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Authenticity analysis of personal identity documents by the methods of holographic interferometry. Part II

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1. Introduction

Forgery of personal identity documents is an integral part of organized crime, the precondition of international smuggling drugs, weapons and other goods, illegal immigration, human trafficking, terrorism, mobility, fraud, money laundering. These sides of organized crime put the greatest threat to internal security of the EU, while the harm made to the economy, including distortions of the domestic market can reach hundreds of billions of euros.

According the data of Interpol National Central Database for December of the year 2013 [1] in 166 countries there were lost or stolen 39 millions of travel documents (ordinary passports or foreigners' passports, sailors books, national personal identity cards, etc.) and the main part of them possibly has got into the hands of organized crime groups. The Most preliminary calculations reveal that a faked passport may result in up to 500,000 EURO damage to the state [2]. Therefore, expeditious inspection of personal identity documents still remains a very important issue for law enforcement bodies (officers of migration, police, State Border Guard Service).

In the Second Report on the implementation of the EU Internal Security Strategy in 2013 presented in COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL it is emphasised that the External Borders Fund (EBF) supported and in future will support Member States in their efforts to fight the use of faked and falsified identity and travel documents. It is stated that EBF assisted the member states in purchasing specific equipment used by border guards and in consular offices to verify the authenticity of documents. The EBF also contributed to the development of FADO (False and Authentic Documents Online), a web-based tool facilitating the exchange of information between the Member States on detected document fraud [3].

At the plenary session of the European Parliament (EP) held on 10-13 of June 2013 was adopted the EP Resolution „On organised crime, corruption and money laundering: recommendations on action and initiatives to be taken" [4], in which recommendations to the Member States in cooperation with the European Parliament, the Commission, with the support of Europol, Eurojust and the EU Fundamental Rights Agency, to devise indicators, which should be as uniform and consistent as possible, in order to measure the extent and economic costs of, and social harm caused by organised crime, corruption and money laundering at EU level are given. The EP calls on the Commission and the Council to consider the establishment of an EU criminal organizations list, the establishment of an European network to link different universities, dealing with organized crime, corruption and money laundering, and to encourage university research in these areas.

In the Public Register of Authentic identity and travel Documents Online PRADO [5], the information about the authentic European identity and travel documents, about validity of the documents and other legal issues related to them, as well as technical and some descriptions of the most important security measures are presented. All EU passports are produced in compliance with the European Council Regulation (EC) No. 2252/2004 of 13 December 2004 „On Standards for Security Features and Biometrics in Passports and Travel Documents Issued by Member States" and European Council Regulation (EC) No. 444/2009 of 28 May 2009 [6, 7]. In majority of the countries in the world, including all EU countries, modern personal identity and travel documents are produced in compliance with international standards, in particular the recommendations of the International Civil Aviation Organisation (ICAO). Almost 200 countries - ICAO members in the world have the signed treaty on issuing Machine Readable Travel Documents – MRP – passport which is in compliance with ICAO recommendations, the requirements of ISO/IEC 7810:1995 and, ISO/IEC 7810:1995 standards [8]. They define additional technical specifications applicable for passports and travel documents: additional security features and requirements including enhanced anti-forgery, counterfeiting and falsification standards. They cover the specific requirements for material properties of the document, the requirements for data page, printing method, copy protection, data recording methods. A particular attention is paid to the optical security measures of the document [9].

Despite all the introduced security measures to protect the documents they continue to be falsified applying for the purpose the latest modern technologies, special features and capabilities provided by them. Although the heavy sentence - the arrest or imprisonment of four to six years is foreseen in Article 300 „Forgery of a Document or Possession of a Forged Document" of Criminal Code of the Republic of Lithuania, but trends of fraud, and illegal migration, using the forged documents, in Lithuania remains the same according the data of the Lithuanian Criminal Intelligence Analysis Centre.

Officers of the Law enforcement bodies (immigration, police, border control) for primary inspection of personal identity documents mainly use mobile document inspection tool kits (e.g. SDK-02 Forgery Detection Kit) (Fig. 1). In case there is a suspicion over authenticity, a thorough inspection of the document is done. For the purpose microscopic analysis methods with reflected, transient and oblique beams of white light reflected as ultraviolet and infrared light beams are used. In the analysis process various ratio magnifying glasses (criminalistics, video spectral ("Regula 4077" and "Regula 4177"), different devices for document inspection („Regula 4303“, „Regula 4305", "Regula 5001", etc.), video spectral comparators are also used.

Fig. 1 The image of mobile document inspection tool kit. (SDK-02 – Forgery Detection Kit): *1* - ultraviolet lamp; *2* - retro viewer; *3* - microscope; *4* - 10x stand loupe; *5* - eye loupe; *6* - size template; *7* - No. 7 tweezers; *8* - spare lamps and batteries [10]

The main object of passport inspection done by the officers of law enforcement bodies as well as the object of forgery done by criminals is MRP data page. According the requirements defined in ISO/IEC 7810:1995 standard and ICAO DOC 9303 its nominal dimensions are 88.0±0.75 mm × 125.0±0,75 mm. The applied in Lithuania MRP data page thickness including any final preparation (e.g. laminate) according the defined requirements is not more than 0.90 mm. Typical structure of MRP data page produced in the majority of EU countries is presented in Fig. 2. The structure of MRP data pages produced in Lithuania is analogous.

Fig. 2 Cross section image of the MRP data page of a travel document used by some EU countries. *1* - protective polycarbonate transparent layer, thickness of which varies in the range of 50 – 100 μm; *2* - polycarbonate transparent layer for data recording of the thickness 100 – 150 μm; *3* - polycarbonate white layer of the thickness 200 – 550 μm; *4* - protective teslin layer of the thickness 400 – 450 μm. [11]

The documents are usually forged in two ways: intellectually and materially. In the first case having available stolen blank documents obtained by fraud, a completely new document with all the requisites and properly documented is made, but content of such the documents is false. In the second case a particular part of the document is replaced - false personal data is added (printed), counterfeit pages are used, stamps and visas are replaced or counterfeit, photos are replaced. In the latter case most frequently MRP data page is falsified.

Analysis of document forging statistics in expert institutions of the foreign countries and Ministry of the Interior and examination of educational materials reveals the main methods of document falsification – „erasing and scraping, etching, washing, additional recording and corrections, photos replacement, changing of other fragments of the documents“ [12].

Investigations of documents (passport) forgery carried out in expert institutions of the Ministry of Interior of the Republic of Lithuania reveal that the most frequently the data pages are damaged by the means of mechanical nature in the zones of photo image and personal data records. As modern computer and laser technologies and other tools as well are applied for the forgery, rather often the primary document inspection cannot reliably determine authenticity of the document. Initial stage of the document forgery, when upper polycarbonate layer of passport data page and the photograph under it are being removed is presented in Fig. 3.

Fig. 3 Initial stage of the photograph replacement process. Arrows at the bottom part show the removal of protective polycarbonate transparent layer presented in Fig. 2. Arrows at the upper part show photograph replacement [13]

After replacement of the photography, which can be inserted by digital means as well, the data page always contains some technological defects: the damage of polycarbonate layer near or beyond the photograph, printing defects near or beyond the photograph, air gaps after repeated fusion of the laminate layers, micro wrinkles on the upper layer and other. When performing thorough authenticity analysis of the passport data page various non-destructive testing methods which differ in their principles and hardware complexity are used. These can be the methods of visual inspection, optical and laser interferometry, ultrasonic, acoustic emission, vibration analysis, the methods of mechanical loading, thermo graphic, thermal emission and others or their combinations.

The results of MRP data page authenticity analysis obtained by applying the methods of non-destructive testing - the methods of holographic interferometry and determining the influence of thermal expansion of the passport data page on its surface deformation are presented in research [11]. Experimental research with original reference (specimen) and forged passports were conducted, the

fixation conditions of the data page in the special holding frame and the parameters of heat loading were determined. The results of the research obtained in the format of holographic interferograms proved statements of the set hypothesis that the surface deformation character of the forged and the original reference data pages should differ.

Further development of theoretical and experimental investigation with regard to technological and forgery peculiarities of the passport data page are provided in the current research. The experimental research the same as in [11] was carried out applying one of the methods of non-destructive testing - the method of two exposition holographic interferometry and real time method allowing observation of thermal expansion process in real time. In the present research the hypothesis given in publication [11] is used –after mechanical damaging of the page structure and putting efforts to restore its initial state, always residual technological defects remain (air gaps in between the layers, missing or excess of the glue, layers fusion and other). These defects should be the reason of physical mechanical properties (including thermal expansion properties of the data page along its width) alteration in the analysed structure what could serve as authenticity indicator of the data page.

2. Theoretical research - FEM analysis of thermally deformed passport

In order to confirm experimental results of the thermal deformations of data page of passport finite element model (FEM) was created. Computational scheme of this process is presented in Fig. 4. All sides of the page are fixed and back side of the analyzed page is heated while deformation of the front part was measured. The data page consists of five layers, as this is explained in details in introduction (Fig. 2).

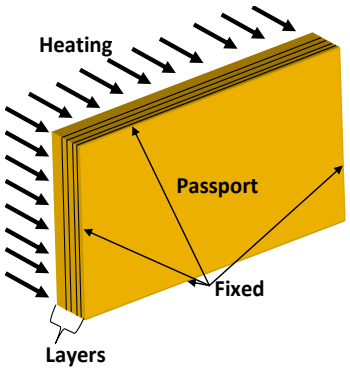


Fig. 4 Computational scheme of thermal deformation of the data page of a passport

Modeling was performed by Comsol Multiphysics software. The tetrahedral quadratic was chosen as a mesh element. Fine mesh guarantees the convergence of the solution. The tetrahedral element (Fig. 5) is defined by ten nodes having four degrees of freedom at each node: the displacements in nodal *x*, *y* and *z* directions and temperature.

Simulation results of thermal deformations of passport data sheet are presented in Figs. 6-10.

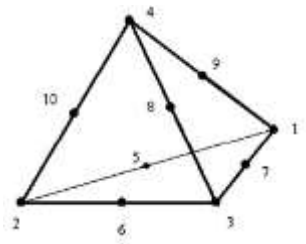


Fig. 5 Tetrahedral finite element [14]

Thermal deformation of the original passport data page can be interpreted as deformation of the center symmetrical membrane (Fig. 6). Because all layers of the original passport are evenly glued, it behaves as a symmetrically fixed, homogeneous object and deforms as concave

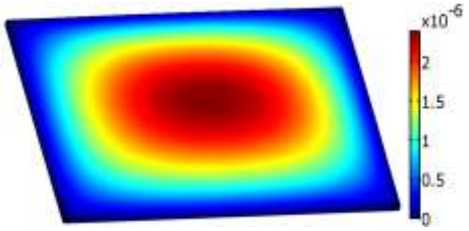


Fig. 6 Thermal deformation of the data page of the original passport

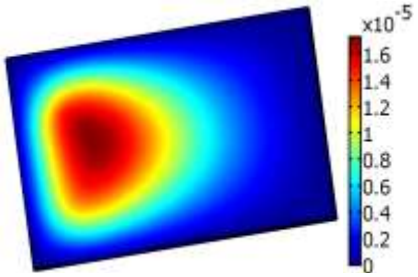


Fig. 7 Thermal deformation of the data page of the forged passport with the defect in the area of photo

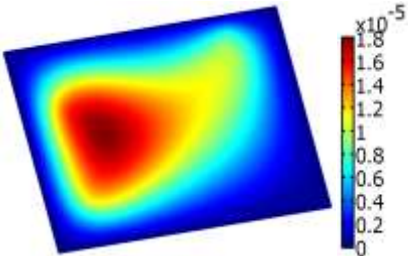


Fig. 8 Thermal deformation of the data page of the forged passport with the defect in the area of photo and personal data

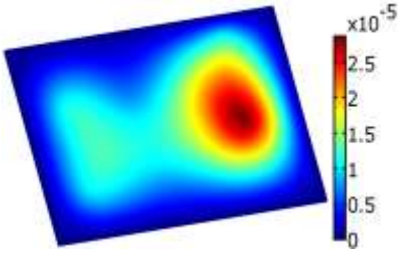


Fig. 9 Thermal deformation of the data page of the forged passport with the defect in the area of personal data record

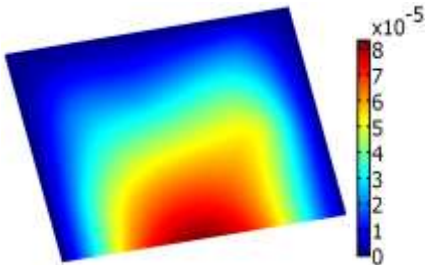


Fig 10 Thermal deformation of the passport data page incorrectly fixed at the bottom edge

or convex surface with the biggest deformation in the center. This result corresponds to the hologram of thermally deformed data page of the passport of Republic of Lithuania (Fig. 13). However, bonding of a forged passport is different, i.e., type of glue varies, layer thickness of glues, one or more layers could be mechanically deformed irreversibly and during thermal experiment it behaves as non-homogeneous object. Thermal deformation of the data page of the forged passport with the defect in the area of photo (Fig. 7), area of photo and personal data (Fig. 8) and area of personal data (Fig. 9) were modeled too. Simulation results show, that vertex of concave or convex deformation is observed in the area of defect (it is not in the center of measurement area). At the same time, this method allows to identify has the passport been properly fixed before the experiment or it has been not. If a passport is fixed correctly, the interference fringes must be parallel to the fixing frame (Figs. 6-9). If the passport is not well fixed, i.e., it is not enough tightened up, fringes cross borders of the fixing frame (Fig. 10).

3. Experimental setup

Experimental research of the MRP data page is based on thermal expansion of the page along its surface normal (page thickness) and on deformation analysis of all the surface of the structure simultaneously when one side of the page is being uniformly heated by a selected heat source and the results recorded by the method of two exposition holographic interferometry [11].

With the aim to make analysis of the influence of technological defects and forgery on thermal expansion of the data page along its normal, holographic research stand PRISM (the faculty of Mechanical Engineering and Design of KTU) [11] and page holding frame of the special structure were used. It uniformly (with the set clamping force) fixes the page along its periphery. A fragment of the holographic research stand PRISM which ensures performance of the whole optical system is presented in Fig. 11.

Green light (λ = 532 nm), 20 mW semiconductor laser was used for the research. Object beam from control block *1* with the help of optical fibre is directed to the lens system where it is spread and directed towards the analysed data page (Fig. 12). Support beam by optical fibre reaches video camera *2* where it interferes with registered object beam reflected from the analysed data page. With the help of control block and video camera the ratio between intensities of object and support beams can be changed seeking for the best brightness of interference fringes. The interference image from the camera is transferred to computer, processed by special software and displayed on the monitor thus enabling real time observation of both dynamical processes taking place in the analysed object and the deformations preconditioned by different internal and external factors. The deformations bellow 20 nm can be recorded.

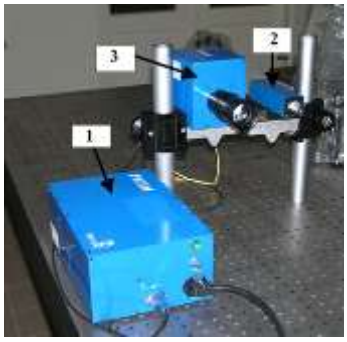


Fig. 11 A fragment of holographic research stand PRISM. *1* - control block; *2* - special video camera; *3* - source of the object beam

During experimentation MRP data pages of six passports were investigated – two passports – Lithuanian and Norwegian with reference (specimen) data pages and other – four Lithuanian passports – A, B, C, D with indications of data pages forgery.

Similarly as in the research [11], at first deformation character in the format of interferograms of the reference (specimen) passport (it was used for comparative analysis of the other passports data pages) were obtained by heating its surface and alternating the data page fixing conditions in special holding frame for data page (Fig. 12). The research was started from the data pages analysis of Lithuanian and Norwegian passports. With the aim to verify whether the results obtained in [11], could be repeated, the same holographic methods enabling to obtain information on deformation character on the entire data page surface of one side simultaneously at the same conditions of external thermal loading and data page fixing were applied.

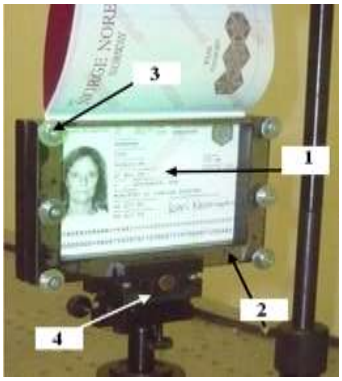


Fig. 12 Special holding frame for data page of a passport: *1* - analysed data page of a passport; *2* - body of the frame for uniform fixing of the page along its perimeter; *3* - clamping force adjusting elements; *4* - three coordinate adjusting system of the frame orientation in holography system

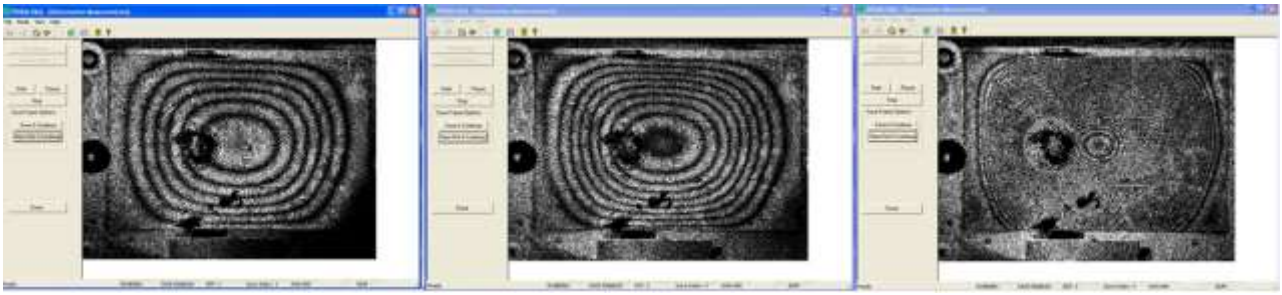
4. Results

The experimental research results are presented in Figs. 13-18. At first Lithuanian passport with reference

(specimen) data page was investigated in order to check repeatability of the results achieved in [11]. This would enable verification of the applied methodology. For this purpose at the initial stage applying the real time method the thermal loading diapason in which thermal deformation of the page holding frame were not observed (it remained stable and had no influence on data page deformation) was determined. At the next stage the influence of the holder on the character of the data page surface deformation was observed. In order to observe the data page deformations along its surface normal, the page should be fixed uniformly clamping all its sides with the help of nuts 3 (Fig 12). As only qualitative assessment of the obtained results (deformation character of the page and its relative value are defined by location shape and density of interference fringes on the page surface) was carried out direction of the page deflection (convexity) was not determined.

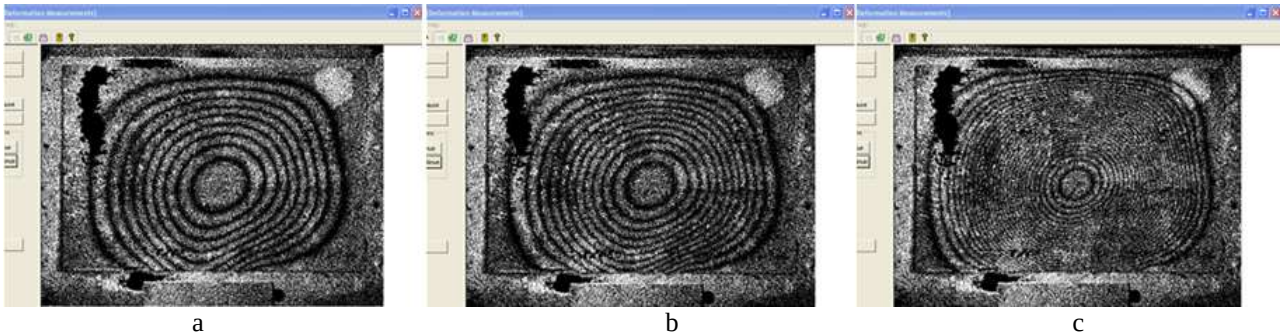
Fig. 13 presents the interferograms a, b, c of the reference data page of Lithuanian passport where the character of deformations due to heating in normal direction to the page surface is displayed by even with respect to the page sides' distribution of closed loop interference fringes. With the rise of heat flow temperature the location and shape of the interference fringes remains the same, only their density change. No interference fringes can be observed at the holding frame sides. This confirms that temperature change and fixation conditions are optimally chosen as they have no influence on the obtained results. No other deformation signs can be observed, what allows concluding that the page structure is homogeneous and no qualitative defects exist in it. Therefore such pattern of interference fringes can serve as the reference (specimen) pattern. It should be emphasized that the obtained experimental results repeat the results of [11]. Thus it can be concluded that the selected methodology is suitable for further research.

In Fig. 14 the interferograms of the reference Norwegian passport obtained under the same experimentation conditions as applied for the investigation of the Lithuanian passport are presented. The character of data page surface deformation along normal in the obtained interferograms is the same as of Lithuanian passport – this can be proved by the same closed loop shape of the interference fringes. Just density of interference fringes differs what can be explained by different thicknesses of the data pages. The obtained results prove that no qualitative defects exist in the reference page. Therefore comparative analysis of interference fringe images of reference passports and other passports under investigation can be performed with sufficient reliability.



a b c

Fig. 13 Interferograms of the reference data page deformation of the passport of Republic of Lithuania output to the monitor of holography system PRISM. a) interferogram of the page deformed along normal when the applied for 4 sec heat flow temperature is 24.5 – 25°C; b) interferogram of the page deformed along normal when the applied for 4 sec heat flow temperature is 26 – 26.5°C; c) interferogram of the page deformed along normal when the applied for 4 sec heat flow temperature is 29.5 - 31°C



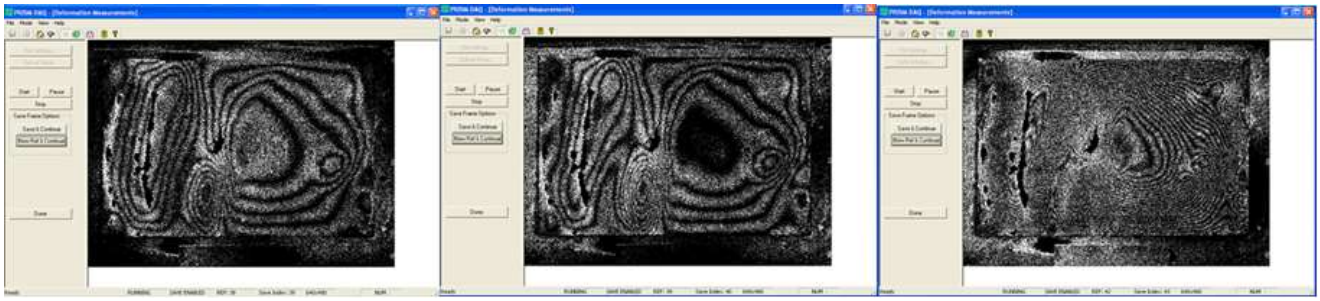
a b c

Fig. 14 Interferograms of the reference data page deformation of the passport of the Kingdom of Norway output to the monitor of holography system PRISM obtained at the same temperature regimes as the interferograms in Fig. 13

In Figs. 15-18 interferograms of the falsified data pages of passports A, B, C, D. obtained applying identical temperature regimes and other parameters of the experiment as for the reference passport are presented. Data page of the passport A as shown in Fig. 15 is evidently forged as location and shape of the obtained interference fringes differs from the reference image. The zones of face image and data recording are defected due to polycarbonate layers delamination, mechanical removal of primary data records, new data recording and uneven joining of the layers. The mentioned facts are the reason of physical and mechanical properties change in the data page what

resulted in the change of thermal characteristics at different page zones causing non even page deformation along its normal.

In Fig. 16 interferograms of the falsified data page of passport B with obviously different localization and shape of interference fringes as compared with the reference data page are presented. The zones of closed loop interference fringes were formed due to thermal loading in face image and personal data recording zones similarly as for the data page presented in Fig. 15. At the same time the fringes crossing the bottom border of the fixing frame indicate that the data page was not properly fixed before the experiment – it is not enough tightened what allows its deformation along surface normal. Therefore in case of such shape fringes appearance during real inspection process, fixation of the data page along its borders should be corrected. Under thermal loading conditions up to +10°±1° from initial ambient temperature the interferograms presented in figures Figs. 15-16 just prove that mechanical defects of the page have significant influence on deformation character and magnitude what allows concluding on the existence of the fact of forgery in the zones of face image and personal data recording.

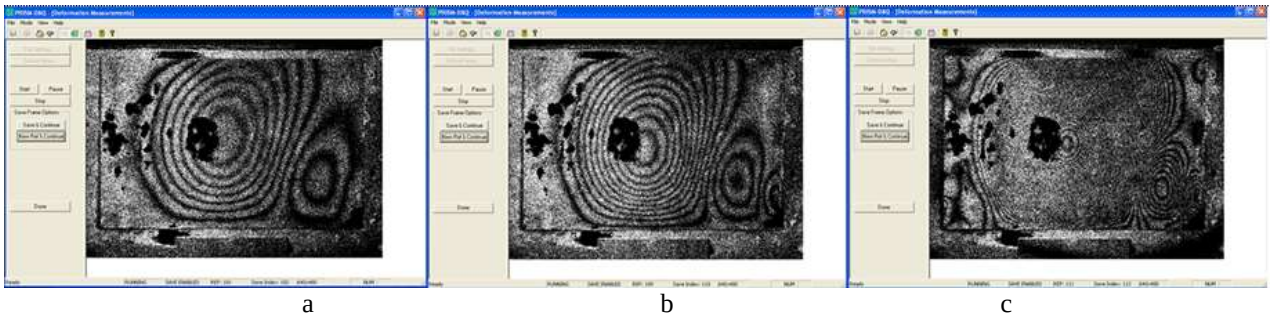


a b c

Fig. 15 Interferograms of the falsified data page deformation of passport A of the Republic of Lithuania. Obtained at the same temperature regimes as the interferograms in Fig. 13

a b c

Fig. 16 Interferograms of the falsified data page deformation of passport B of the Republic of Lithuania. The passport data page incorrectly fixed at the bottom edge. Obtained at the same temperature regimes as the interferograms in Fig. 13



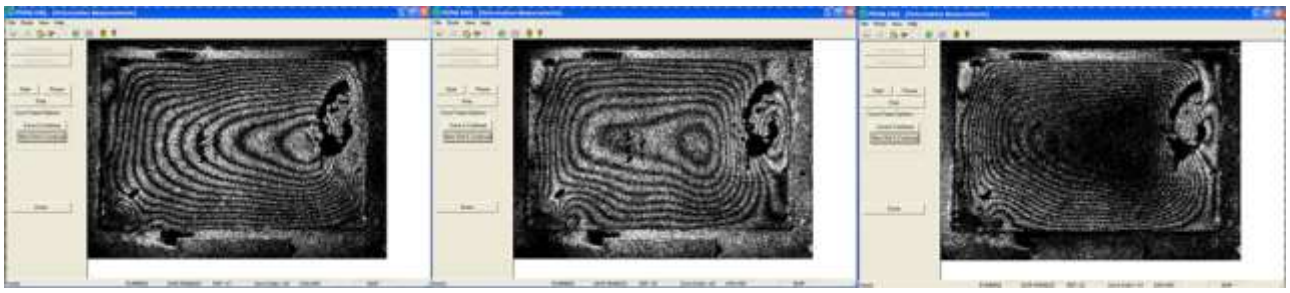
a b c

Fig. 17 Interferograms of the falsified data page deformation of passport C of the Republic of Lithuania. Obtained at the same temperature regimes as the interferograms in Fig. 13

In Figs. 17-18 interferograms of data page deformations of the passport the falsification quality level of which is „significantly higher“ than of the passports shown in Figs. 15-16 are presented. They are obtained at the same temperature regimes and experiment conditions as for Lithuanian and Norwegian passports. Two zones of interference fringes in which deformation character due to temperature loading yet differs from that of the reference data page can be distinguished. Under thermal loading when the applied for 4 sec heat flow temperature is 29,5 – 31°C the interference fringes as shown in Fig. 17 can be observed also near the left side of the data page holder. This leads to the unambiguous conclusion on forgery of the passport. As the methods of holographic interferometry are the methods of non-destructive testing, in order to determine by what means exactly the passport was forged the other methods,

evaluating composition of the material should be applied.

Deformation character of the data page of passport D as shown by the interferograms of Fig. 18 is rather close to the character of deformations of the reference data page. Nevertheless the existence of differences in deformation is more obviously highlighted at thermal loads. The fact that the data page is forged can be concluded from the analysis of the interferograms in Fig. 18, b and Fig. 18, c under the applied for 4 sec heat flow of the temperatures 26.0-26.5°C and 29.5 – 31.0°C accordingly. In these interferograms the deformations at the right side and the left bottom zone can be clearly distinguished. These indicators allow concluding that the passport is forged, nevertheless in order to determine by what means this "high quality" forging was performed special methods of criminal expertise are to be applied.



a b c

Fig. 18 Interferograms of the falsified data page deformation of passport D of the Republic of Lithuania. Obtained at the same temperature regimes as the interferograms in Fig. 13

5. Coclusions

1. The methodology for non-destructive authentisity verification of MPR data page based on the influence of thermal expansion on its surface deformations which are visualized by high resolution methods of holographic interferometry is proposed for throrough inspection of the documents.

2. The carried out experimentation with MPR data page selecting thermal loads on it as well as its fixing conditions allowed determining surface deformation shapes of the reference MPR data page to which surface deformation shapes of other inspected passports can be compared.

3. Computational model of MPR data page thermal behaviour taking into account the change of physical mechanical properties of the data page which precondition the variation of its thermal deformations along the normal over the surface was obtained.

4. Simulation results of the MPR data page deformations due to thermal loading and the influence of its fixing conditions for the reference and forged passports were validated by experimental methods of holographic interferometry.

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ASMENS TAPATYBĘ PATVIRTINANČIO DOKUMENTO AUTENTIŠKUMO TYRIMAI HOLOGRAFINĖS INTERFEROMETRIJOS METODAIS. II DALIS

R e z i u m ė

Asmens tapatybę patvirtinančių dokumentų klastojimas yra neatskiriama organizuoto nusikalstamumo, tame tarpe tarptautinės kontrabandos narkotikais, vaistais, ginklais ir kitomis prekėmis, nelegalios imigracijos, prekybos žmonėmis, terorizmo mobilumo, sukčiavimo, pinigų plovimo, prielaida. Šios organizuoto nusikalstamumo sritys kelia didžiausias grėsmes ES vidaus saugumui, o daroma žala ekonomikai, įskaitant vidaus rinkos iškraipymus, siekia šimtus milijardų eurų. Todėl ir toliau labai aktualiu klausimu teisėsaugos subjektams (imigracijos, policijos, sienų kontrolės pareigūnams) išlieka operatyvi asmens tapatybę patvirtinančių dokumentų patikra.

Šis darbas skirtas asmens tapatybės dokumento – paso duomenų lapo autentiškumo eksperimentiniams tyrimams paremtiems neardančios kontrolės - holografinės interferometrijos metodais, nustatant paso duomenų lapo šiluminio plėtimosi įtaką jo paviršiaus deformacijai. Atlikti eksperimentiniai tyrimai su originaliais ir suklastotais pasais, nustatytos duomenų lapo įtvirtinimo sąlygos specialiame laikiklyje, nustatyti temperatūrinio apkrovimo parametrai. Gauti tyrimų rezultatai holografinių interferogramų pavidalu patvirtino iškeltos hipotezės teiginius, kad suklastotų pasų duomenų lapo paviršiaus deformacijos akivaizdžiai skiriasi nuo originalių pasų duomenų lapų. Sudarytas duomenų lapo šiluminio plėtimosi matematinis modelis. Atliktas duomenų lapo paviršiaus deformacijos proceso modeliavimas, esant temperatūriniam apkrovimui. Gauti teoriniai ir eksperimentiniai rezultatai patvirtina galimybę taikyti pasirinktą neardančios kontrolės tyrimo metodiką pasų autentiškumui nustatyti.

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AUTHENTICITY ANALYSIS OF PERSONAL IDENTITY DOCUMENTS BY THE METHODS OF HOLOGRAPHIC INTERFEROMETRY. PART II

S u m m a r y

Forgery of personal identity documents is an integral part of organized crime, the precondition of international smuggling drugs, weapons and other goods, illegal immigration, human trafficking, terrorism, mobility, fraud, money laundering. These sides of organized crime puts the greatest threat to internal security of the EU, while the harm to made to the economy, including distortions of the domestic market, can reach hundreds of billions of euros. Therefore, expeditious inspection of personal identity documents continues to remain a very important issue for law enforcement bodies (officers of migration, police, State Border Guard Service).

This research deals with the authenticity inspection of personal identity document – passport data page – which is based on non-destructive testing – holographic interferometry methods and the analysis of thermal behaviour impact on the MPR data page surface deformation. Original and forged passports were investigated, thermal load parameters on the data page and its fixation conditions in a special holder were determined. The analysis of the obtained holographic interferograms allowed confirming the hypothesis claims that the character of surface deformation of forged MPR data page significantly differs from the character of original MPR data. Computational model of MPR data page thermal behaviour was developed. Simulation of the process of data page surface deformation with the applied thermal loading was carried out. Theoretical and experimental results confirming the application possibility of non-destructive testing methodology for determining authenticity of the passports were obtained.

Keywords: Thermal expansion, thermal loading, holographic interferometry, surface deformation.

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