does not allow the transition *T1 to be* triggered again, because node *P1* must have at least three black tokens. Such a set of markers can occur, for example, when a transition for which node *P1* is the source node is triggered.

Transitions that are triggered in model time.

In order to model dynamic systems, you need to be able to associate the moments of transition triggering with the model time. There are several types of transitions: instantaneous, exponential, and deterministic. An instantaneous transition is not associated with a moment in time, and its switching is performed as described above. This type of transition is usually displayed on a Petri dish diagram as a line or a narrow rectangle.

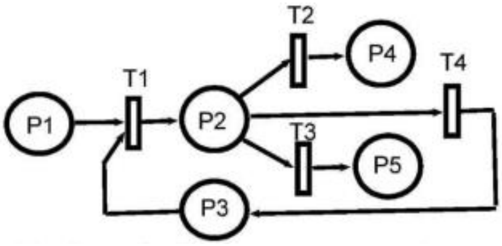


Figure 3: Petri net for displaying the process of checking for composite inclusions.

If the response time of a transition is distributed according to an exponential law, then such a transition is represented by an unpainted rectangle, and if the response time of a transition is deterministic, then it is represented by a painted rectangle. A Petri net in which the response time of transitions is given by a probability distribution is called a stochastic Petri net [14].

Parallel triggering of transitions.

With a sufficient number of tokens in the input nodes, transitions can be triggered several times in parallel until they run out of tokens. This allows you to describe quite complex real-world processes and systems. The number of transitions is set by the parallelism value in the system being modeled. For example, the standard value of parallelism in POSES++ systemis 2^{32}, that is, it can vary from 1 to 4294967295, which is sufficient to achieve practical goals.

Transition *T1* is triggered three times simultaneously because the parallelism limit is not defined. If you set the parallelism value for transition 2, it could only be triggered twice in parallel. The parallelism limit does not affect transitions that do not have a trigger time specified. When this time is defined (for example, a fixed time of 10 s), the functioning of the transition is noted in the statistics of the simulation results, for example: "At time 0, two triggering events start simultaneously and last for 10 s". At the simulation time of 10 s, the third triggering starts and continues for 10 s (until the simulation time reaches 20 s).

Transition priorities.

Since a transition needs to check the excitation rules to be triggered, a situation arises when individual transitions compete with each other for the possession of markers. As long as no priorities are set, competing transitions solve problems randomly, i.e., a random number generator determines which of them should be checked first with the same probability for all transitions. If a rule is fulfilled for this transition, it is triggered before those that could also be triggered.

3.3. Petri net that reproduces the process of composite verification

The transition triggering time can be fixed or calculated. It depends on the time scale used in the model and the time tick that the model developer determines [15].

The simulation time is advanced with some fixed value of the time tick, for example, every second. Time rounding errors do not affect accuracy if the simulation time is specified as an integer data type Fig. 4.

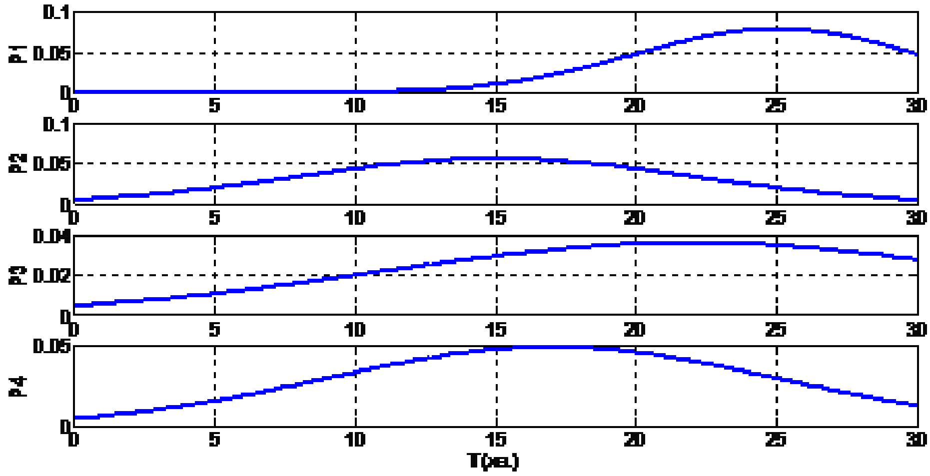


Figure 4: Probabilistic distribution of the time spent by the test material on the working positions P1, P2, P3, P4.

The deterministic value of the triggering time can be directly assigned to the transition attribute, while the arbitrary value of the time must be determined (or rather calculated) during the modeling process, since it may depend on the values of the marker [16].

Status of the working positions of the measuring unit during the control process Fig. 5.

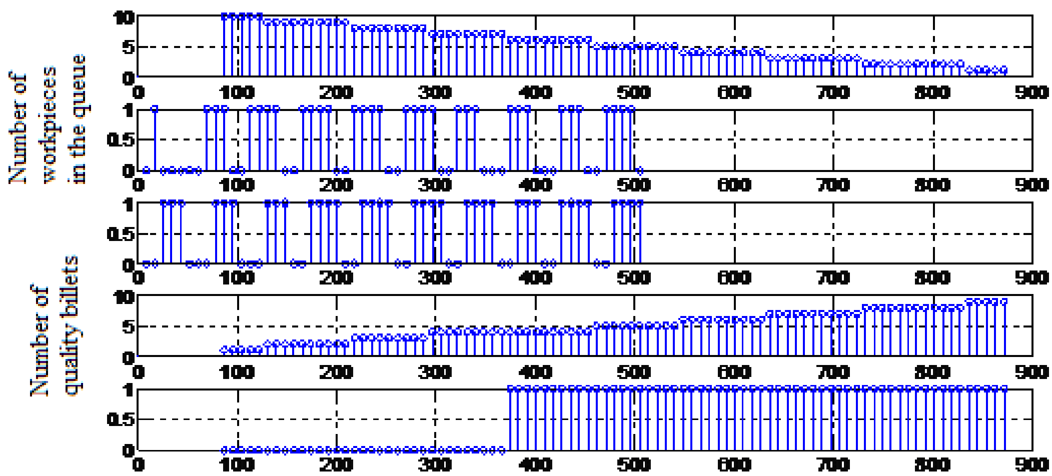


Figure 5: Status of the working positions of the measuring unit during the control process.

Thus, a new arbitrary time value for the transition is set for each beat of the model time, just as for the triggering of the transition.

4. Program and results of visualization of the internal structure of the composite

Calculation program

```
clear all
%generation of random numbers according to a given law
N=10;
Q=0.3;
M1=25;
D1=5;
t1=normrnd(M1,D1,1,N);
 M2=15;
D2=7;
t2=normrnd(M2,D2,1,N);
 M3=22;
D3=11;
t3=normrnd(M3,D3,1,N);
 M4=17;
D4=8;
t4=normrnd(M4,D4,1,N);
 q=rand(1,N);
 % distribution density functions
 x=[0:.1:30];
 f1=normpdf(x,M1,D1);
 f2=normpdf(x,M2,D2);
 f3=normpdf(x,M3,D3);
 f4=normpdf(x,M4,D4);
subplot(4,1,1)
 plot(x,f1), grid
subplot(4,1,2)
  plot(x,f2), grid
  subplot(4,1,3)
 plot(x,f3), grid
 subplot(4,1,4)
plot(x,f4), grid
 % positions P0 P1 P2 P4 P5
k=100;
tt=0;
 s1=0;
s2=0;
i1=1;
i2=0;
for i=1:N
   T(i)=t1(i)+t2(i)+t3(i)+t4(i);
     Ni(i)=N-i+1;
          if ((q(i)>=Q)&(i==1))
       s1=1;
     end
     if ((q(i)>=Q)&(i>1))
     s1=s1+1;
     end
         if ((q(i)<Q)&(i==1))
       s2=1;
   end
     if ((q(i)<Q)&(i>1))
        s2=s2+1;
     end
      p4(i)=s1;
       p5(i)=s2;
          tt=tt+T(i);
          t(i)=tt;
           tii=[0:T(i)/50:T(i)];
     n =length(tii);
     i2=i2+n;
       p1(i1:i2)=0;
    p2(i1:i2)=0;
    for j=1:n
       if (tii(j)>=t1(i))&&(tii(j)<(t2(i)+t1(i)))
        p1(j)=1;
       end
       if
(tii(j)>=(t1(i)+t2(i)))&&(tii(j)<(t2(i)+t3(i)+t(1)))
         p2(j)=1;
       end
            end
     P1(i1:i2)=p1(1:n);
       P2(i1:i2)=p2(1:n);
       i1=i2+1;
end
nP1=length(P1);
nP2=length(P2);
figure
ti=[0:t(N)/k:t(N)];
Ni1=interp1(t,Ni,ti,'nearest');
p11=interp1((1:nP1),P1,ti,'nearest');
p21=interp1((1:nP2),P2,ti,'nearest');
p41=interp1(t,p4,ti,'nearest');
p51=interp1(t,p5,ti,'nearest');
 subplot(5,1,1)
stem(ti,Ni1,'o')
grid
subplot(5,1,2)
stem(ti,p11,'o')
grid
subplot(5,1,3)
stem(ti,p21,'o')
grid
subplot(5,1,4)
stem(ti,p41,'o')
grid
subplot(5,1,5)
stem(ti,p51,'o')
grid
```

5. Visualization of the digitized data set on the composite structure

To conduct simulation modeling of the digitized data set on the composite structure, a MATLAB program code was developed and four random samples `t1`, `t2`, `t3` and `t4` of size `N=10` each were generated using a normal distribution with different parameters `M` (mean) and `D` (standard deviation) for each sample. The probability density of the distribution is then calculated for each sample using the `normpdf` function to display a distribution density plot.

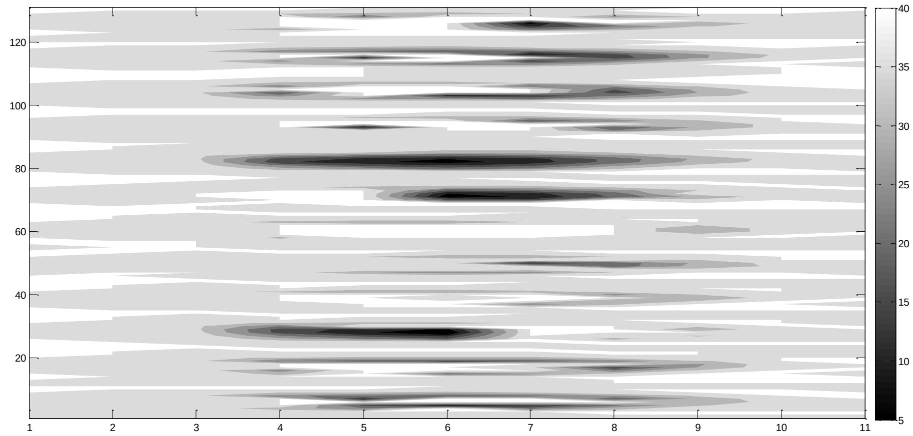
Using ``subplot (4,1,1)`` to ``subplot (4,1,4)`` creates four plot windows, each plotting the density of the distribution for the corresponding sample. Each plot is located on the corresponding row of the subplot grid, with the `subplot` arguments indicating the row number, the number of rows in the grid, and the number of subplots per row.

The results of the measurement data are digitized and visualized in the information block for easier interpretation.

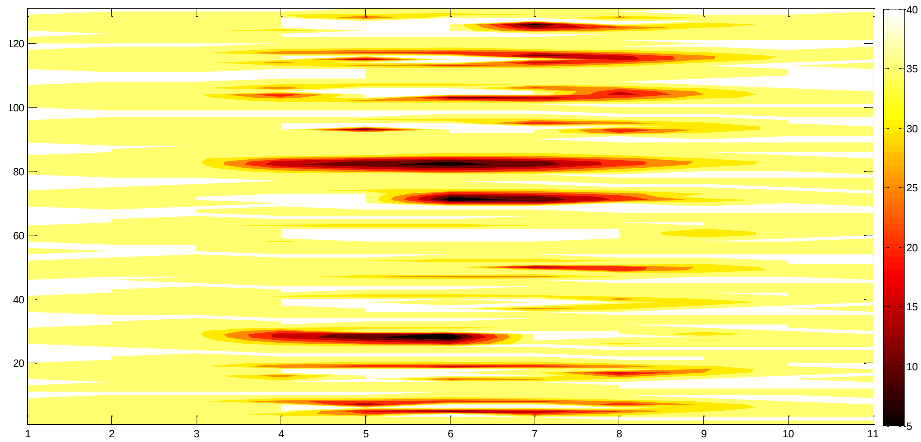
A digitized data set on the structure of a composite may contain information on various parameters that characterize its internal structure.

The digitized data can be presented in the form of a table, where each row corresponds to a specific composite sample, and the columns represent various parameters characterizing its structure. This allows for further analysis and modeling of the composite structure. To visualize the measurement data, the information block uses a graphical interpretation in the form of a color map, and a function with an offset of 40 is used to construct a contour plot. It should be noted that the conductive cathode is located in the center of the material, and their anodes are usually somewhat spaced along the edge of the mirror.

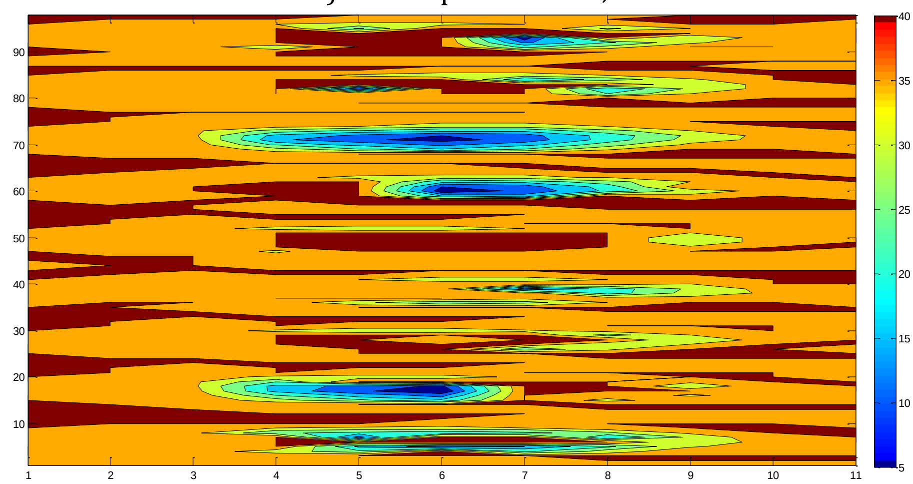
The resulting graphical representations in Fig. 6 (a,b,c) allow us to draw conclusions about the structure of the composite material. We can say that the material is suitable for use without negative inclusions and surface cracks. It is of higher quality in the center, and closer to the edge it has fewer non-conductive inclusions.



a) monochrome representation;



b) color representation;



c) refractive representation;

Figure 6: Processing of measurement data in the information block at l - length, and s - depth. with a current measurement from 0 to 40 mA:

a) monochrome representation of the structure of the composite material;
b) color representation of the structure of the composite material;
c) refractive representation of the composite material structure.

All this is depicted graphically and can be seen in the visualization program.

6. Visualization of the digitized data set on the composite structure

Program for visualizing the internal structure of a composite

```
clear all
F=[1 1 1 0 0 0 0 1 1 1 1;
   1 1 2 1 1 1 1 0 0 0 0;
   0 1 1 1 0 0 0 0 0 0 0;
   0 1 3 7 14 0 16 8 1 1 3;
   0 2 3 0 21 28 25 16 6 1 1;
   1 3 4 0 0 0 0 0 10 2 0;
   1 3 4 0 27 0 0 20 9 1 0;
   1 2 4 14 17 19 17 11 4 0 0;
   0 1 2 5 6 7 5 2 0 0 0;
   0 0 0 0 0 1 1 0 0 0 1;
   0 0 0 0 0 0 1 2 1 1 1;
% 1 1 1 2 2 1 1 0 0 0 0;
% 0 1 1 1 1 1 1 0 0 0 0;
% 0 0 0 0 0 0 0 0 0 0 0;
% 0 1 1 7 0 16 12 4 0 0 3;
% 0 1 2 13 0 0 0 14 4 0 0;
% 1 2 3 0 0 0 04 23 10 1 0;
% 1 3 4 0 0 0 0 0 11 1 0;
% 0 2 4 14 18 21 20 14 6 0 0;
% 0 1 3 6 7 8 7 4 1 0 0;
% 0 0 1 1 1 1 1 0 0 1 2;
% 0 0 1 0 0 0 0 0 0 1 2;
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The significant results obtained in the simulation of the heterogeneity of composite materials of shell structures using the conductometric method are the basis for their use in instrumentation and radio engineering [17-20] and cyber-physical biosensor systems [21-23]. As an example, for the rapid and reliable transmission of information and data to specialized clinics of the results of assessment and prediction of medical indicators of human health, which is especially relevant for the transmission of data and diagnostic information in telemedicine systems or other systems.

7. Conclusions

An important task for the instrumentation industry is to provide production, control, and repair facilities with high-quality and reliable instruments. Different industries are closely interconnected, and therefore, to fulfill the above task, the metallurgical and metalworking industries are faced with the task of improving the quality of metal materials and alloys. To evaluate mechanical properties due to a wide variety of operating and processing conditions, tests are carried out that to some extent simulate these conditions. At the same time, for the most reliable prediction of serviceability in a structure, a set of mechanical properties determines the performance.

In the course of the work, the methods of manufacturing antenna systems and manufacturing reflective surfaces based on new technological and design ideas are considered. The process of formation of shells from mesh material that can be used for the manufacture of axisymmetric and non-axisymmetric reflectors or individual elements of mirror antennas is investigated.

One of the tasks investigated in shell formation is to find the position of the mesh elements after deformation, which in our case is reduced to finding the position of the mesh nodes after deformation. finding the position of the mesh elements after deformation, and applying the composite material.

It should be noted that most test methods were developed long ago and over time, the equipment used to conduct them has only improved. The conductometric method allows us to draw conclusions about the suitability of the material and is effective for identifying inhomogeneities or surface cracks.

Designing embedded systems on a modern element base significantly increases development efficiency by reducing time, miniaturizing power consumption, and increasing speed and reliability. Today, the task of acquiring skills in the development of information and control devices based on microcontrollers and programmable logic devices that allow the implementation of algorithms of high complexity is relevant. Carry out automated collection, display and transmission of measurement information to a computer and automated processing of data on the results of the experiment in order to assess the quality of the technological process of its manufacture.

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