Different door systems in industrial buildings considering energetic, building climatologic and economic aspects

Abstract

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1. Current situation

Industrial buildings are characterized by high heat loads and a wide range of different uses, depending on the prevailing processes [Rössel et al. 2012]. Industrial doors are common components in the building envelope of these buildings, which are primarily designed to ensure the supply or the removal of goods. An open door has many influences on the building, such as high air volume flows with large temperature differences between inside and outside, especially during cold ambient conditions. This leads to an uncomfortable indoor environment situation and increases the heating demand of the building.

In a cooperative research project supported by *Zukunft Bau* and *The Federal Association for Drives and Control Systems (BAS.T)*, the effect of door systems with regard to energy demand, indoor climate and economic impact are investigated.

2. Method of examination

Based on a thermal building simulation model, both building-specific parameters (e.g. internal heat loads, thermal stratification) and door-specific parameters (e.g. u-values, leakages, opening and closing speed) are taken into consideration. For the volume flow calculation through a single opening, a new calculation method by [Phaff et al. 1982] and [Larsen, 2006] was implemented. This algorithm includes the thermally induced and the wind-induced air exchange. The ventilation model was verified and validated on a measurement under real conditions at the Department of Building Climatology and Building Services. The results of these thermal building simulations are energetic values such as the heating and cooling demand of the building as well as transmission and ventilation heat losses through the door.

In a first step, various door-specific parameters like heat transfer coefficients (u-values) and different opening times are examined in order to determine their influence on the energy demand of the building. In a second step, practice-orientated scenarios with corresponding door opening times are investigated. The aim is to identify efficient door types for each scenario. As a final step, various measures to increase energy efficiency and thermal comfort, such as a variable height opening, were studied. The main objective is to develop proposals to increase the energy efficiency of industrial buildings.

The general approach is shown in Figure 1.

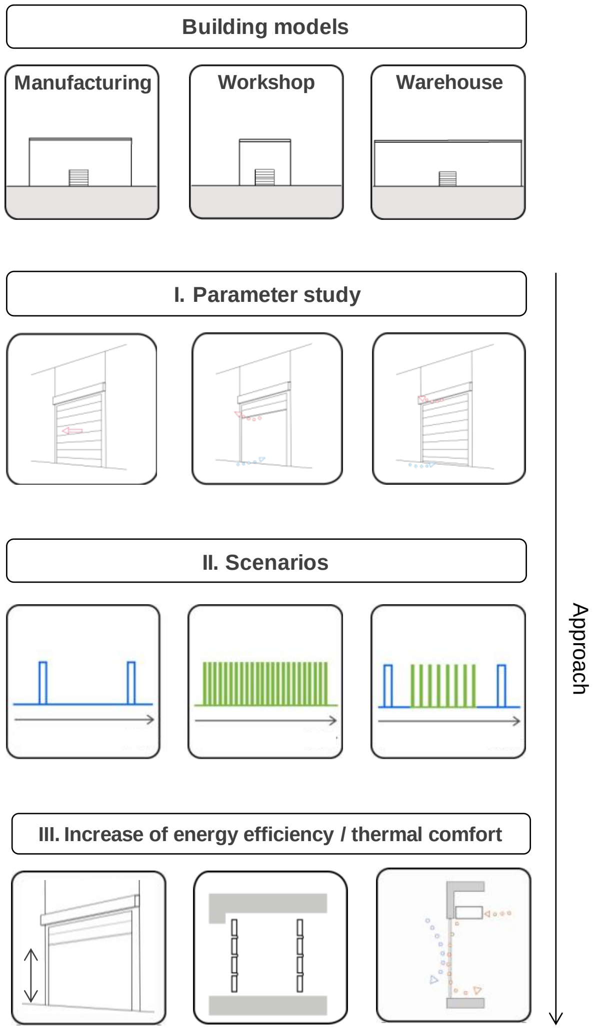

Figure 1: General approach of the research project

3. Industrial door systems

Industrial door systems differ in construction, material and insulation, opening and closing speed as well as in control techniques. Numerous investigations were carried out to analyze the different types of doors using a questionnaire, which was sent to various manufactures of doors, drives and control systems. It was decided to focus on the most common door types in industrial buildings: sectional doors, rolling doors and high-speed spiral doors. According to a study of [B + L 2010, 61, 67], these three types of industrial doors cover a market share of over 90 %. The results of the questionnaire was supplemented by a literature research, see Table 1.

Table 1: Specific characteristics of the studied types of doors

	sectional door	**roller door**		**high-speed spiral door**
		rolling shutter	flexible high-speed door	
				
u-value [$W/(m^2 \cdot K)$][1,2] (weighted average)	0.5-3.6 (1.8)	4.1-5.0 (4.7)	5.9 (5.9)	0.9-5.9 (1.9)
opening speed [m/s] (weighted average)[1]	0.2-0.44 (0.31)	0.2-0.3 (0.23)	0.8-3.0 (1.5)	0.5-2.5 (1.6)
closing speed [m/s] (weighted average)[1]	0.2-0.25 (0.21)	0.2-0.3 (0.23)	0.5-1.0 (0.6)	0.5-1.0 (0.75)
air permeability class[1,3]	2-3 (2)	0 (0)	0 (0)	0-3 (2)
maximum size[1] (width·height) [m·m]	10 · 8	12 · 10	6 · 7	8 · 8
investment[3,4] [€] (weighted average)	2,900 – 6,500 (4,700)	2,500 – 4,100 (3,100)	4,600 – 5,500 (4,800)	8,000 – 16,000 (11,000)
maintenance interval[1] [yr]	0.5	0.5		1

Figure 2: sectional door

Figure. 3: flexible high-speed door

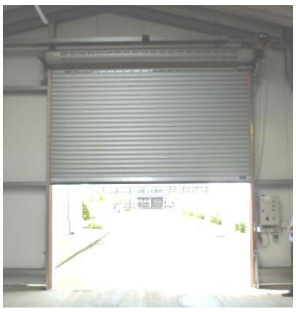

Figure. 4: rolling shutter

Figure. 5: high-speed spiral door

[1] the specific values were obtained from the questionnaires and data sheets of doors from different manufacturers

[2] the u-value refers to a door size of 16 m² according to [DIN EN 12428]

[3] air permeability class according to [DIN EN 12426]

[4] the investment refers to a door size of 16 m² and the manufacturer's list price including control system and drive

4. Parameter study

In a parameter study, various characteristics and attributes of industrial doors are examined in order to determine their influence on the energy demand of the building. The following results can be summarized:

- The ventilation heat losses caused by an open door exceed the heat losses by transmission and leakage, even with a 3-minute opening period per hour, regardless of the building model.
- The ventilation heat losses are higher than the resulting heating demand to maintain a certain comfort level. This requirement to the minimum temperature is not deceeded by each door opening, so that it is not always necessary to reheat the building. The effect is enhanced by internal heat loads of the building.
- The influence of u-value and air permeability can be considerable especially if there are a high number of doors in the façade and they are rarely opened. The difference between a highly and a slightly insulated door can be up to 1,900 kWh/yr (air permeability of a highly and slightly tight door: up to 1,600 kWh/yr) for the defined building models.
- The ventilation heat losses caused by an open door are largely proportional to the duration of opening for the building models *manufacturing* and *warehouse* due to large room volumes. In contrast, the building model *workshop* with a small room volume cools down very fast, which causes a regressive characteristic between ventilation heat losses and duration of opening.
- Simultaneously opened doors on opposite sides have an increasing effect on the ventilation heat losses and, respectively, on the resulting heating demand. This heating demand is up to 11% higher than if the doors are opened successively.
- The electrical energy required for door operations (drive, control system and sensors) is relatively small compared to the ventilation heat losses caused by an open door.

5. Scenarios

Within the research project, practice-oriented scenarios with corresponding door opening times were developed, see Table 2. The scenarios are based on site visits and a questionnaire, which was sent to various manufactures of door systems. The aim is to identify efficient door types for each scenario considering energetic and economic aspects.

For each scenario, different door types were examined: an *ideal door* is defined as a reference to evaluate a benchmark for a comparison to the different industrial doors, see Table 1. The *ideal door* is characterized by ideal characteristics: no opening and closing times, same u-value as the building facade and absolute tightness in a closed state. The summarizing conclusions of these examinations are:

- In almost all scenarios, the ventilation heat losses through the open door are higher than the heat losses by transmission and leakage through closed doors, independent of the considered door type. The reduction of the ventilation heat losses shows the largest potential for energy savings.
- The room temperature can fall below the set temperature in up to 30% in the period of use.
- If there is only a small amount of opening cycles, a high insulation and tightness of the door are necessary with regard to the heating demand of the building. The opening and closing speed has no appreciable effect on the heating demand. Concerning costs, (insulated) sectional doors or rolling shutters with low investment are recommended.
- The opening and closing speed is extremely significant in scenarios with frequently opened and closed doors, while insulation and tightness of the door have a minor impact on the heating demand of the building. In these cases, low-speed doors are unsuitable. Sometimes the opening and closing procedure needs more time than the actual opening period, so an additional high ventilation heat loss results. Considering economic issues, flexible high-speed door doors (lower investment, higher heating costs) as well as high-speed spiral doors (higher investment, lower heating costs) are recommended.

Table 2: developed scenarios for the building models *manufacturing, workshop, warehouse*

6. Increase of energy efficiency and thermal comfort

For the examined scenarios, several measures were considered to increase energy efficiency and thermal comfort.

To reduce the energy demand in the *truck loading / unloading* scenario, the long opening time is divided in several opening cycles. Therefore, a utilization of high-speed doors is essential, which enable fast and frequent openings and closings. Furthermore, the installation of an airlock has been analyzed in order to decrease the air exchange and the inflow of cold air. With frequent short-term opening processes, an object-size-adapted door aperture was investigated to reduce the ventilation heat losses.

The following results can be pointed out:

- The heating demand caused by long opening periods can be reduced by up to 30% by frequent openings and closings. Due to the high number of cycles, such measures can be implemented reasonably with high-speed doors only.
- An object-size-adapted door opening can be implemented by means of sensory systems. For the scenario of *continuous fork-lift traffic* the opening height can be reduced to 2.5 m. With the reduction of the air exchange significant energy savings of up to 63% are possible.
- With a use of an airlock, the ventilation heat losses and the resulting heating demand can be decreased significantly. Depending on the door type and the building model, savings of the heating demand by up to 90% are achievable. In addition, the thermal comfort in the building can be increased. For a rational use, an air-lock function has to be coordinated with the logistics processes. Moreover, this measure creates additional construction costs.
- Air curtains or air wall systems allow an increase of the thermal comfort. A general statement about the energy savings potential of air curtains cannot be made because the efficiency depends on the quality of the air shield between inside and outside. A possible increase in efficiency is to be determined separately for individual applications.

7. Conclusion

The importance of the energy efficiency in the sector of industries, trade and services is increasing. In addition to the continuous development and the optimization of industrial processes, industrial and commercial buildings have to contribute a significant share to the planned energy turnaround in Germany in terms of their future energy consumption.
Avoidance or minimization of ventilation heat losses caused by open doors represent the largest potential for energy savings of industrial door systems in buildings. These savings can be achieved with a slight effort by means of control systems and sensors.

In the sense of sustainable and energy efficient construction, it is essential that in the planning process doors are taken into account early. Likewise, a suitable combination of door type, drive, control and sensor has to be made depending on the case of application. Therefore, the study provides energetic and economic guidance to choose an appropriate door system for various applications.

8. References

[B+L 2010]	B+L Marktdaten GmbH: Marktstudie Automatisierung von Industrietoren, Bonn, June 2010
[DIN EN 12426]	DIN EN 12426: Tore, Luftdurchlässigkeit, July 2000
[DIN EN 12428]	DIN EN 12428: Tore, Wärmedurchgangskoeffizient, January 2012
[Larsen 2006]	Larsen, T.S.: Natural Ventilation Driven by Wind and Temperature Difference. Ph.D. thesis, Aalborg University Denmark, Department of Civil Engineering, Group of Architectural Engineering. ISSN 1901–7294, Aalborg, 2006
[Phaff et al. 1982]	de Gids, W., Phaff, H., et.al.: Ventilatie von Gebouwen. Onderzoek naar de Gevolgen van Het Openen van een Raam op Het Binnenklimaat von een Kamer, Instituut voor Milieuhygiene en Gezondheidstechniek, Rapport C 448, Delft, Niederlande, 1982
[Rössel et al. 2012]	Rössel, T., Klimke, K., Vohlidka, P., Riemer, H.: Green Factory – energieeffiziente Produktionsstätte, Lehrstuhl für Bauklimatik und Haustechnik, TU München, Munich, 2012