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APPLICATION OF ENERGETIC MATERIALS IN CIVILIAN SPHERE

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A b s t r a c t :

The aim of this paper is to acquaint the readers with civilian application of energetic materials, i.e. solid propellants when they are practically applied in different civilian spheres. These are successfully used for dynamic tests of different types of structures, or in those cases when they are used against the hailstorms damaging from time to time the agricultural products, which have to be replaced from other outer sources, as well as it is necessary to compensate the agricultural producers financial losses.

1. Introduction

The application of the **e***nergetic* **m***aterials – (EM)* mainly the different kinds of **s***olid* **p***ropellants – (SP)* in the civilian sphere represents very important task. The principle of this task is – *the application of the rocket engine* as either exciting mean, or as a *propulsion system* securing transportation of the active chemical compound to the storm clouds, where this active agent is able to prevent the formation of ice, which, when falling to the ground, can damage the agricultural products.

The non-destructive tests of a structure (concrete, mechanical etc.) had now some history dated from the beginning of the *70th practically till now*.

When considering the performance of the non-destructive dynamic tests there are two possible solutions are usually applied, i.e.

1. *The structure excitement can be realized with the help of "**m**echanical **e**xciters"(vibrators) - (ME).*
2. *The structure excitement can be done with the help of so called "**i**mpulse **f**orce **e**xciters"- (IFE).*

Mechanical exciters are usually of a relatively big dimension that means, they have relatively high mass and for their operation it is necessary the supplementary source of the energy (*electrical, propulsion systems etc.*). These facts can in some cases cause some complications regarding their displacement on the tested structure.

Impulse force exciters are the exciters based on the reactive force principle of action during operation of some special rocket motor, using for its operation *solid propellant charge*.

Regarding the period and number of the performed dynamic tests with the mentioned type of the *IFE* it is possible to point out the following:

- *IFE's* of existing types has small overall dimensions and acceptable mass; therefore they can simply be placed on the structure tested. The influence of the *IFE* on the structure behaviour during the dynamic test is due to this practically negligible.
- *IFE's* are safe enough. The statement mentioned can be proved by the survey of performed dynamic tests. During the period of *IFE* application (i.e. from the year 1970 up to the year 1991) there was not happen any accident or subsidiary effect on the structure tested. Moreover the reproducibility of the acting exciting forces is within the permitted technical limits.
- *IFE's* are cheep enough. The production of the IFE unit's do not represents special problems and do not require special expenses. The price of the complete *IFE* unit depends on the amount of **s***olid* **p***ropellant* - (*SP*) being necessary in order to create the required exciting force [1].

The idea of rocket engine principle is historically known and was successfully used in different countries. In the late Czechoslovak Republic it was first applied at the end of the year 1968, i.e. in a period of design, development and testing of the plane *L–39 Albatross*, produced by the Aero Vodochody factory, mainly for determination of the real flutter flight conditions. In order to verify the testing method had been chosen the plane *L–29 Dolphin*, which had passed through all the types of flight tests. The producer had stated the main technical parameters, i.e. the *excitation force* – F_{ex} and *time of excitation* – t_{ex}. Both the values had been selected according to presupposed frequencies – causing the flutter effect. Principle of the testing arrangement of RE for the flutter flight tests can be seen in Fig. 1.

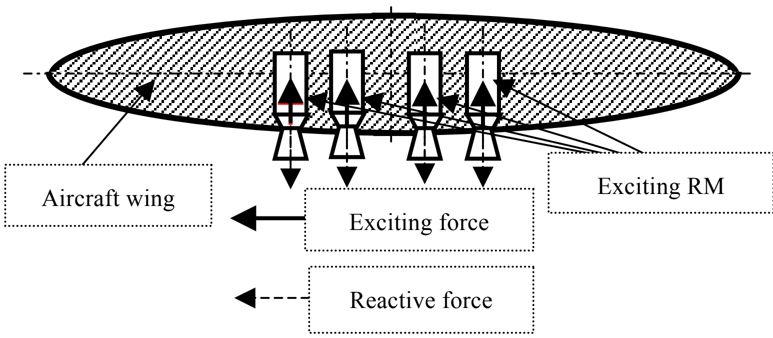

Fig. 1. Principle arrangement of rocket exciters on aircraft wing

The **R***ocket* **E***ngine – (RE)* presupposed as an exciting unit had been designed, produced and tested. Their parameters were acceptable and very near to the required ones. Also the tests on the wing construction on the ground had proved that the exciting units together with the measuring equipment could verify the plane parameters. At the base of all static tests the plane was prepared for flight tests. The period of the flight test (had been piloted by testing pilot) of the plane *L–29* with *8 exciting* units located in the wings started in the years 1969-70. All the tests were carried out and evaluated and regarding the improved construction of the plane *L–39* were stated new, unfortunately controversial technical requirements. In order to fulfil these new technical requirements had been started the new period of the design, development, production and testing. The reasons were the following. Original design had required the exciting force $F_{ex} = 980.7\ N\ (100\ kp)$ and $F_{ex} = 1961.3\ N\ (200\ kp)$ and the exciting time $t_{ex} \approx 1\ s$, meanwhile the plane *L–39* could be tested for the exciting forces within the range $(490.3 \div 1961.3)\ N$ *with* the difference $\Delta F_{ex} = 490.3\ N$. The time of excitation had been required to be within the range $t_{ex} = 0.1\ s$; $0.0025\ s$ and $0.008\ s$.

Worst requirements were the times of excitations – $t_{ex} = 0.0025$ s and $t_{ex} = 0.008$ s. The respective solution was found and the tests on plane *L–39* were prepared and full extent of the tests was carried out beginning from the year 1971.

Remark: *The flutter tests had been later applied on the aircraft construction of planes L -410 as well as L -610 (during its prototype tests).*

At the same time (year 1970) was solved excitation unit for the testing of *side wind action* on mowing automobile (really carried out during the year 1971 – for Indian aspirant on VUT Brno). During the years 1977 - 78 similar tests were carried out in cooperation with the Research institute of motor vehicles in Prague. These tests were directed for investigation of the side wind effect on motor vehicles on highways. Possible construction arrangement is introduced in Fig. 2.

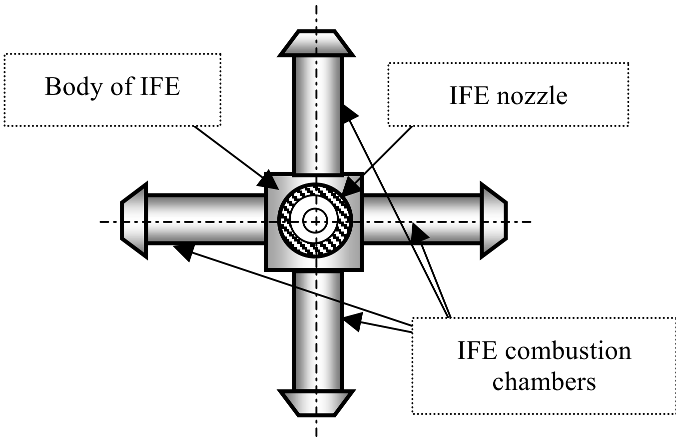

Fig. 2. Principle arrangement of IFE for tests of automobile

The next period of the dynamic tests had been started for bigger structures as e.g. TV tower "*Ještěd*" and different types of bridges (first one the bridge in Prague called "*Nusle bridge*"). These dynamic tests were carried out for larger exciting forces having the order of tons of Newton's. The principle of the IFE application on bridges or other big structures is shown in Fig. 3.

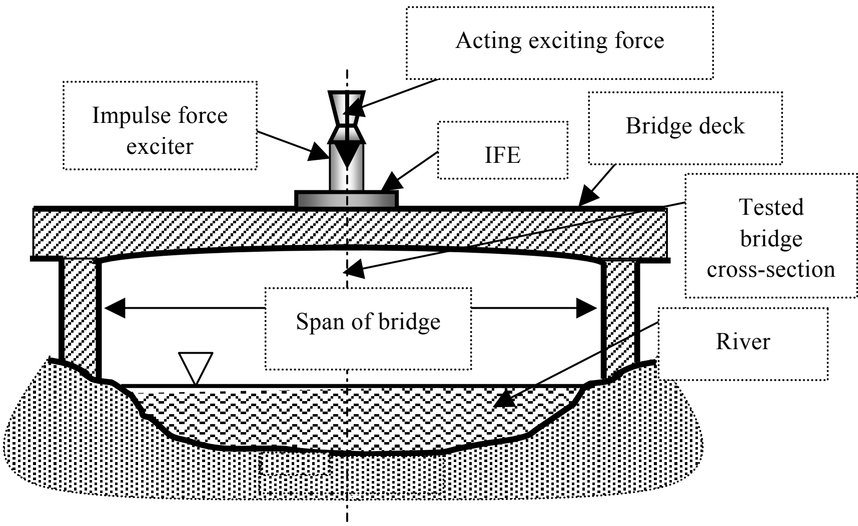

Fig. 3. Principle of dynamic test of the bridge

The history of these dynamic tests from 1969 till 1991 contains more than 90 big dynamic tests. E.g. all highway bridges on *highway D-1* were tested when using this way, other tower and chimneys, buildings, automobile, railway structures as well as the new bridge in Switzerland, canton Valise and bridges in the Slovak Republic.

The results of all these tests correspond with laying down technical conditions, so that the method of testing by exciting units based on *rocket principle* in comparison with other types of exciters was of lower costs, safe and with good reproducibility.

The performance of the dynamic tests of structures being of a mechanical or building construction character are usually the test, which verify the structure quality from the point of view of acting frequencies. Each the structure has to be proposed so that there is not the danger of vibrations due to the action of the *own frequencies* causing the structure destruction.

2. General requirements on impulse force exciters

Regarding the time of the IFE operation they can be classified as follows:

- ♦ *IFE having the time of operation of the order of seconds;*
- ♦ *IFE having the time of operation of the order of fractions of seconds.*

Requirements laid on IFE can be introduced in the following way:

- ∗ *General;*
- ∗ *Ballistic;*
- ∗ *Special.*

General requirements – the character and magnitude of the acting exciting force – F_{ex}; duration of the exciting force from the point of view of required frequency – t_{ex}.

The frequency of the IFE can be estimated as follow [1]

$$f_i = \frac{1}{(2 \div 3) t_{exi}} \quad . \tag{1}$$

It is evident from the equation (1) that the smaller the IFE time of operation will be; the higher frequencies will be obtained.

The character of IFE – F_{ex} can be as follows [2]

$$\begin{aligned} F_{ex} &= \text{cons.}; \\ F_{ex} &\neq \text{cons.} \end{aligned} \tag{2}$$

Ballistic requirements – they are related to the properties of the **s**<u>*olid*</u> **p**<u>*ropellant*</u> – *(SP),* i.e.:

- *Acting chamber pressure – p_{CC};*
- *Burning law of the used SP.*

The chamber pressure – p_{CC} plays an important role, mainly regarding the mechanical properties of the SP **R***ocket* **M***otor - (SPRM),* time of the IFE operation. The used SP burning law influences mainly the IFE time of operation.

Special requirements – they are mainly related to the IFE application, i.e. if they are used in normal or some extreme temperature conditions. To these requirements usually there are also related the conditions of the noise during the IFE operation.

The impulse of IFE unit can be generally expressed as follow:

$$I_F = \int_0^{t_E} F_{ex}(t)dt \ . \tag{3}$$

Total impulse of IFE – I_{ex} will be a variable value, when $F_{ex} \neq cons.$ and I_{ex} is a constant value when $F_{ex} = cons.$

The thrust of the IFE in accordance with the general theory of SPRM is as follow [4]

$$F_{ex} = \dot{m}_{SP} i_s = S u \rho_{SP} i_s \ , \tag{4}$$

where $\dot{m}_{SP}$ is the mass flow rate (mass emission of SP), S is the SP charge burning surface, u is the burning rate of used SP, ρ_{SP} is the SP density, i_s is a specific impulse.

The burning rate of the SP used is generally as follow [4]

$$u = u_0 \exp\left[K_T\left(t_{SP} - t_N\right)\right] p_{CC}^{\alpha} \ , \tag{5}$$

where u_0 is the burning rate at pressure of 1 Pa, K_T is the SP temperature sensitivity coefficient (depends on SP chemical composition), t_{SP} is the SP charge initial temperature, t_N is the SP charge normal temperature (e.g. 15^0C), α is the burning law exponent.

The character of the IFE operation therefore depends on the SP charge burning surface *S.* If there is used the SP charge having the *constant* burning surface the character of the IFE exciting force will be *neutral.* If the SP charge burning surface will be *variable* value, then the character of IFE exciting force will also be variable, i.e.:

- *Degressive;*
- *Progressive.*

The possible course of the IFE exciting force is illustrated in Fig. 4. Degressivity, progressivity or neutrality of the IFE operation is therefore the function of the SP geometric shape.

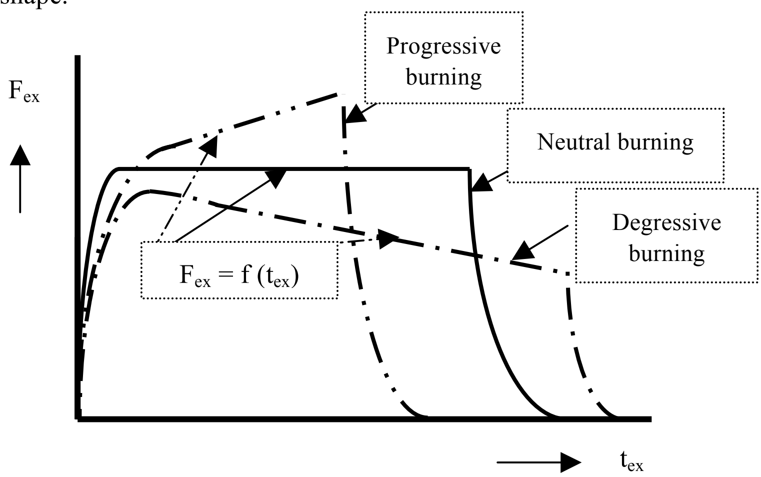

Fig. 4. Exciting force – time course

Regarding the IFE design there is usually selected the kind of the propellant (chemical composition, colloidal or heterogeneous) so that the physical-chemical characteristics are known values. The force F_{ex} is also an allocated value. Therefore the necessary weight of the SP is also known value, i.e. [2]:

$$m_{SP} = \frac{\int_0^{t_E} F_E(t)\,dt}{i_s} \quad . \tag{6}$$

Another important requirement laid on the IFE during loading the structure is that the exciting force will act in the required place so that the force will be perpendicular to the plane of a structure. Such a requirement can be secured in a different way, i.e. by:

- *Packet of the IFE units (see Fig. 5);*
- *Single IFE (see Fig. 6);*
- *IFE with so called central body (see Fig. 7 universal IFE).*

The advantage of the *packet IFE arrangement* is relative simplicity (the packet is composed from several IFE units of the same performance). The disadvantage of such an arrangement is that the individual IFE units can be realized with a certain exciting force deviation – $F_{exi} = F_{ex} \pm \Delta F_{ex}$. The deviation is the result of the production tolerances of the IFE parts and tolerances of the used SP grains. The most serious disadvantage is the *delay* of the individual unit's ignition. The needed exciting force will not be reached when there will be some delay of the individual exciting unit.

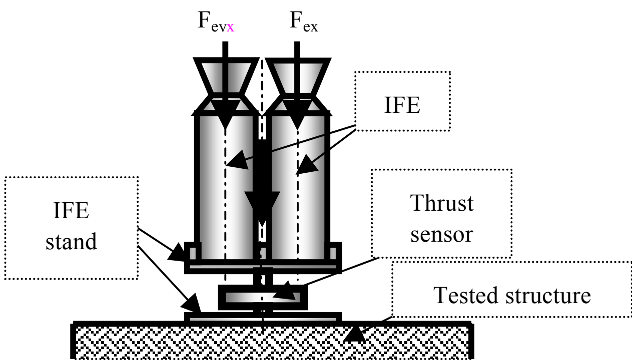

Fig. 5. Packet arrangement of IFE

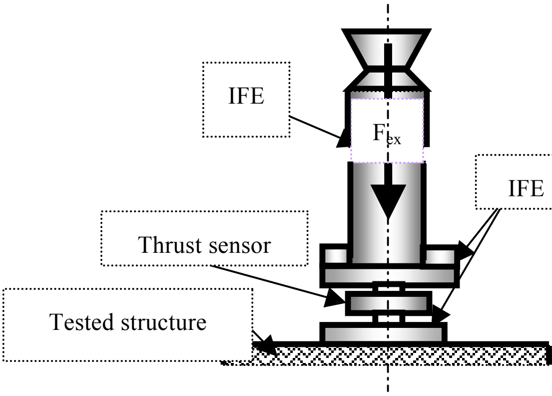

Fig. 6. Single arrangement of the IFE

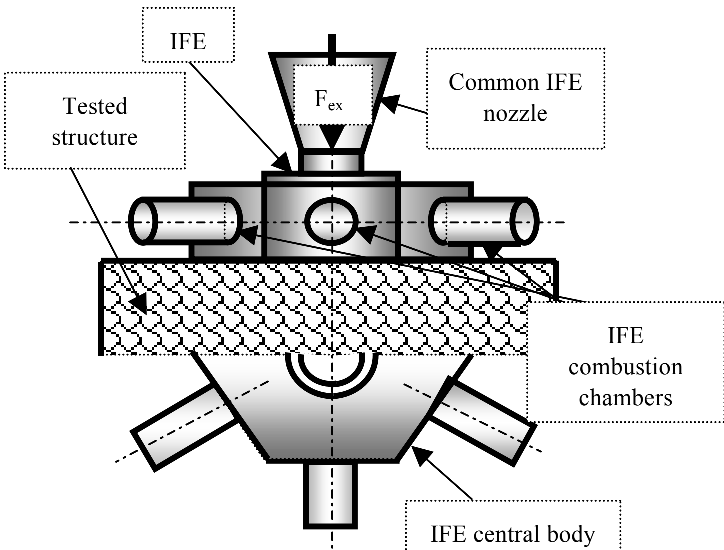

Fig. 7. Universal IFE type

The advantage of the IFE with the central body (universal type of IFE) is that the exciting force always acts in the axis of the IFE. The number of IFE combustion chambers regulates the magnitude of the exciting force. The malfunction of a certain combustion chamber practically isn't possible (if the ignition of the IFE is the correct one). The disadvantage of such an IFE arrangement is more complicated construction and production.

When evaluating the IFE it is possible to point out the following:

- *IFE is reliable source for dynamic tests;*
- *IFE can be used many times without the substantial variation of the exiting force;*
- *IFE secures reproducibility of the exciting forces and their time of operation.*

The above mentioned facts about IFE can further be extended regarding the way of dynamic tests of structures performance. Beside the classical procedure of dynamic tests the attention has to be paid to the *modal dynamic analysis of dynamic test* of structures. This approach usually requires the excitation by exciting forces having very short time of excitation (of the order of hundredth or tenth of a second). Such tests can be carried out in two possible ways:

- *The structure is excited from one place of IFE displacement; meanwhile the transducers for the measurement of the structure response are distributed in prescribed position on the structure tested.*
- *The structure is excited from different places meanwhile the transducers are distributed in the fixed places of the structure.*

Regarding the results of tests it is necessary to point out that the second way of the structure modal analysis seems to be more correct, because of more convenient distribution of exciting energy into the tested structure [3].

Ballistic and Mass Design of Impulse Force Exciter when Using Solid Propellant Charge of Spiral Shape

SP charge shape is evident on Fig. 8.

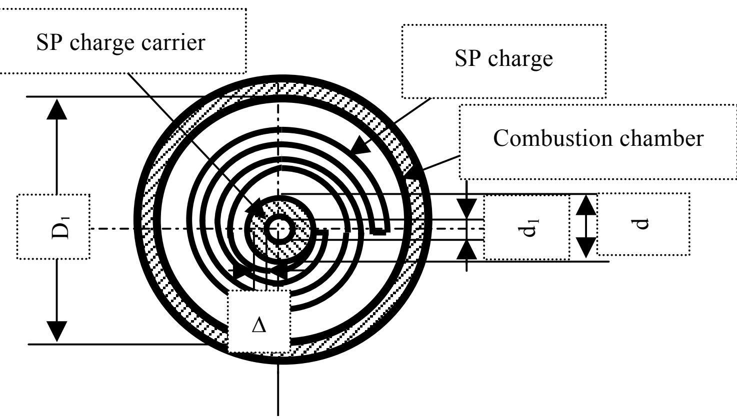

Fig. 8. Solid propellant charge in shape of the spiral

The principle shape of this type of SP charge is a "*strip*" as it is evident on Fig. 9.

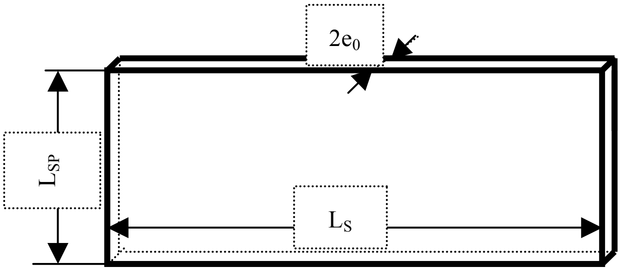

Fig. 9. Shape of strip solid propellant charge

IFE **B***allistic and* **M***ass* **D***esign – (BMD) algorithm of the solution* when using above mentioned geometric shape of SP charge is given by the following set of equations [2].

$$\begin{aligned}
&1.\quad a_i = \frac{\pi}{4}\overline{\Theta}^2 \rho_{SPi}\ ;\\
&2.\quad K_1 = \frac{F_{ex1} t_{ex1}}{c^{\times}}\ ;\\
&3.\quad K_2 = \left[u_0 f(t_{SP}) t_{ex1}\right]^3\ ;\\
&4.\quad K_{4i} = \frac{\pi}{4}\left[\overline{\Theta}^2 - \left(\overline{d}_i^2 - \overline{d}_{1i}^2\right)\right]\ ;\\
&5.\quad \varphi(\kappa) = \kappa^{0.5}\left(\frac{2}{\kappa+1}\right)^{\frac{\kappa+1}{2(\kappa-1)}}\ ;\\
&6.\quad c_{Fi}^0 = \varphi(\kappa)\sqrt{\frac{2\kappa}{(\kappa-1)}\left[1-\left(\frac{p_e}{p_{CC}}\right)_i^{\left(\frac{\kappa-1}{\kappa}\right)}\right]}\ ;\\
&7.\quad \left(\frac{A_e}{A_{CR}}\right)_i = \frac{\varphi^2(\kappa)}{\left(\frac{p_e}{p_{CCi}}\right)_i^{\frac{1}{\kappa}} c_{Fi}^0}\ ;\\
&8.\quad c_{Fi} = c_{Fi}^0 + \left(\frac{A_e}{A_{CR}}\right)_i\left[\left(\frac{p_e}{p_{CCi}}\right) - \frac{p_A}{p_{CCi}}\right]\ ;
\end{aligned}\tag{7}$$

$$9.\quad A_i = \frac{\overline{\Delta}_i \left(\frac{Z}{C}\right)_i}{\left[\left(\frac{Z}{C}\right)_i + 2\right]} \quad ; (7)$$

$$10.\ B_i = \frac{4c_{Fi} a_i \overline{\Delta}_i^2 \left(\frac{Z}{C}\right)_i^2 K_2 n_t^2}{K_1 n_f K_{4i} \left[\left(\frac{Z}{C}\right)_i + 2\right]} \quad ;$$

$$11.\ C_i = -\frac{c_{Fi} a_i \overline{\Delta}_i \left(\frac{Z}{C}\right)_i^2 K_2 n_t^2}{K_1 n_F \left[\left(\frac{Z}{C}\right)_i + 2\right]} \quad ;$$

$$12.\ \overline{e}_{0i}^3 + \overline{e}_{0i}^2 A_i + \overline{e}_{0i} B_i p_{SKi}^{3\alpha} + C_i p_{SKi}^{3\alpha} = 0;$$

$$13.\ D_i = \left\{ \frac{K_1 n_F n_t K_{4i} \left\| 4\overline{e}_{0i} + 2\left(\frac{Z}{C}\right)_i \left(\overline{e}_{0i} + \overline{\Delta}_i\right) \right\|}{c_{Fi} a_i 2\overline{e}_{0i} \left[\overline{\Delta}_i \left(\frac{Z}{C}\right)_i^2 \left(K_{4i} - 4\overline{e}_{0i}\overline{\Delta}_i\right) \right]} \right\}^{\left(\frac{1}{3}\right)} \quad ; \qquad (7)$$

$$14.\ K_{Li} = \overline{\Delta}_i \left(\frac{Z}{C}\right)_i \quad ;$$

$$15.\ L_{SPi} = D_i K_{Li} \quad ;$$

$$16.\ K_{LSi} = \frac{\left[\left(\frac{Z}{C}\right)_i \left(K_{4i} - 4\overline{e}_{0i}\overline{\Delta}\ \right)\right]}{\left[4\overline{e}_{0i} + 2\left(\frac{Z}{C}\right)_i \left(\overline{e}_{0i} + \overline{\Delta}_i\right)\right]} \quad ;$$

$$17.\ L_{Si} = D_i K_{LSi} \quad ;$$

$$18.\ 2e_{0i} = 2\overline{e}_{0i} D_i \quad ;$$

$$19.\ \Delta_i = D_i \overline{\Delta}_i \quad ;$$

$$20.\ S_{0i} = 2D_i^2 \left[K_{Li} K_{LSi} + 2\overline{e}_{0i}\left(K_{Li} + K_{LSi}\right)\right] \ ;$$

$$21.\ A_{CRi} = \frac{S_{0i} c^* u_0 f(t_{SP}) \rho_{SPi}}{p_{CCi}^{(1-\alpha)}} \ ;$$

$$22.\ D_{CRi} = \sqrt{\frac{4A_{CRi}}{\pi}} \ ;$$

$$23.\ A_{ei} = A_{CRi} \left(\frac{A_e}{A_{CR}} \right)_i \ ; \ (7)$$

$$24.\ D_{ei} = \sqrt{\frac{4A_{ei}}{\pi}} \ ;$$

$$25.\ F_{exi} = c_{Fi} p_{CCi} A_{CRi} \ ;$$

$$26.\ t_{exi} = \frac{e_{0i}}{u_0 f(t_{SP}) p_{CCi}^{\alpha}} \ ;$$

$$27.\ I_{Ti} = F_{exi} t_{exi} \ .$$

The solution of an arbitrary IFE is possible for the allocated values F_{ex1} and t_{ex1}, allocated extent of n_F and n_t, chosen extent of the values as $(Z/C)_i$, p_{CCi}, p_{ei}, $\overline{\Delta}_i$ and given ρ_{SP}, c^*, κ; u_0, $f(t_{SP})$, α and $\overline{\Theta}$. The optimum solution can be selected in dependence on the strip dimensions – $2e_0$, i.e. the strip thickness from which the SP charge is produced (i.e. such thickness, which from technological reasons is possible).

The introduced IFE BMD algorithm had been practically verified when designing the universal IFE.

Remark: *The introduced algorithm being expressed by equations (7) is original and isn't published in any reference. These algorithms were used during the design and also for until now existing IFE for the dynamic loading tests.*

3. Economical advantages of impulse force exciters

According to the experiences gained in the Czech Republic from the year 1970 until now, it is possible to mention that the sound effect of the IFE is within the acceptable extent; moreover, the sound intensity drops with increasing distance from the IFE position. They are also safe from the ecological point of view (the content of dangerous agents in the stream of combustion products is usually very small), so that they can be used in areas of different nature.

The classical *IFE* (e.g. $F_E = 10\ kN$, $t_E = 1.0\ s$) needs *4.5 kg* of the solid propellant. The price of 1 *kg* of the *SP* is from *(1000 ÷ 1500) Czech crowns*, so that for *10 kN* of the exciting force the price of SP charge is of about *(4500 ÷ 6750) Czech crowns (≈ 173 ÷ 260 USD)*. When the required exciting force will be e.g. *50 kN* within *1.0 s* than the assumed price will be *≈ (22500 ÷ 33750) Czech crowns (≈ 865 ÷ 1298 USD)*. The total cost of the dynamic tests of structure will represent the number of *IFE* firings e.g. *20 tests*, then the total expense will be *(450000 ÷ 675000) Czech crowns (≈ 17308 ÷ 25962 USD)*.

In case of the *IFE* with the short time of operation for the force *10 kN* and time *0.01 s*, the mass of the SP will be approximately *0.05 kg*, i.e. the price of the SP needed will be reduced to *(50 ÷ 75) Czech crowns (≈ 1.923 ÷ 2.885 USD)*.

Remark: *Recalculation of SP price in USD is related to the actual USD value.*

The comparison of the classical *IFE* with the *IFE* more convenient for modal analysis application is introduced in table 1 and table 2. Presupposed number of *IFE* firings $n_{EX} = 20$.

Tab. 1

n_{EX} = 20; classical IFE type

T_{EI} (S)	0.4	0.6	0.8	1.0
10 (kN)	36000÷54000	54000÷81000	72000÷108000	90000÷135000
30 (kN)	108000÷162000	162000÷243000	216000÷524000	270000÷405000
50 (kN)	186000÷270000	270000÷405000	3600000÷540000	450000÷675000
f_i (Hz)	1.25 ÷ 0.83	0.83 ÷ 0.56	0.625 ÷ 0.417	0.50 ÷ 0.33

Tab. 2

n_{EX} = 20; IFE (modal)

T_{EI} (S)	0.02	0.04	0.06	0.08	0.10
10 (kN)	2000÷3000	4000÷6000	6000÷9000	8000÷12000	10000÷15000
30 (kN)	6000÷9000	12000÷18000	18000÷27000	24000÷36000	30000÷45000
50 (kN)	10000÷15000	20000÷30000	30000÷45000	40000÷60000	50000÷75000
f_i (Hz)	25.00 ÷ 16.7	12.50 ÷ 8.3	8.33 ÷ 5.6	6.25 ÷ 4.17	5.00 ÷ 3.33

Remark: *Prices in table 1 and table 2 are introduced in Czech crowns. The extent in prices is due to the chemical compounds, forming the SP charge.*

The results in the introduced tables show that in case of the *IFE* (modal), the price of the SP charge drops sharply. When comparing e.g. the *IFE* of classical type (t_E = *1.0 s*), the price as function of the exciting force varies from *(90000÷135000) Czech crowns to (450000÷675000) Czech crowns*, meanwhile for the *IFE* (t_E = *0.1 s*), the price of the SP for the same extent of exciting forces will be from *(10000÷15000) Czech crowns* to *(50000÷75000) Czech crowns*. Generally speaking in case of the *IFE* with relatively short time of operation the larger number of firings regarding the price of exciting energy needed can be performed. Such conclusion is therefore very important and should be seriously taken into consideration, when the tasks of dynamic tests should be performed with the help of *IFE*.

Regarding the above mentioned, the priority should therefore be paid to the IFE having relatively short times of excitation, i.e. the IFE of new generation.

Another sphere of the rocket principle application is in the battle with the hail-storm effect against agricultural products. The rocket in such case is the carrier of effective payload (so called transport of the active agent into the hailstorm clouds) acting against the formation of the hailstones.

There are known different systems used as an active agent, e.g. *silver iodide* or *leaded iodide*, unfortunately both the agents have some effect on the living environment. Therefore in the year 1977-78, in cooperation with the Slovak meteorological institute in Bratislava, there was solved the project of the "*Dispersion of Active Agent in the Troposphere*". The project was based on the ecologically pure agent application, i.e. "*benthonic powder"*. More over the rocket carrier was assumed to be made from convenient *plastic* material, which will be *destructed* after fulfilment of the rocket task, i.e. transportation of active agent into the required height. Main reason for such requirement was the density of *roads, railways, flight corridors* etc.

The project of the presupposed meteorological rocket hasn't been finished due to the official interference. But the principle of the benthonic powder dispersion was verified. Regarding the facts influencing the climate conditions and the possible agricultural losses show that such a project is still prospective because in the territory of the Czech Republic there exist the regions where the hailstones action regularly appears.

The principle of the active agent dispersion is illustrated in Fig. 10.

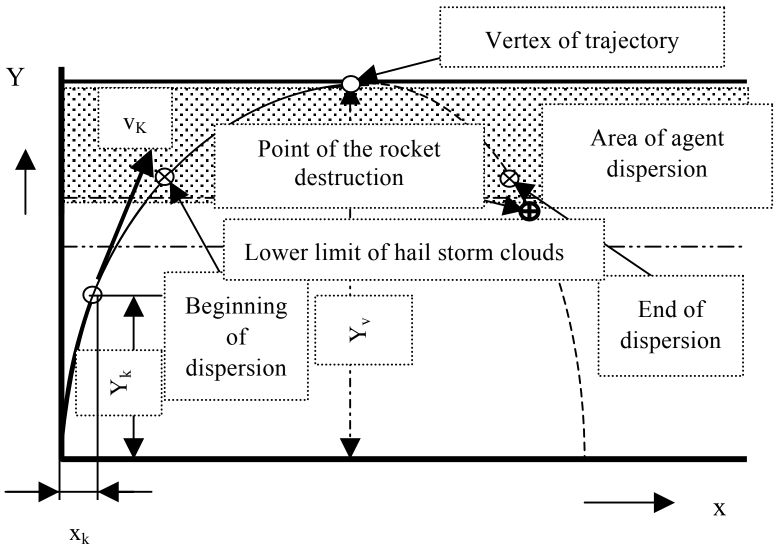

Fig. 10. Principle of active agent dispersion and destruction of the rocket on its trajectory

4. Conclusion

The above mentioned facts about the IFE can further be extended; regarding the way of the dynamic tests of structures. Beside the classical procedure of dynamic tests the attention has to be paid to *modal dynamic analysis of the dynamic test* of the structures. This approach usually requires the excitation by the exciting forces having very short time of excitation (of the order of hundredth or tenth of a second). Such tests can be carried out in two possible ways:

- *The structure is excited from one place of IFE displacement; meanwhile the transducers for measurement of the structure response are distributed in the prescribed position on the structure tested.*
- *The structure is excited from different places; meanwhile the transducers are distributed in the fixed places of the structure.*

Regarding the results of the performed tests it is necessary to point out that the second way of the structure modal analysis seems to be more correct, because of the more convenient distribution of the exciting energy into the tested structure [3].

According to the gained experiences from the year 1970 until now, it is possible to mention that the sound effect of the IFE is within the acceptable extent; moreover the sound intensity drops with an increasing distance from the IFE position. They are also safe from the ecological point of view (content of dangerous agents in the stream of combustion products is usually very small) so that they can be used in areas of the different nature.

Finally it is possible to point out that introduced examples of the civilian application of the solid propellant as an energetic material is still prospective. Moreover, for the dynamic tests of structures there aren't necessary very high energetic requirements. In case of the active influence on the climate conditions regarding the height of hailstorm clouds, there should be taken into consideration the rocket carrier velocity which influences the needed trajectory associated with the active agent dispersion. But also in this case there aren't such high requirements regarding the energetic properties of the solid propellant used.

Therefore the mentioned examples of the energetic materials utilisation in civilian sphere have positive features and can contribute to the process of dynamic tests, as well as when considering the active influence on the climate conditions.

References:

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