



Severe accidental water vapour explosions in a foundry in China in 2012



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ARTICLE INFO

Article history:

Received 14 January 2016

Received in revised form

1 March 2016

Accepted 1 March 2016

Available online 3 March 2016

Keywords:

Metal casting industry

Seeping of ground water

Water vapour explosion

Accidental explosion

Quantitative analysis

ABSTRACT

On 20th February 2012 a severe water vapour explosion occurred in China. The site of the explosion was an in-door molding pit of the Steel Casting Plant of the Heavy Machinery Co. Ltd., a part of the Anshan Iron and Steel Group in the Liaoning Province in north–east China. The pit, located inside a large factory building, had been in use for a number of years. When the pit was first made years ago, a large hole of square cross section was dug out of the ground and lined with a whole-welded steel box of 10 mm wall thickness. Then the inside of the steel box was lined with a 0.7 m thick water-proof concrete layer. The completed pit was 4.5 m deep and the side-wall lengths were about 12 m. When the explosion occurred, a conical stainless-steel ring weighing about 90 tonnes and intended to be the foundation of a water turbine was being cast in a sand mold. The ground water level was about 2 m below the ground level at the location of the pit. Hence, the bottom of the pit was 2.5 m below the ground water level. Due to a holiday break during the preparation of the sand mold in the pit ground water seeped into the sand at the bottom and corners of the pit via eroded holes in the steel lining and cracks in the concrete layer. When the completed sand mold received the molten stainless steel the sand was exposed to a substantial heat flux from the hot metal. The heat was conducted downwards and side-ways into the regions of the sand in the pit containing water. The water evaporated and highly pressurized water vapour was gradually generated throughout the sand bed below the mold. Pouring of the molten stainless steel into the mold continued without any observable problems for about 30 min before the violent water vapour explosion occurred. Then the entire sand mold, with its content of molten stainless steel, was suddenly lifted at 5 m up in the air, just as by a piston, and shattered all around, killing 13 workers and injuring another 17.

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1. Introduction

Large-scale sand-mold casting comprises a multiple of processes (Yu et al., 2008). Metal casting is one of the most hazardous processes in metallurgical industries, involving a number of hazard factors. As discussed by Grousset et al. (1999), Dong (2006) and Kumar (2010) both physical accidents and occupational diseases have been caused by such processes quite frequently. According to Zhao (2008) some quite severe metal casting accidents had occurred in China up to that time.

The accidental water vapour explosion on February 20th 2012 in the steel-casting plant of Heavy Machinery Co. Ltd. of the

Anshan Iron and Steel Group is probably the most severe sand mold explosion accident in China's metal casting history. The purpose of the present paper is to provide an analysis of the basic cause and development of this accident, and to suggest some measures that can be taken to prevent similar accidents to occur in the future.

2. Description of the accident

2.1. Description of the plant

The steel-casting plant of Heavy Machinery Co. Ltd., Anshan Iron and Steel Group, was founded in 1936, i.e. about 70 years ago. The plant can produce large-scale steel castings, steel ingots, electro slag ingots and arc-continuous steel billets. In 2014 the annual

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production of cast objects was about 450,000 tonnes, of which 70,000 tonnes was steel casting, 280,000 tonnes steel billets and 100,000 tonnes steel ingots. The main production facilities include a 75 tonnes arc furnace, a 120 tonnes LF refining furnace, a 120 tonnes VOD furnace, a 20 tonnes intermediate frequency induction furnace, a movable sand-mixing machine, a casting-sand regeneration system, a casting pit and various cranes.

2.2. Sand mold preparation and casting

The explosion occurred when during the stainless-steel casting of a bottom ring of a hydraulic turbine in the large sand molding pit of Heavy Machinery Co. Ltd. The estimated weight of the ring was about 95 tonnes. The shape and main dimensions of the ring are shown in Fig. 1.

Pit casting was adopted because of the large size of the object to be cast. When the pit was first made years ago a large hole of square cross section had been dug out of the ground and lined with a whole-welded steel box of 10 mm wall thickness. Then the inside of the steel box had been lined with a 0.7 m thick water-proof concrete layer. The net internal dimensions of the completed pit were a depth of about 4 m and side-wall lengths of about 12 m.

The workers began to prepare the sand mold for the casting inside the pit on Jan. 14, 2012. The work had to be interrupted on Jan. 23 when they started their 7-day spring festival holidays. By that time they had removed most of the old sand in the pit except that in the four corners of the pit. On Jan. 30 the preparation of sand mold was restarted, including blowing hot air from the both casting nozzle into the mold cavity for drying it for 4 h and it was completed on Feb 19. The casting of the stainless steel ring started on Feb. 20. Two steel ladles were used during the casting. One was mounted in a special stand, whereas the other was hanging from a crane. Each ladle had been charged with 90 tonnes of molten stainless steel. Before pouring was started, the sand mold had been dried for 8 h according to the factory's safety rules for casting. 52 workers participated in the pouring.

2.3. The accidental explosion and its consequences

After about 30 min of pouring, shortly before the second ladle of molten steel had being emptied, an abnormal buzzing sound could be heard from the interior of the mold cavity. Suddenly everything in the mold cavity was thrown at least 5 m up in the air as one single entity. Then the ring-shaped sand mold with the molten metal in it turned over and hot sand and molten metal was shattered all over the place.

Thirteen people were killed, six seriously injured and 11 moderately/slightly injured. The molten steel and the hot sand caused serious damage to the power supply system, various

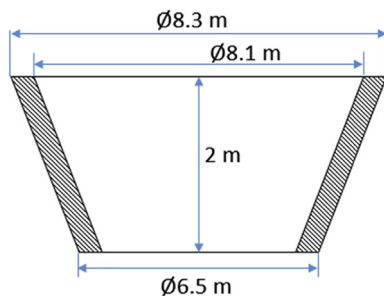


Fig. 1. The stainless-steel ring being cast in the sand mold at the moment of the water vapour explosion.



Fig. 2. . The sand mold with the stainless-steel metal being thrown at least 5 m up in the air at moment of the accident. The picture was taken by a video camera mounted in the production hall.



Fig. 3. Explosion site the large factory hall one day after the accident.

pipelines, the gantry crane, the excavator etc. Fig. 2 shows the moment when the accident happening. Fig. 3 shows the same scene one day after the accident. The cake-like residual (Fig. 4) has reached the pit ground and released a lot of heat deforming the steel bar seriously (see Fig. 5).



Fig. 4. Cake-like residues inside the molding pit after explosion.

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