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NEW INDUSTRIAL ENGINE – PRIORITY AND FIELD OF APPLICATION

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Abstract: *A new industrial engine is presented – Industrial Rocket Engine (IRE). It was developed in Bulgaria and certified in Russia. That engine is applicable for propelling hammering machines – a high-speed forging hammer and a diesel hammer for pile fixing. Possibilities for broadening the technological capabilities of these machines by the use of IRE are also shown. Better parameters of deformation of special alloys with little plasticity and better parameters in the production of complex shape details were achieved by using such machienes. Using diesel pile-fixing hammer, fixing of piles at any angle can be achieved, very important technique for landslides and earthquake region stabilization. The IRE uses hydrogen (gaseous or liquid) which brings ecological advantage of that industrial engine.*

Key words: *engine, impact, impact machines, hammers*.

1. INTRODUCTION

The most important parameters of the producing machines depend on the performances of their propelled devices. Every new type of industrial engine led to the creation of new machines with better producing parameters. Because all industrial engines (electric, hydraulic, pneumatic, turbine) have reached their constructional and ecological limits this fact influences the technological capabilities of all type of machines.

In this paper the rocket industrial engine (IRE) is presented. This type of engine is suitable for propelling impact industrial machines – hot forging hammers, briquetting and pile fixing machines. The possibility of controlling this engine's parameters (effort, speed, time of action, and timing of switching on and off) in broad limits increases substantially the technological capabilities of those machines.

2. TECHNICAL PARAMETERS OF THE FIRST IRE

Technical data of the first Industrial Rocket Engine (Fig. 1) :

- Thrust	from 5 kN to 20 kN
- Pressure in the fair-box (combustion chamber)	max. 6 MPa
- Fuel	kerosene
- Oxidizer	air
- Fuel consumption	max. 0.62 kg/s
- Oxidizer consumption	max. 8.90 kg/s
- Efficiency	0.92
- Mass of the engine	25 kg

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Exhaust gas components and the working noise are in acceptable limits. IRE can work indoors (factories) and outdoors (open-air).

It is important for ecology that IRE can alternatively use hydrogen (gas or liquid). This may be the first application of hydrogen for propelling industrial machines.

Fig. 1. The First Industrial Rocket Engine (IRE).

3. HIGH-SPEED FORGING HAMMER

This type of hammer works at speeds of the ram 16-20 m/s (the speed of conventional hammer is 5–7 m/s). A high speed forging hammer HFH-36 [1] propelled by IRE is produced in Bulgaria – Fig. 2 [2].

The technical data for IRE propelled HFH –36 hammers are:

- Max. hit energy 36 kJ
- Ram speed up to 18 m/s
- Ram stroke up to 1 650 mm
- Height above floor level 3 350 mm
- Width x depth 1 250 × 800 mm
- Total mass (with a 22 000 kg anvil) 28 000 kg
- time for one working cycle 2 s

The hammer works with hydraulic upper and bottom pushing mechanisms.

The use of IRE also allows for the performance of a controlled (complex) hit. E. g. if the engine continues to work during and after impact the height of the rebound is decreased (sticking hit). That increases the time of deformation of the metal and allows better filling of the mold especially for details of complex shape.

In order to achieve a sticking hit it is necessary to define the force needed for pressing F_R [6]. This force can be determined if the rebound acceleration a_R is known from the formula

$$F_R = m_2 . a_R . \quad (1)$$

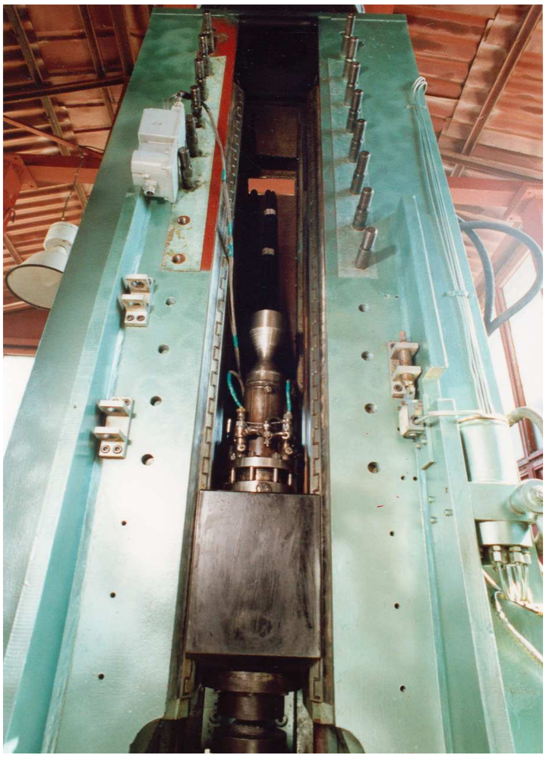

Fig. 2. View of HFH-36 forging hammer (front cover removed).

In [1] it is determined the rebound speed V_{RA} of the anvil as follows:

$$V_{RA} = \frac{2km_2V_1 + \left[4k^2m_2^2V_1^2 - 4m_2V_1^2(m_1+m_2)(\eta_i + k^2 - 1)\right]^{1/2}}{4(m_1+m_2)}, \quad (2)$$

where: k –coefficient of restitution; m_1, m_2 – mass of the anvil and the ram; V_1 – impact speed; η_i – impact efficiency coefficient.

After transformation of (2) we have

$$V_{RA} = \frac{V_1\left(km_2 + \left[k^2m_2^2 - m_2(m_1+m_2)(\eta_i + k^2 - 1)\right]^{1/2}\right)}{2(m_1+m_2)}. \quad (3)$$

In [3] it is shown that in the case of rocket propelled hammer the speed of the falling parts is determined by the expression

$$V_1 = \sqrt{2gS(R/m_2 + 1)}, \quad (4)$$

where: g is the acceleration of gravity, m/s^2; R – rocket engine trust, kg; S – falling parts path, m.

After substitution of (4) in (3) and after replacing

$$A = 2g(R/m_2 + 1)$$

$$B = \frac{\left(km_2 + \left[k^2m_2^2 - m_2(m_1+m_2)(\eta_i + k^2 - 1)\right]^{1/2}\right)}{2(m_1+m_2)}.$$

We have for V_{RA} :

$$V_{RA} = B\sqrt{AS} . \quad (5)$$

For rebound speed of the ram V_{RR} it is received

$$V_{RR} = B\sqrt{AS} - kV_1,$$

or

$$V_{RR} = B\sqrt{AS} - k\sqrt{AS}$$

and for V_{RR} we finally have

$$V_{RR} = (B-k)\sqrt{AS} . \quad (6)$$

In (6) S is a time function, and other members of this expression are numerical.

For acceleration a_R it is received

$$a_R = \frac{\partial V}{\partial t} = \frac{(B-k)A}{2\sqrt{AS}}\frac{\partial S}{\partial t} . \quad (7)$$

If we have in mind that $\partial S/\partial t = V_1$ and after substitution V_1 with expression (4)

it is received:

$$a_R = \frac{(B-k)A}{2\sqrt{AS}}\sqrt{AS}, \quad (8)$$

or

$$a_R = \frac{(B-k)A}{2}. \quad (9)$$

In keeping with (9) for F_{RR} (rebound force of the ram) we have:

$$F_{RR} = m_2 a_R = \frac{m_2(B-k)A}{2}. \quad (10)$$

Then for additional force F_R we get:

$$F_R \geq F_{RR} = \frac{m_2(B-k)A}{2}. \quad (10)$$

and after substitution of *A* and *B* we have

$$F_R \geq F_{RR} = g(R+m_2)\left(\frac{km_2 + \left[k^2 m_2^2 - m_2(m_1+m_2)(\eta_i + k^2 - 1)\right]^{1/2}}{2(m_1+m_2)} - k\right) \quad (1))$$

Let us calculate the force F_R for the existing rocket propelled hammer, for which [2]: m_1 = 22 000 kg, m_2 = 220 кg, *R* = 500 ÷ 2 000 kg, for *k* = 0.1; 0.15; 0.2; 0.25; 0.3 and η_i = 0.9 (Table 1). It can be seen that with existing rocket engine it is possible to realize die forging with "sticking impact" when *k* is *k* = 0.1 and partially when *k* = 0.15, i.e. in the case of one pass die forging, which is a technology often used in high speed hammer forging.

Table 1

Values of additional force F_R

***R*, kg**	***k*=0.1**	***k* =0.15**	***k*=0.2**	***k*=0.25**	***k*=0.3**
500	600	950	1318	1688	2069
1000	1017	1610	2234	2860	3506
1500	1434	2270	3150	4032	4943
2000	1851	2930	4066	5205	6381

4. PILE FIXING MACHINE WITH IRE

Diesel engine propelled hammers are currently used for pile fixing on land. Most often it is done in vertical direction or at up to 15^0 declination. In earthquake regions horizontal quakes are better stabilized if piles are fixed into the earth at 300 – 600 to the vertical, which is impossible to be achieved by the existing machines. Horizontal poured piles are used for stabilization of slides. So there is a clear necessity to be able to fix piles in various directions. That capability is created by the use of IRE for propelling of pile fixing machines – Fig. 3 [4].

Fig. 4 [5] shows a drawing of a diesel hammer before and after installing an IRE. Fig. 5 shows a moment of the assembly of the diesel hammer piston with IRE (produced in Bulgaria) mounted on it.

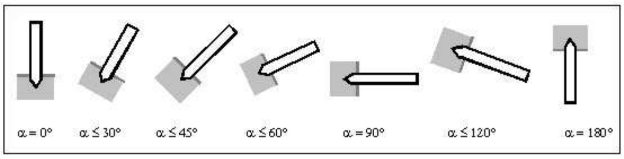

Fig. 4. Scheme of various angles of fixing the piles.

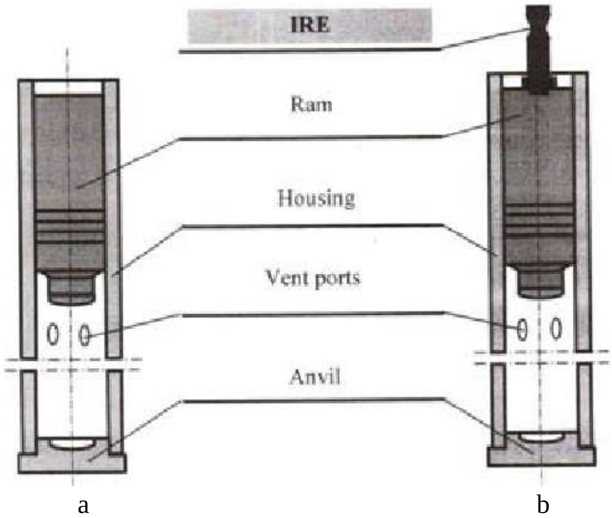

Fig. 4. *a* – diesel pile driving; *b* – hammer IRE propelled hammer.

Fig. 5. Mounting of IRE propelled diesel pile fixing hammer.

5. CONCLUSIONS

The use of IRE for propelling of machines significantly improves their technological performance parameters:

1. A complex (controlled) hit can be performed with stamping hammers. As a result we have achieved better parameters of deformation of special alloys with little plasticity and better parameters in the production of complex shape details.

2. With diesel pile-fixing hammers fixing of piles at any angle is achieved which is particularly important for landslides and earthquake regions stabilization.

3. The use of hydrogen (gaseous or liquid) for IRE defines the great ecological advantage of that industrial engine.

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