RECYCLING OF CORRODED NdFeB MAGNETS BY HYDROMETALLURGICAL ROUTE

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ABSTRACT

Rare Earth Elements (REEs) have excellent magnetic, electric and optical properties, therefore they play a critical role in the improvement of high technological products. Worldwide demand for REEs has increased strongly due to the utilization of these elements in various applications. Increasing concerns about REEs supply and environmental problems in their ore production, limited resources and national policies have led to an increase in studies about recovery of REEs from scrap materials. Most REEs have been used in the production of rare-earth magnets. This paper proposes a hydrometallurgical recycling methods for corroded NdFeB magnets by leaching and precipitation iron in an autoclave.

AIM

- Waste to raw material conversion to contribute circular economy.
- Optimization of the proposed process using statistical analysis based on experimental design techniques
- Investigation of oxidative leaching and selective leaching parameters
- Following the leaching process of NdFeB magnets, investigation of the process parameters of iron precipitation in an autoclave for the removal of remaining iron in the leach liquor
- After the iron precipitation achieving high purity REEs

METHODS

In this study, two different routes were proposed for the recovery of REEs from spent NdFeB magnets. In the first route, corroded NdFeB magnets were oxidized in an air atmosphere subsequently extraction of REEs from oxidized NdFeB magnets was performed via a selective leaching process. During the selective leaching process, iron extraction was also observed. Afterwards, the extracted iron was precipitated in an autoclave at different temperatures. In the second route, corroded NdFeB magnets were directly leached and then iron was precipitated in the autoclave at different temperatures.

1-Direct Leaching and Iron Precipitation in the Autoclave

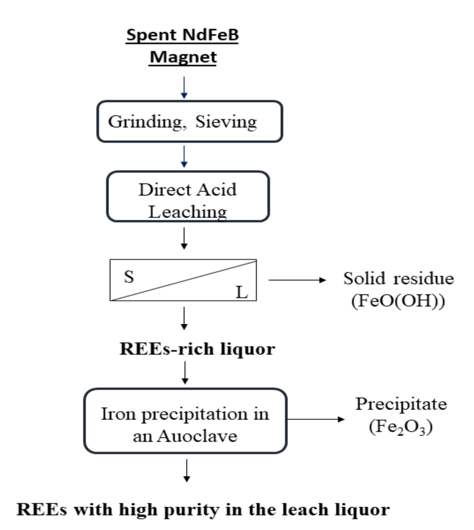

Figure 1: A general flowsheet for the recovery of REEs by direct leaching

2-Selective Leaching and Iron Precipitation in the Autoclave

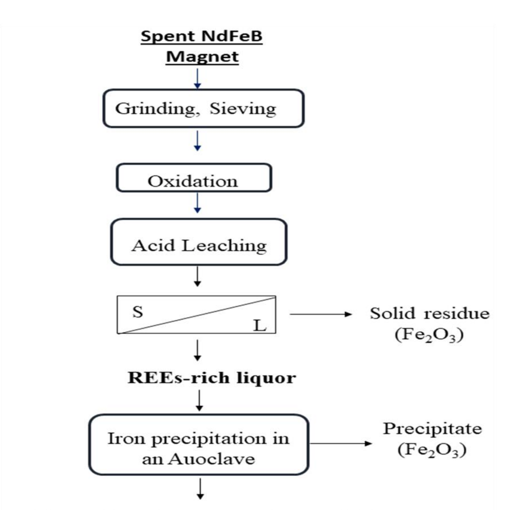

Figure 2: A general flowsheet for the recovery of REEs by selective leaching

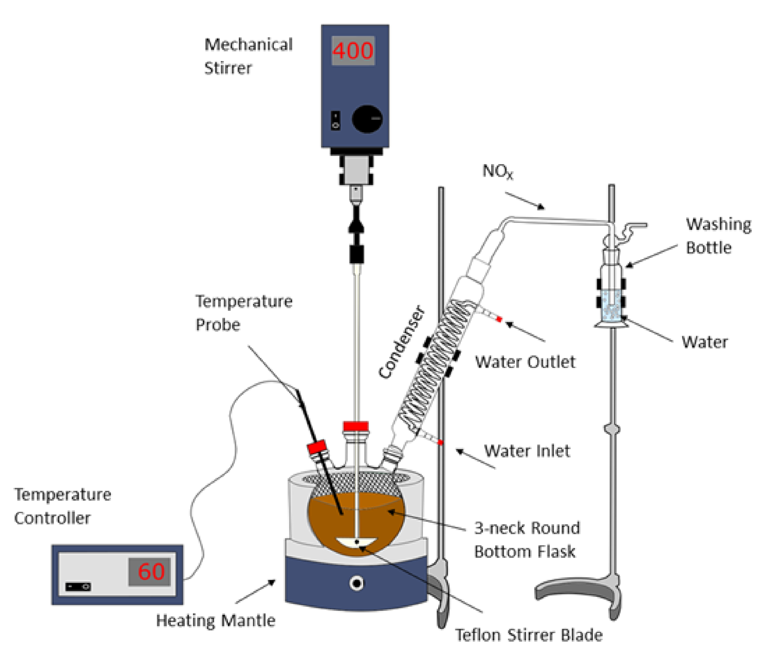

Figure 3: Schematic diagram of experimental setup for leaching experiment.

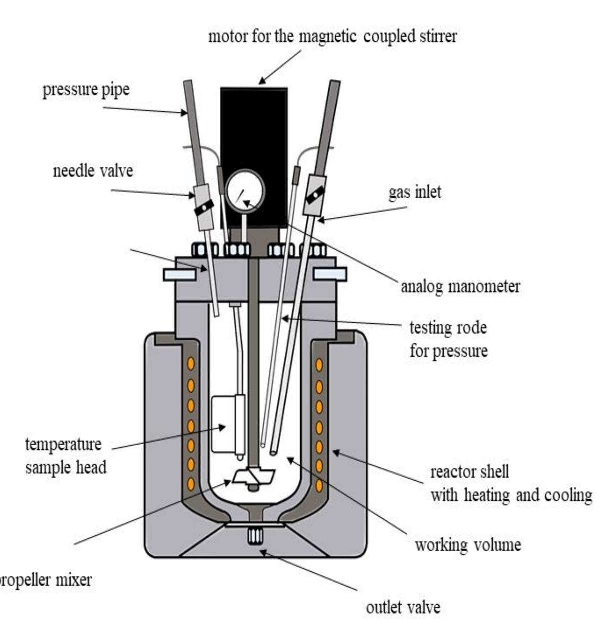

Figure 4: Schematic diagram of the autoclave.

RESULTS & DISCUSSION

COMPARISON of DIRECT LEACHING AND SELECTIVE LEACHING ROUTES

Table 1: Direct leaching process parameters results of experiments based on L9 orthogonal arrays.

Code	Molarity of Acid (mol/L)	S/L Ratio	Temperature (°C)	Stirring Speed (rmp)	Leaching Eff. [Fe] %	S/N for Fe (db)	Leaching Eff. [REEs] %	S/N for [REEs] (db)
D1	1	1:10	RT	200	19	14.43	23	12.765
D2	1	1:20	40	350	50	6.02	59	-4.58
D3	1	1:30	60	500	63	4.01	79	-2.05
D4	2	1:10	40	500	10	20.26	69	-2.97
D5	2	1:20	60	200	75	2.5	78	-2.15
D6	2	1:30	RT	350	99	0.08	96	-0.35
D7	3	1:10	60	350	30	10.46	91	-0.81
D8	3	1:20	RT	500	87	1.21	84	-1.51
D9	3	1:30	40	200	93	0.63	88	-1.11

Table 2: Selective leaching process parameters and results of experiments based on L9 orthogonal arrays.

Code	Molar. of Acid (mol/L)	S/L Ratio	Temperature (°C)	Stirring Speed (rpm)	Leach. Eff. [Fe]	S/N for Fe (db)	Leach. Eff. [REE]	S/N for REE (db)
L1	1	1:10	RT	200	19.7	-5.88	255	48.13
L2	1	1:30	40	350	60.5	-15.63	170	44.60
L3	1	1:50	60	500	218	-26.76	205	46.23
L4	2	1:10	40	500	162	-24.19	523	54.37
L5	2	1:30	60	200	915	-39.22	515	54.23
L6	2	1:50	RT	350	< 1	20.0	57	35.11
L7	3	1:10	60	350	2530	-48.06	1457	63.26
L8	3	1:30	RT	500	12.2	-1.727	115	41.21
L9	3	1:50	40	200	157	-23.91	178	45.00

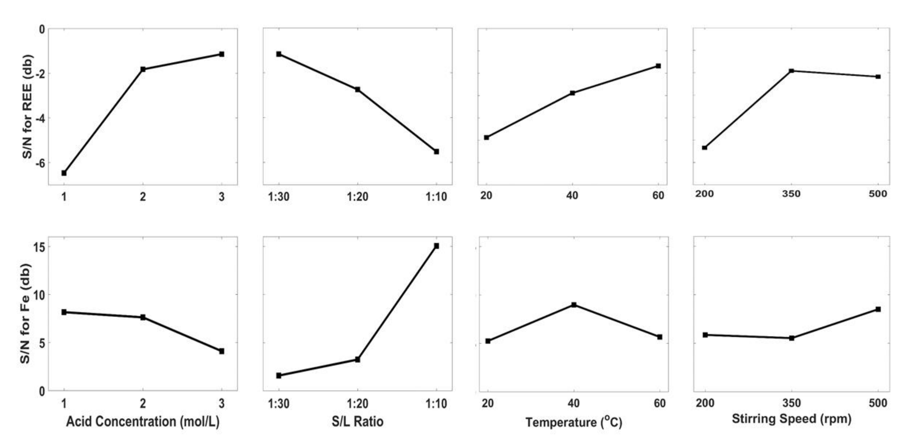

Figure 5: The effect of the leaching parameters on the optimization criteria for both REE and iron.

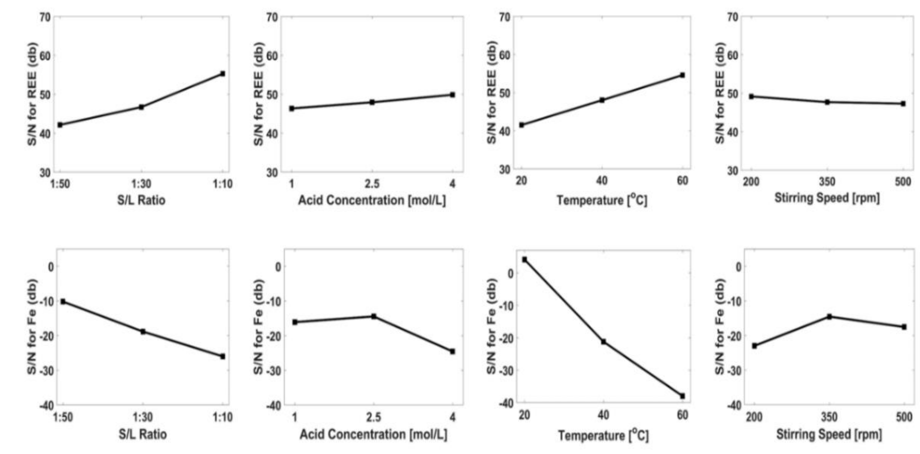

Figure 6: The effect of the leaching parameters on the optimization criteria for both REE and iron.

Table 3: Box-Behnken matrix and the results concerning the percentage of iron and REEs content in the leach liquor after iron precipitation in the autoclave

Sample	Process Temperature [°C]	Time [h]	Water Addition [vol %]	Recovery Rate of REEs %	Removal Rate of Iron %
A1	120	2	25	89	1
A2	160	2	25	47	0.06
A3	120	6	25	72	0.7
A4	160	6	25	21	0.06
A5	120	4	0	71	0.3
A6	160	4	0	31	0.05
A7	120	4	50	80	1.7
A8	160	4	50	40	0.1
A9	140	2	0	56	0.4
A10	140	6	0	52	0.05
A11	140	2	50	62	1
A12	140	6	50	41	0.1
A13	140	4	25	82	0.07
A14	140	4	25	79	0.04
A15	140	4	25	83	0.05

Table 4: Box-Behnken matrix and the results concerning the percentage of iron and REEs content in the leach liquor after iron precipitation in the autoclave

Sample	Process Temperature [°C]	Time [h]	Water Addition [vol %]	Recovery Rate of REEs %	Removal Rate of Iron %
A1	160	6	0	99.13	0.63
A2	180	6	25	94.64	0.15
A3	180	4	0	96.27	0.52
A4	180	4	50	91.61	0.02
A5	160	2	50	92.13	0.09
A6	180	2	25	96.54	0.31
A7	140	2	25	93.34	2.09
A8	160	4	25	94.12	0.35
A9	160	6	50	92.30	0.06
A10	140	4	0	96.54	1.52
A11	160	2	0	94.18	1.04
A12	160	4	25	91.35	0.27
A13	160	4	25	93.25	0.30
A14	140	6	25	90.92	0.35
A15	140	4	50	90.57	0.11

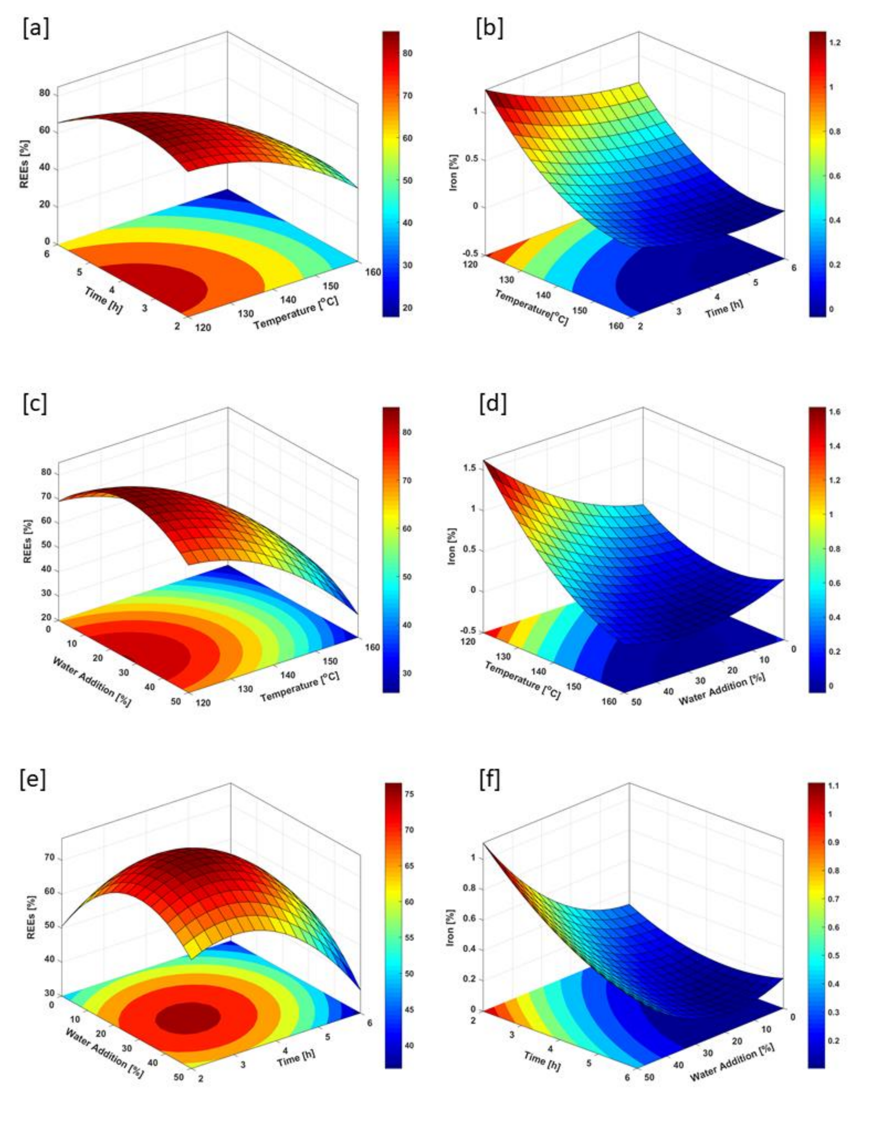

Figure 7: Three-dimensional response surface counter plots [a], [b] for the effect of time and temperature, [c], [d] the effect of water addition and temperature [e], [f] the effect of water addition and time.

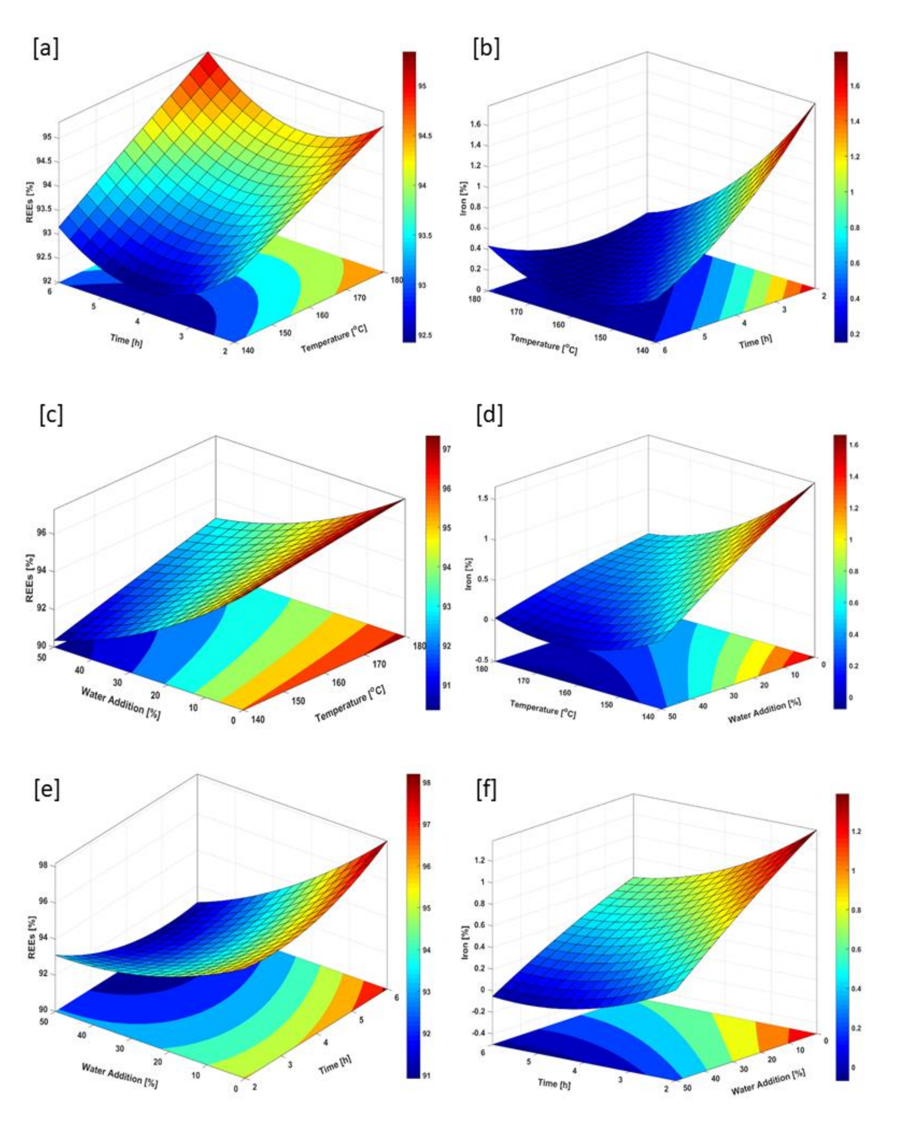

Figure 8: Three-dimensional response surface counter plots (a), (b) for the effect of time and temperature, (c), (d) the effect of water addition and temperature (e), (f) the effect of water addition and time.

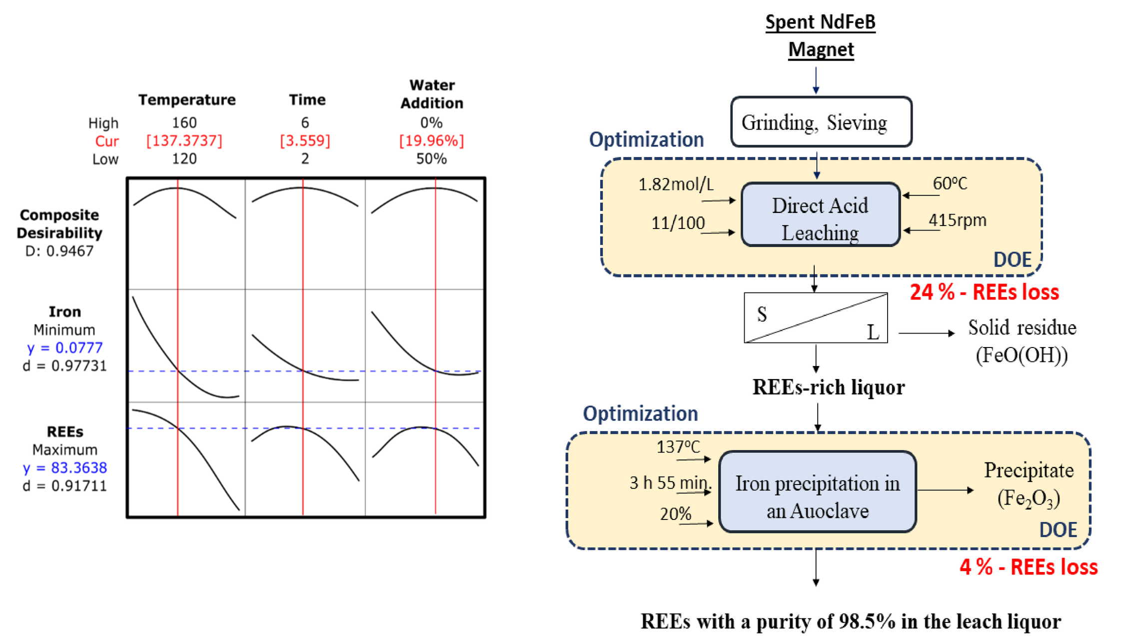

Figure 9: Optimization plots for and the proposed conceptual flowsheet for high REEs recovery from spent NdFeB magnets

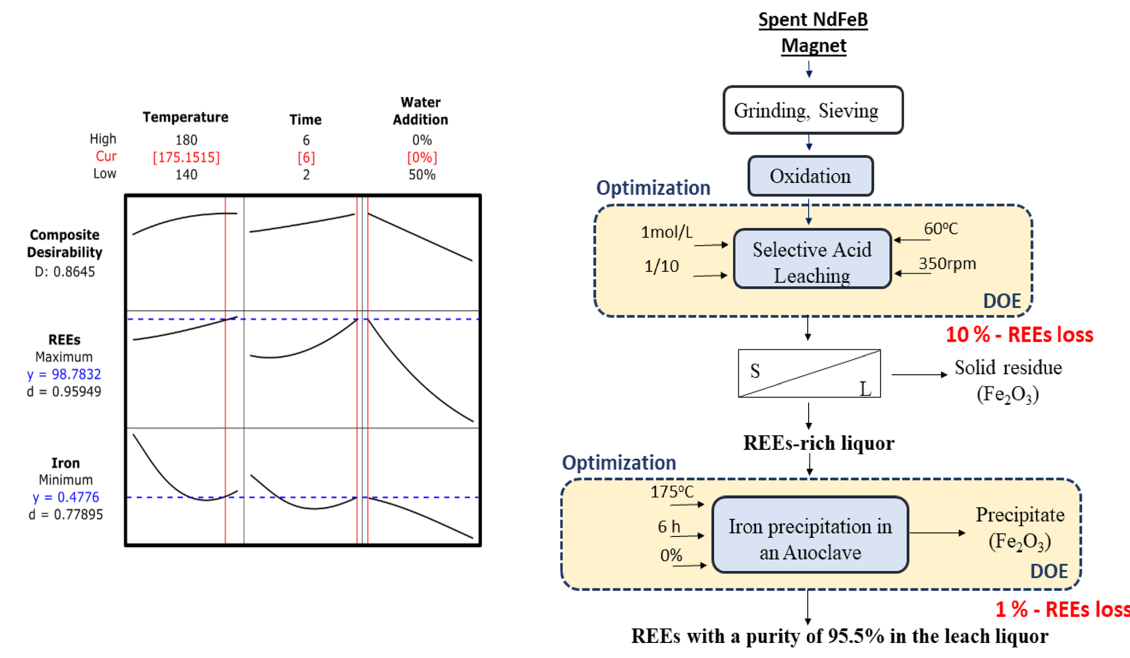

Figure 10: Optimization plots for and the proposed conceptual flowsheet for high REEs recovery from spent NdFeB magnets

ACKNOWLEDGEMENT

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