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# STUDY OF A CAST IRON STOVE DESIGNED BY FARKAS BOLYAI

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**Abstract**

Farkas Bolyai is known among mathematicians. However, he was also interested in the design and construction of stoves and ovens. In our paper we study a cast iron stove designed by Farkas Bolyai, based on a specimen found in the Museum Teleki Téka on Târgu-Mureș. Although the technical real-ization is nearly two hundred years old, the problem of inspiration is still a concern of our society today. We believe that, looking back, we can find answers, perhaps partial or complete solutions to the problem of the economical stove.

**Keywords**: *oven, stove, thermal energy saving, Farkas Bolyai.*

## 1. Presentation of the cast iron oven/ stove

Farkas Bolyai (1775–1856) ) was also concerned with economical heating and energy use. In Târgu Mures, in the Bolyai room of Teleki Téka, there is a tiled stove and a cast iron stove, which were designed and built by him. The cast iron stove is unique in shape and design, and its history is interesting.

We can express our respect for this great ex-pert by a professional evaluation of his work [1, 2, 3]. Thus, in this thesis we will study the cast iron stove designed by Farkas Bolyai.

In his manuscript, in the Oven-Theory, Bolyai called the combustion apparatus an oven, the clarification being solved by the adjectives he attached to it. He wrote about the heating oven, cooking oven and baking oven, respectively stoves, cookers and ovens [1].

The heating equipment in this study was used for heating, and can therefore be referred to as a stove.

Bolyai formulated his requirements for stoves in his Oven-Theory: the heating should be with-out smoke; the furnace should use fuel economically; the cost should be low; the fire should be easy to light. The heat should spread to the ground; the stove should be durable; it should decorate the room [1].

The stove was cast in Hunedoara in 1840, and was in use in various locations in Târgu Mureș for nearly 150 years before being donated to the museum [1]. Its construction can be seen in Fig. 1.


**Fig. 1.** *The construction of the studied Bolyai stove.*

The stove is intended for wood-saving heating. The firebox provides for the containment and combustion of the firewood. No evidence of the use of a grate was found. The several horizontal stove elements above the firebox are box shaped, hollow, with a flue gas channel snaking through them. The vertical members between the stove elements are involved in the formation of the flue outler. The serpentine flue makes better use of the heat of firewood. The stove elements can be placed on top of each other in any number to increase the heating capacity of the stove **[3]**. The length of the flue can be varied by means of a damper, called a throttle by Farkas Bolyai, **Fig. 2** .

The damper is located between stove elements II and III, **Fig. 2**. The open orifice allows easy firing up , while the closed orifice results in a longer flue outlet, a larger heating surface and more heat emitted. The picture shows the closed position.

For easy cleaning, the stove can be dismantled into elements. The splined cleaning apertures per element makes this even easier. Post assembly, the smoke lessness was achieved with clay, but history has it that plum jam was also used for this purpose **[1]**.

## 2. The Study of the Bolyai cast iron stove

The design and operation of today's modern heating systems is strongly related to mathematical modelling and a series of measurements **[4, 5]**. The combination of these principles and tools allows designers and engineers to create energy efficient and optimized systems **[6, 7]**.

The sizing of a stove is based on the determination of the rated output, the heat storage time, the maximum fuel volume and the corresponding flue length **[2]**.

In the present case we will only check and test the stove designed by Farkas Bolyai.

**Method of the study**:

- accurate determination of the dimensions of the stove, construction of a body model, determination of the type of stove;
- study of the firebox;
- calculate and analyse the length of the flue;
- calculate the flue gas temperature and the efficiency of the stove;
- modelling and visualisation of the processes in the stove using Ansys software.

### 2.1. The stove dimensions, body model, stove type

The dimensions of the stove were determined using a digital calliper, tape measure and micrometer. It was observed that the thickness of the walls was not uniform, which can be explained by the immature casting technique. Several measurements were taken to ensure the accuracy of the model. The averages of the data is summarized in **Table 1** .

Based on the measured data, the three-dimensional model of the stove was created using Autodesk Inventor technical drawing software, **Fig. 3**.

The cast-iron stove designed by Farkas Bolyai is an intermittent, solid-fuel, single-shell, air-gapless combustion appliance **[2]**.

The firebox is a box-shaped, single-space, horizontal arrangement. The combustion air is introduced into the solid firebox bottom through a door. The location of the combustion air inlet is important for the efficient operation of the stove


**Fig. 2.** *The damper of the flue gas.*

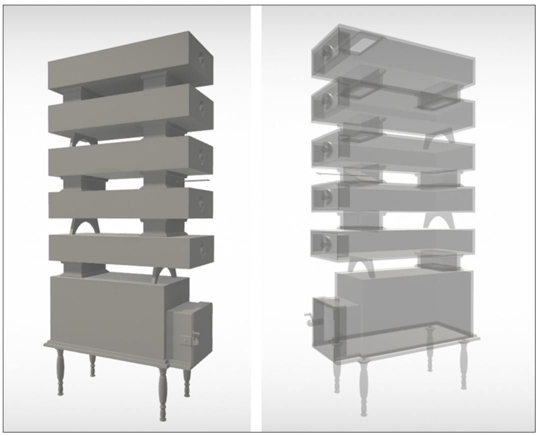

**Fig. 3.** *The body model of the Bolyai stove.*

**Table 1.** *The dimensions of the stove parts*

| Averages of measured data (mm) | Firebox | I. elem | II. elem | III. elem | IV. elem | V. elem | Flue channel |
|---|---|---|---|---|---|---|---|
| Lenght | 605 | 715 | 717 | 716 | 717 | 722 | 100 |
| Width | 314 | 314 | 314 | 314 | 314 | 314 | 314 |
| Height | 322 | 124 | 122 | 123 | 10 | 119 | 75 |
| Wall thickness | 9.15 | 9 | 9.2 | 8.85 | 9 | 9.15 | - |

and should be 50 mm above the plane of the firebox bottom, [2]. This cannot be determined accurately for the stove under investigation because the door has been modified.

The heat storage body, the system of flue outlet formed inside the stove elements, extends from the exit of the firebox to the flue exit from the stove. The longer flue way sections are horizontal, so this stove design can be considered a horizontal flue design [2].

## 2.2. The investigation of the heating surface and the firebox

Heat transfer in the stove is a complex process. Hot flue gas flowing through the stove passages transfers heat to the walls of the stove elements. From there, the heat is conducted to the colder surface, which transfers it to the air in the space to be heated by heat transfer and radiation [1, 2]. The operation of stoves is characterized by constant variation [4]. To simplify calculations, some data are accepted as standard in the literature, based on decades of experience and standards [2].

The heating surface $A_k$ of the stove can be calculated from the measured data. The heating surface is 1.01 m$^2$ for the open damper and 2.3 m$^2$ for the closed damper.

Correlation between the maximum amount of wood fuel that can be loaded into the stove and the size of the firebox is based on the Central European sizing method and according to the standard MSZ EN 15544 [2]:

$$A_{tmax} = \frac{900 \cdot m - (25 + m) \cdot K}{2} \quad [cm^2], \qquad (1)$$

where: $A_{tmax}$ is the maximum firebox area [cm$^2$]; $K$ is the firebox base perimeter [cm]; $m$ is the maximum fuel mass [kg].

Equation (1) can be used to determine the amount of wood that can be placed in a firebox of a given size:

$$m = \frac{2\,A_t + 25\,K}{900 - K} \quad [kg]. \qquad (2)$$

The calculated value $m = 11.33$ kg.

The maximum amount of wood calculated according to the empirical correlation of the standard created based on the experiments of the Österreichischer Kachelofenverband [2]:

$$m = \frac{O_t}{900} \; [kg]\,, \qquad (3)$$

where $O_t$ is the inner surface of the firebox [cm$^2$].

The value calculated as follows: $m$=10.30 kg.

## 2.3. The investigation of the flue

The standards specify a minimum flue length for 78% efficient operation. Accordingly, the temperature of the flue at the exit from the firebox will be 550°C and at the exit from the stove will be 240°C. The determination of the minimum flue length in the case of a single-shell stove with an air-gapless and horizontal flue design, can be calculated using the following empirical relationship [2]:

$$L_{jmin} = 1{,}3\,\sqrt{m} \;\; [m], \qquad (4)$$

where $m$ is the maximum amount of wood that can be placed in the firebox, [kg].

The calculated value: $L_{jmin}$=4.37 m, if $m$=11.33 kg.

To analyse the flue of the stove, we drew the route of the flue channel. The routes in the two positions of the flue gas damper are shown in Fig. 4.

The length of the routes was calculated based on the data in Table 2.

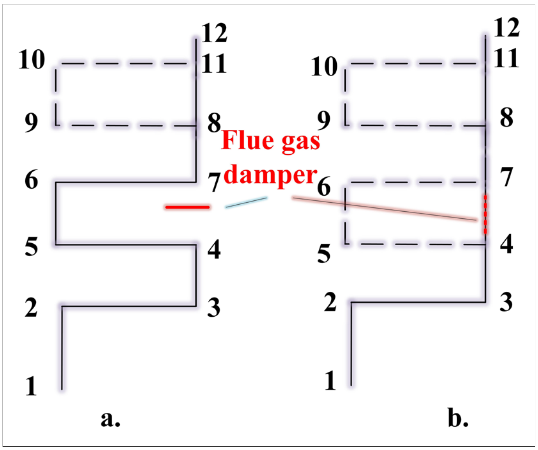


**Fig. 4.** *The flue routes: a-Long route, closed flue gas damper; a-Short route, open flue gas damper.*

**Table 2.** *Calculation of the flues of the Bolyai stove*

| **Long flue route [mm]** | | | **Short flue route [mm]** | |
|---|---|---|---|---|
| **Closed flue gas dampe** | | | **Open flue gas dampe** | |
| 1---2 | 298 | | 1---2 | 298 |
| 2---3 | 615 | | 2---3 | 615 |
| 3---4 | 197 | | 3---4 | 197 |
| 4---5 | 617 | | 4---7 | 198 |
| 5---6 | 198 | | 7---8 | 195 |
| 6---7 | 593 | | 8---11 | 194 |
| 7---8 | 195 | | 11---12 | 134.5 |
| 8---11 | 194 | | | |
| 11---12 | 134.5 | | | |
| $L_{J\ closed}$ | **3041.5** | | $L_{J\ open}$ | **1831.5** |

In both cases, the length of the flue of the stove is less than the minimum flue length expected based on the area of the firebox.

If there were also a damper between points *8* and *11*, then in its closed state, the flue route would approach the expected 4.37 m. There are photographs that refer to the flue damper also placed in the upper flue gas channel.

## 2.4. The flue gas temperature

The combustion of wood is a complex process. Temperature data: ignition, 230-370 °C; combustion, 400-1000 °C; the after-carbonization, where the combustible materials run out and the charcoal incandescence at a temperature of 500-800 °C.

To calculate the efficiency of the stove, the temperature drop along the flue is necessary. This can be calculated using the following formula [2]:

$$t = 550\ e^{-\frac{0{,}83\ L_j}{L_{jmin}}}\ [°C]\ , \quad (5),$$

where: $t$ is the flue gas temperature [°C]; $L_j$ the flue length [m]; $L_{jmin}$ is the minimum flue length [m]; 550 [°C] is the reference temperature value of the flue gas leaving the firebox.

The calculated values are $t_{long}$ = 308.74C at the end of the longer flue, and $t_{short}$ = 388.47 °Cat the exit of the shorter flue. Both are greater than 240 °C.

Fig. 5 illustrates the evolution of the flue gas temperature along the flues.

The temperature of the flue gas leaving the shorter way is higher than the temperature of the flue gas leaving the longer way.

## 2.5. The efficiency of the stove

The following empirical formula is used to calculate the efficiency [2]:

$$\eta = 101{,}09 - 0{,}0941\ t_k - 6{,}275 \cdot 10^{-6}\ t_k^2 - -3{,}173 \cdot 10^{-9}\ t_k^3\ [\%], \quad (6),$$

where: $t_k$ is the temperature of the flue gas at the flue exit [°C].

The values of the calculated efficiencies along the two flue routes, based on the wood volumes determined according to the two standards, are shown in Fig. 6.

The efficiency of the stove is lower with the shorter flue route.

The smaller amount of wood improves the efficiency of the stove.

## 2.6. Visualization of the stove processes

We visualized the complex processes taking place in the Bolyai stove with the modelling solutions of Ansys Discovery Student [8]. Gas flow analysis performed with the Ansys Discovery Student program are shown in Fig. 7–8.

The velocity of the exiting gas at the end of the long flue route is $v$ = 1.12 m/s. The velocity of the

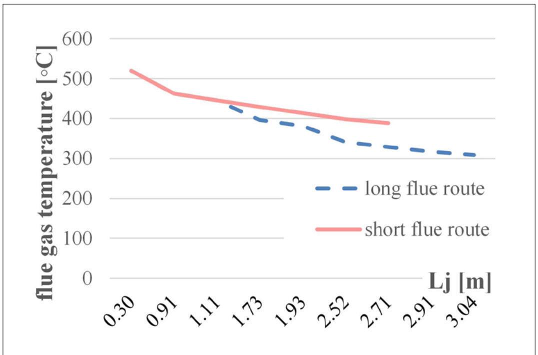


**Fig. 5.** *Flue gas temperature evolution along the flue.*

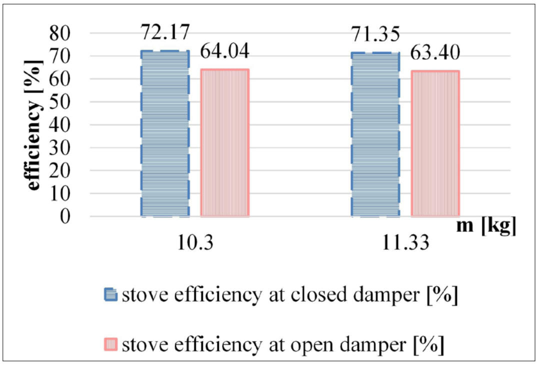


**Fig. 6.** *The efficiency of the Bolyai stove.*

exiting gas at the end of the short flue route is $v = 3.99$ m/s.

The models prove that gases flow faster along the shorter flue.

The heat generated during combustion is transferred from the hot flue gases to the stove elements by heat transfer. The models are hollow, with an inlet temperature of 700 °C, and their outlet temperatures are calculated using equation (5). In fact, the thermal analysis of the stove only illustrates the phenomena, **Fig. 9–10**.

The models show that the firebox heats in both positions of damper, so the stove also emits heat in the space close to the floor.

Along the long flue, **Fig. 9**, the stove elements heat up more than along the shorter flue, **Fig. 10**. This can be easily followed by the colour code of the stove elements. This proves that the exiting flue gas contains more heat at leaving the stove and at entering in the chimney than during long flue route.

## 3. Conclusions

The paper gave us an insight into the manuscripts of the Oven-Theory.

The implemented body model gives an insight into the internal construction of the stove.

The flue length of the stove is shorter than the minimum flue length expected for the given firebox area, but the staged firing and presumably less wood volume could ensure a smokeless heating with sufficient efficiency.

Bolyai created stoves of unique construction.

Although the theoretical issues of thermodynamics were still obscure at the time, his experience helped him to identify the essential elements and to use them in his work: the longer flue length, the better the flue gas cools, the more heat it transfers to the space to be heated.

In the stove, the fire could be easily ignited along the short flue gas route without smoking, because of the higher velocity of the flue gas.

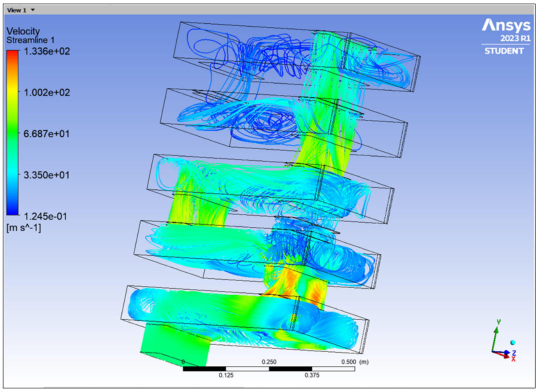


**Fig. 7.** *The flow of flue gas through the long flue route.*

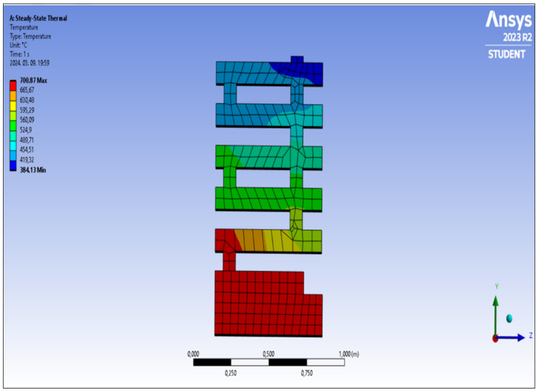


**Fig. 9.** *Thermal analysis of the interior of the stove at the long flue route.*

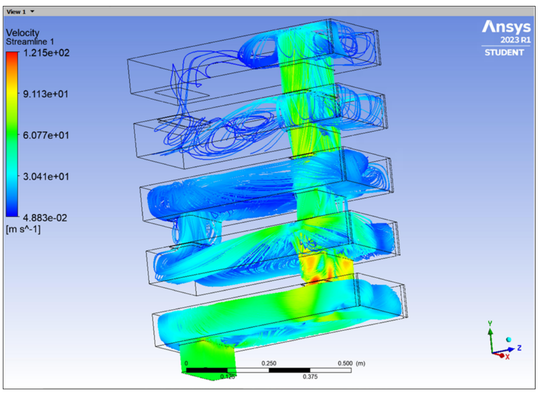


**Fig. 8.** *The flow of flue gas through the short flue route.*

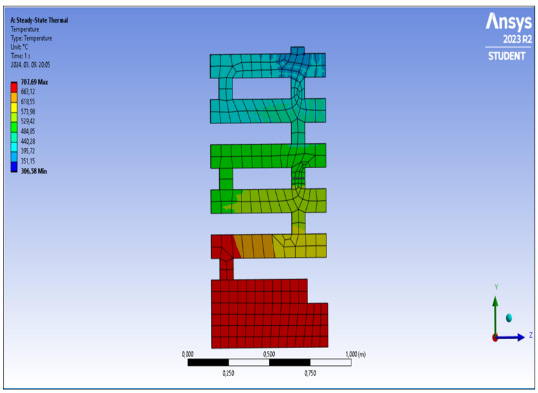


**Fig. 10.** *Thermal analysis of the interior of the stove at the short flue route.*

During operation and heating, the heat could even spread to the floor.

The durability of the stove is proven by the fact that the Reformed Church in Luncani, in Cluj County still uses such a stove for heating.

The stove's interesting design can also be integrated into modern spaces, thus fulfilling the wish that it should decorate the room.

Examination of the stove's construction and modelling of its operation suggests that the then novel design could meet modern standards.

By studying the stove, combining the values of the past with the techniques and knowledge of the present, we have achieved a better understanding the heating it provides.

## Acknowledgements

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