Extrusion Briquettes – Efficient Charge Component for Blast Furnace

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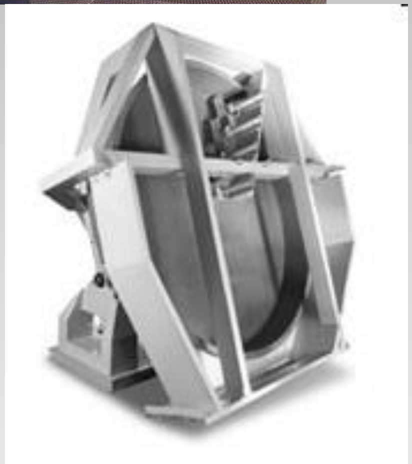
Main Industrial Agglomeration Technologies

- *Sintering*
  (1400-1500 C^o)

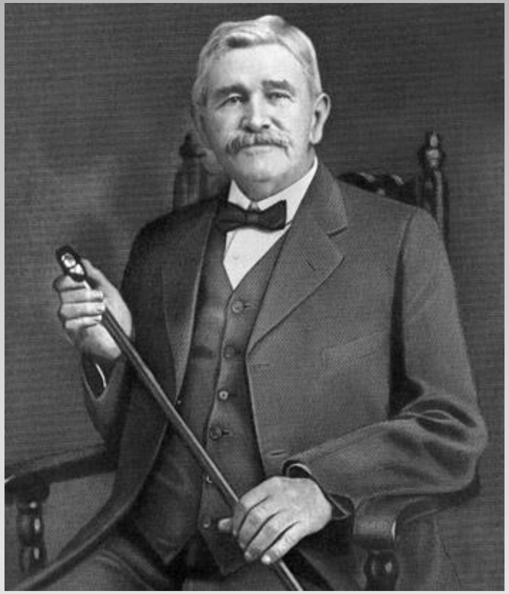


- *Pelletizing*
  (1200 C^o)

- *Briquetting*
  (ambient)

Brick making and Briquetting

1889, J.C.Steele&Sons

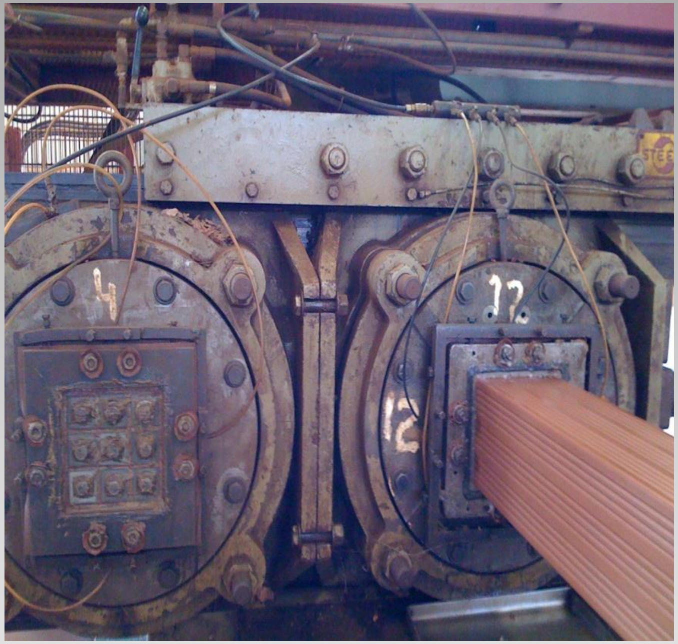


1899, The Gröndal Process. Equipment similar to applied for shaping of clay bricks. BF charge. Finland, Russian Empire.)

1990s, J.C.Steele&Sons,Inc. Auger agglomeration of BOF sludge, BF charge. Bethlehem Steel, USA.

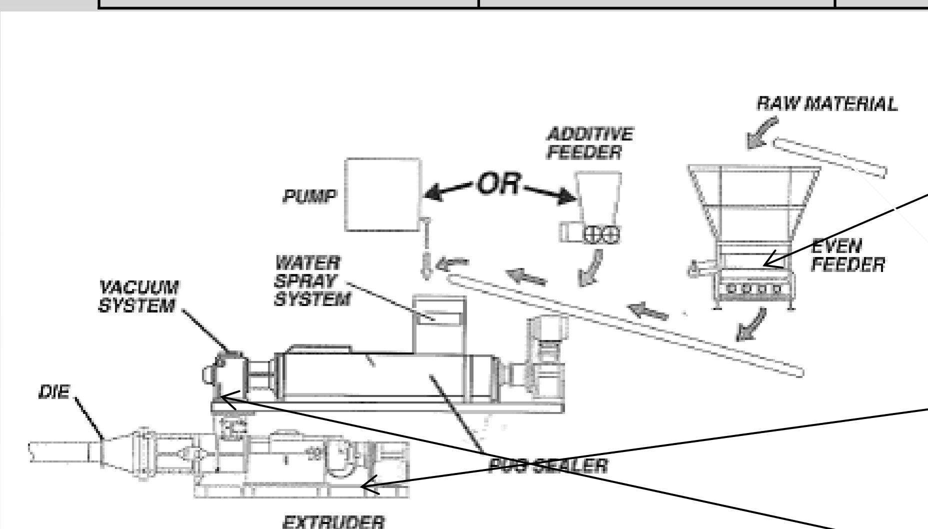
2018, J.C.Steele&Sons,Inc. Stiff Extrusion Agglomeration of iron ore concentrate, and coke , sludge, NLMK Group, Russia

Stiff Extrusion for Brick Making



Classification of Extrusion Types

Type of extrusion	Low pressure extrusion	Medium pressure extrusion	High pressure extrusion	
Description used in ceramic industry	Soft extrusion	Semi-stiff extrusion	Stiff extrusion	
Extrusion moisture	10-27	15-22	12-18	10-15
Extrusion pressure, MPa	0.4-1.2	1.5-2.2	2.5-4.5	Up to 30



Spiral Couette-Poiseuille Flow in Simplified Model of Extruder

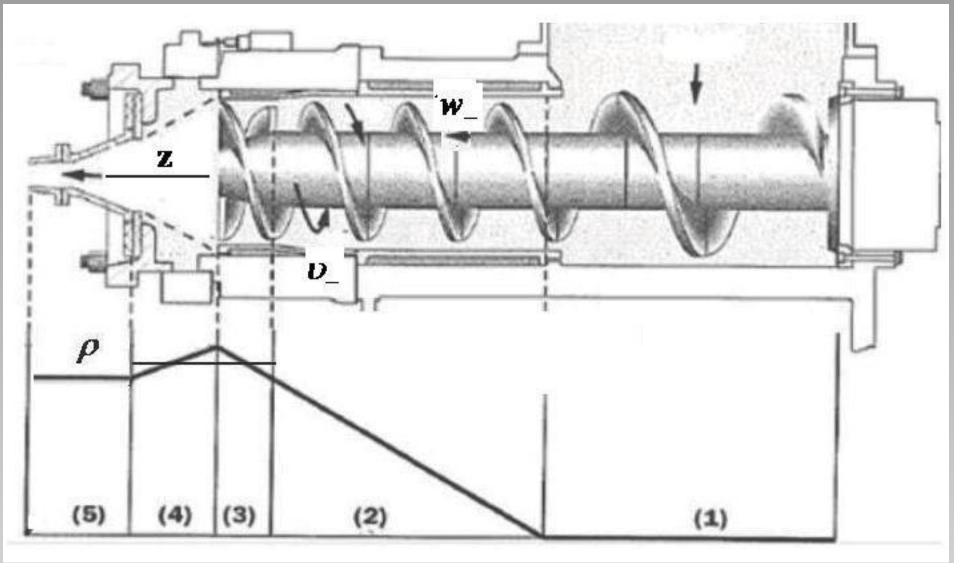
$$w=\frac{\varepsilon^{\gamma_+}w_+-w_-}{\varepsilon^{\gamma_+}-\varepsilon^{\gamma_-}}\left(\frac{r}{a}\right)^{\gamma_-}+\frac{\varepsilon^{\gamma_-}w_+-w_-}{\varepsilon^{\gamma_-}-\varepsilon^{\gamma_+}}\left(\frac{r}{a}\right)^{\gamma_+}$$

$$+\frac{-p_z a^2}{\mu(4-\alpha)}\left(\frac{\varepsilon^{\gamma_+}-\varepsilon^2}{\varepsilon^{\gamma_+}-\varepsilon^{\gamma_-}}\left(\frac{r}{a}\right)^{\gamma_-}+\frac{\varepsilon^{\gamma_-}-\varepsilon^2}{\varepsilon^{\gamma_-}-\varepsilon^{\gamma_+}}\left(\frac{r}{a}\right)^{\gamma_+}-\left(\frac{r}{a}\right)^2\right)$$

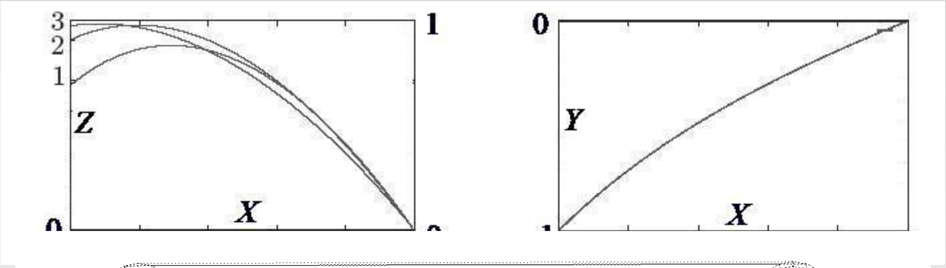
$$\gamma_{\mathrm{m}}=\frac{\alpha}{2}\,\mathrm{m}\sqrt{\left(\frac{\alpha}{4}-1\right)\alpha}\qquad\left(\frac{\alpha}{4}-1\right)\alpha>0$$

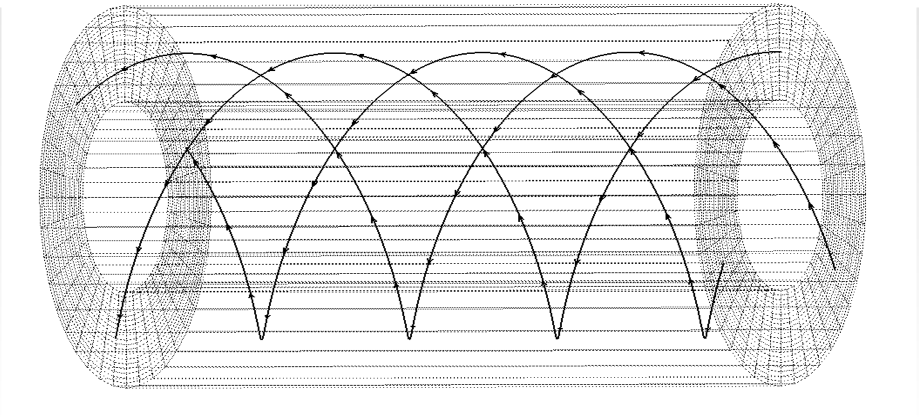
$$\upsilon=\frac{\varepsilon^{\beta_+}\upsilon_+-\upsilon_-}{\varepsilon^{\beta_+}-\varepsilon^{\beta_-}}\left(\frac{r}{a}\right)^{\beta_-}+\frac{\varepsilon^{\beta_-}\upsilon_+-\upsilon_-}{\varepsilon^{\beta_-}-\varepsilon^{\beta_+}}\left(\frac{r}{a}\right)^{\beta_+}$$

$$\beta_{\mathrm{m}}=\frac{\alpha}{4}\,\mathrm{m}\left(\frac{\alpha}{2}+1\right)=-\frac{\alpha}{4}-1,\frac{3\alpha}{4}+1$$

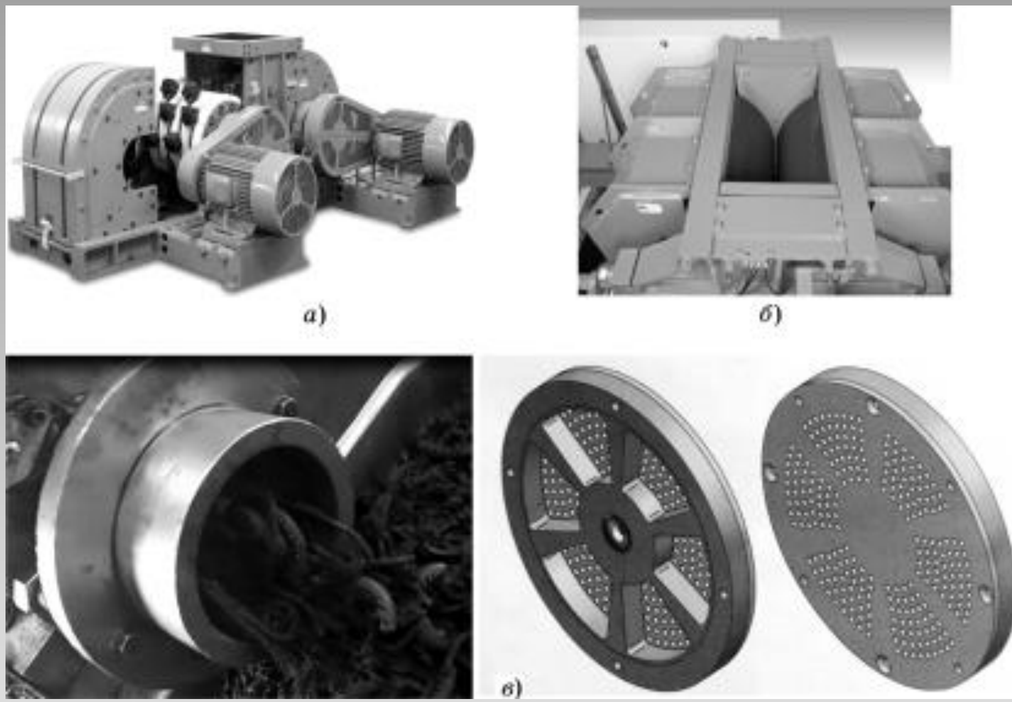


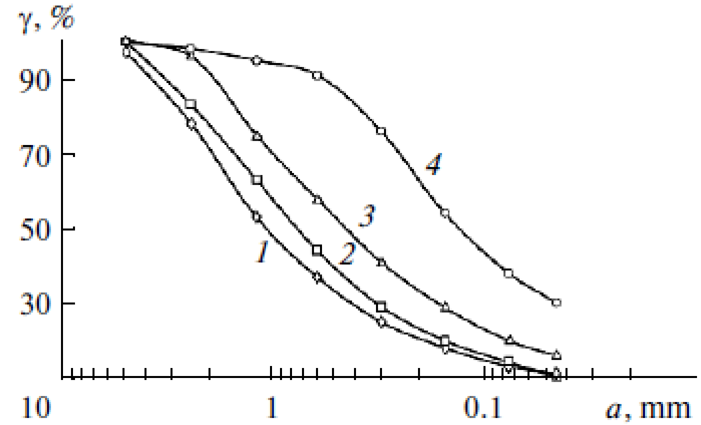
1 conveying, 2 densifying, 3 – metering, 4 pressure distributing, 5- die



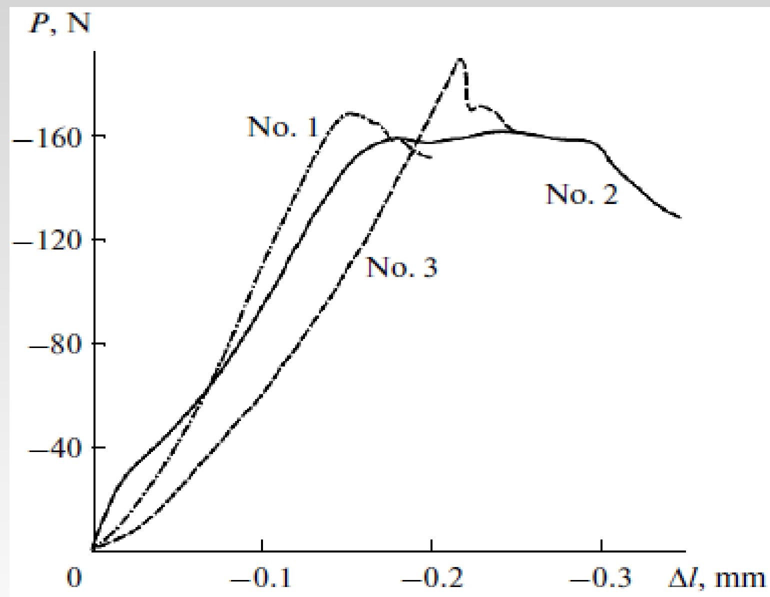


Influence of Shear Stress





Granulometric composition of coke breeze in the following states: (*1*) initial and (*2–4*) after additional grinding in a hammer mill, in a roll crusher, and double extrusion in an extruder. respectively.

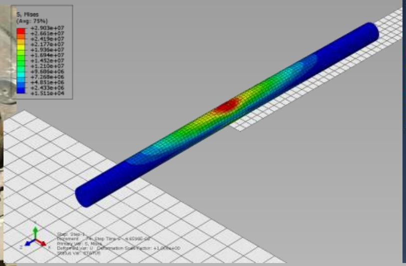
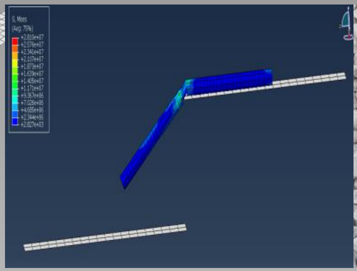


Extruded briquettes made of coke breeze(94%; 5% PC; 1% Bentonite.

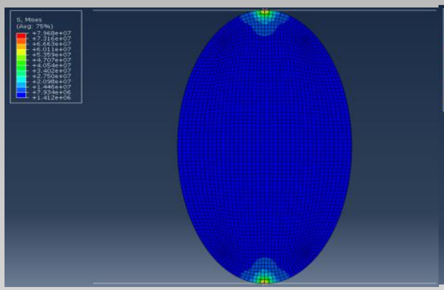
No.1 – roll crusher
No. 2 – double extruded
No. 3 – hummer milled

Specific Features of Stiff Extrusion

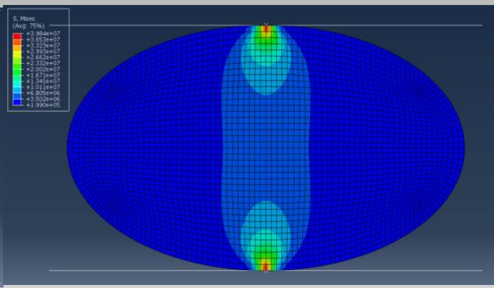
Length

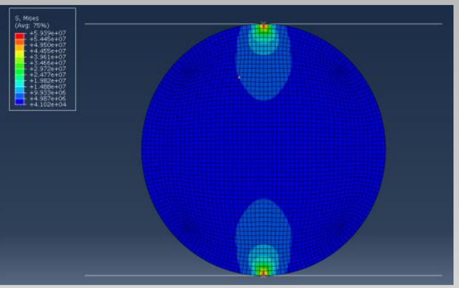

Shape



39.8 MPa

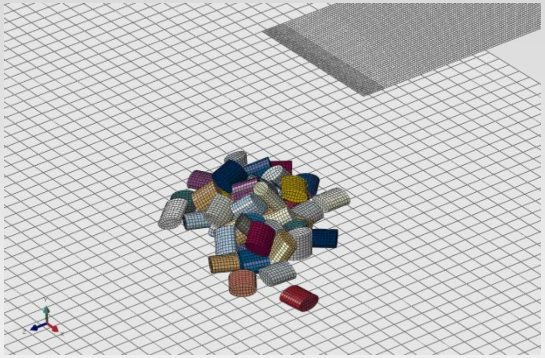


79.6 MPa



59.3 MPa

Stockpiling of extrusion briquettes

Statistics of briquettes orientation in the pile: 56.25% have the orientation of the "flat" (the long axis of the oval is parallel to the horizon), 12.5%- target long axis perpendicular to the hearth, 12.5%- stands vertically and 18.75% on the "edge".

Migration of fines


$$V = \frac{\rho}{12\mu}(u - U)\frac{du}{dy}r^2$$

$$V_{large} = -\frac{r_{large}^2}{r_{small}^2}V_{small} = -9V_{small}$$

Briquetting Technologies Main Parameters Comparison

The characteristics of the process and properties of briquette	Machines for briquetting and their characteristics		
	Vibropress	Roller-press	Extruder
Maximum capacity, ton/hour	30	50	100
Cement binder content,%	8-10	15-16	3-9
Thermal processing of raw briquettes	80 ^{o}C (16-20 hours)	-	-
Wastes generation	-	30 % of production	-
Shape of briquette	cylinder, prism	pillow	any
Dimensions, mm	+80x80	30x40x50	5-35
Moisture content of charge,%	<5%	<10%	8-15%
Possibility of immediate stacking	-	possible	possible

Main types of Raw Materials for Briquetting in BF Production

Component	$Fe_{общ.}$	FeO	Fe_2O_3	K_2O+Na_2O	Al_2O_3	CaO	MgO	MnO	SiO_2	ZnO	S	C
BF sludge	35,8	11,1	44,6	0,17	0,8	6,4	1,2	0,05	7,8	0,6	0,4	27,3
Flue dust	48,1	9,0	58,7	0,4	0,8	4,45	1,04	0,05	5,9	1-2	0,1	17,0
BOF sludge	56,3	52,0	22,7	-	0,3	12,0	1,3	0,05	2,0	1,5-2,5	0,1	2,3
Pellets fines	65			0,034	0,95	1,3	0,75	0,10	2,50		0,015	-
Iron ore concentrate	66,3	27,9	63,7	0,108	0,18	0,26	0,48	-	7,22	0,003	0,02	-
Mill scale	73,5	65,1	32,7	1,07	0,1	0,36	0,02	-	0,6	-	2	0,5
Coke breeze	1,7	-	-	2,24	3,2	1,0	0,5	-	7,5	-	0,5	85,6

Composition of briquettes for BF (EVRAZ), 2010

Mill scale:	57%
BF and BOF sludge	4%
Flue dust:	4%
Binder 1:	3%
Binder 2:	10%
Binder 3:	5%
fines:	12%
water:	5%

Share of briquettes in charge – up to 30 kg/t of HM

ILVA S.p.A., Italy

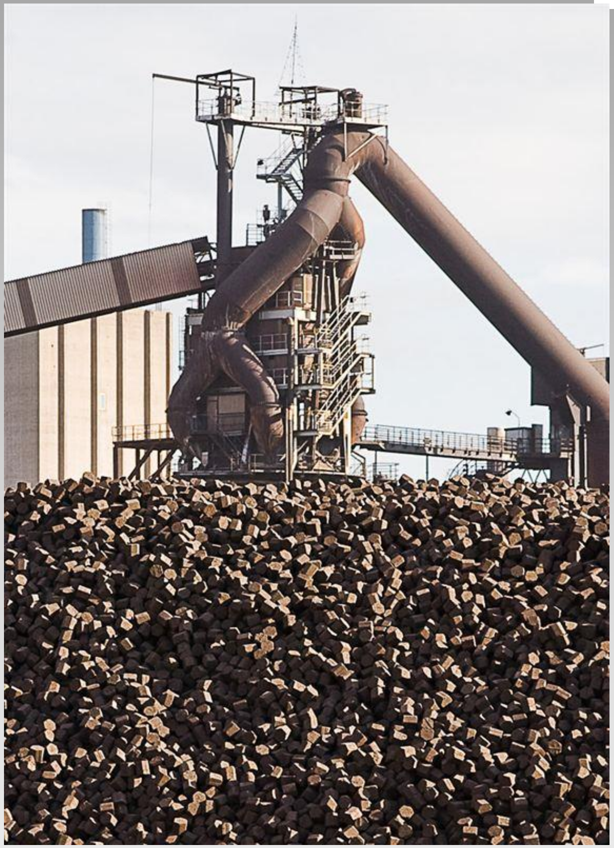
Capacity 240 kty of briquettes

Fe content 50-60%
Binders: lime and molasses

Briquettes share in BF charge 12 kg/ t HM.

Coke rate – 2 kg/t HM

Sinter rate reduction– 9 kg/t HM



In operation since 1993

Vibropressed briquettes (60x60mm), shape - hexagonal prism

Composition: 10-12 % PC, 25% flue dust, 5-8 % water, 50% scrap and LD sludge mix (0-5mm) 5-8% aspiration dust. Including 12% of briquettes fines (34,000 Mt)
Share in BF charge 40-85 kg/t HM

In Russia the first vibropressing factory was put into operation at the company JSC Tulachermet in 2003 year.

Capacity - 8000 ton of briquettes per month.

Design compressive strength of briquettes - at least **6.0 MPa**. After drying -3.83 **MPa**, after heat-moisture treatment **- 6.9 MPa**.

Total amount produced **52 thousand** tons of briquettes Maximum share of briquettes in blast furnace charge BF 1- 32 kg/t of HM, BF 2- 56 kg/t of HM.

2003, NLMK. Vibropressed briquettes of different composition with cement binder in charge of blast furnace with volume 1000 m^3

The first stage: recycling of iron-zinc-containing sludge, smelting of **2500** tons of briquettes (65% BOF sludge, 20% of the coke breeze and 15% Portland cement).

Briquette consumption **50-70** kg/t of HM in the first 5 days and up to **190** kg/t in the last 24 hours and averaged 121 kg/t of iron.

The second stage: **2475 tons** of briquettes (iron ore concentrate, coke breeze and Portland cement), share in the charge (consequently) **- 122, 198, 303 kg/t of HM**.

The results confirmed that these briquettes are ***high-grade self-reducing components*** of BF charge, which ensures reduction of Coke consumption in ironmaking, proportional to their consumption. The proportion of such a component in the blast furnace charging only slightly limited by the decrease in performance of the furnace due to lower iron content in charge and can reach **50%** or more.

The third stage: **2560 tons** of briquettes (BF sludge **- 59 %**, mill scale **- 20 %**, coke breeze **- 10 %** and Portland cement **- 11 %**) were smelted in BF with volume **2000 m^3**.

Average share in charge **- 62 kg/t of HM**.

A slight decrease in performance of blast furnace was due mainly to a decrease in iron content in the charge, as well as the negative impact of high basicity and viscosity of slags, formed from oxides of briquettes gangue.

The results of the campaigns are as follows:

•Vibropressing can provide the required values of the strength of briquettes with Portland cement as a binder not less than **8-10%** by weight of the briquette.

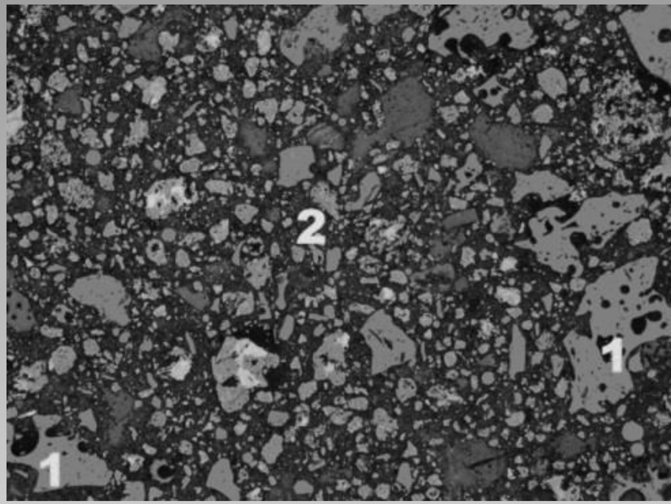
•The value of the compressive strength was not less than **30 kg/cm^2** and ensure their safety during overloads and transportation with the fines generation (-10 mm) less than **5-7%**.

Testing of Metallurgical Properties of Extruded Briquettes for Blast Furnace

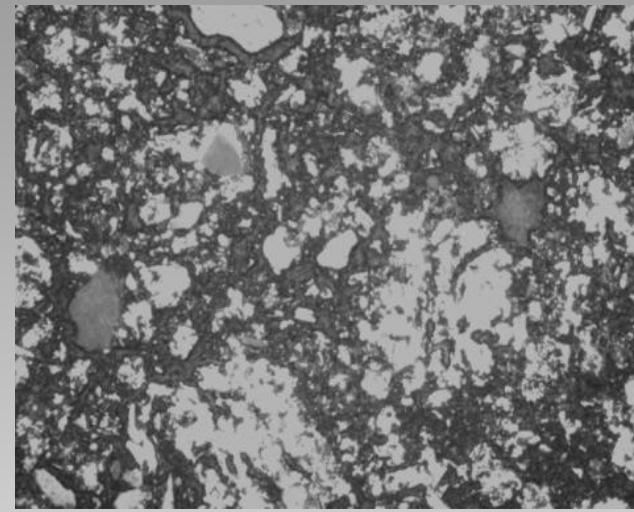
Components	Mass share, %	
	#1	#2
Portland cement	9.1	9.0
Coke breeze	-	13.5
Bentonite	-	0.9
BF sludge	54.5	-
BOF sludge	36.4	-
Iron ore concentrate	-	76.6

Test material	$RDI_{(+6.3)}$, %
Extruded briquette #1 (1.93)	**61.9**
Extruded briquette #2 (basicity 0.75)	**96.5**
Sinter (basicity 1.2)	64
Sinter (basicity 1.4)	60
Sinter (basicity 1.6)	77

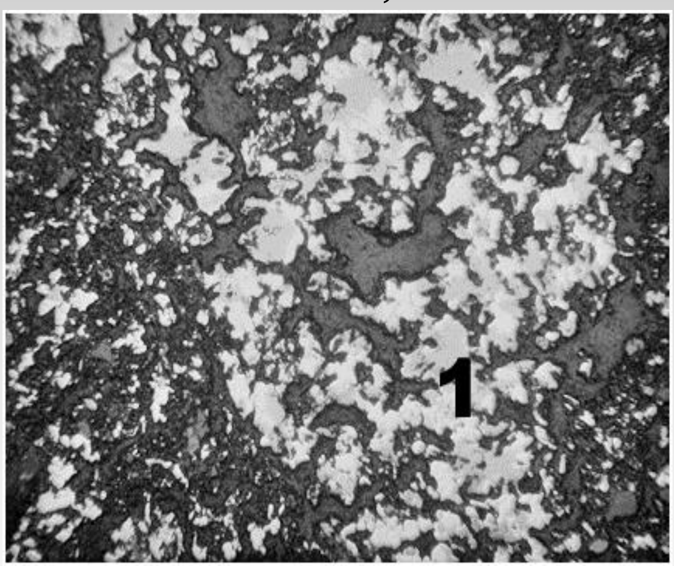
Mineralogical Study of Raw and Reduced Extruded Briquettes



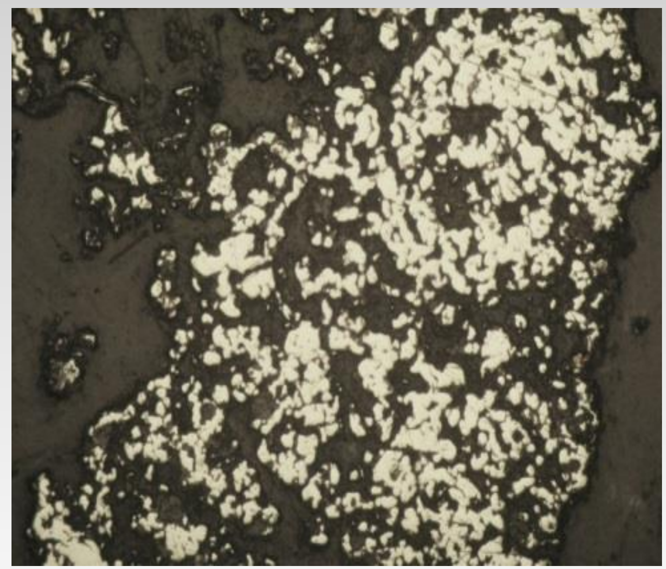
1 – Coke breeze; 2 – iron ore



Core, 900 °C

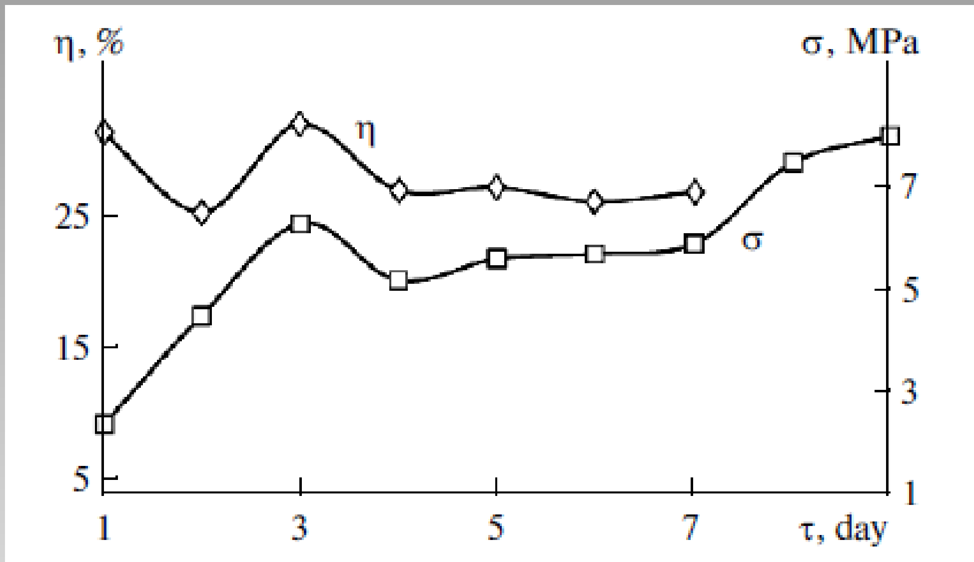


1 – metal, shell, 900°C,

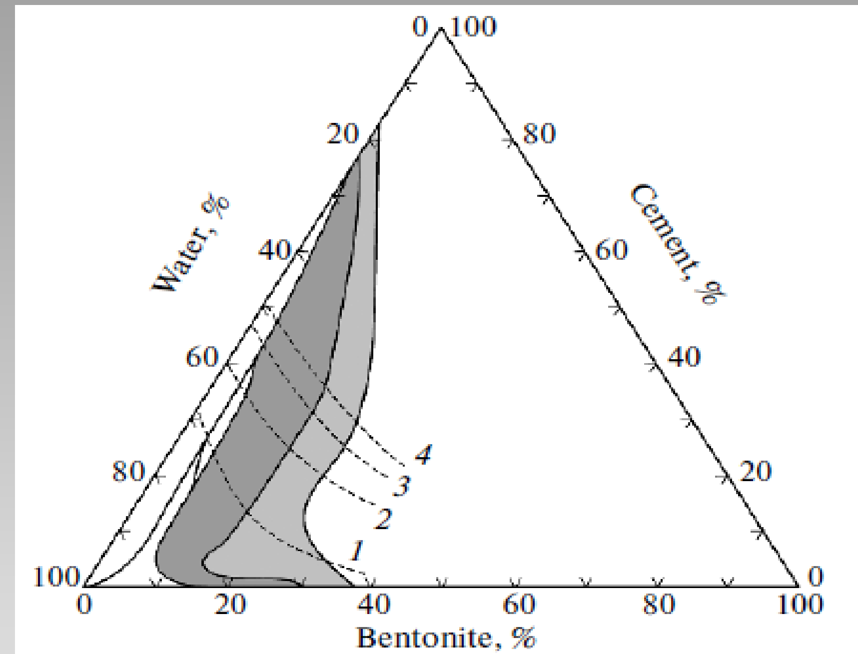


Shell, 1100 °C

Industrial Extruded Briquettes for Blast Furnace



Changes in compressive strength σ and porosity η of brex during strengthening 9-day storage.



Compressive strength

day 3 day 7

Tensile splitting

day 3 day 7

Blast Furnace Operation with 100% of Extruded Briquettes

The performance of blast furnace	100 % iron ore	80 % extruded briquettes	100 % extruded briquettes
Consumption, kg/t:			
Iron ore	1500	372	-
extruded briquettes	-	1425	1960
limestone	150	-	-
Dolomite	144	-	29
scrap	132	-	-
Quartzite	-	-	13
Mn ore extruded briquettes	-	19	75
Coke, 15-25mm	680	530	490
$Fe_{total.}$ in fluxed charge, %	57.6	50.4	45.5
Capacity, t/m^3 per day	1.9	1.62	2.0
Blow temperature, °C	925	900	1000
Blow pressure, kg/cm^2	0.5	0.34–0.38	0.38–0.42
[Si], %	1.0–1.8	1.0–1.5	0.8–1.1
[Mn], %	0.2	0.4–0.5	0.7–0.8
[C], %	3.8–4.0	3.75–3.90	3.80–3.95
[S], %	0.050–0.060	0.038–0.050	0.038–0.042
Hot metal temperature, °C	1380–1440	1400–1450	1410–1450
(CaO), %	34.86	33.12	38.0–39.0
(SiO_2), %	31.98	30.23	30.0–32.0
(Al_2O_3), %	23.87	17.98	16.0–18.8
(MgO), %	9.46	9.48	8.0–9.5
(FeO), %	1.01	1.26	0.6–1.15
(MnO), %	0.35	0.75	1.3-1.4

Briquettes in the skip of Blast furnace

Simulation of BF with extrusion briquettes in the charge

Mathematical model of BLAST FURNACE on the basis of software developed in Moscow Institute of Steel and Alloys (DOMNA).

Blast furnace volume **4297 m^3**.

Charge of 3-components- sinter, pellets and briquettes The share of pellets is determined by the capacity in pelletizing factory (6 million tons of pellets per year).

Basicity of briquettes consisting of iron ore concentrate and coal is determined on the basis of the binder share in the mass (6%) and bentonite (1%), basicity of briquettes (B2) is **0.50-0.55**.

Basicity of sinter is determined on the basis of the accepted concept of replacing the sinter by briquettes and by their basicity. When replacing 50% of sinter in blast furnace by briquettes sinter basicity should be between **2.8-3.2**. It should be noted that in the structure of sinter of this basicity dominating are the phases with increased strength compared with sinter with basicity in the range **1.5-1.7** (produced by NLMK at present).

Simulation results

The performance of the furnace	Traditional charge	Option 1	Option 2
Sinter consumption B2 = 1.7 kg/ton	1109	-	-
Sinter consumption B2 = 3.0 kg/ton	-	557	575
Pellets consumption, kg/ton	546	557	541
Extruded briquettes consumption, kg/ton	-	557	575
Iron ore consumption, kg/ton	-	17	-
Fe content in charge, %	58.2	57.45	57.15
Coke rate, kg/ton	391	354	284
Natural gas consumption, nm^3/ton	125	125	35
Pulverized coal consumption, kg/ton	-	-	160
Blow rate, m^3/min	7483	7568	7340
Blow temperature, ^oC	1240	1240	1240
O_2 content in blow, %	30,5	30,5	30,5
Blast humidity, g/m^3	10	10	20
Top gas, m^3/ton	1545	1540	1470
Top gas pressure, kPa	240	240	240
CO content,%	24.4	24.9	26.2
CO_2 content, %	23.2	22.6	23.9
H_2 content, %	9.7	9.9	8.2
Slag ratio, kg/ton	318	314	323
Slag basicity, B2	1,01	1,01	1,02
Capacity, ton/day	12465	12624	12708
Capacity, ton/m^2·day	92,48	93,66	94,3
Reduction efficiency,%	94.2	94.2	94.2

The main conclusions of the results of R&D for the applicability of stiff extrusion in for metallurgy are:

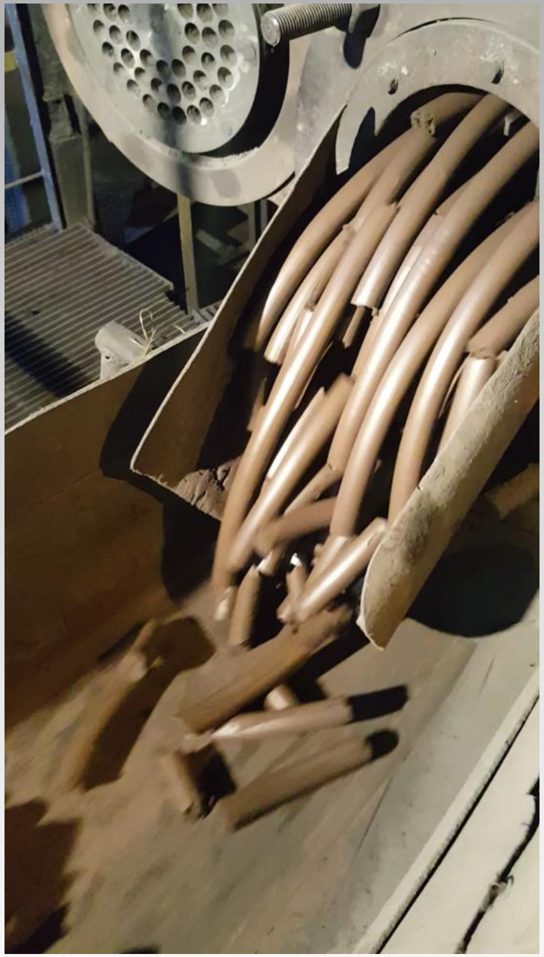
- The results of the comparative analysis of technical and economic parameters of three main industrial briquetting technologies allow to consider stiff extrusion as the core technology for cold agglomeration of anthropogenic and natural raw materials used in the processes of extractive metallurgy of ferrous metals;

- It is found that stiff extrusion technology can be competitive in agglomeration of fine iron containing materials, able to serve as a partial or complete substitute for sintering;

- Industrial experience of 3 years of operation demonstrated the ability to economically efficient operation of blast furnaces with 100% of extrusion briquettes in charge.

Drop Test of Brex

Brex Making



Brex making

THANK YOU FOR ATTENTION!