Pack Carburizing, *Steel Heat Treating Fundamentals and Processes*. Vol 4A, *ASM Handbook*, ASM International, 2013, p 560–564.

Pack Carburizing*

Introduction

Pack carburizing is a process in which carbon monoxide derived from a solid compound decomposes at the metal surface into nascent carbon and carbon dioxide. The basic reactions are:

$$2\,C + O_2 \rightarrow 2\,CO \quad \text{(Eq 1)}$$

$$2\,CO + Fe \rightarrow C_{active} + CO_2 \quad \text{(Eq 2)}$$

$$CO_2 + C \rightarrow 2\,CO \quad \text{(Eq 3)}$$

The nascent carbon is absorbed into the metal, and the carbon dioxide immediately reacts with carbonaceous material present in the solid carburizing compound to produce fresh carbon monoxide.

Energizers or catalyst compounds are very often added with carbon to force the reaction in the direction favoring the formation of carbon monoxide (Ref 1). The energizing compounds include barium carbonate ($BaCO_3$), calcium carbonate ($CaCO_3$), potassium carbonate (K_2CO_3), and sodium carbonate (Na_2CO_3). The energizers facilitate the reduction of carbon dioxide with carbon to form carbon monoxide, and the amount of energizer does not change in a closed system. Carburizing continues as long as enough carbon is present to react with the excess carbon dioxide. Pack carburizing is typically conducted at approximately 920 to 940 °C (1690 to 1720 °F) for 2 to 36 h (Ref 2), but higher process temperatures are used (see the section "Process Control" in this article).

In pack carburizing, as in other carburization processes, the carbon-concentration gradient obtained is a function of carbon potential, carburizing temperature and time, and the chemical composition of the steel. Two process-control attributes peculiar to pack carburizing are:

- There may be a variation in case depth within a given furnace load due to dissimilar thermal histories within the carburizing containers.
- Distortion of parts during carburizing may be reduced because the compound can be used to support the parts.

Steel Composition. Any carburizing grade of carbon or alloy steel is suitable for pack carburizing. It is generally agreed that the diffusion rate of carbon in steel is not markedly influenced by the chemical composition of the steel. Chemical composition does have an effect on the activity of carbon and can affect the carbon level at saturation for a particular temperature.

Depth of Case. Even with good process control, it is difficult to obtain parts with total case-depth variation of less than 0.25 mm (0.010 in.) from maximum to minimum in a given furnace load, assuming a carburizing temperature of 925 °C (1700 °F). Commercial tolerances for case depths obtained in pack carburizing begin at ±0.25 mm (0.010 in.), and, for deeper case depths, increase to ±0.8 mm (0.03 in.). Lower carburizing temperatures provide some reduction in case-depth variation because variation in the time required for all parts of the load to reach carburizing temperature becomes a smaller percentage of total furnace time. Because of the inherent variation in case depth and the cost of packing materials, pack carburizing normally is not used on work requiring a case depth of less than 0.8 mm (0.03 in.). Typical pack-carburizing temperatures selected to produce different case depths on a variety of production parts are given in Table 1.

Table 1 Typical applications of pack carburizing

	Dimensions[a]			Carburizing

Part	OD		OA		Weight		Steel	Case depth to 50 HRC		Temperature	
	mm	in.	mm	in.	kg	lb		mm	in.	°C	°F
Mine-loader bevel gear	102	4.0	76	3.0	1.4	3.1	2317	0.6	0.024	925	1700
Flying-shear timing gear	216	8.5	92	3.6	23.6	52.0	2317	0.9	0.036	900	1650
Crane-cable drum	603	23.7	2565	101.0	1792	3950	1020	1.2	0.048	955	1750
High-misalignment coupling gear	305	12.0	152	6.0	38.5	84.9	4617	1.2	0.048	925	1700
Continuous-miner drive pinion	127	5.0	127	5.0	5.4	11.9	2317	1.8	0.072	925	1700
Heavy-duty industrial gear	618	24.3	102	4.0	150	331	1022	1.8	0.072	940	1725
Motor-brake wheel	457	18.0	225	8.9	104	229	1020	3.0	0.120	925	1700
High-performance crane wheel	660	26.0	152	6.0	335	739	1035	3.8	0.150	940	1725
Calender bull gear	2159	85.0	610	24.0	5885	12,975	1025	4.0	0.160	955	1750
Kiln-trunnion roller	762	30.0	406	16.0	1035	2280	1030	4.0	0.160	940	1725
Leveler roll	95	3.7	794	31.3	36.7	80.9	3115	4.0	0.160	925	1700
Blooming-mill screw	381	15.0	3327	131.0	2950	6505	3115	5.0	0.200	925	1700
Heavy-duty rolling-mill gear	914	36.0	4038	159.0	11,800	26,015	2325	5.6	0.220	955	1750
Processor pinch roll	229	9.0	5385	212.0	1700	3750	8620	6.9	0.270	1050	1925

(a) OD, outside diameter; OA, overall (axial) dimension

Distortion normally becomes more pronounced as processing temperature is increased. In some instances, carburizing temperature is selected on the basis of the maximum amount of distortion that can be tolerated. In any case, following proper container packing procedures will help minimize distortion.

Selective Carburizing. Stopoff techniques described in the article on gas carburizing in this Volume apply to selective carburization by pack carburizing. In addition, it may be possible to permit any portion of a part that is not to be carburized to protrude from the carburizing container. Alternatively, an inert or lightly oxidizing material may be packed around those areas of a part that are not to be carburized.

Footnote

* Revised from R.W. Foreman, Pack Carburizing of Steels, *Heat Treating*, Vol 4, *ASM Handbook*, ASM International, 1991, p 325–328

References cited in this section

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2. W.F. Gale and T.C. Totemeier, Ed., Chap. 29, Heat Treatment, *Smithells Metals Reference Book*, 8th ed., Elsevier Butterworth-Heinemann, 2004