

# SCIENCE & MILITARY



No 2 | Volume 16 | 2021

The rationale for publishing this periodical by the Armed Forces Academy of General Milan Rastislav Štefánik is to enable the authors to publish their articles focused on particular scientific issues in the following areas: Military science, Natural Sciences, Engineering and Technology.

Original scientific articles will be published twice a year.

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**Dear readers,**

you are holding this year's second issue of the *Science & Military* journal. It is coming out at Christmas time, when the year is slowly coming to an end and we all tend to look back, appraise and give thanks for everything good we have experienced in the past year. On behalf of the editorial board, I would like to express our gratitude for your support, trust and cooperation.

I am pleased to say that the *Science & Military* journal has again served its purpose – to provide the space for papers written by Slovak and foreign authors, who focus on military, natural and technical sciences.

The editorial board began to use the benefits of the Digital Object Identifier System (DOI) in this year's first issue in order to promote the journal and enhance its prestige. The purpose of the DOI system is to identify and promote scientific publications as well as to encourage cooperation between the authors and share scientific knowledge. In addition, it facilitates academic communication and improves publication and citation ethics. We will further our efforts to enhance the journal's quality so that it can gain its position amongst high-quality academic publications.

Dear readers, I firmly believe that this issue of the *Science & Military* journal contains the papers you will find interesting and useful.

The first among the peer-reviewed articles in this issue is the article written by Eva Popardovská and Vladimír Popardovský titled „Active Thermography as a Method for Non-destructive Testing of Polymer Composite Materials”. Infrared (IR) thermography is a method for imaging thermal fields on the target surfaces in real time. The main goal of the article is to introduce a basic overview of IR active thermography.

The solution for the replacement of plastic lubricants of the Mobil-NLGI 00 type (to the PSU-planetary directional device) and Total-NLGI 0 (to the KP-final gear) for the MAPU-1 (in PSU) and MAKN-2 (in KP) lubricants is the main topic of the article by Miroslav Marko and Vladimír Kadlub titled „Testing the Replacement of Total and Mobil Plastic Lubricants with MAPU-1 and MAKN-2 Lubricant”. Testing of PM (plastic lubricants) was performed on a special vehicle type GM 578. This article was prepared on the basis of documents of the VV1 Project: Design and application of tribodiagnostic methodologies for operation and maintenance of ground equipment of the Armed Forces of the Slovak Republic in the years 2018 - 2020.

Another article titled „Analysis of Current Trends in the Development of DSLs and the Possibility of Using them in the Field of Information Security” was written by Patrik Harnoš and Lubomír Dederá. The most significant result of the paper is a closer look on what DSLs are, when it is appropriate to use them in a project and when not. In the last part of this article the focus is given on the possibilities of using DSLs in the field of information security.

The authors Eva Popardovská, Vladimír Popardovský and Lukáš Novotný wrote the article titled „Strength Calculation of UAV's Wing Connector Tube”. The use of unmanned vehicles (both civilian and military) is clearly a technological trend today. In the military, this is especially true of Unmanned Aerial Vehicles (UAVs). The flight itself represents a number of different types of stress affecting the design of the unmanned aircraft. The authors deal with the strength analysis of the most exposed structural element - the wing connector.

The final article by Miroslav Marko and Vladimír Kadlub titled „Tribodiagnostic Control of Motor Oil (MO) Properties in IVECO Crossway Buses” was prepared on the basis of documents of the VV1 Project: Design and application of tribodiagnostic methodologies for operation and maintenance of ground equipment of the Armed Forces of the Slovak Republic in the years 2018 - 2020. The aim of the project was to conduct, on the basis of the performed experimental measurements, experimental verification of parameters of operating substances and materials of newly introduced ground military equipment.

Dear readers, on behalf of the editorial board and all our colleagues who are involved in publishing the *Science & Military* journal, I would like to wish you a wonderful new year filled with joy and happiness.

Enjoy your reading.

Brig. Gen.(ret.). Assoc. Prof. Eng. Boris ĎURKECH, CSc.  
Editor-in Chief

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## ACTIVE THERMOGRAFY AS A METHOD FOR NON-DESTRUCTIVE TESTING OF POLYMER COMPOSITE MATERIALS

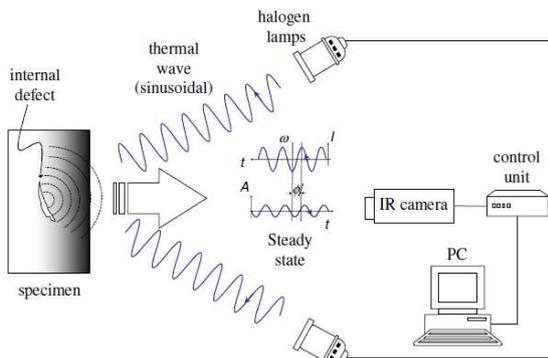
Eva POPARDOVSKÁ, Vladimír POPARDOVSKÝ

**Abstract:** Infrared (IR) thermography is a method for imaging thermal fields on the target surfaces in real time. It is a non-contact and non-destructive method of obtaining thermogram of tested material surface or inside of it. We can divide the IR thermographic testing methods into two basic groups – passive and active thermography. This article introduces a basic overview of IR active thermography.

**Keywords:** Thermography; Defectoscopy; Nondestructive testing (NDT); Discrete Fourier transform (DFT).

### 1 INTRODUCTION

Lock-in thermography (LiT) is a method of an active thermography [1][2][5], uses sinusoidal thermal excitation in order to obtain information from the observed phase and magnitude of reflected thermal wave. The phase angle has the advantage that it is independent of local variations of illumination or surface emissivity.



**Fig. 1** Principle of Lock-in thermography  
Source: [6].

### 2 THERMAL WAVE THEORY

Sinusoidal waves are typically used in LiT [2]. Using sinusoid input signal has the advantage that the frequency and shape of the response are preserved - change is only in the amplitude and phase delay. The periodic wave propagates by radiation through the air until it touches the sample's surface where heat is next propagates through the material. Defects inside, act as barrier for heat propagation and produces changes in amplitude and phase of the response signal at the specimen surface.

Heat diffusion through a solid material is a complex 3D problem that can be described by the Fourier's law of heat diffusion

$$\nabla^2 - \frac{1}{\alpha} \frac{\partial T}{\partial t} = 0 \quad (1)$$

where

$\alpha = \frac{k}{\rho c_p} [m^2 \cdot s^{-1}]$  is the thermal diffusivity of the tested material

$k [W \cdot m^{-1} \cdot K^{-1}]$  is the thermal conductivity

$\rho [kg \cdot m^{-3}]$  is the density

$c_p [J \cdot kg^{-1} \cdot K^{-1}]$  is the specific heat at constant pressure

The Fourier's law 1D solution for a periodic thermal wave propagating through a semi-infinite homogeneous material may be expressed by equation

$$T(z, t) = T_0 e^{-\frac{z}{\lambda}} \cos\left(\frac{2\pi z}{\lambda} - \omega t\right) \quad (2)$$

where

$T_0 [^{\circ}C]$  is the initial change in temperature produced by the heat source

$z [m]$  is the thermal wave penetration depth

$\omega = 2\pi f [rad \cdot s^{-1}]$  is the modulation frequency

$\lambda \equiv 2\pi\mu [m]$  is the thermal wavelength

$\mu [m]$  is the thermal diffusion length

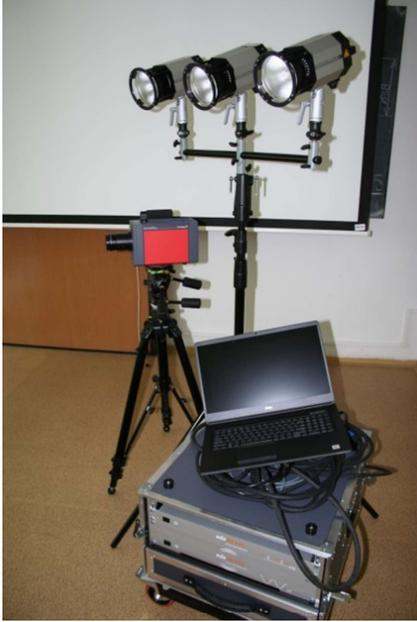
which determines the rate of decay of the thermal wave as it penetrates through the material and is defined by formula

$$\mu \equiv \sqrt{\frac{2\alpha}{\omega}} = \sqrt{\frac{\alpha}{\pi f}} \quad (3)$$

For deeper penetration of thermal wave, the use of lower frequencies are needed.

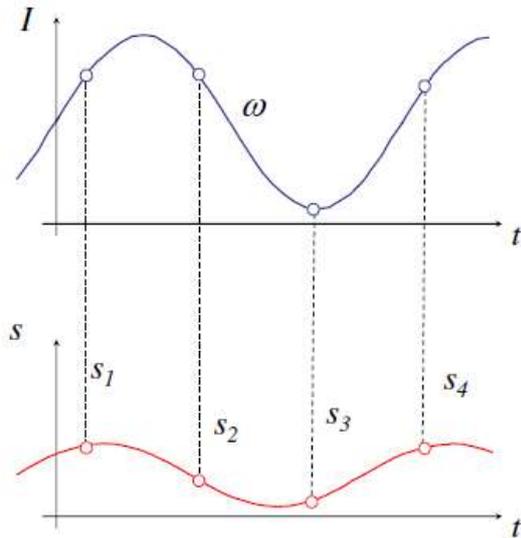
Fig. 1 shows a lock-in thermography experiment. The lamps send periodic input thermal waves at a given modulation frequency  $\omega$ , for at least one cycle. In practice however a few cycles are needed

to adequately retrieve phase and amplitude data of response thermal wave.



**Fig. 2** Edevis-OTvis/Infracore thermography system  
Source: authors.

The sinusoidal input signal  $I$  and the response signal  $S$  is depicted at Fig. 3. As mentioned before, input and output have the same shape when sinusoids are used.



**Fig. 3** Input and output thermal wave  
Source: [2].

There is only a change in amplitude and phase that can be calculated as follows

$$A = \sqrt{(S_1 - S_3)^2 + (S_2 - S_4)^2} \quad (4)$$

$$\varphi = \tan^{-1} \left( \frac{S_1 - S_3}{S_2 - S_4} \right) \quad (5)$$

This 4-point method can be used only for sinusoidal stimulation and is affected by noise. The signal can be denoised by averaging of several points instead of a single one and/or by increasing the number of cycles. Alternatively, the DFT can be used to extract amplitude and phase information from LiT data, according to the expression

$$F_n = \Delta t \sum_{k=0}^{N-1} T(k\Delta t) e^{-i2\pi mk/N} = Re_n + Im_n \quad (6)$$

where

$k$  is the number of measuring cycles,

$i$  is the imaginary number ( $i^2 = -1$ ),

$n$  is the frequency increment ( $n = 0, 1, \dots, N$ ),

$\Delta t$  is the sampling interval.

In this case, real and imaginary parts of the complex transform are used to estimate the amplitude and the phase

$$A_n = \sqrt{Re_n^2 + Im_n^2} \quad (7)$$

$$\varphi_n = \tan^{-1} \left( \frac{Im_n}{Re_n} \right) \quad (8)$$

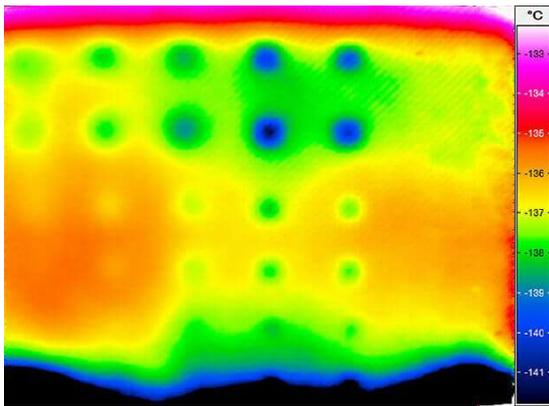
The DFT can be used with any waveform and has the advantage of denoising the signal. One of the most interesting characteristics of LiT testing is the possibility of performing quantitative operations in a straightforward manner. There is direct relationship between the depth of a defect and the thermal diffusion length  $\mu$ . Empirical expressions have been proposed to extract the depth of a given defect from LiT data using a relationship of the form

$$z = C_1 \mu = C_1 \sqrt{\frac{\alpha}{\pi f_b}} \quad (9)$$

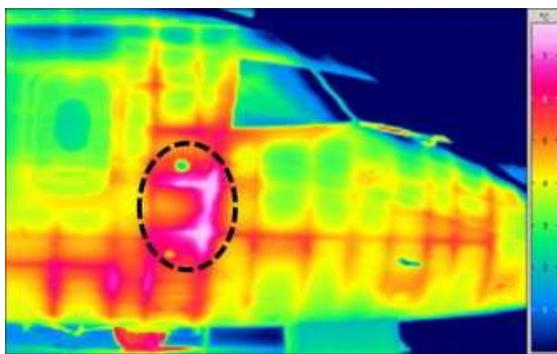
where

$f_b$  is known as the blind frequency.

It is the frequency at which a given defect have enough (phase or amplitude) contrast to be detected (at frequencies higher than  $f_b$  is not possible to detect it),  $C_1$  is an empirical constant. It has been observed that  $C_1 = 1$  when using amplitude data. For working with the phase  $C_1$  is in the range  $1,5 < C_1 < 2$ , with  $C_1 = 1,82$  as the typical value. The phase is therefore more interesting in NDT than the amplitude, since it provides deeper probing capabilities.



**Fig. 4** Artificial defects (circle shapes) inside composite sample  
Source: [7].



**Fig. 5** Unspecified defect in aircraft's fuselage (violet colored shape)  
Source: [8].

### 3 EXPERIMENTAL EXAMPLE OF LIT THERMOGRAPHY

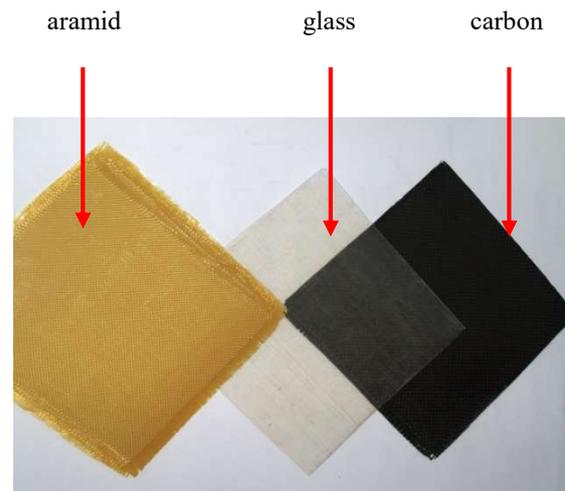
Subject of interest (for LiT application) at Department of mechanical engineering of the Armed Forces Academy Liptovský Mikuláš is polymer composites material research [3][4]. These materials are widely used for example in advanced military technologies of ground and aerial vehicles.

A polymer composite is a multi-phase material in which reinforcing fillers are integrated with a polymer matrix, resulting in synergistic mechanical properties that cannot be achieved from either component alone.

Modern composites are usually made from two components – fiber and matrix. The fiber is most often glass, but sometimes Kevlar, carbon, or polyethylene. The matrix is usually a thermoset like an epoxy resin, polydicyclopentadiene, or a polyimide.

The performance of polymer composites is generally determined by

- the properties of the fiber,
- the properties of the polymer matrix,
- the ratio of the fiber to the polymer matrix in the composite (fiber volume fraction),
- the geometry and orientation of the fiber in the composite.

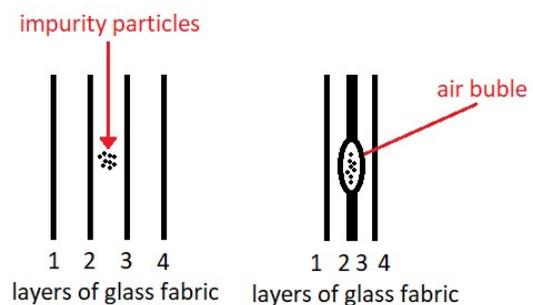


**Fig. 6** Composite plates  
Source: authors.

The performance is usually referred to as the mechanical properties of the polymer composites.

Hidden defects can occur in the production process of these materials, which have an impact on the mechanical properties. Therefore, it is important to detect these defects. One option is to use the active thermography.

Experimental sample (glass composite plate 300x300 mm) was created by four layers of glass fabric (with weight per unit area 390g/m<sup>2</sup>). By inserting of impurity particles, between layers 2 and 3, was created three localities of artificial defects.



**Fig. 7** Structural arrangement of the sample  
Source: authors.

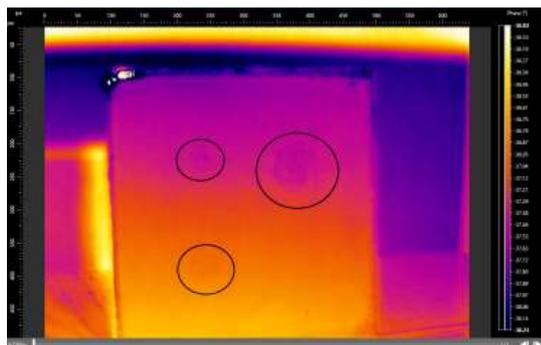
In these localities, inserted impurity particles prevented connection of layers 2 and 3 - in the same areas, air bubbles were created.

Sequence of figures (Fig. 8 – Fig. 11) shows dependency of depth thermal wave penetration on its frequency. For experiment was used Edevis-OTvis/Infracat thermography system.

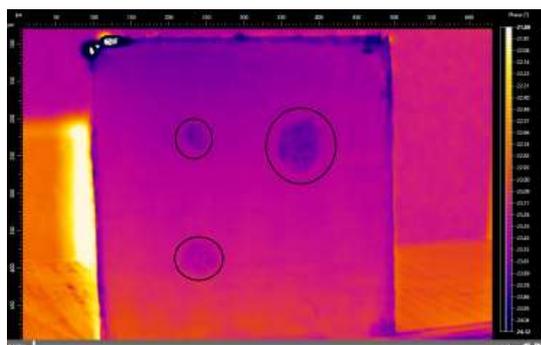
Fig. 8 represents thermal wave penetration just below the surface - a faint hint of defective areas appears (circled areas).

Fig. 9 a Fig. 10 shows thermal wave penetration into depth of impurities.

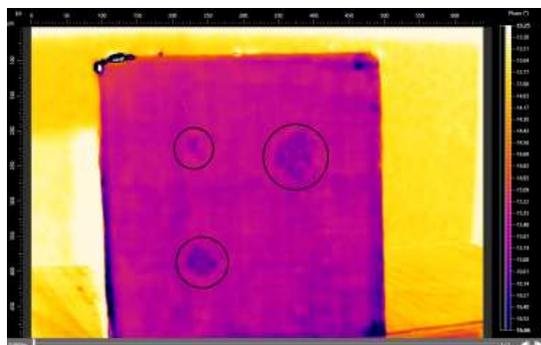
Fig. 11 shows thermal wave penetration into depth beyond impurities.



**Fig. 8** Phase thermogram from LiT data (Thermal wave frequency 0,25 Hz)  
Source: authors.



**Fig. 9** Phase thermogram from LiT data (Thermal wave frequency 0,125 Hz)  
Source: authors.



**Fig. 10** Phase thermogram from LiT data (Thermal wave frequency 0,06 Hz)  
Source: authors.



**Fig. 11** Phase thermogram from LiT data (Thermal wave frequency 0,015 Hz – probably close to blind frequency)  
Source: authors.

## 4 CONCLUSION

Active thermography is very useful method of structural investigation and detection of local invisible defects. The advantage of thermography method is fact, that it is a NDT method, without mechanical damage of the tested surface.

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## TESTING THE REPLACEMENT OF TOTAL AND MOBIL PLASTIC LUBRICANTS WITH MAPU-1 AND MAKN-2 LUBRICANTS

Miroslav MARKO, Vladimír KADLUB

**Abstract:** Solution of the replacement of plastic lubricants of the Mobil-NLGI 00 type (to the PSU-planetary directional device) and Total-NLGI 0 (to the KP-final gear) for the MAPU-1 (in PSU) and MAKN-2 (in KP) lubricants. The design of plastic lubricants was performed in cooperation with Armed Forces Academy of General Milan Rastislav Štefánik represented by Ing. Miroslav Marko, PhD. and CMAŠ ZZ II Žilina, represented by Ing. Stanislav Kolomazník within the Project VV-1/2018 to 2020. Testing of PM (plastic lubricants) was performed on a special vehicle type GM 578. After changing MAPU-1 and MAKN-2 lubricants for PM (NLGI 00 and 0) and running 197 km was carried out "1. Check collection". Further inspections will follow in the next period. On behalf of Armed Forces Academy of General Milan Rastislav Štefánik, Major was also actively involved in tribodiagnostics Ing. Vladimír Kadlub and Capt. Ing. Pavol Lukášik.

**Keywords:** PSU-Planetary directional device; KP-Final transfer; PM-Lubricants; NLGI-Lubricant penetration scale, which is standardized in ISO 6743/9, resp. in STN ISO 65 6901.

### 1 INTRODUCTION

Within the Project VV1 (VV4) „Design and application of tribodiagnostic methodologies for operation and maintenance of ground equipment of the Armed Forces of the Slovak Republic in the years 2018 - 2020, the requirement was set: and MT-55 through the CMAŠ ZZ II Quality Control Department, Žilina. The specification will be processed by CMAŠ Žilina in cooperation with AOS.

To procure the currently available proposed compensations from the funds allocated for the solution of the VV-4 project. In terms of meeting the objectives of the VV-1 Project, substitutes were proposed for the special vehicle GM 578 as follows: For PSU-Mobil Mobilux EO 004, classification DIN 51 502, NLGI 00 and KP-Total Ceran AD Plus, classification DIN 51 502, NLGI 0.

Other types of the above vehicles and PM will not be mentioned in the article.

### 2 TESTED PARTS OF A SPECIAL VEHICLE

Lubricants were replaced by PM at the department in the presence of designated specialists, for Project VV-1- Eng. Miroslav Marko, PhD., Eng. Stanislav Kolomazník and Capt. Eng. Martin Marchveka, PhD.



**Fig. 2** GM 578 test vehicle  
Source: authors.



**Fig. 1** GM 578 test vehicle  
Source: authors.



**Fig. 3, 4, 5** Left PSU and right and bottom KP  
Source: authors.



**Fig. 6** Sampling  
Source: authors.



**Fig. 9** Laboratory of Tribodiagnostics, Armed Forces Academy of General Milan Rastislav Štefánik  
Source: authors.

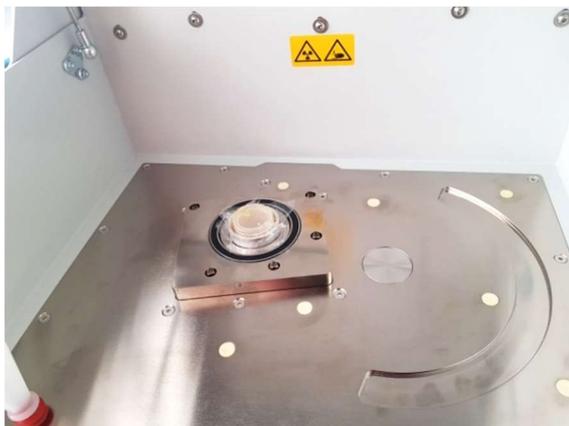
### 3 SOME MEANS OF TRIBODIAGNOSTICS

Tribodiagnostic means for detecting “Drop point [°C]; Penetration at 25 °C [penetration unit]; Corrosivity to copper, 3h / 100 °C [Comparative standard] - photo not available - performed by CMAŠ ZZ II Žilina.

Tribodiagnostic tool for detection of selected elements-Tribodiagnostic laboratory Armed Forces of General Milan Rastislav Štefánik:



**Fig. 7** SpectroCUBE X-ray spectrometer  
Source: authors.



**Fig. 8** X-ray measuring part-Column  
Source: authors.

The SPECTRO CUBE ED-XRF analyzer is intended for screening for compliance with restricted elements. For each analysis, it displays the full spectrum of all relevant elements. Importantly, as the lists of restricted materials continue to grow, the user can activate new configurations so that they can work with other matrices, elements, and compounds in the future through simple software updates.

### 4 MEASURED PM AND THEIR TRIBODIAGNOSTICS

#### 4.1 Visual diagnostics

Visualization of PM Mobil Mobilux EP 004, NLGI 00, UNUSED, BEFORE the first test filling into the PSU:

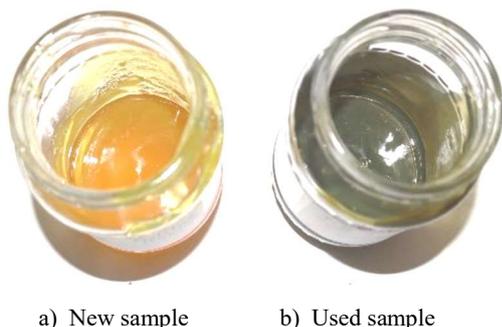


**Fig. 10** PM Mobil Mobilux EP 004, NLGI 00, NEW  
Source: authors.

Visualization of PM Mobil Mobilux EP 004, NLGI 00.

WHEN TAKING A TEST SAMPLE, 08.09.2020, AFTER approx. 197 km / 292 days from the submission of the PM for performance to the PSU GM 578.

Comparison of UNUSED and USED samples from 08. 09. 2020.



**Fig. 11** PM Mobil Mobilux EP 004, NLGI 00.  
Comparison of Reference and used sample  
Source: authors.

Comparison of samples of UNUSED PM and samples of USED PM: See a very slight darkening of used PM, which indicates a workload (PM was at a workload of 197 km / 292 days approximately from 21.11.2019 to 08.09.2020). PM is clear and visually shows no signs of sedimentation / separation of solid particles.

From the point of view of this test PM Mobil Mobilux EP 004, NLGI 00 SUITABLE for further use.

Visualization of PM Total Ceran, NLGI 0, UNUSED, BEFORE the first test filling into PSU:



**Fig. 12** PM Total Ceran, NLGI 0, NEW  
Source: authors.

Comparison of samples of UNUSED PM and samples of USED PM: See a very slight darkening of used PM, which indicates a workload (PM was at a workload of 197 km / 292 days approximately from 21.11.2019 to 08.09.2020). PM is clear and visually shows no signs of sedimentation / separation of solid particles.

In view of this PM Total Ceran AD Plus test, NLGI 0 SUITABLE for further use.



**Fig. 13** PM Total Ceran, NLGI 0  
Comparison of Reference and used sample  
Source: authors.

#### 4.2 Tribodiagnostic control of PM properties on the SPECTRO CUBE device, PM Mobil Mobilux EP 004, NLGI 00 in PSU

**Measured parameters of reference sample (RI.MO) PM Mobil Mobilux EP 004 in PSU:**

Trace occurrence: 26Fe, 28Ni

Occurrence: 38Sr; 39Y; 40Zr; 41Nb; 42Mo; 43Tc; 44Ru; 45Rh; 46Pd; 47Ag; 48Cd; 49In.

**Measured parameters of the sample of used (PI.MO) PM Mobil Mobilux EP 004 in PSU:**

Change in monitored elements:

Occurrence: 25Mn-track new; 26Fe-increase; 28Ni-foot; 29Cu-foot-new; 30Zn-occurrence-new-increase; 32Ge-occurrence-new-increase; 37Rb-foot-new. The occurrence of other monitored elements is similar to that of RI.MO.

**Measured parameters of reference sample (RII.TO) PM Total Ceran AD Plus in KP:**

Trace occurrence: 26Fe, 28Ni.

Occurrence: 20Ca; 21Sc; 38Sr; 39Y; 40Zr; 41Nb; 42Mo; 43Tc; 44Ru; 45Rh; 46Pd; 47Ag; 48Cd; 49In.

**Measured parameters of the sample used (PII.TO) PM Total Ceran AD Plus in KP:**

Change in monitored elements: (20Ca-occurrence unchanged; 21Sc-occurrence unchanged).

Occurrence: 26Fe-increase; 28Ni-occurrence; 30Zn-occurrence-new-increase; 32Ge-foot; 33As-occurrence-new; <sup>35</sup>Br-foot. The occurrence of other monitored elements is similar to that of RII.TO.

### 4.3 Tribodiagnostics of PM in the Laboratory CMSaOTD - ZZ II, quality control department, Žilina

#### Dropping point [° C] -Total Ceran AD Plus:

Reference sample:  $\pm 20\%$  (240-360) >300

PM used: -118 / -39.3 % 182

#### Penetration at 25 ° C [penetration unit] -Total Ceran AD Plus:

Reference sample:  $\pm 20\%$  (267 -401) 334

PM used: + 45 / + 13.5 % 379

#### Corrosivity to copper, 3h / 100 °C [Comparative standard]] -Total Ceran AD Plus:

Reference sample: 1a

PM used: 1a

#### Drop point [° C] -Mobil Mobilux EP 004:

Reference sample: Not measured

PM used: Not measured

#### Penetration at 25 °C [penetration unit] - Mobil Mobilux EP 004:

Reference sample:  $\pm 20\%$  (327-491) 409

PM used: + 19 / + 4.6 % 428

#### Corrosivity to copper, 3h / 100 °C [Comparative standard]] - Mobil Mobilux EP 004:

Reference sample: 1b

Used PM: 1b

Reference sample Total Ceran AD Plus: Meets the requirements of the manufacturer's specification.

Sample of PM Total Ceran AD Plus used: DOES NOT MEET the requirements of the manufacturer's specification in the "Dropping point" parameter.

Reference sample Mobil Mobilux EP 004: Meets the requirements of the manufacturer's specification.

Sample of PM used Mobil Mobilux EP 004: Meets the requirements of the manufacturer's specification.

## 5 CONCLUSION

Overall conclusion on the evaluation of PM MOBIL and TOTAL in GM 578:

#### Visual examination:

Filling PM to G 578 - tachometer: 2,957 km. PM sampling - tachometer: 3,154 km.

Samples were taken from the RIGHT PSU and KP - The same PM, which was filled into the given machine nodes at the beginning of the test, was supplemented after sampling to the volume prescribed by the regulation for treatment in terms of technology for replacement and replenishment of PM.

Comparison of samples of UNUSED PM from 21.11.2019 and UNUSED PM from 08.09.2020 - samples are without visible color changes, lubricating oils are not separated from penetrators, no signs of disturbance of PM colloidity can be seen), i.e., the

separation of the oil from the solids-penetrating component PM is not visible.

Comparison of samples of UNUSED PM (from 21.11.2019, 08.09.2020) and samples of USED PM: See a very slight darkening of used PM, which indicates a workload (PM were at a workload of 197 km / 292 days from approximately 21.11.2019 to 08.09. 2020). PMs are clear and visually show no signs of sedimentation-separation of solid particles.

In view of this test, PM Mobil Mobilux EP 004, NLGI 00 and PM TOTAL Ceran AD Plus, NLGI 0 are SUITABLE for further use.

#### Spectral analysis of monitored elements:

#### **Measured parameters of the sample of used (PI.MO) PM Mobil Mobilux EP 004 in PSU:**

Change in monitored elements:

**Occurrence:** 25Mn-track new; 26Fe-increase; 28Ni-foot; 29Cu-foot-new; 30Zn-occurrence-new-increase 32Ge-incidence-new-increase; 37Rb-foot-new

The occurrence of other monitored elements is similar to that of RI.Mo

#### **Measured parameters of the sample used (PII.TO) PM Total Ceran AD Plus in KP:**

Change in monitored elements: 20Ca-occurrence without change; 21Sc-occurrence without change.

**Occurrence:** 26Fe-increase; 28Ni-occurrence; 30Zn-occurrence-new-increase; 32Ge-foot; 33As-occurrence-new; 35Br-foot;

The occurrence of other monitored elements is similar to that of RII.TO.

Despite the naturally increased occurrence of ferrous metals and other elements from the contact surfaces of the given machine nodes, PM IS APPLICABLE IN FURTHER OPERATION GM 578.

The PM in the PSU and KP on the right side of the vehicle were, after sampling, supplemented with a new unused PM of the given specifications.

The PM in PSU and KP on the left side of the vehicle was left without additions for comparison in the next period.

#### **PM evaluation performed by CMSaOTD Žilina:**

Reference sample PM Total Ceran AD Plus, NLGI 00, used in KP - sample no. 214/20: **SUITABLE** requirements of the manufacturer's specification. Sample of used PM TOTAL CERAN AD PLUS - SAMPLE NO. 215/20: DOES NOT MEET THE FLIP POINT PARAMETER according to the requirements of the manufacturer's specification.

Note: Ing. Miroslav Marko, PhD., Armed Forces Academy of General M. R. Štefánik: "The decrease in the drip point was probably caused by insufficient drying of kerosene, which was used to clean KP from the previous MAKN-2 type lubricant. Total Ceran AD Plus grease, NLGI 0, was replaced by new-unused ones in KP".

Reference sample PM Mobil Mobilux EP 004 - sample no. 217/20: MEETS the requirements of the manufacturer's specification.

Sample of used PM Total Ceran AD Plus, sample no. 215/20: MEETS the requirements of the manufacturer's specification.

#### **Acknowledgments:**

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## ANALYSIS OF CURRENT TRENDS IN THE DEVELOPMENT OF DSLS AND THE POSSIBILITY OF USING THEM IN THE FIELD OF INFORMATION SECURITY

Patrik HARNOS̃, Eubomír DEDERA

**Abstract:** Use of an appropriate DSL can significantly reduce development time. This is due to the fact that DSLs are limited to the use of terms relating to the explicit domain, which makes them much easier for programmers to understand and learn. Despite these and other advantages of DSLs over GPLs, programmers will only exceptionally turn to DSLs in development process. Therefore, in this article, we will look closer on what DSLs are, when it is appropriate to use them in a project and when not. In the last part of this article, we will focus on the possibilities of using DSLs in the field of information security.

**Keywords:** Computer languages; DSL; Language workbenches; Alternative Computation Model; Information security.

### 1 INTRODUCTION

Domain-specific languages (DSLs) have been part of computer science for several decades, but like with other academic research in computer science, their potential is not yet used too much in practice. Nevertheless, many DSL experts are of the opinion that in these days when it is more relevant to focus on programming time than on processing time, the future of programming languages lies in the use of DSLs. The productivity of software development is just one of the advantages of using DSLs, although one of the most important ones. As for some DSLs, there are even efforts to completely omit the programmer from the software development process. However, in most cases of DSLs, one needs to have at least basic programming skills along with knowledge of a particular domain to create useful software. Therefore, in the process of developing a software project, the programmer's communication with domain experts is very important. Insufficient communication with domain experts or customers is the most common source of project failures during development [1]. Understandable code created by using a domain-appropriate DSL is an invaluable advantage, at this stage of project development, over general-purpose languages (GPLs).

The acronym DSL has gained popularity only with the advent of Domain-specific modeling [2]. You can find many papers written about DSLs, and probably every programmer has already worked with some DSLs. In spite of that, most programmers usually do not decide to implement their own DSL in the project anyway. However, GPLs do not always support the computational models of all projects. For example, when you want to change behaviour at runtime, or express aspects of behaviour in a more self-sense. This has led to an increasing use of XML configuration files, even in project where a custom syntax would be more readable and not harder to do. We may also encounter the use of parsers when a fluent interface in their regular language would be a lot less work. Martin Fowler, the author of "Domain-Specific Languages", came up with a hypothesis that this fact is caused by knowledge

gap. This hypothesis speaks to the fact that skilled programmers have little awareness of the benefits of DSLs and how to implement them. Therefore, in this article, we will briefly summarize what DSLs are.

Domain Specific Language (DSL) is a computer programming language with limited expressiveness that is targeted to a particular kind of problem in focused domain [1]. So obviously DSLs are not Turing-complete. This is the main difference from a general-purpose language that is aimed at any kind of software problem. But this definition of DSL, like most things in software, is not sufficiently defining, and therefore there are a number of cases where determining whether it is DSL or not is the reason for disagreement.

For this reason, the experts have formed four main elements identifying whether it is DSL:

- A. DSL is used by people, so it is as simple as possible to understand, but it is still executable by computer.
- B. DSL should be as smooth as possible, that is, it consists not only of separate expressions but also of composite ones.
- C. DSL is created for use in a particular aspect of the system in its domain and at the same time should be as simple as possible to understand. For these reasons, DSL should contain only the necessary minimum functions to cover domain requirements.
- D. DSL is effective only when it is focused only on a small domain.

### 2 TYPES OF DSLs

DSLs are mostly divided into two main categories: external DSLs, internal DSLs, but DSLs created by language workbenches can be recognized as a third category [1].

An external DSL is a domain-specific language represented in a separate language. An external DSL has a custom syntax, but it may follow the syntax of another representation such as XML. Host application of external DSL uses text parsing techniques to parse script written in this language. External DSLs usually come with tools like IDEs that

are designed to support specific functions of the language. This can result in a much-improved user and developer experience. Static analyses, code completion, visualizations, debuggers, simulators and all kinds of other niceties can be provided. These features can improve the productivity of users exponentially and they also make it easier for new team members to become productive. Examples of external DSLs that you have probably come across include regular expressions, SQL, and XML configuration files, but there are plenty of other less known external DSLs. Good examples are textual DSLs, which verbally describe graphical output, like graph or diagram. This group includes, for example, DOT and PlantUML.

In contrast to external DSLs, internal DSLs do not include tool support like debuggers and testing tools in its language design. Internal DSLs just define specific way how to use host GPL in order to use it effectively in specific domain. So, a script in an internal DSL is valid also in its host GPL. The most common way to accomplish this is by implementing a library or framework and then manipulate this framework through command-query API calls, or alternatively by a DSL. In this view, a DSL is a more understandable front-end to a library. That is why internal DSLs are sometimes called fluent API. From language design perspective, API defines the vocabulary of the abstraction, whereas an internal DSL adds a grammar [1]. So, the goal of developers of an internal DSL is mostly to create a language with understandable syntax for a domain expert, however, without language tool support, this language cannot increase productivity exponentially and it will probably be unpopular among developers.

A language workbench is a term coined by Martin Fowler in 2005. This term describes an environment designed to help people create new DSLs. A language workbench will typically include high-quality tools to support the definition, reuse and composition of domain-specific languages. To define the DSLs, the workbench supports:

1. Defining the schema for a Semantic Model for the language
2. Defining one or more rich editing environments for the language
3. Defining the behavioural semantics for the language, through a mix of interpretation and code generation.

All of this is valuable, but the truly interesting aspect of language workbenches is that they allow a DSL designer to go beyond the traditional text-based source editing to different forms of language. Anyway, they did not become mainstream, but developers continue to be interested in them and many of them reckon that they can change programming landscape significantly.

To be completely precise, internal and external DSLs can also be divided into two groups, based on

how they are combined with other languages: to fragmentary and stand-alone DSLs [1]. To put it simply, fragmentary DSLs are modules of code inside a GPL and such code is hardly understandable for nonprogrammers. An example of an external fragmentary DSL is SQL request to take action on database inside some GPL. A good example of an internal fragmentary DSL is unit testing. On the other hand, stand-alone DSLs contain files consisting exclusively of a DSL, and therefore there are understandable for domain experts.

### 3 WHEN IT IS APPROPRIATE TO USE DSL

After the previous sections, where we introduced you to various DSL types, you can see advantages of using DSLs in your project. However, this does not mean that it is suitable to use one in every project. The first obvious obstacle to the deployment of DSLs in a project is the cost of building. This obstacle is enlarged by the fact that developers are not used to building them and therefore the deployment of DSLs may require learning new techniques. And that can be time consuming. However, if we can spend some time on development of one or more DSLs in a project, we are likely to benefit from this investment of time later in project, in its easier testing and longer lifecycle. A good example is HTML, well known domain specific language. Technologies like web browsers have been evolving from the beginnings of HTML, but this DSL itself, representing domain logic, is still widely used. This is ensured by the characteristics of well-designed DSLs, and the resulting benefits. But you can create well-designed DSLs only if you can clearly define its scope. So, if we cannot exactly specify the domain of DSLs in a project, their use would not be effective and therefore we should not use them in such a project.

Now we have an idea when it is not appropriate to develop DSLs, so let's summarize why you should consider using DSLs in your project by naming their benefits. Firstly, a DSL helps knowledge workers doing their job, because it captures errors. Next, but maybe the most obvious advantage, is better communication with domain experts, but only some stand-alone DSLs fulfil this aspect (for example, regular expressions do not make communication easier). You can streamline communication with client and domain experts by adding some kind of visualization to your DSLs language support portfolio. Great examples of how it can be done are DOT and PlantUML.

DOT is a language for describing graphs, thanks to which we can verbally define a graph and then, using a program working with that language, generate the graph in a graphical form. Generating graphs using comprehensible commands is practical, but DSLs can bring more added value to the project. For example, PlantUML, which allows you to shape different types of UML diagrams by textual based commands, can provide a valuable tool to support

whole development process, e.g. for easier versioning. UML can be modified by anyone without special tools and PlantUML can be big help during discussions with client and domain experts by allowing immediate changes. For a better idea, we have prepared an example of the code in PlantUML:

```
@startuml
title <b>Use of a DSL</b>\n Creation of
standardised documents
left to right direction
skinparam packageStyle rect
skinparam shadowing false

actor :Document creator: as user
actor :Template creator: as admin
note left of user: Inserts data into a template.
note left of admin: Inserts templates into the
database.

rectangle semanticModel{
(Add Data) as addData
(Add Template) as addTemplate
(Generate Document) as generate
(View Database) as database

addData.> generate: includes
user --> addData
user --> database
admin --> addTemplate
admin --> database
}
@enduml
```

We can edit this code during a discussion and, by using a generator (for example, online at <http://www.plantuml.com>), we can interpret changes almost immediately. You can see output of our PlantUML code, interpreted by generator, in Figure 1:

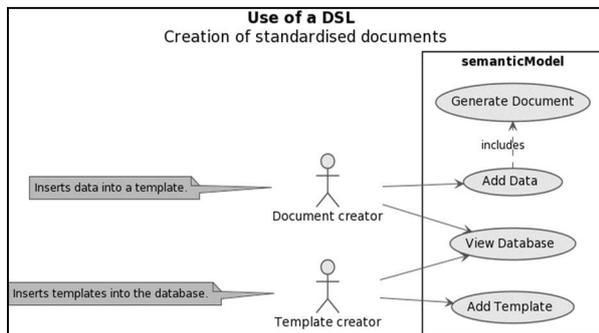


Fig. 1 Use case diagram  
Source: author.

Another aspect of using a DSL in any project is the increase of productivity across whole project lifecycle, but mostly during specification (feedback cycles are much shorter), testing (verifying can be done directly by domain experts), using, modifying

and maintaining. There are many well designed DSLs that can greatly facilitate work within their given scope. But in this article, as an example, we present only one, LaTeX.

Name LaTeX denotes a high-quality typesetting system; it includes unique DSL and other features designed for creating technical and scientific documentation. LaTeX runs on top of Donald E. Knuth's TeX typesetting system. LaTeX is available as free software [3]. LaTeX belongs to a group of languages that receive the specified sequence of commands on the input and interpret them as a separate artifact — a document on output. This is our example code in LaTeX:

```
\documentclass{article}
\usepackage{utf8}{inputenc}

\title{Pdf created by LaTeX}
\author{Patrik Harnoš}
\date{January 2021}

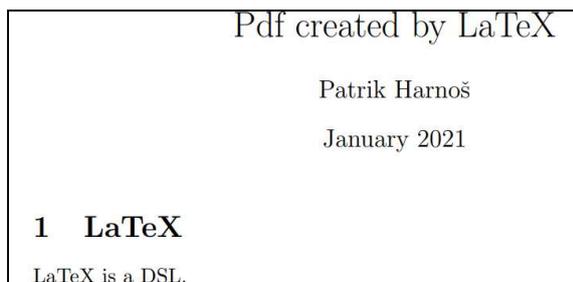
\begin{document}
\maketitle
\section{LaTeX}
LaTeX is a DSL.
\end{document}
```

We can easily convert this code to a Pdf document by the “pdflatex.exe” application, which is a part of LaTeX system.

```
D:\Phd\DSL\Clanky\LaTeX\instalacia\miktex\bin\x64>pdflatex LaTeX.txt
This is pdfTeX, Version 3.14159265-2.6-1.40.21 (MiKTeX 20.12)
entering extended mode
LaTeX.txt
LaTeX2e <2020-10-01> patch level 2
L3 programming layer <2020-12-07> xparse <2020-03-03>
(D:\Phd\DSL\Clanky\LaTeX\instalacia\tex\latex\base\article.cls
Document Class: article 2020/04/10 v1.4m Standard LaTeX document class
(D:\Phd\DSL\Clanky\LaTeX\instalacia\tex\latex\base\size10.clo))
(D:\Phd\DSL\Clanky\LaTeX\instalacia\tex\latex\base\inputenc.sty)
(D:\Phd\DSL\Clanky\LaTeX\instalacia\tex\latex\l3backend\l3backend-pdftex.def)
No file LaTeX.aux.
[1{C:/Users/Pato/AppData/Local/MiKTeX/pdftex/config/pdftex.map}] (LaTeX.aux) )
<D:/Phd/DSL/Clanky/LaTeX/instalacia/fonts/type1/public/amsfonts/cm/cmbx12.pfb><
D:/Phd/DSL/Clanky/LaTeX/instalacia/fonts/type1/public/amsfonts/cm/cmr10.pfb><D:
/Phd/DSL/Clanky/LaTeX/instalacia/fonts/type1/public/amsfonts/cm/cmr12.pfb><D:/P
hd/DSL/Clanky/LaTeX/instalacia/fonts/type1/public/amsfonts/cm/cmr17.pfb>
Output written on LaTeX.pdf (1 page, 42462 bytes).
Transcript written on LaTeX.log.
pdflatex: major issue: So far, you have not checked for MiKTeX updates.
```

Fig. 2 Example of using the "pdflatex.exe"  
Source: author.

You can see a part of the Pdf document created by “pdflatex.exe” in Figure 3. LaTeX is based on the idea that the author of the document handles only the text of the article, while the formatting is taken care of by the document developers. Similar idea of DSLs helping users effectively check and add data to systems can be used in various domains including information security.



**Fig. 3** Pdf created from example code  
Source: author.

#### 4 DSLs IN THE FIELD OF INFORMATION SECURITY

The field of information security follows the trend of using DSLs in whole computer science. We can say that there are just a few of them, mostly XML-based, some of them are DSLs only in a narrower point of view, but new ones are being developed. For example, identity access management and security auditing, as subfields of the information security, have been enriched by several narrow-scoped languages. So, we picked some DSLs to describe in this chapter, and we divide them into these two information security subfields.

##### 4.1 Identity and access management

Most organizations still use legacy systems with inbuilt authorization logic. Sometimes, one organization contains a large number of information systems and applications and each system or application uses their own process for authorization. Today, authorization has become more complex because users within organizations and outside need access to shared data and need to collaborate efficiently. Therefore, it is a challenging task to manage such legacy systems, custom authorization systems. However, XACML offers a solution to this problem, as a standard which is ratified by the OASIS standardisation organization [4]. Before we start with XACML, let's take a look at its domain and access control management. There are four main types of access control:

1. **Access Control Lists** – Oldest and most basic form of access control. This type is easy to implement due to the use of maps, but it was primarily adopted for use in operating systems. So, it can become difficult to manage larger user bases.
2. **Role-base Access Control (RBAC)** – This is a static permission model which provides access control to authorized users based on their role. This type of approach reduces management overhead and therefore it is used by the majority of enterprises with more than 500 users.
3. **Attribute-based Access Control (ABAC)** – This is a new, more flexible and fine-grained approach in comparison with RBAC. Access rights are

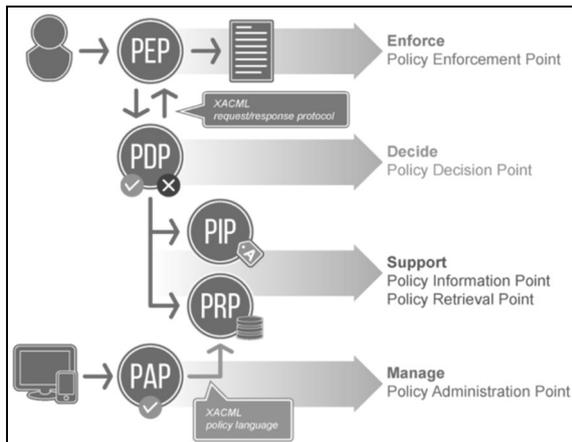
granted to users through the use of policies that combine attributes together. Because of it there is no need to know the user prior to granting access.

4. **Policy-based Access Control** – This is the most complex form of access control and it addresses the requirement of larger enterprises to have more uniform access control mechanism for the large amount of organization units. This involves specifying policies unambiguously using XACML and using authorized attribute sources in the enterprise.

So, now we know that XACML is used in access control management, mostly for specifying policies in Policy-based access control approach. But there is much more behind the label XACML. XACML is very popular as a fine-grained authorization method among the community. XACML was introduced as a standard by OASIS in 2003 and it defines an access control policy language, request/response language (protocol), and reference architecture. The policy language is used to express access control policies (who can do what, when). The request/response language expresses queries about whether a particular access should be allowed (requests) and describes answers to those queries (responses). The reference architecture proposes a standard for deployment of necessary software modules within an infrastructure to allow efficient enforcement of policies.

The XACML reference architecture illustrated below, in Figure 4, consists of the following four blocks:

1. **Policy Administration Point (PAP):** This entity allows the administrator to create, update and change a policy or policy set, by defining them in XACML policy language. These defined policies are stored in policy store. PAP makes policies and policy sets available to the PDP by Policy Retrieval Point (PRP). These policies or policy sets represent the complete policy for a specified target.
2. **Policy Enforcement Point (PEP):** The access requester sends a request for access to the PEP and this point performs access control by enforcing authorization decisions. This is the entity that sends the XACML request to the PDP and receives back an authorization decision (response).
3. **Policy Decision Point (PDP):** This entity evaluates policies against access requests sent by PEP. To provide the decisions, PDP may also need to query a PIP to gather descriptive attributes about the user or any other missing attribute in the request.
4. **Policy Information Point (PIP):** If there are missing attributes in the XACML request that is sent by PEP, PIP would find them for the PDP to evaluate the policy. PIP acts as a source of attribute values.



**Fig. 4** Diagram of XACML Architecture  
Source: [18].

The most important part of XACML, for this article, is XACML policy language structure and syntax. XACML policy language is XML-based because it is an industry standard and experts of this domain are familiar with it. XACML supports policy-based access control, based on attributes. XACML categorizes attributes in policies into four groups: subject (user, workstation, etc.), resource (server, database, etc.), action (read, write, etc.) and environment (SAML, J2SE, etc.). But from XACML 3.0, custom categories are also supported. The elementary unit of policy is a Rule.

A *Rule* is a single statement using Boolean logic, defined by *RuleId*, that specifies the individual rule in the policy. Each Rule has a particular effect on an access request (deny or permit the access). Each *Rule* is composed of a *Target* and a *Condition*.

A *Target* is an XACML component that defines categories applied on a policy. A *Target* consists of *AnyOf* and *AllOf* components and each *AllOf* consists of *Match*. Each *Match* contains only one particular category to be matched with the request.

A *Condition* specifies the applicability of the rule [5].

XACML policy language syntax, with components mentioned above, is demonstrated on the following example policy:

```
<Policy xmlns="urn:..." PolicyId="hr-admin-
access"...>
<Target>
<AnyOf>
<AllOf>
<Match MatchId="...function:string-equal">
<AttributeValue DataType="...#string">hradmin
</AttributeValue>
<AttributeDesignator AttributeId=".../role"
Category="...:subject-category:access-
subject"
DataType="...#string"
MustBePresent="true"/>
</Match>
```

```
</AllOf>
</AnyOf>
</Target>
<Rule Effect="Permit" RuleId="Rule-1">
<Target>
<AnyOf>
<AllOf>
<Match MatchId="...:function:string-equal">
<AttributeValue DataType="...#string">/Employee
</AttributeValue>
<AttributeDesignator
AttributeId="...:resource:resource-id"
Category="...:attribute-category:resource"
DataType="...#string"
MustBePresent="true"/>
</Match>
</AllOf>
</AnyOf>
</Target>
<Rule Effect="Deny" RuleId="Deny-Rule"/>
</Policy>
```

This reduced example of the policy permits only GET access to the resources /Employee by everyone with role hradmin. You can write XACML policies with any XML editor, but there are more friendly solutions how to create and publish similar, but mostly more complex, policies to Policy Administration Point (PAP). One of them is WSO2 Identity Server.

WSO2 Identity Server provides secure identity management for enterprise web applications, services, and APIs by managing identity and entitlements of the users by including the role-based access control (RBAC) convention, fine-grained policy-based access control, and Single-Sign-On (SSO) bridging. The Identity Server enables enterprise architects and developers to reduce identity provisioning time and guarantee secure online interactions. WSO2 Identity Server uses XACML as a tool for controlling access to applications. The Identity Server supports XACML 3.0, which is based on Balana XACML implementation. The source code, distribution and documentation are available for free and it is released under Apache Software License Version 2.0, one of the most business-

friendly licenses available today. The XACML engine of the WSO2 Identity Server has two major components Policy Administration Point (PAP) and Policy Decision Point (PDP) [4].

Usage of XACML in WSO2 is demonstrated in the figures below. The Identity Server enables you to create or edit policies in PAP, not only by using XML

editor, but with five other creation methods. You can use Simple, Basic and Standard Policy Editors or Policy Set Editor. Importing Existing Policy is also available. As you can see in Figure 5, thanks to Simple Policy Editor, creating a policy is a matter of filling in its name, description, and defining which role can perform what actions on which resources.

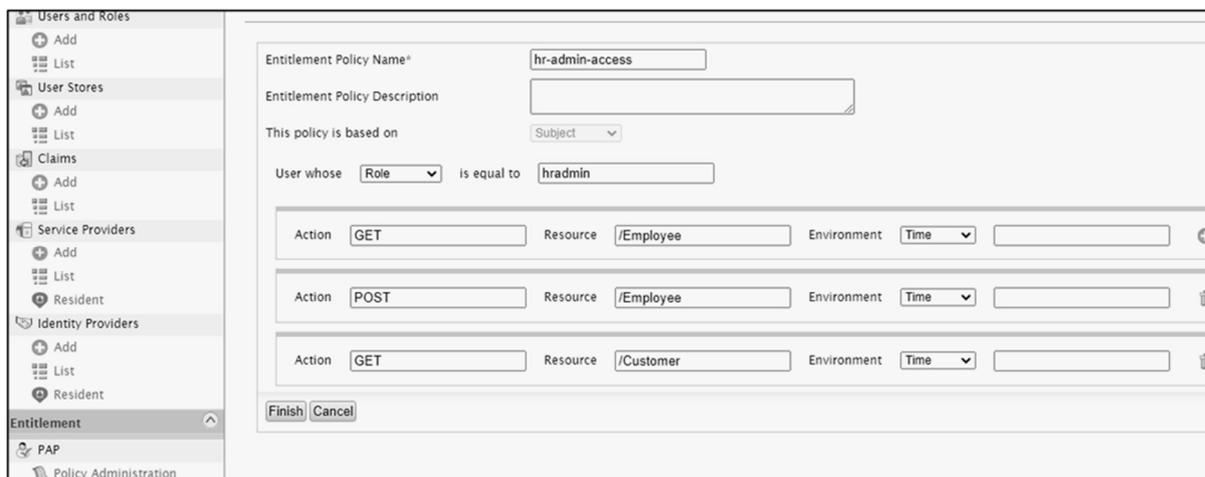


Fig. 5 Creation of example policy in the Simple Policy Editor  
Source: author.



Fig. 6 Part of the XML code of example policy created in Simple Policy Editor  
Source: author.

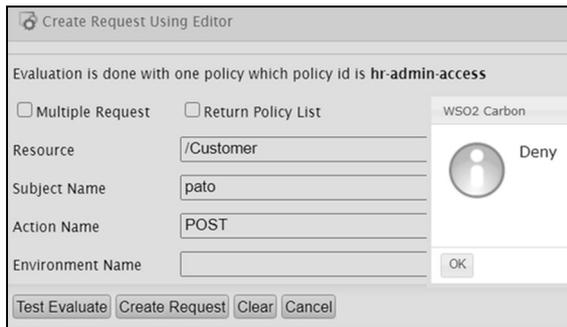
Fig. 6 shows a part of the example policy, created using Simple Policy Editor, displayed in XML. As you can see, this policy specifies rules for the role *hradmin*. Before we can publish and test this policy, we need to create user with this specific role.

As you see in Fig. 7, this is not a problem because the Identity Server enables you to create, maintain and terminate user accounts along with user identities across multiple systems including Cloud applications.

Testing of a policy is also very intuitive by creating resource request in WSO2 request editor. You just need to fill XACML attributes in request. Then, WSO2 Carbon (componentized middleware platform) will evaluate request according to policy and informs you about the response (deny, permit or not applicable when attributes in request are not specified in the policy).

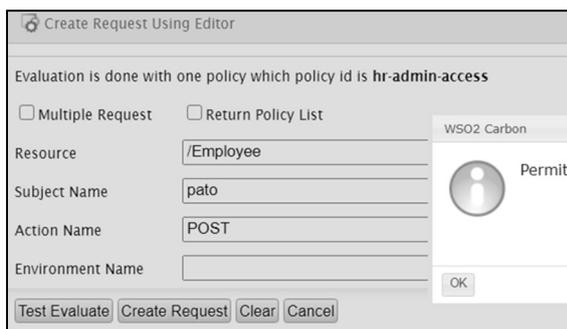


**Fig. 7** User with *hradmin* rule  
Source: author.



**Fig. 8** Denied response to the request  
Source: author.

Fig. 8 above shows a denied response sent by identity server as an answer to the request. Response is denied because user *pato* in *hradmin* role is not allowed to post in */Customer* resource based on our tested policy. On the other hand, request from user *pato* to post in */Employee* resource is in accordance with our example policy, so it is permitted as you can see in Fig. 9.



**Fig. 9** Permitted response to the request  
Source: author.

So, at the end we can say that XACML is very viable and successful DSL because of robustness of XACML and support from identity management environments like WSO2. The main advantage of XACML is its extensibility. A good example of that is in the GeoXACML. It defines a geo-specific extension standardised by Open Geospatial Consortium (OGC), which allows location-based authorisation where the access control policy can contain geographic primitives (points, lines, polygons

etc.) as well as operations on these (contains, within, distance etc.) within the authorisation policy. This is quite a unique feature of XACML. XACML from version 3.0 and GeoXACML meet changing requirements from developers who prefer the JSON format over XML by enabling encoding based on JSON. GeoXACML standard defines geospatial data interchange format based on JSON, with name GeoJSON. There are more languages that can be included in the group of DSLs in the field of access control, but we are not describing them in detail here. It is because they are similar to XACML in terms of the syntax (they are all XML or JSON based) and also because they are DSLs only from a certain point of view.

**SAML (Security Assertion Markup Language)** is an open XML security standard for exchanging authentication and authorization data between an identity provider and a service provider and it is also an XML-based markup language for access-control decisions statements.

**Privacy and Identity Management for Europe (PRIME)** project has developed a privacy-aware access control policy language and a data handling policy language able to protect user's personal information and to provide a framework that can be smoothly integrated with current architectures and online services. PRIME defines three types of privacy policies, Access control, Release and Data handling policies, to fully achieve privacy-aware access control system [6].

**A P3P Preference Exchange Language (APPEL)** is a policy language which enables users to specify their privacy preferences. Language (APPEL), similarly to PRIME languages, proposes a XML-based language for regulating secondary use of data and provides restrictions on the recipients. Main difference with PRIME languages is that users in fact can only accept the server privacy practices or stop the transaction, APPEL does not support definition of policies based on attributes of the recipients and protection against releases to third parties.

**Rei** is a policy language based in OWL-Lite (OWL-Lite uses only some features of Web Ontology Language which is used to define how applications process content of information) that allows policies to be specified as constraints over allowable and obligated actions on resources in the environment [7].

**Web Services Policy** is policy layer standard and a simple language that has four elements - Policy, All, ExactlyOne and PolicyReference - and two attributes - *wsp:Optional* and *wsp:Ignorable*. It offers mechanisms to represent combinations of capabilities and requirements, of policies and to associate them with Web service metadata constructs [8].

**ODRL (Open Digital Rights Language)** is a licencing standard and a policy expression language that provides flexible and interoperable mechanisms to support transparent and innovative

use of digital content in publishing, distributing and consuming of digital media across all sectors and communities.

#### 4.2 Security auditing and system monitoring

Computer security has become increasingly important and security auditing is one of the techniques to detect vulnerabilities and schedule a procedure to reduce them before possible attack. The goal of every company, using some information system, should be to properly implement security guidance, as target computers need to be hardened and continuously monitored during their lifecycle. Organizations can achieve this by implementing their security policy in the form of automation protocol SCAP with its XML based languages OVAL, OCIL, XCCDF and ARF.

**Security Content Automation Protocol (SCAP)** is a collection of standards managed by National Institute of Standards and Technology (NIST). It was created to enable users to perform the security audit on multiple remote systems from a single, centralized environment and also to provide a standardized approach for checking system security configuration settings, monitoring systems for signs of compromise and automatically verifying the presence of patches. Users can achieve it by using SCAP Workbench, GUI tool that serves as an SCAP scanner and provides functionality for SCAP content. SCAP includes languages [9]:

- **OVAL**: The Open Vulnerability and Assessment Language is an XML-based community standard and language for making logical assertions about the state of an endpoint system by a three-step assessment process: representing configuration for testing; analysing the system for the presence of vulnerability, configuration, patch state, etc.; and reporting the results which can be transferred across the entire spectrum of information security tools and services.
- **XCCDF**: A language to express, organize, and manage security guidance that references OVAL.
- **OCIL**: The Open Checklist Interactive Language defines a framework to provide a standard way of querying a human user. It represents a set of questions to a user and interprets responses to these questions. Although the OCIL specification was developed for use with IT security checklists, other possible use cases include research surveys, academic course exams, and instructional walkthroughs.
- **ARF**: Asset Reporting Format is a language to express the transport format of information about assets, and the relationships between assets and reports.

**The Insider Threat Prediction and Specification Language (ITPSL)** is an external

XML based DSL created to provide a systemic way to describe insider threats and misuse incidents. This is an early language compiler prototype and its underlying insider threat monitoring framework are not fully released but they have huge potential because various information security surveys and case studies indicate the importance and manifestation of the insider threat problem. ITPSL can be described as a specialized language that is able to encode system level data made by legitimate user actions, in order to create the process of misuse threat prediction. ITPSL can be of help to domain experts like the security analyst, as well as the IT administrator in charge of system operation and security issues. Both of these types of domain experts should be able to examine insider misuse incidents and express insider misuse scenarios by using the language semantic. The process of doing so starts with the security analyst writing the description of a particular insider misuse scenario, using the ITPSL semantics. The signature is validated by a compiler that translates the signature directives to query commands and uses a logging infrastructure (ITPSL use LUARM audit engine, relational model and SGL interface to audit logs), in order to examine whether the specified criteria exist in the system. The Evaluated Potential Threat is score indicating the likelihood of threat occurring according to a given detected conditions [10].

**Panoptis** is an anomaly detection system for security administrators, based on Unix process-accounting records, which consists of a single program that reads accounting records and updates profile tables, optionally reporting cases that fall outside the existing profiles. Its arguments are a DSL-based configuration file that directs the program operation, the database to update, the interval to operate upon, and an optional list of process accounting files. Panoptis is quite unique for using DSL-based instead of traditional XML-based configuration files which are used more often for real time setting of a system. Panoptis was published in 2002, so it could be a milestone in the new trend of using custom made DLSs in configuration files.

PowerShell is still used in managing operation systems from Microsoft, so to be more complex we can mention a PowerShell module that was implemented as a DSLs or even Pester, testing and mocking framework for PowerShell, which allows to create a mini-DSL for writing your tests. Pester uses a simple set of functions: Describe, Context, It, Should and Mock. So, your test can be readable and fluent [11]:

```
It 'Earth is the third planet in our Solar System' {
    $allPlanets = Get-Planet
    $allPlanets[2].Name | Should -Be 'Earth'
}
```

As a conclusion of this chapter, we can see that in the field of information security there are mostly XML-based DSLs. These languages meet the DSL properties we mentioned in the introduction, but like the original XML, universal data exchange languages, they are more machine-readable rather than smooth languages. But nowadays we can create smoother DSLs thanks to language workbenches.

## 5 LANGUAGE WORKBENCH

The definition of language workbench is provided in the second chapter of this article, but without mentioning examples. There are many language workbenches under active development, both in industry and academia. Notable examples include JetBrains MPS, MetaEdit+, Xtext, Rascal, Spoofox, SugarJ, Melange, Cedalion, Epsilon, EMFText, Intentional Software, Whole Platform, DrRacket, Eco, Ensō, MontiCore, and others. Anyway, there is a lot to choose from, but the choice should depend on the type of DSL that will be built. It is caused by the fact that some language workbenches are suitable for textual languages, others for graphical, but most exciting and powerful are projectional editors.

### 5.1 Textual DSLs

**Xtext** is an open-source framework and a solid solution for developing programming languages and DSLs. Unlike standard parser generators, Xtext generates full infrastructure, including parser, linker, typechecker, compiler as well as editing support for Eclipse, any editor that supports the Language Server Protocol (for example IntelliJ) or a web browser. But for advanced features you have to be familiar with Eclipse technology, for example Xtext produces parser using Eclipse Modeling Framework (EMF). You can see simple Hello World grammar definition from Eclipse examples in the code below [12].

```
grammar org.example...
generate domainmodel
"http://www.example.org/..."
Model:
greetings+=Greeting*;
Greeting:
'Hello' name=ID '!';
```

**textX** is very similar alternative because it was inspired by Xtext. Major difference between textX and Xtext is that textX is a Python framework, it does not use EMF, it does not generate code and editor support like Xtext because it uses metaprogramming power of Python to define classes in memory [13].

**Spoofox** is an open-source language workbench for creating textual DSLs. It can generate parsers, type checkers, compilers and interpreters. But it is more academic than an industrial-grade language workbench aimed to separate definition and implementation of a language. Spoofox can be used

inside Eclipse or IntelliJ. It is based on a set of hi-level declarative DSLs (meta-languages) aimed at various concerns of textual DSL creation process. With this approach, designers are not distracted by language implementation details. These meta-languages abstract language implementation and focus on the language design. For example, Spoofox users are addressing the issue 'what is the syntax of my language?', instead of 'how do I implement a parser for my language?' [14].

### 5.2 Graphical DSLs

In comparison with textual languages, graphical languages are more user friendly for domain experts in many cases. But on the other hand, they require building specific editors to be used and they are less flexible than textual languages. So, they are less frequent and even the tools to build graphical they are not fully tuned and easy to use. GMF is a good example of this statement.

**Graphical Modeling Framework (GMF)** can help you when you need extreme flexibility to build your very own graphical editor. The core of GMF is GMF Runtime, a Java based framework to run graphical editors inside Eclipse. It uses EMF, similarly to Xtext, to define the structure of your data and then GMF permits to specify how the different elements are represented, how their connections are displayed and so on. It provides a highly customizable way to render any model element with several kinds of graphical shapes by filling out the form and editing the details of each element in a separate panel. An example of a GMF editor is displayed in Fig. 10 below.

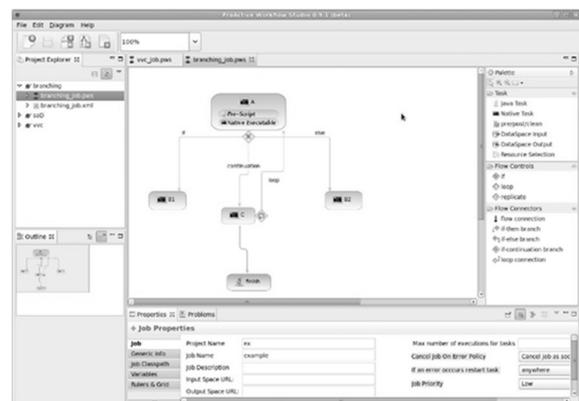


Fig. 10 Example usage of GMF  
Source: [19].

GMF is flexible and powerful with potential but without solid documentation and supporting community, therefore it offers a painful experience for the language designer. For this reason, there are tools like Eclipse Eugenia and Eclipse Sirius, built on top of GMF to make better user experience. Sirius is more complex and it uses model introspection instead

of code generation approach. It is decently supported, and it offers reasonable usability.

**MetaEdit+** is a commercial solution among graphical language workbenches. It provides a simple metamodeling language and tool for designing language concepts, their properties, associated rules, symbols, checking reports and generators. MetaEdit+ makes modeling tool development fast, intuitive, and cost-effective by allowing you to get started straight away with the reuse of language components from extensive library [15].

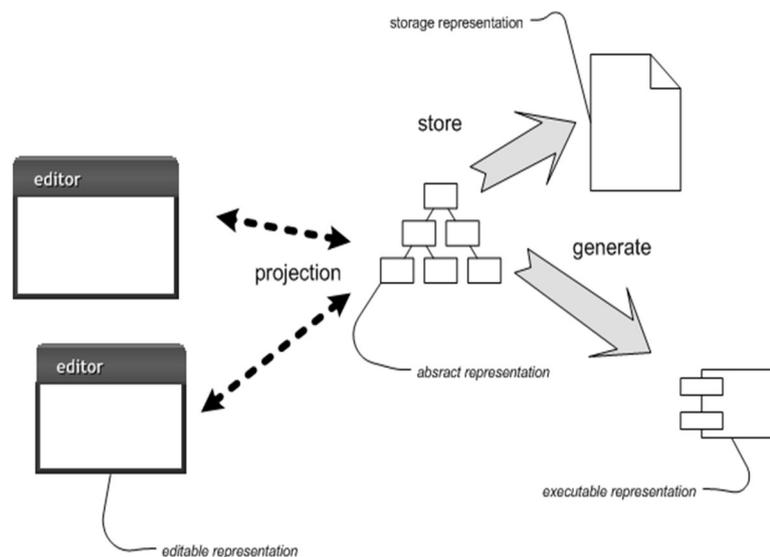
### 5.3 Projectional editors

Projectional editing is a superset of the graphical editing, so you can define graphical languages using a projectional editor like Jetbrains MPS, but projectional editors are much more flexible than typical graphical languages. Projectional editors offer combination of different notations and support all sorts of representation you need for your case. With projectional editing, the abstract representation is the core definition of the system and projectional editor shows a projection of the content stored on file, as you can see in Fig. 11.

It is a similar solution to graphical workbenches, but different in comparison with a text editor which stores user changes directly to a disk. When a user interacts with projection, in the projectional editor, he can edit text, tables or diagrams, but the editor

translates those interactions and they will be stored in a different format like XML or even binary. As a result, while thinking about your editable representations you actively think about how an editor works with them. This leads to different ideas than you would get from a purely passive editable representation such as text. The point is that you can work with those files only inside their special editor [1].

**JetBrains MPS** (Meta Programming System developed by JetBrains) is an extremely powerful tool for designing domain-specific languages and it is the most mature projectional editor available now. It uses projectional editing which allows overcoming the limits of language parsers, and building DSL editors, such as ones with tables and diagrams. It implements language-oriented programming. MPS combines an environment for language definition, a language workbench, and an Integrated Development Environment (IDE) for such languages. MPS can be useful to build families of interoperable languages with advanced tooling to describe the logic of your problems, to define tests and documentation. This platform has built in all sorts of simulators, debuggers and tools to analyse code coverage. In Fig. 12 below there is a demonstration of MPSs sample named ChemMastery from chemistry knowledge worker perspective. Model situation is that a domain expert wants to create and maintain models expressed in the provided DSL.



**Fig. 11** Manipulating representations with a language workbench  
Source: [20].

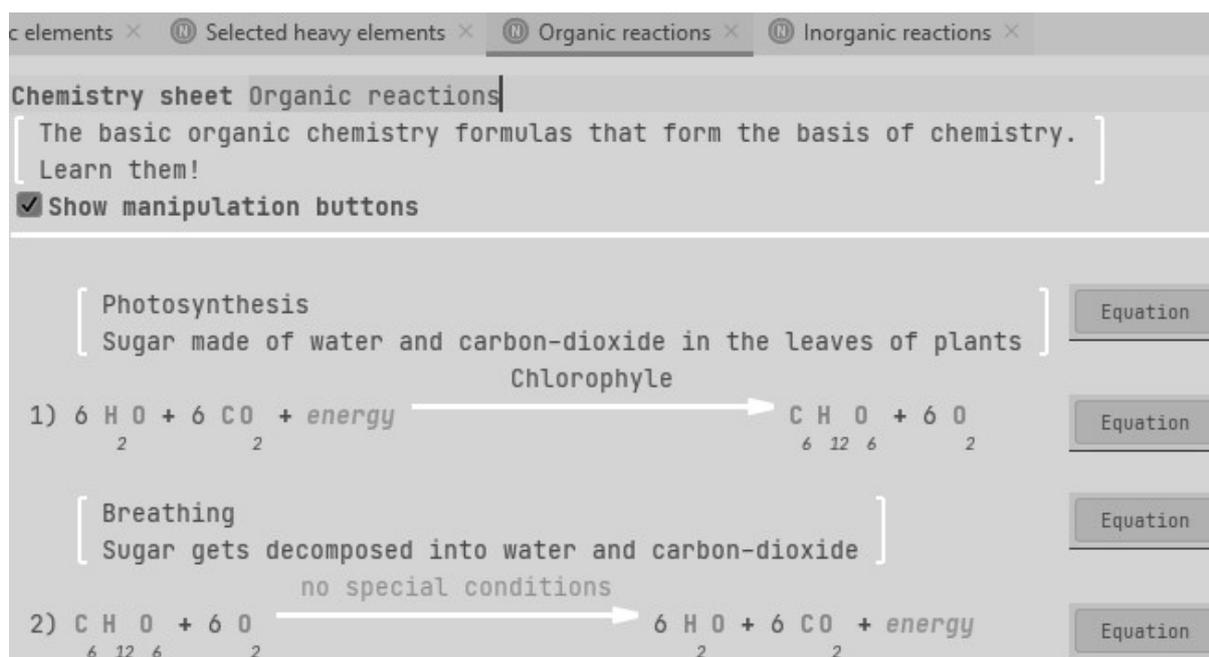


Fig. 12 MPSs sample named ChemMastery from user perspective  
Source: author.

**Whole Platform** is another overlooked but good language workbench supporting existing formats and adapting advanced language-engineering approaches. This editor also offers the idea of Pattern Language, it means that you can take the model and define its variability points that could be filled with values from another model.

There are more projectional editors like Intentional Platform or Modeling SDK for Visual Studio, but International Platform is not publicly available yet. Modeling SDK offers valuable alternative to MPS for language developers who prefer working with Microsoft Visual Studio. DSL designed in this kit can be distributed as part of a Visual Studio Integration Extension (VSIX) package, so users can work with the DSL in Visual Studio [16]. The user interface of DSL Tools solution in Visual Studio will resemble the following Fig. 13:

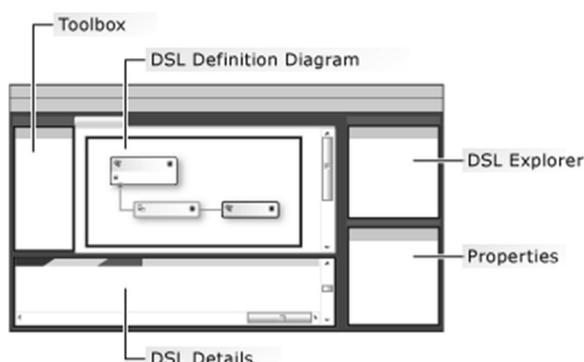


Fig. 13 Domain-Specific Language Tools User Interface  
Source: [16].

You can also use Windows Forms to display the state of a DSL model, instead of using a DSL diagram. [17].

## 6 CONCLUSION

One of the goals of this work was to get ourselves familiar with the DSLs and their potential in information security, and with language workbenches. This is accomplished and we can focus on creating an experimental DSL for the field of information security. Based on the information written in this article to date, we know that new DSLs have been developed in this area of computer science in recent years, but the majority of them are XML-based. We also know that if we want to create an efficient and popular DSL, it should be as readable and simple as possible, but at the same time it must support all common tasks performed by domain experts.

Our challenge is to create a DSL that would allow knowledge workers to effectively control and add data to the system based on a template set up by the organization. Initial use case diagram of this DSL is in Figure 1. After writing this article, we have a solid idea of the capabilities of various types of language workbenches and we can conclude that we will probably use one of the projectional editors, such as JetBrains MPS, to create a DSL.

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## STRENGTH CALCULATION OF UAV'S WING CONNECTOR TUBE

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**Abstract:** The use of unmanned vehicles - both civilian and military - is clearly a technological trend today. It is reasonable to assume that this trend will continue in the future. Especially in the military field, an unmanned vehicle can be considered a benefit, especially in applications where the use of "standard" equipment is difficult or impossible. This is especially true of Unmanned Aerial Vehicle (UAV). The flight itself represents a number of different types of stress affecting the design of the unmanned aircraft. Therefore, the design of such a device must be subjected in the first step to a computational strength analysis and subsequently to a real stress test. Our paper deals with the strength analysis of the most exposed structural element - the wing connector. Proper sizing of the wing connector is therefore crucial for the successful operation of the UAV.

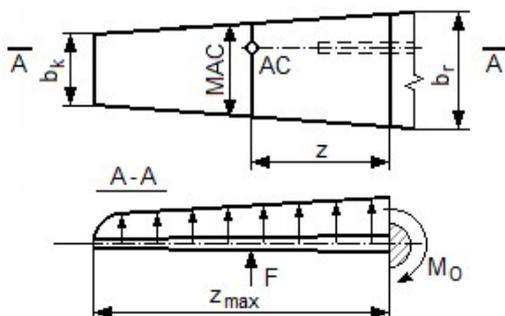
**Keywords:** UAV; Wing connector; Normal bending stress; Strength calculation.

### 1 INTRODUCTION

The structural element that is subject to particularly high stresses (especially in bending) in the case of UAVs is the wing connector. This component connects both halves of the wing to each other and at the same time the wing with the fuselage. In our paper, the strength calculation of a bending of a wing connector is shown.

### 2 NORMAL BENDING STRESS OF A RIGID WING

We assume the existence of a connecting element of the tube type (Fig.1). The tube is stressed by the bending moment  $M_0$ .



**Fig. 1** Normal bending stress of the wing (AC – aerodynamic center, MAC – middle aerodynamic chord)  
Source: authors.

The wing is stressed by a continuous load  $q$ , which is replaced by a tangential force  $F$ , which stress wing connector in bending. The bending moment induces a normal bending stress in cross section  $\sigma = f(M_0(x))$  and a tangential force induces a shear stress:  $\tau = f(T(x))$ .

We calculate the normal bending stress according to:

$$\sigma = \frac{M_0}{w_0} = \frac{F \cdot z}{w_0} \quad [MPa] \quad (1)$$

$\sigma$  – normal tension

$M_0$  – bending moment

$F$  – tangential force

$z$  – distance of the tangential force from the root of the wing

$w_0$  – cross-sectional module

We determine the tangential force  $F$  from the following equation:

$$F = n_p \cdot G \cdot \frac{S_k}{S_c} \quad [N] \quad (2)$$

$n_p$  – load factor

$G$  – gravity of aircraft

$S_c$  – total surface

$S_k$  – wing surface

Load factor  $n_p$  we determine from the following equation:

$$n_p = \frac{F_p}{G} \quad [-] \quad (3)$$

$F_p$  – lift force

$G$  – gravity of aircraft

Gravity of UAV is determined by relation:

$$G = m \cdot g \quad [N] \quad (4)$$

$m$  – weight [kg]

$g$  – gravity acceleration 9,81 [m/s<sup>2</sup>]

Values of load factor for different types of UAVs are listed in Tab. 1.

**Tab. 1** Numerical multiple of  $n_p$  for different types of UAVs

| Type of UAV        | $n_p$ |
|--------------------|-------|
| Motorized aircraft | 15    |
| Glider             | 10    |

Source: authors.

Wing surface  $S_k$  we calculate according to the following relation

$$S_k = (b_r + b_k) \cdot \frac{z_{max}}{2} [mm^2] \quad (5)$$

$b_r$  – wing root depth  
 $b_k$  – depth of wingtip  
 $z_{max}$  – wingspan

The distance of the tangential force from the wing root is determined from the following relation

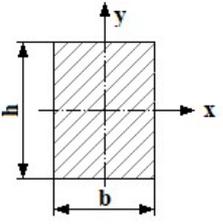
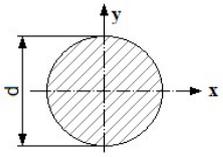
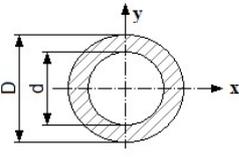
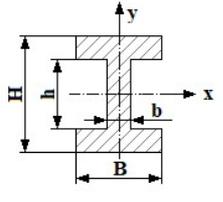
$$z = \frac{z_{max}}{3} \cdot \left(1 + \frac{\eta}{\eta+1}\right) [mm] \quad (6)$$

$\eta$  – ratio factor

$$\eta = \frac{b_k}{b_r} [-] \quad (7)$$

The cross-sectional module in the bend  $W_o$  depends on the cross-sectional area. The values of the cross-sectional module to the x-axis passing through the center of gravity for different cross-sections are given in Tab. 2.

Tab. 2 Section modulus  $W_o$

| Cross-section profile   | $W_o$  |
|---|--|
|  | $W_o = \frac{b \cdot h^2}{6}$                    |
|  | $W_o = \frac{\pi \cdot d^3}{32}$                 |
|  | $W_o = \frac{\pi \cdot (D^4 - d^4)}{32 \cdot D}$ |
|  | $W_o = \frac{(B \cdot H^3 - b \cdot h^3)}{6H}$   |

Source: authors.

The strength condition for pure bending is:

$$\sigma_{max} < \sigma_D \quad (8)$$

The course of the maximum normal stress for circular cross-sections is shown in Fig. 2. and rectangular cross-sections is shown in Fig. 3.

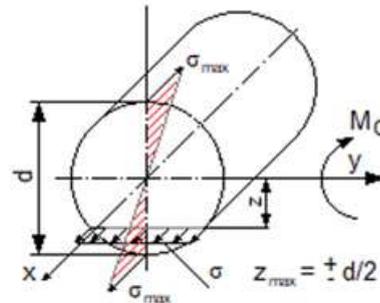


Fig. 2 Stress course in circular cross section  
 Source: authors.

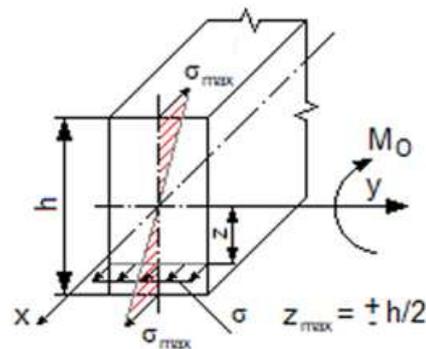


Fig. 3 Stress course in rectangular cross section  
 Source: authors.

For metallic (tough) materials, the normal tensile stress is the same as the normal compression stress. For wood and brittle materials, the normal tensile stress is not equal to the normal compression stress  $\sigma_{maxt} < \sigma_{maxd}$ .

Allowed normal tension  $\sigma_D$  we determine from strength limit  $R_m$  and safety factor  $k$

$$\sigma_D = \frac{R_m}{k} [MPa] \quad (9)$$

$\sigma_D$  – allowed normal tension  
 $R_m$  – strength limit  
 $k$  – safety factor  $k = 1,2 \div 2,5$

**Tab. 3** Strength limit  $R_m$  of some materials

| Material        | $R_m$<br>[MPa] | $R_m$ (after precipitation<br>hardening)<br>[MPa] | Note                          |
|-----------------|----------------|---|-------------------------------|
| Steel, class 11 | 400            | -   | ČSN 11 373                    |
| Steel L-ROL     | 550            | 1100  | ČSN 14 331.7 (aircraft steel) |
| Duralumin       | 230            | 450   | 42 4203.6                     |
| European spruce | 40             | -   | Along the threads             |
| Pine            | 40             | -   |                               |
| European beech  | 45             | -   |                               |
| Soft balsa      | 5              | -   | 0,15 kg/dm <sup>3</sup>       |
| Hard balsa      | 20             | -   | 0,25 kg/dm <sup>3</sup>       |

Source: authors.

### 3 STRENGTH CONTROL OF THE WING CONNECTING TUBE OF UAV – EXAMPLE

The basic dimensions of the wing are shown in Fig. 4. The weight of the aircraft is  $m = 10 \text{ kg}$ . The connecting pipe is made of duralumin with a diameter of  $35 \times 1.5 \text{ mm}$ .

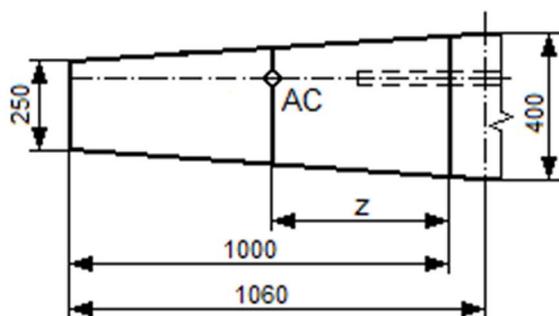


Fig. 4 Basic dimensions of the wing  
AC – place of force  $F$   
Source: authors

Wing surface:

$$S_k = (b_r + b_k) \cdot \frac{z_{max}}{2}$$

$$S_k = (400 + 250) \cdot \frac{1000}{2}$$

$$S_k = 325\,000 \text{ mm}^2$$

Total surface:

$$S_c = 2(S_k + S_T)$$

$$S_c = 2(325\,000 + (60 \cdot 400))$$

$$S_c = 698\,000 \text{ mm}^2$$

$S_T$  – the area of the fuselage between the wings

Ratio factor:

$$\eta = \frac{b_k}{b_r}$$

$$\eta = \frac{250}{400}$$

$$\eta = 0,625$$

The distance of the tangential force from the wing root:

$$z = \frac{z_{max}}{3} \cdot \left(1 + \frac{\eta}{\eta+1}\right)$$

$$z = \frac{1000}{3} \cdot \left(1 + \frac{0,625}{0,625+1}\right)$$

$$z = 462 \text{ mm}$$

Tangential force:

$$F = n_p \cdot G \cdot \frac{S_k}{S_c}$$

$$F = 15 \cdot 10,981 \cdot \frac{325\,000}{698\,000}$$

$$F = 685 \text{ N}$$

Cross-sectional module:

$$W_o = \frac{\pi \cdot (D^4 - d^4)}{32 \cdot D}$$

$$W_o = \frac{\pi \cdot (35^4 - 32^4)}{32 \cdot 35}$$

$$W_o = 1\,268 \text{ mm}^3$$

Normal tension

$$\sigma = \frac{M_o}{W_o} = \frac{F \cdot z}{W_o}$$

$$\sigma = \frac{685 \cdot 462}{1\,268}$$

$$\sigma = 250 \text{ MPa}$$

Strength condition

Allowed tension:

$$\sigma_D = \frac{R_m}{k}$$

$$\sigma_D = \frac{450}{1,2}$$

$$\sigma_D = 375 \text{ [MPa]}$$

$$\sigma = 250 \leq 375 = \sigma_D$$

Dural tube 35x1.5 mm meets the normal bending stress requirements.

#### 4 CONCLUSION

The above calculation represents the basic strength control – only in bending. For a more comprehensive assessment of the strength of the wing connector, it would be necessary to supplement the shear control and then we should consider the combined stress (bending + shear).

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## TRIBODIAGNOSTIC CONTROL OF MOTOR OIL (MO) PROPERTIES IN IVECO CROSSWAY BUSES

Miroslav MARKO, Vladimír KADLUB

**Abstract:** Within the Project VV1 "Design and application of tribodiagnostic methodologies for operation and maintenance of ground equipment of the Armed Forces of the Slovak Republic in the years 2018 - 2020, she was performed motor oil (MO) sampling series and property measurement series (MO) PETRONAS URANIA FE LS, SAE 5W-30, (O-1178), in IVECO CROSSWAY vehicles. The aim was to perform on the basis of the performed experimental measurements experimental verification of parameters of operating substances and materials of newly introduced ground military equipment.

**Keywords:** Motor oil; Appearance; Density; Kinematic Viscosity; TBN; TAN; Fash Point; Flow Point.

### 1 INTRODUCTION

Motor oils are technologically very complex products with lots of parameters which must be fulfilled during various loading conditions. Increasing their quality parameters affect the stability, performance as well as the relative prolongation of life norm. Ever higher requirements in terms of emission load are imposed on them. They are made from petroleum and synthetic base oils or from their mixtures, and are modified by complex of additives to the required properties. In the engine they perform a wide range of essential functions under various conditions. And their operation is exactly one of the determining factors on their degradation during the life norm. It is clear that the demands on the quality of motor oil are really high. It is therefore not desirable to underestimate the choice of motor oil as some so called "quasi-motorists" do. Its recommended characteristics for the engine are given by the vehicle manufacturer in the service and operation documentation. For the choice of motor oil from the perspective of the end-user, two parameters are particularly important and that is the viscous and performance specification. Motor oil has to provide excellent lubrication of the working surfaces, to reduce wear of contact surfaces, to serve as a sealing material between working surfaces, to provide heat dissipation, cleanness of working surfaces, to protect against corrosion - by conservation of engine parts, to mediate the transfer of energy, to act as a sound insulator, etc. To perform the required functions, motor oil must maintain the original properties as long as possible (especially stability in oxidative and thermo oxidative processes during high temperatures, pressures, humidity, light, radiation, etc., together with catalytic action of various metals). So in order to ensure reliable engine lubrication it is necessary that the engine oil meets the required properties, such as:

- optimal life.

### 2 SAMPLING OF TEST VEHICLES



**Fig. 1** IVECO Crossway vehicle tested  
Source: authors.

IVECO Crossway bus; Cylinder displacement: 7,790.0 cm<sup>3</sup>; Oxidation catalyst + AdBlue; Synthetic urea; Power: 243.00 kW / 2,500 rpm. Min-1; Fuel: NM min. 51 CC.



**Fig. 2** MO sampling from the vehicle engine  
Source: authors.



**Fig. 3** MO sampling from the vehicle engine  
Source: authors.



**Fig. 4** Engine nameplate  
Source: authors.

### 3 TESTED ENGINE OIL

#### Basic specification:

SAE 3W-30; API CF; ACEA E7, E.4.

#### Company specifications:

MACK EO-M Plus; MAN M3277; MB-Approval 228.5; SCANIA LDF; VOLVO VDS-3; MTU OIL TYPE 3; DAF HP1 / HP2; IVECO 18-1804 CLASSE TFE-contracted TECHNICAL REF. N ° I023.M01; RENAULT VI RXD Performance.

#### Typical physical data:

Density @ 15 °C, 0.855 [g / cm<sup>3</sup>], ASTM D 4052.  
Kinematic Viscosity / 100 °C 11.5[cSt]: ASTM D 445.  
Viscosity Index; 159ASTM D 2270.  
CCS Viscosity / -30 °C; 6100 [mPa.s]; ASTM D 5293.  
Pour Point; -40 [°C]; ASTM D 97.  
TBN; 13 [mg KOH / g]; ASTM D 2896.



**Fig. 5** Tested motor oil  
Source: authors.

### 4 CRITERIA FOR EVALUATING MO PROPERTIES

#### *Appearance (comparison of clarity, gloss, odor and turbidity)*

According to own methodology (practical experience and expertise) to determine the satisfactory or unsatisfactory. Do not allow turbidity - matt surface with light reflection.

#### *Kinematic viscosity (primary and essential property for the usability of the engine oil in the vehicle engine)*

Only allow engine oil to operate within the viscosity range of  $\pm 20\%$  of the reference sample and diesel engine oil manufacturer's data.

#### *Viscosity index*

Temperature dependence of oil fluidity. The degree of viscosity index determines the guarantee of sufficient lubrication under operating conditions. Allow the engine oil to be operated only within a viscosity index of  $\pm 15$  points from the reference sample.

#### *Flash point (basic parameter for lubrication of piston rings, especially in the exhaust phase)*

Do not allow engine oil operation when point for a diesel engine.

#### *TBN - alkalinity number (parameter for the dispersion of acid sludge, its state expresses the life of the oil)*

Do not allow the operation of the engine oil when the TBN value is reduced by more than 50 % of the value of the reference sample and the engine oil manufacturer's data.

*Antioxidant content (durability and foaming, ...)*

Do not allow the operation of engine oil when the antioxidant content decreases by more than 50 % the values of the reference sample and the data of the engine oil manufacturer.

*Aromatic content (effect on carbonization of engine working parts)*

Do not allow the operation of engine oil when the value of the aromatics content is increased by more than 300 % of the value of the reference sample and the data of the engine oil manufacturer.

*Wear elements (concentration of elements - assessment of the state of wear of work surfaces)*

Carry out the assessment of wear elements by statistical observation and comparison of values for the same engine types with a focus on values in accordance with ISO 14830.

*Total contamination (for assessments of particulate matter in engine oil)*

Assessment of total pollution in accordance with the ISO 14830 standard with a focus on mileage and hours worked, not to allow operation at above-limit, ie. - very high pollution according to purity class.

*Glycol content* (Ethylene Glycol-  $C_2H_6O_2$ , or Propylene Glycol-  $C_3H_8O_2$ ) is not permitted in engine oil. The glycol causes the additive to separate from the base oil in the engine oil and to cause overall viscosity and thickening of the engine oil. The presence of glycols in the engine oil is not permitted.



**Fig. 6** Demonstration of MO degradation by fuel and ethylene glycols  
Source: authors.

*Total engine oil additive*

The engine oil must be usable in the working parts of the engine in all conditions. It must have this applicability, regardless of how hot, cold, harsh or dusty the environment is in which it is used and regardless of the extent to which the engine is used. Additives are chemicals of complex composition, the addition of which to the base oil improves the performance of engine oils, slows down their aging and degradation, thus enabling the oils to safely and reliably meet all the requirements of modern engines. Do not allow the operation of engine oil when the

value of the total additive is reduced by more than 50 %.



**Fig. 7** Demonstration of MO degradation at contamination with ethylene glycols (Ethylene Glycol-  $C_2H_6O_2$ , or Propylene Glycol-  $C_3H_8O_2$ ), also at sulfation  
Source: authors.

*Carbon black content (Carbon residue (CCT))*

The increased content of soot in the exhaust gases is a manifestation of the great richness of the mixture ( $\lambda$ ) of the engine. An engine that works with a rich mixture not only produces black smoke from the exhaust, but also produces more soot and unburned hydrocarbons (HC). These soot and unburned HC are trapped on the contact parts of the engine and also get into the engine oil, which leads to faster carbonation (clogging of low and high heat sludge) piston rings, clogging oil filter or lubrication channels through which the engine oil is passed. As a result, it is devalued motor oil and insufficient lubrication, which leads to higher wear of individual engine parts.

The maximum CCT value is up to 2 % w / w.

*Water content* has the effect of triggering chemical reactions, such as sulfation and nitration, in which additives fall out of the base oil. Water is a strong activator of corrosion (rusting) of engine parts. The limit value of the water content in motor oil is 0.5 % w / w / 5,000 ppm (concentrations of 0.1 - 0.3 % w / w / 1,000-3,000 ppm are already a risk factor).

*Fuel content* has the effect of triggering chemical reactions, such as sulfation and nitration, in which additives fall out of the base oil. The limit value for the fuel content in engine oil is 5 % w / w / 50,000 ppm (some engine manufacturers already state value of 4 % w / w / 4,000ppm). The percentage weight of fuel in the engine oil also affects the flash point of the engine oil. For diesel-diesel engine oils, the limit value is 180 °C (The risk factor is already 190 °C). The limit value for petrol-ignition engine motor oils is 160 °C (the risk factor is already 170 °C). By this is meant engines with a directly normal reciprocating movement of the piston.

*Nitration products.* Nitration is the introduction of one or more NO<sub>2</sub> groups into organic compounds.

Nitration is the conversion of ammonium salts into nitrites by the action of bacteria. These processes in engine oil cause the breakdown of the base oil components and additives. It is a negative parameter in engine oil.

*Sulphation products.* Sulfation is the process of forming sulfates. Sulfates are salts of sulfuric acid, sulfates. These processes in engine oil cause the breakdown of the base oil components and additives. It is a negative parameter in engine oil.

*Ferroparticle Content (26Fe55,845; 27Co58,933; 28Ni58,693) - Measured by a Laboratory Tribodiagnostic Instrument - FerroCheck 2000 Series:* Ferromagnetic metals are metals with magnetic properties. Their presence in engine oils indicates wear of the respective engine contact surfaces. For the assessment of motor oils, the following limitation was set for Ferroparticles:

- FerroCheck 2000 is set to an interface of 1,000 ppm.
- Amount <0 ppm - 30 ppm> Occurrence of Ferroparticles.
- Amount <30 ppm - 70 ppm> Increased occurrence of Ferroparticles.
- Amount <70 ppm - 100 ppm> Hazardous amount of Ferroparticles.
- Amount <101 ppm and more> Intolerable amount of Ferroparticles.

*Note:* 1 ppm = 0.0001 %.

## 5 MEANS OF TRIBODIAGNOSTICS

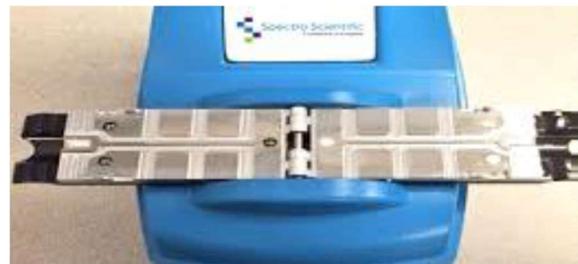
Means of measuring MO O-1178, SAE 5W-30 in the Laboratory of Tribodiagnosics, Armed Forces Academy of General M. R. Štefánik, Liptovský Mikuláš are shown in the following photo.



**Fig. 8** Laboratory of Tribodiagnosics-SpectroVisc 3050-blue, Spectro Q 1000 Fluidscan-yellow, Ferro Check 2000-blue with screen  
Source: authors.



**Fig. 10** In-vehicle COPMBO measurement kit  
Source: authors.



**Fig. 11** SpectroVisc Tribovisc measuring cell 3050  
Source: authors.



**Fig. 12** Spectro Q 1000 Fluidscan  
Source: authors.

## OVERALL EVALUATION

**Tab. 1** Change of individual properties during the course of measurements at Iveco Crossway; EVČ 687-55-02 and EVČ 687-55-40 for R 2019 and 2020

| P.č.                 | Property / Unit   | 06/18/2019                               | 06/18/2019  | 10/27/2019   | 09/10/2020   | 09/18/2019  | 10/27/2019   | 09/10/2020   |
|----------------------|---|--|---|--|--|---|--|--|
|                      |   | Reference Not used                       | EVČ 687 30 02<br>For comparison 04.11.2020 as Sample No. 1 AOS-1        | EVČ 687 30 02<br>For comparison 04.11.2020 as Sample No. 1 AOS-1               | EVČ 687 30 02<br>For comparison 04.11.2020 as Sample No. 1 AOS-1             | EVČ 687 55 40<br>For comparison 04.11.2020 as Sample No.2 AOS-2             | EVČ 687 55 40<br>For comparison 04.11.2020 as Sample No.2 AOS-2                  | EVČ 687 55 40<br>For comparison 04.11.2020 as Sample No.2 AOS-2              |
|                      |   | REFERENCE no. R AOS 06/18/2019 SAE 5W-30 | Sample No.1 AOS-1 taken 14.05.2019 SAE 5W-30 IVECO Crossway / 68 73 002 | * Sample No.2 AOS-2 taken from 26.09.2019 SAE 5W-30 IVECO Crossway / 68 73 002 | Sample No.1 AOS-1 taken from 07.09.2020 SAE 5W-30 IVECO Crossway / 687 30 02 | *** Sample No.1 AOS-3 taken 14.05.2019 SAE 5W-30 IVECO Crossway / 68 75 540 | *** Sample No.2 AOS-4 taken from 26.09.2019 SAE 5W-30 IVECO Crossway / 68 75 540 | Sample No.2 AOS-2 taken from 07.09.2020 SAE 5W-30 IVECO Crossway / 687 55 40 |
| COMBO-AOS 06/18/2019 | COMBO-AOS Measured 06/18/2019                             | Laboratory-AOS Measured 27.10.2019       | Lab.Tribo.Diag.- AOWITH Measured 10.09.2020                             | AOS LM Measured 06/18/2019   | AOS LM Measured 27.10.2019   | Lab.Tribo.Diag.- AOWITH Measured 10.09.2020                                 |  |  |
| x.1.                 | Number of works km / Mh from production-vehicle [km / Mh] | xx                                       | <b>7,733 from production</b>  | <b>20,761 from production</b>  | <b>39,738 from production Mixed operation</b>                                | <b>9,839 from production</b>  | <b>22,224 from production</b>  | <b>48,209 from production 95% - Long rides</b>                               |
| x.2.                 | Number of works km / Mh from exchanges-MO [km / Mh]       | xx                                       | <b>7,733 th most common</b>   | <b>20,761 th most common</b>   | <b>39,738 th most common</b>   | <b>9,839 th most common</b>   | <b>22,224 th most common</b>   | <b>48,209 th most common 17.07.2019, oil pan resealing</b>                   |
| x.3.                 | Life standard-MO [km / Mh]                                | xx                                       | <b>80,000 / 2 years</b>   | <b>80,000 / 2 years</b>  | <b>80,000 / 2 years</b>  | <b>80,000 / 2 years</b>   | <b>80,000 / 2 years</b>  | <b>80,000 / 2 years</b>  |
| 1.                   | Appearance [visual]                                       | Clear with reflection yellow-orange      | <b>Slightly dark with reflection</b>                                    | <b>Slightly dark with reflection</b>   | <b>Dark with reflection</b>  | <b>Slightly dark with reflection</b>  | <b>Slightly dark with reflection</b>   | <b>Dark with reflection</b>  |
| 2.                   | xx  | xx                                       | xx  | xx   | xx   | xx  | xx   | xx   |
| 3.                   | Ferroparticles-Fe, Ni, Co [ppm]                           | 0.0                                      | xx  | <b>9.8928 +9.8928</b>  | <b>1.2500 +1.2500</b>  | <b>1.33867 +1.33867</b>   | <b>4.55454 +4.55454</b>  | <b>3,2000 th most common +3.2000</b>   |
| 4.                   | Kinematic viscosity 40 °C [cSt]                           | +20% 88.09<br>73.41<br>-20% 58.73        | <b>76.59</b><br>+3.18 / + 4.33%   | <b>77.68</b><br>+4.27 / + 5.81%  | <b>80.40</b><br>+6.99 / + 9.52%  | <b>74.09</b><br>+ 0.68 / + 0.93%  | <b>76.80</b><br>+3.39 / + 4.61%  | <b>80.50</b><br>+7.09 / + 9.65%  |
|                      | Kinematic viscosity 100 °C [cSt]                          | +20% 14.49<br>12.08<br>-20% 9.67         | <b>12.47</b><br>+ 0.39 / + 3.22%  | <b>12.60</b><br>+ 0.52 / + 4.30%   | <b>12.93</b><br>+0.85 / + 7.03%  | <b>12.31</b><br>+ 0.23 / + 1.90%  | <b>12.46</b><br>+ 0.38 / + 3.14%   | <b>12.93</b><br>+0.85 / + 7.03%  |
| 5.                   | xx  | xx                                       | xx  | xx   | xx   | xx  | xx   | xx   |
| 6.                   | xx  | xx                                       | xx  | xx   | xx   | xx  | xx   | xx   |
| 7.                   | TBN [mg KOH / g]  | 8.15                                     | <b>8.55 +0.4</b>  | <b>7.60 -0.55</b>  | <b>6.50 -1.65</b>  | <b>8.50 +0.35</b>   | <b>7.60 +0.55</b>  | <b>6.30 -1.85</b>  |
| 8.                   | Soot [% w / t]  | 0.0                                      | <b>0.055 +0.05</b>  | <b>0.115 +0.115</b>  | <b>0.190 +0.190</b>  | <b>0.040 +0.04</b>  | <b>0.120 +0.120</b>  | <b>0.220 +0.220</b>  |
| 9.                   | xx  | xx                                       | xx  | xx   | xx   | xx  | xx   | xx   |
| 10.                  | Oxidation [abs / 01]                                      | 16.15                                    | <b>15.25 -1.0</b>   | <b>16.25 +0.10</b>   | <b>17.10 +0.95</b>   | <b>15.60 -0.55</b>  | <b>16.50 +0.35</b>   | <b>18.1 +1.95</b>  |
|                      | Nitration [abs / cm]                                      | xx                                       | xx  | xx   | xx   | xx  | xx   | xx   |
|                      | Sulfation [abs / 01]                                      | 25.15                                    | <b>22.12 -3.03</b>  | <b>22.05 -0.10</b>   | <b>22.50 -2.65</b>   | <b>22.12 -3.03</b>  | <b>22.55 -2.60</b>   | <b>23.50 -1.65</b>   |
|                      | Glycols [%]   | 0.0                                      | <b>0.0</b>  | <b>0.0</b>   | <b>0.0</b>   | <b>0.0</b>  | <b>0.0</b>   | <b>0.0</b>   |
| 11.                  | Water content [ppm]                                       | 366 ?!                                   | <b>290.5 +290.5</b>   | <b>312.0 +312.0</b>  | <b>349.0 -17</b>   | <b>408.0 +408</b>   | <b>294.0 +294</b>  | <b>368.0 +2</b>  |
| 12.                  | Additive [%]  | 100                                      | <b>94.25 -5.75</b>  | <b>91.00 -9.00</b>   | <b>68.00 - 32.00</b>   | <b>95.00 -5.00</b>  | <b>92.00 -8.00</b>   | <b>74.00 -26.00</b>  |

\* Note: In 2019 it was referred to as Sample No.2 AOS-2 - In this evaluation it is compared only from the point of view of EVČ 68 73 002 - Ing. Miroslav MARKO, PhD., AOS LM

\*\* Note: In 2019 it was referred to as Sample No. 2 AOS-2 - In this evaluation it is compared only from the point of view of EVČ 68 73 002 - Ing. Miroslav MARKO, PhD., AOS LM

Source: author.

## 6 CONCLUSION

2 samples of MO type O-1178, SAE 5W-30, were measured in the Tribodiagnosics Laboratories, in 3 series, from Iveco Crossway buses.

**Reference sample no. R** - AOS showed the state: Kinematic viscosity at 40 °C: COMPLIES [73.41 cSt.  $\pm 20\%$  <58.73 cSt; 88.09 cSt>]. Kinematic viscosity at 100 °C: COMPLIES [12.08 cSt.  $\pm 20\%$  9.67 cSt; 14.49 cSt>]. water contamination 366 [ppm], slight degradation by sulphation 25.15 [abs / 01], probably by the action of water + air O<sub>2</sub> present; oxidation 16.15 [abs / 01], measured alkalinity number TBN 8.15 [mg KOH / g]).

**Sample No. 1 - AOS-1** used MO O-1178, Taken on 07.09.2020 / measured 10.09.2020, (MO inspection at tachometer 39.738 km), Iveco Crossway bus, EVČ 687-30-02: SUITABLE for further use in operation. - Satisfactory kinematic viscosity / 40 °C: 80.40 [cSt], increase in MO viscosity is +6.99 [cSt] - increase in MO viscosity by +9.52 [%]. The allowable tolerance is derived from a reference sample of 73.41 [cSt],  $\pm 20\%$  (-20 % = 58.73 [cSt], + 20 % = 88.09 [cSt]), cf. table no. II / 6.4.3.

- Satisfactory kinematic viscosity / 100 °C: 12.93 [cSt], increase in MO viscosity is +0.85 [cSt] - increase in MO viscosity by +7.03 [%]. The allowable tolerance is derived from a reference sample of 12.08 [cSt],  $\pm 20\%$  (-20 % = 9.67 [cSt], + 20 % = 12.08 [cSt]), cf. table no. II / 6.4.3.

Other parameters of the monitored properties, measured in the Laboratory of Tribodiagnosics of AOS, are within the tolerances of the usability of MO (see Table No. II / 6.4.3), applies to the used MO No. 1, AOS-1:

- Ferroparticles-Fe, Ni, Co [ppm] (1 ppm = 0.0001 % of the total) / 1.2500 / Occurrence of ferroparticles the range of applicability is given above in point II / 5, last 17 sub-point. Do not allow operation when more than 101 ppm of Ferroparticles appear in the MO. Satisfies.

- Alkalinity number (TBN) [mg KOH / g] / 6.50 / decrease compared to R-AOS by 1.65 [mg KOH] do not allow the operation of engine oil when the TBN value decreases by more than 50 % of the value of the reference sample / Complies . -Setting [% w / t] / 0.19 / increase over R-AOS by 0.19 [% w / t] / maximum value is up to 2 % w / t / Satisfactory. -Oxidation [abs / 01] / 17.10 / increase over R-AOS by 0.95 [abs / 01] / do not allow MO operation when the value of antioxidant content decreases by more than 50% of the value of the reference sample / Satisfies.

- Nitration-Nitritation [abs / cm] / xx / was not measured. -Sulphation [abs / 01] / 22,50 / these processes in motor oil cause the decomposition of the base oil components and the additive, the trigger is the presence of water in the MO-it is monitored in

proportion to the presence of water / Boundary compliant.

-Water content [ppm] / 349 / reference sample was contaminated with water-366 ppm / sample no. 1 / AOS-1/349 ppm / monitored and limit values of water content in motor oil are: 0.5 % w / w / 5,000 ppm (risk factors are already concentrations 0.1 - 0.3% w / w / 1,000- 3,000 ppm) / Complies. -Glycols [%] / 0,0 / same value as for R-AOS / the presence of glycols in the engine oil is not permissible / Satisfactory. - Addivation [%] / 68.00 / decrease compared to R-AOS by 32.00 [%] / do not allow operation of engine oil when the value of total additive decreases by more than 50 % / Satisfies.

**Sample No. 2** - AOS-2 used MO O-1178, Taken on 07.09.2020 / measured 10.09.2020, (MO inspection at tachometer 48.209 km), Iveco Crossway bus, EVČ 687-55-40: SUITABLE for further use in operation. - Satisfactory kinematic viscosity / 40 °C: 80.50 [cSt], increase in MO viscosity is +7.09 [cSt] - increase in MO viscosity by +9.65 [%]. The allowable tolerance is derived from a reference sample of 73.41 [cSt],  $\pm 20\%$  (-20 % = 58.73 [cSt], + 20 % = 88.09 [cSt]), cf. table no. II / 6.4.3.

- Satisfactory kinematic viscosity / 100 °C: 12.93 [cSt], increase in MO viscosity is +0.85 [cSt] - increase in MO viscosity by +7.03 [%]. The allowable tolerance is derived from a reference sample of 12.08 [cSt],  $\pm 20\%$  (-20 % = 9.67 [cSt], + 20 % = 12.08 [cSt]), cf. table no. II / 6.4.3.

Other parameters of the monitored properties, measured in the Laboratory of Tribodiagnosics of AOS, are within the tolerances of the usability of MO (see Table No. II / 6.4.3), applies to the used MO No. 2, AOS-2:

- Ferroparticles-Fe, Ni, Co [ppm] (1 ppm = 0,0001 % of the total) / 3,2000 / Occurrence of ferroparticles the range of applicability is given above in point II / 5, last 17 sub-paragraph. Do not allow operation when more than 101 ppm of Ferroparticles appear in the MO. Satisfies.

- Alkalinity number (TBN) [mg KOH / g] / 6.30 / decrease compared to R-AOS by 1.85 [mg KOH] do not allow the operation of engine oil when the TBN value decreases by more than 50% of the value of the reference sample / Complies . -Setting [% w / t] / 0.22 / increase over R-AOS by 0.22 [% w / t] / maximum value is up to 2% w / t / Satisfactory. -Oxidation [abs / 01] / 18.10 / increase compared to R-AOS by 1.95 [abs / 01] / do not allow MO operation when the value of antioxidant content decreases by more than 50 % of the value of the reference sample / Satisfies.

- Nitration-Nitritation [abs / cm] / xx / was not measured.

- Sulphation [abs / 01] / 23,50 / these processes in motor oil cause the decomposition of the base oil components and the additive, the trigger is the presence of water in the MO-it is monitored in proportion to the presence of water.

- Water content [ppm] / 368 / reference sample was contaminated with water-366 ppm / sample no. 1 / AOS-1/349 ppm / monitored and limit values of water content in motor oil are: 0.5 % w / w / 5.000 ppm (concentrations of 0.1 - 0.3 % w / w / 1.000- 3,000 ppm) / Complies.

- Glycols [%] / 0,0 / value same as for R-AOS / the presence of glycols in the engine oil is inadmissible / Satisfactory.

- Additivation [%] / 74.00 / decrease compared to R-AOS by 26.00 [%] / do not allow operation of engine oil when the value of total additive decreases by more than 50 % / Satisfies.

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