БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ • BULGARIAN ACADEMY OF SCIENCES

ПРОБЛЕМИ НА ТЕХНИЧЕСКАТА КИБЕРНЕТИКА И РОБОТИКАТА, **63**
PROBLEMS OF ENGINEERING CYBERNETICS AND ROBOTICS, **63**

София • 2011 • Sofia

High Speed Rocket Propelled Industrial Hammer

Todor Penchev[1]*, Petar Bodurov*[2]*, Dimitar Karastoyanov*[3]

[1]*Technical University, 1797 Sofia*
[2]*B+K Ltd, Sofia*
[3]*Institute of Information and Communication Technologies, 1113 Sofia*
Emails: tzpenchevi@abv.bg pbodurov@abv.bg dimikara@abv.bg

Abstract: *This paper discusses the characteristics of an Industrial Rocket Engine (IRE) and the constructive features of the machines, propelled by it. The conditions were defined to produce hits of various duration, according to the specifics of the technological processes, requiring the use of such machines: a hammer for die forging; a hammer for pile driving, and a high-speed metal scrap briquetting.*

Keywords: *high-speed hammer, forging, pile driving, briquetting.*

1. Introduction

Hammers are used for 3D die forging and pile driving. In the first case the hammer is propelled by a pneumatic cylinder, and in the second – by a modified diesel engine. The speed of the falling parts of these machines is 5-7 m/s. For forging of special alloy forgings and forgings of complex shape, high-speed gas forging hammers are used with speed of the falling parts of 16-20 m/s.

In the 70-ties of the 20th century Dr. Petar Bodurov patented a high speed forging hammer, propelled by an Industrial Rocket Engine (IRE) [1]. In the early 90-ties the first licensed IRE – Fig. 1 [2], and a hammer propelled by this engine were produced. Several hundred conical gears were produced by it. IRE has a maximum thrust of 2 t.

Fig. 1. A photograph of IRE

The technical characteristics of IRE are:

thrust	5-20 kN;
combustion chamber pressure	max 6 MPa;
fuel	kerosene;
oxidizer	air;
fuel consumption	max 0.62 kg/s;
oxidizer consumption	max 8.90 kg/s;
coefficient of performance	0.92;
engine mass	25 kg.

In 2008 The Pile Driving Hammer was patented [3], propelled by IRE and one year later the first prototype was produced.

The use of the new type of IRE expands the technological capabilities of the respective machines and allows the development of new processes. These possibilities will be discussed below.

2. Basic description

Construction and scope of application of a die forging hammer propelled by IRE

Fig. 2 [2] shows a photograph of a die forging_hammer with IRE attached to the ram. It is seen that the construction of the hammer is significantly simpler compared to currently used pneumatic and gas high speed hammers. The element connecting the propeller and the hammering part was removed. One-way acting hydraulic cylinder is used to return the ram up. The retrieval of the forging from the shape is done by a hydraulic pusher.

The technical parameters of the IRE propelled die forging hammer are:

maximum blow energy	36 kJ;
ram speed	10-18 m/s;
ram stroke	max 1659 mm;

height above the floor level	3350 mm;
width × depth	1250 × 800 mm;
total mass (with a 22 000 kg anvil)	28 000 kg;
time of one working cycle	2 s.

Fig. 2. Photographs of IRE propelled die forging hammer

The value of the IRE thrust "R" can be continuously adjusted within the limits $0 \le R \le R_{\max}$. The reaction time is 0.001 s. Since the time of contact in die forging is from 0.030 up to 0.050 s [5] it is seen that the time of reaction is completely sufficient to perform the change of the IRE thrust "R". This makes possible the achievement of a new quality level of the technological process in the following direction:

- When the ram is thrusted downwards by IRE and it is switched off just before the moment of impact, a high speed deformation is performed at 16-18 m/s. As mentioned in a great number of publications during the 70-ties and 80-ties of the last century [4, 5], forging at such speeds (called high-speed forging) allows us to produce complex shape forgings or forgings from hard-to-deform or special alloys.
- If IRE works, during deformation some conditions are created to decrease (a combined blow) or completely eliminate the ram rebound (a sticking blow). In this case the time of outflow of the metal in the die is increased. This improves the quality of the complex shape forgings, which cannot be obtained by current technologies and decrease of forging stages. In order to have a combined or sticking blow it is necessary to define the force generated at rebound. This force is denoted as P_1. The following formula to calculate P_1 has been empirically obtained [6]:

$$(1) \qquad P_1 = g(R + m_2)\left(\frac{km_2 + \left[k^2 m_2^2 - m_2(m_1 + m_2)(\eta_i + k^2 - 1)\right]^{1/2}}{2(m_1 + m_2)} - k\right),$$

where g is earth gravity, m/s^2; R – thrust of IRE, kg; m_1 – anvil mass, kg; m_2 – mass of ram, kg; η – coefficient of performance; k – coefficient of recovery. Fig. 3 shows a diagram of the change of the force $P_1(R,\ k)$ for the existing hammer where m_1 = 22 000 kg; m_2 = 220 kg; R = 500÷2000 kg.

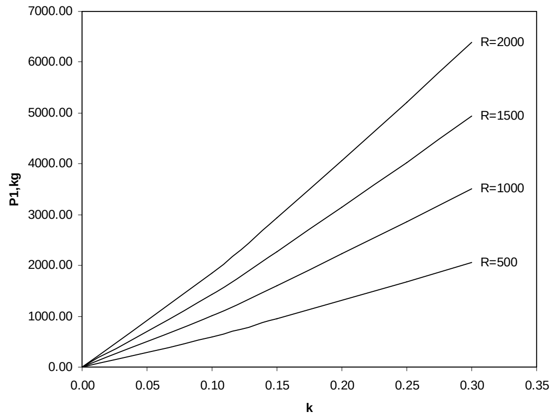


Fig. 3. A diagram of the change of the force $P_1(R, k)$ for the hammer shown on Fig. 2

After defining the rebound force P_1 we can tune IRE so that $R \geq P_1$ and thus get a blow with the necessary characteristics – a combined or sticking blow.

The features of an IRE propelled forging hammer mean that a guided blow can be obtained by using IRE.

A similar IRE propelled construction can be used to produce briquettes out of metal or non-metal waste. The currently used briquette production technology is based on hydraulic presses. The quality of the briquettes is relatively good, but the density is too small. For example, metal briquettes have 0.55-0.60 of the density of monolithic metal.

In the 70-ties of the 20th century high-speed briquetting machines were produced in the then USSR. The force to lute the waste was obtained from the explosion of a substance – Fig. 4 [7]. These technologies did not become popular because of low reliability due to the use of explosives. The density of aluminum and titan shavings is increased up to 0.7.

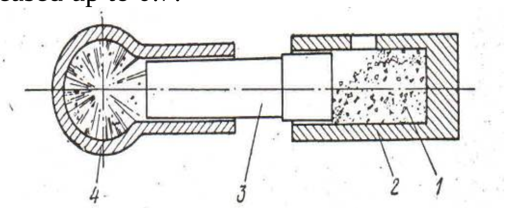


Fig. 4. Drawing of a high speed press for briquetting: 1 – waste; 2 – container; 3 – piston; 4 – explosion chamber

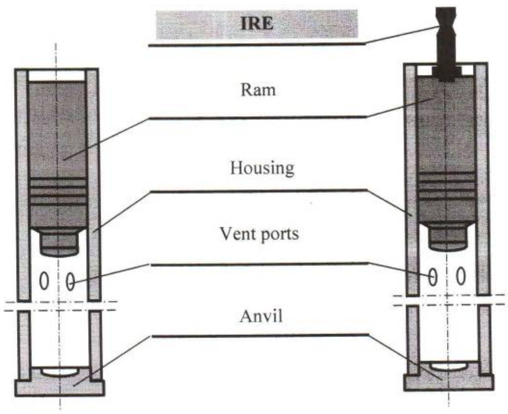
Experiments conducted by us via an IRE propelled laboratory device showed that the density of briquettes made of steel and cast iron shavings is from 0.65 up to 0.75. The production of briquettes from small size steel metallurgic waste is of particular interest. Briquettes are usually made of steel metallurgic scrap with particles size bigger than 5 mm and about 10 % connecting organic substances. The waste of the smaller size, which is about 10-15% of the total quantity, is not utilized. When stuffing metallurgic waste with particles size ≤ 5 mm in an IRE propelled device, briquettes were obtained with density of 0.55 without the use of a connecting substance.

The existence of a pusher in the construction of an IRE propelled hammer allows the achievement of full automation of the briquetting process.

3. IRE with a pile driving hammer

The current technologies for pile driving use diesel hammers with ram mass from 500 up to 2500 kg. An important feature of those machines is that they can drive vertically or at angles of up to 20° off the vertical direction. In a number of cases, such as pile driving in quake areas or installing of drain tubes in landslides, they have to be put at greater angle off the vertical direction. Since they cannot be driven, they are made by effusions which are expensive and slow.

Installing IRE on the ram significantly increases the technological capabilities of diesel hammers. Fig. 5 [8] shows a drawing of a diesel hammer before and after installing an IRE. Fig. 6 [5] shows the driving capabilities of such a hammer. It is seen that an IRE propelled hammer does not have any limitations of the angle of driving – it can even drive vertically upwards.



a b

Fig. 5. A drawing of a diesel pile driving hammer (a); IRE propelled hammer (b)

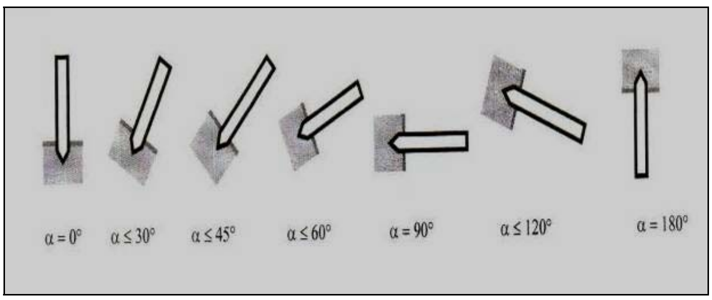


Fig. 6. A drawing of the possible directions for pile driving

4. Conclusions

The construction details of an IRE propelled hot die 3D forging hammer are described.

Based on a formula to determine the force of rebound of forging hammers a diagram has been drawn $P_1(R, k)$, out of which one can determine the necessary thrust R of the rocket engine to produce combined or sticking blow.

The capacities and scope of application of an IRE propelled blow-hammer for briquetting of waste and pile driving are also described.

Acknowledgments: This research has been sponsored by the National Scientific Research Fund of Bulgaria, Grant No 02-262/2008.

References

1. B o d u r o v, P. High Speed Hammer. BG Patent No 24567/1978.
2. B o d u r o v, P., T. P e n c h e v. Industrial Rocket Engine and Its Application for Propelling of Forging Hammers. – Journal of Mater. Processing Technology, Vol. **161**, 2005, 504-508.
3. B o d u r o v, P. Device for Pile Driving. BG Patent No 65331/2008.
4. S o g r i s h i n, J. P., L. P. G r i s h i n, V. M. V o r o b j e v. High Speed Die Forging. Moskva, Mashinostroenie, 1978. 166 p. (in Russian).
5. G l a n v i l l-J o n e s. Progress in High-Energy-Rate Forging. – Journal Inst. of Metals, IX, Vol. **97**, 1970, 257-270.
6. P e n c h e v, T., P. B o d u r o v, D. K a r a s t o y a n o v. Rebound Force Calculation in the Case of Hot Forging by Rocket Engine Proppeled Hammer. John Atanasoff Celebration Days, International Conference Automatics and Informatics ’09, Symposium Robotics and Automation, Sofia, Bulgaria, 29 September-4 October 2009, II41-II44.
7. S t e p a n o v, V. G., I. A. S h a v r o v. High Energy Impuls Methods for Metal Procedimg. Leningrad, Mashinostroenie, 1975. 204 p. (in Russian).
8. Jet Technologies for Ground Protection and Other Building Works. “B+K” Ltd. Prospect, Sofia, 2006, 4-22.

Высокоскоростный промышленный молоток, приводимый в движение реактивным двигателем

Тодор Пенчев[1], *Петр Бодуров*[2], *Димитр Карастоянов*[3]

[1] *Технический университет, 1797 София*
[2] *B+K Ltd, София*
[3] *Институт информационных и коммуникационных технологий, 1113 София*
Emails: tzpenchevi@abv.bg pbodurov@abv.bg dimikara@abv.bg

(Р е з ю м е)

В статье обсуждаются характеристики промышленного реактивного двигателя (IRE) и конструктивные качества машин, которые приводятся им в движение. Определены условия создания ударов разной продолжительности в зависимости от особеностей технологических процессов, требующих использование таких машин: молотка для ковки в штампах, для забивки мостовых конструкций, а также и для высокоскоростного брикетирования метального скрапа.