



Experimental Batch-type Controlled Atmosphere Furnace for Sintering Practices

Rungtip Krataitong, Pongsak Wila, Pisan Siriphol, Anan Daraphan, Ornmanee Coovattanachai, Nattaya Tosangthum, Monnapas Morakotjinda, Thanyaporn Yotkaew, Bhanu Vetayanugul and Ruangdaj Tongsri

National Metal and Materials Technology Center (MTEC), 114 Thailand Science Park, Paholyothin Road, Klong Luang, Pathum Thani, 12120 Thailand.

*Author for correspondence; e-mail: sayanm@mttec.or.th

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ABSTRACT

A batch-type controlled-atmosphere furnace (BCAF) was designed, assembled and tested. The furnace consisted of important components namely, sintering chamber, controller and residual gas burnout igniter. The sintering chamber was made of stainless steel shell lined with refractory insulators. Heating element coils were put next to the liner inside the chamber. The controller was installed so it could make a heating profile and control inlet gases. The gas burnout igniter was installed for burning of some organic residuals resulting from delubricating and residual sintering gases. The experimental furnace was capable to sinter stainless steels. This was confirmed by physical and mechanical properties of sintered stainless steels.

1. BACKGROUND

Sintering is a complicated phenomenon, in which powder particles are bonded together so that the sintered parts made from the powders are densified and strengthened. Bonding of powder particles is closely related to various diffusion mechanisms [1-3]. Metal powder sintering is different from ceramic sintering. The former requires not only a considerably high temperature but also a suitable atmosphere. During sintering of metal powders, a furnace is heated to a temperature that is usually below the melting point of the major powder constituent. The high temperature is needed to drive atomic diffusion. The suitable atmosphere is required to perform several functions, [4] including to prevent air from entering the furnace, to reduce surface oxides on the metal powder

particles, to control carbon on the surface and in the core of steel parts, to remove carbon in special applications, to provide controlled oxidation during cooling in special applications and to convey and remove heat efficiently and uniformly.

There are several sintering furnaces employed in production lines [5]. These include continuous, batch-type and vacuum furnaces. The continuous furnaces are not suitable for laboratory works because of high operating and repairing costs. The vacuum furnaces are usually employed in research and development units. However, to design and to produce a good vacuum furnace need highly experienced personnel, high technological knowledge and high investment. The batch-type controlled atmosphere furnace (BCAF)

requires components which are able to control a temperature and an atmosphere. Thus the BCAAF is possible to be designed and assembled with a considerably low investment cost.

Needs for more laboratory batch-type sintering furnaces have been raised due to numbers of active R&D activities in powder metallurgy field in Thailand. In general, acquisitions of R&D facilities have a close linkage with import. However, imported R&D machines mean researcher difficulties in some developing countries. These include budget limitation, procurement process, training requirement and maintenance ability. In order to meet requirement for R&D machines and to solve some after-service problems, the in-house design and manufacturing of R&D machines have been carrying out at MTEC. In this work, the aimed output was a BCAAF capable to sinter several metal powders under pure hydrogen and/or mixed hydrogen and nitrogen gases. Due to

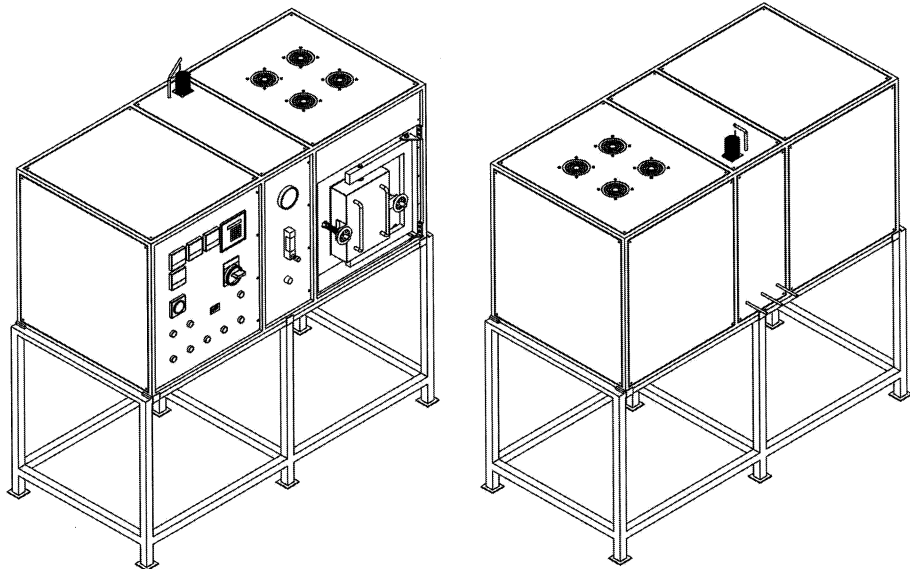
the main objective, activities including design, assembly and test of the BCAAF prototype were performed. After assembly the furnace was tested by sintering of green parts made of stainless steel powders. Sintered density and mechanical properties (tensile properties and hardness) were chosen as indicators of sintering success.

2. DESIGN OF THE BCAAF PROTOTYPE

2.1 Specifications

Specifications of the BCAAF prototype included the following items:

- Approximate weight was 200 kg
- Maximum temperature was 1300 °C
- Normal working temperature was not more than 1280 °C
- Temperature gradient in the work space was ± 10 °C
- Adjustable heating profile
- Capable to work under pure hydrogen and mixed hydrogen and nitrogen
- Work space was 20 x 20 x 25 cm³





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	CHEK.			No.	DESCRIPTION	MAT.SIZE	MATERIAL	DRAWING No.	Q'TY
	APP.			PART LIST No.	PL-SF-01.XLS	MACHINE TYPE	SF1500		
	DESIGN			SCALE	GROUP NAME	SYSTEM	COMP.CODE		
		NAME	DATE	1:15	SINTERING FURNACE		SF-01-0000.DWG		

Figure 1. Sketch of the BCAAF prototype.

- Equipped with residual gas burnout igniter

2.2 General feature

The BCAF prototype was designed as shown in Figure 1. The furnace was supported by a six-legged stand. The box was divided into 3 zones. On the left-hand side, electronic controller was installed. On the right-hand, a sintering chamber was located. Between the controller and the chamber, the zone was designed for accommodating of a pressure gauge and inlet and outlet gases.

(2.3) Component details

(a) Structural materials (Figure 2(a))

- Stand: mild steel
- Frame: mild steel

(b) Furnace materials (Figure 2(b))

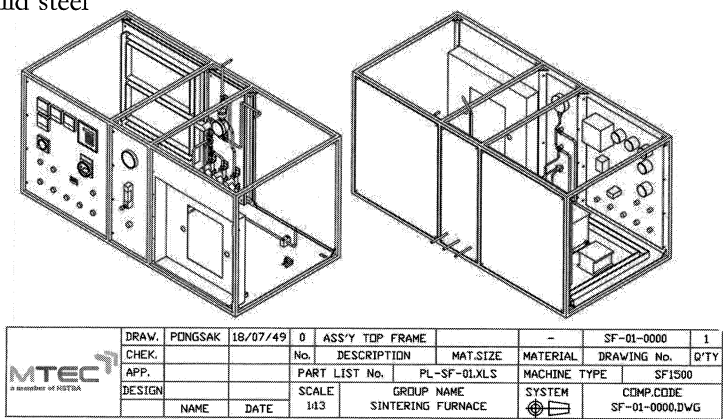
- Furnace shell: stainless steel 304
- Refractory insulators: layer #1 = Blankets, layer #2 = Fibre Board and layer #3 = Fibre Board
- Heating element: pure molybdenum

(c) Power source and controller

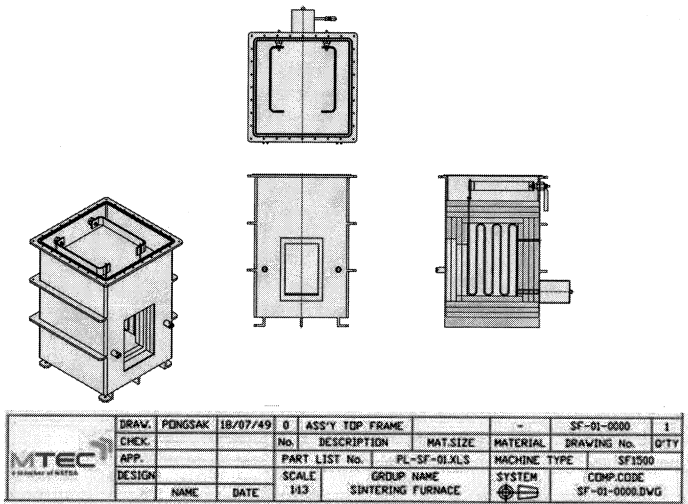
- Electricity: 3 x 380V/50Hz and approx. 6.0 kVA,
- Electronic circuit: secret
- Controller: RKC REX-P300

(d) Other components

- Gas pipelines: stainless steel 316L pipes
- Valve: Swagelok and solenoid
- Pressure guage: Schroder



(a) The furnace frame



(b) The sintering chamber

Figure 2. The furnace frame and sintering chamber.

3. ASSEMBLY OF THE BCAF PROTOTYPE

The assembled furnace is shown schematically in Figure 3. Assembly of the furnace had been carried out using simple methods. Some of the furnace components

were welded together. Some were bolted. After assembling, test of gas leakage was also performed throughout the gas pipelines. Painting /color coating was the final activity.

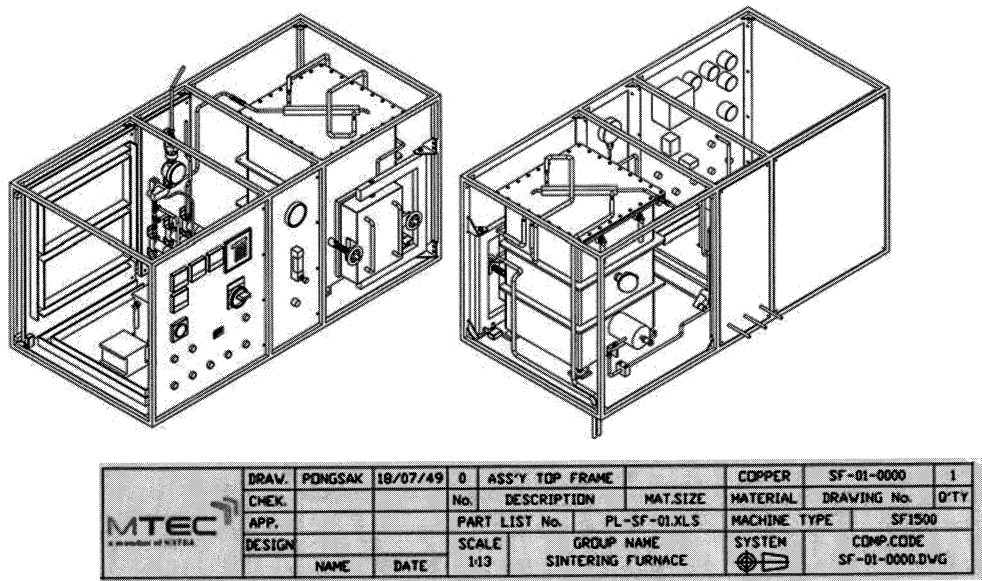


Figure 3. The assembled furnace.

Assembling methods for any components were chosen according to the following considerations:

- Assembling convenience
- Function/machine operating convenience
- User-friendliness
- Safety practices
- Strength/machine stability
- Maintenance/retrofitting

4. TESTS OF THE BCAF PROTOTYPE

Stainless steel powders (Coldstream, Belgium) series 300 and 400, whose nominal compositions are shown in Table 1, were

processed using P/M processing steps. Each type of powders was pressed into tensile test bars (ASTM E8-04) with green density of $6.50 \pm 0.05 \text{ g/cm}^3$, using a uniaxial press. Green parts were debinded at 600 °C for 1 hour in argon and then sintered at 1280°C for 45 minutes in pure hydrogen.

Density of the sintered samples was determined using the Archimedes method. A universal testing machine (Instron model 8801) was employed to determine the tensile properties of the sintered samples. Hardness (HRB, Instron UHM 930/250) was also investigated.

Table 1. Stainless steel powders employed for testing of the BTCASF prototype.

Powder	Nominal composition (%)												D _[v,0.5] (μm)
	C	S	Mo	Cu	Ni	Mn	Cr	Si	O	N	Nb	Fe	
303L	0.01	0.19	-	2	12.6	0.1	17.1	0.8	0.223	0.062	-	Bal.	60.47
304L	0.01	0.01	-	-	11.5	0.1	19.4	0.8	0.141	0.037	-	Bal.	71.46
310L	0.012	-	-	-	20.1	0.4	24.1	1.1	-	-	-	Bal.	81.85
316L	0.021	-	2.25	-	12.7	-	17.04	0.71	-	-	-	Bal.	64.84
409L	0.01	0.01	-	-	-	0.12	12.24	0.84	0.22	0.02	0.61	Bal.	71.01
410L	0.009	0.01	-	-	0.25	0.09	12.1	0.66	0.199	0.033	-	Bal.	76.81
430L	0.01	0.01	-	-	-	0.12	16.03	1.08	0.215	0.032	-	Bal.	85.85
434L	0.012	0.01	1.04	-	-	0.1	16.7	0.8	0.193	0.061	-	Bal.	93.68

Table 2. Mechanical properties of sintered stainless steels quoted from [6].

SS	UTS		YS		Elongation	Hardness (HRB)
	10 ³ psi	MPa	10 ³ psi	MPa	(%)	
303L	48	331.03	24	165.52	20	35
304L	57	393.10	26	179.31	26	45
310L						
316L	57	393.10	30	206.90	21	45
409L						
410L	48	331.03	26	179.31	16	45
430L	50	344.83	30	206.90	20	45
434L	50	344.83	30	206.90	15	50

4.1 Sintered stainless steels series 300

Final density of the sintered stainless steels series 300 (Fig. 4) indicated successful sintering of the powders. Increased densities of about 8-12 % were evidences of densification. The 316L material showed highest sintered density whereas the 303L showed the smallest. When

tensile properties were tested, it was observed that all sintered materials (Figure 5), produced from stainless steel series 300 powders, showed considerably good tensile properties (compared to Table 2). The sintered 304L and 316L materials showed promising mechanical properties.

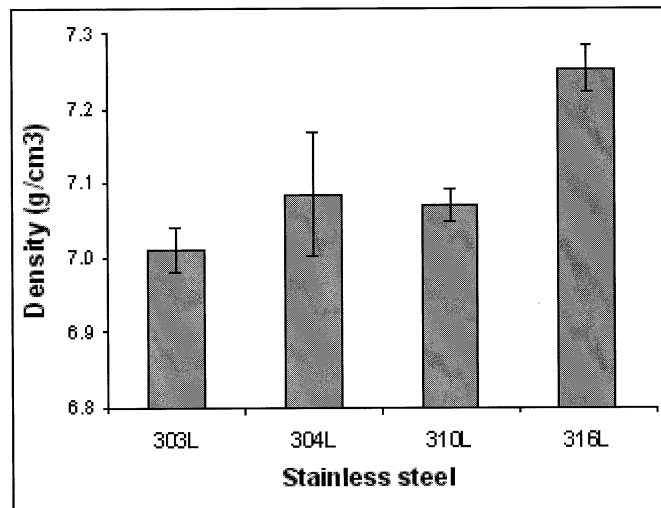
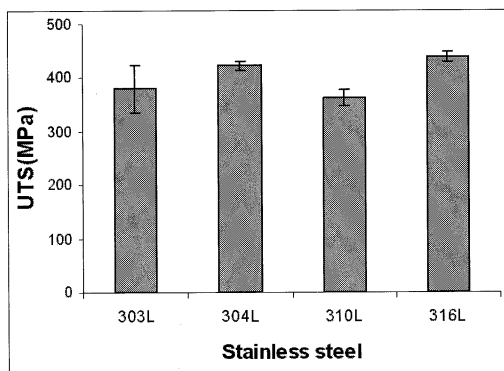
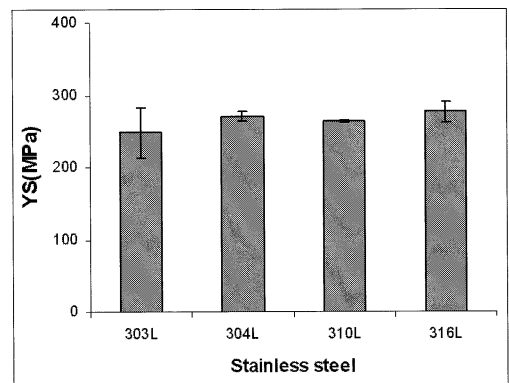


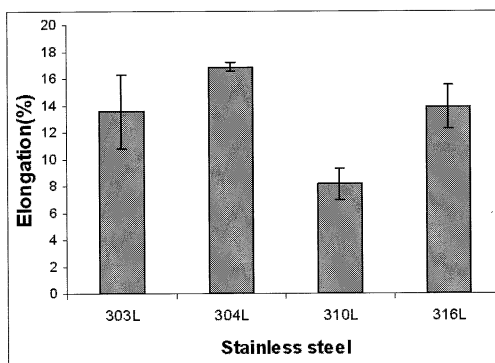
Figure 4. Final density of the sintered stainless steels series 300.



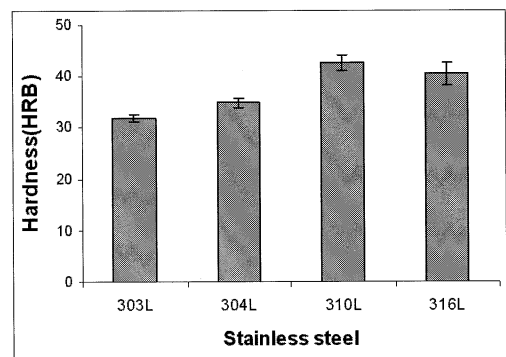
(a) UTS



(b) YS



(c) Elongation



(d) Hardness

Figure 5. Mechanical properties of sintered stainless steels series 300.

4.2 Sintered stainless steels series 400

Final density of the sintered stainless steels series 400 (Figure 6) also indicated successful sintering of the powders. Increased densities of about 7-10 % were evidences of densification. The 410L material showed highest sintered density whereas the 430L showed the smallest. When tensile properties

were tested, it was observed that all sintered materials (Figure 7), produced from stainless steel series 400 powders, also showed considerably good tensile properties (compared to Table 2). The sintered 409L, 410L and 434L materials showed promising mechanical properties.

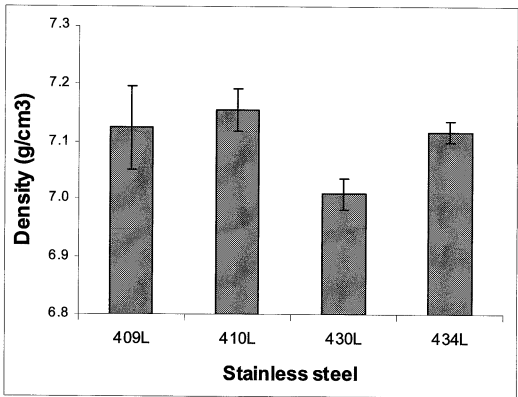
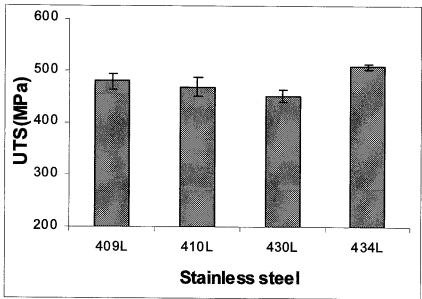
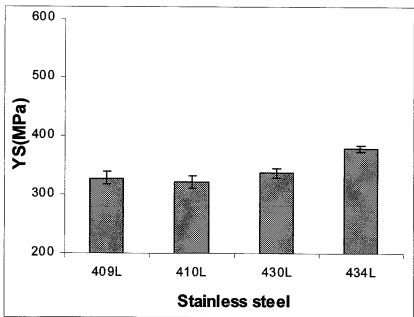


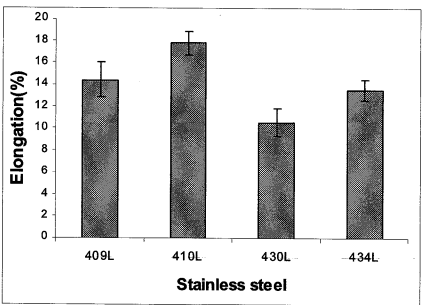
Figure 6. Final density of the sintered stainless steels series 400.



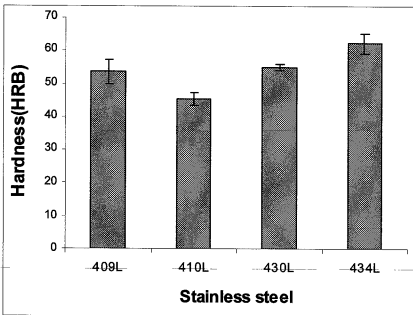
(a) UTS



(b) Yield



(c) Elongation



(d) Hardness

Figure 7. Mechanical properties of sintered stainless steels series 300.

CONCLUSIONS

The BCAF prototype was designed, assembled and tested. The furnace consisted of important components namely, sintering chamber, controller and residual gas burnout igniter. The prototype furnace was capable to sinter stainless steels. Final density and mechanical property of the sintered stainless steels series 300 and 400 indicated the success of this work.

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