Fachbereich AKTUELL

FBHM-058

DGUV
Fachbereich Holz und Metall
Berufsgenossenschaft
Holz und Metall

Sachgebiet Maschinen, Robotik und Fertigungsautomation

Reduced speed
for fluid power control systems

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Translation of German version

The European Machinery Directive [1] and the principles for design in DIN EN ISO 12100 [2] specify requirements for specific modes of operation, such as e. g. setting, retooling and trouble-shooting on machines with open (deactivated) safeguard.

It includes the requirement to permit operation only on the condition of reduced risk (e. g. by reduced speed). For this purpose, a variety of different technical solutions are conceivable.

This "Fachbereich AKTUELL" deals with some examples of practical solutions for reduced speed implemented by a hydraulic or pneumatic control design.

Figure 1: Pneumatic linear axes

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1 Requirements

The European Machinery Directive (EMD) and DIN EN ISO 12100 state the following requirements if tasks such as setting, retooling, trouble-shooting as well as cleaning / maintenance have to be carried out on machines with the (deactivated) safeguard open:

- all other control modes are switched-off,
- operation is only permitted by continuous actuation of an enabling device, a two-hand control device or a hold-to run control device,
- operation is only permitted on reduced risk conditions (e. g. reduced speed).
- further requirements of the EMD and DIN EN ISO 12100 with regard to the control system, the control unit / control actuator have to be met. All requirements apply regardless of the technology used (electric, electronic, hydraulic, pneumatic).

The specific control requirements and possibly required reduced speeds can be taken from the product standards (Type C standards) for the relevant machines or other regulations. Depending on the branch of industry and the type of machine, (e. g. plastics processing machinery, presses, machine tools), different maximum values for the reduced speed ranging from 10 mm/s up to 2 m/min (=33,33 mm/s) are permitted. A linear drive (or rotatory drive) should therefore maintain the required reduced speed (or circumferential speed) for the relevant technical safety requirement.

For reducing the volume flow and thus reducing the speed of a fluid power drive, fixed orifices or fixed throttles should be applied. When the medium flows through the cross-sectional constriction of a fixed orifice or fixed throttle, the travel speed of the power element (e.g. cylinder) is reduced. Depending on the cross section of the fixed orifice or the fixed throttle, a certain velocity can be reached. In case of vertical axes or movements, changes in speed occur with very different load weights. Furthermore, speed variations have to be taken into account for different cylinder sizes with the same fixed orifice or fixed throttle.

In particular with pneumatic drives, the physical characteristics (compressibility of pressure medium) have to be taken into account in order to fulfill the requirement „reduced risk“ e. g. by reduced speed.

2 Hydraulic control systems

The following two examples describe control circuits (see figures 2 and 3) for the implementtation of reduced speed. The control systems mentioned have been elaborated at the „Institut für Arbeitsschutz IFA“. They do not, however, constitute a compulsory requirement to machinery manufacturers.

The safety level of a hydraulic control system or hydraulic control function which is actually required must always be determined for the particular application.

Figures 2 and 3 show examples of two basic options for implementing hydraulic control systems with reduced speed by means of hydraulic system diagram sketches. Only the hydraulic part of the control system is shown.

The speed is reduced through the fixed orifice or the fixed throttle (see DIN EN ISO 13849-2 [3], table C.2).

The following hydraulic control systems are subject to compliance with category B requirements and proven safety principles (see DIN EN ISO 13849-2, Annex C). Further explanations are given in IFA Report 2/2017 [4].

> The electrical part of the control system of the valves is not shown, but has to be assessed in any case.

2.1 Single-channel hydraulic control system

Figure 2 shows a single-channel hydraulic control system, with the fixed orifice 1V3 operating in the rest position, i. e. the speed is reduced.

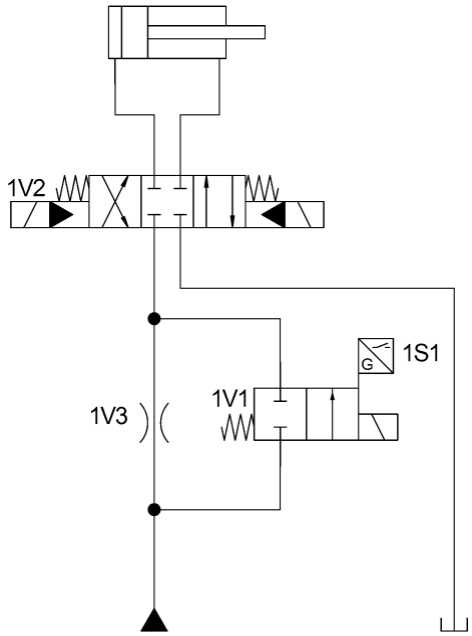

Figure 2: Reduced speed in a single-channel hydraulic control system (category 2)

In normal operation (at working speed), the directional control valve 1V1 is actuated. The movement of the hydraulic cylinder is controlled by directional control valve 1V2. For interrupting the cylinder movement (control voltage off), the directional control valve 1V2 switches to “mid-position closed”, i. e. to the safety-related switching position and directional control valve 1V1 switches to reduced volume flow (through the fixed orifice 1V3).

For operation with reduced speed, the directional control valve 1V1 is not actuated, so that the volume flow is limited by the fixed orifice 1V3. The hydraulic cylinder is controlled by actuation of the directional control valve 1V2.

The directional control valve 1V1 employs an electrical position monitoring 1S1, so that sticking in the (open) switching position (operating position) is detected. If this fault is detected, no cylinder movement must be initiated by the directional control valve 1V2 or the movement has to be stopped (higher-level shut-off path). Reaction times and overrun distances have to be taken into account. The testing is performed immediately before and during the safety function is demanded.

This control system corresponds to category 2. On adequate selection and interconnection of the components ($MTTF_d$, DC, CCF), it can achieve Performance Level (PL) d according to DIN EN ISO 13849-1 [5] for the safety function „Prevention of leaving the speed-reduced movement“.

2.2 Two-channel hydraulic control system

Figure 3 shows a two-channel hydraulic control system, which switches over to reduced speed redundantly.

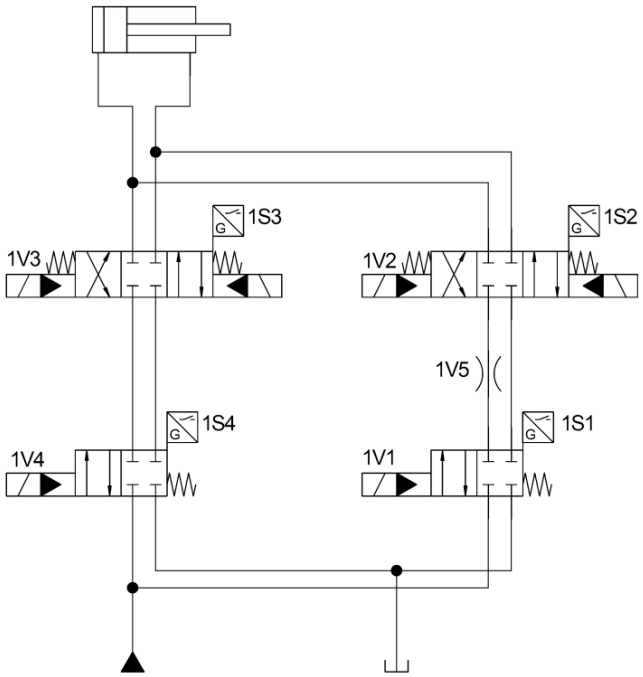

Figure 3: Reduced speed in a two-channel hydraulic control system (category 4)

In normal operation (at working speed), the movement of the hydraulic cylinder is controlled in two channels through the directional control valve 1V4 and the directional control valve 1V3.

For operation at reduced speed, the valves 1V3 and 1V4 are not actuated. This ensures a redundant shutdown of the movement at working speed (not reduced speed). The movement control of the hydraulic cylinder at reduced speed is performed in two channels through the directional control valve 1V1 and the directional control valve 1V2. The volume flow is limited by fixed orifice 1V5.

For interrupting the movement (control voltage off), all directional control valves switch into the closed rest position, i. e. in the safety-related switching position.

All directional control valves (1V1, 1V2, 1V3 and 1V4) are provided with an electrical position monitoring. This hydraulic part of the control system corresponds to category 4 and can, on adequate selection and interconnection of the components ($MTTF_d$, DC, CCF), achieve Performance Level (PL) e according to DIN EN ISO 13849-1 for the safety function „Prevention of leaving the speed-reduced movement“.

2.3 Further information

The examples mentioned in figures 2 and 3 show basic options for implementing a hydraulic control structure with reduced speed.

For the specific design of a machine control system, the impact of external forces has to be taken into account (e. g. layout and design of the fixed orifice or the fixed throttle, use of leakage-free stop valves).

Flow control valves or controllable pumps do normally not fulfill the requirement on reduced speed.

Operation at reduced speed over a longer period of time may result in a temperature increase in the hydraulic system. This has to be taken into account on the design and for the equipment.

3 Pneumatic control systems

In relevant publications, e. g. IFA Report 2/2017, numerous general examples for safety-related pneumatic control systems without reduced speed are shown. For implementing a pneumatic control system with reduced speed, different variations are possible, which, however, cannot be dealt with entirely in a single information sheet.

Therefore, figures 4 and 5 show two examples of principal options for implementing a pneumatic control system for gravity-loaded axes at reduced speed. These control systems have been elaborated in the “Institut für Arbeitsschutz IFA“, but they do not constitute a compulsory requirement to machinery manufacturers.

The examples shown assume that the reversing or the stopping of the movement is not hazardous.

Failure and return of power must not lead to a hazardous movement.

The pneumatic cylinder is held under pressure in the upper end position.

The speed is reduced by means of a fixed orifice or fixed throttle (see DIN EN ISO 13849-2 [3], table B.2).

The level of safety which is actually required for a pneumatic control system or control function shall always be determined for the specific application.

The following pneumatic control systems are subject to compliance with category B requirements and proven safety principles (see DIN EN ISO 13849-2, Annex B). Further explanations are given in IFA Report 2/2017.

> The electrical part of the valve control system is not shown but has to be assessed in any case.

3.1 Pneumatic control system example 1

Figure 4 shows a single-channel pneumatic control system with the cylinder in the upper end position, pressurized with compressed air, in the rest position of the valves.

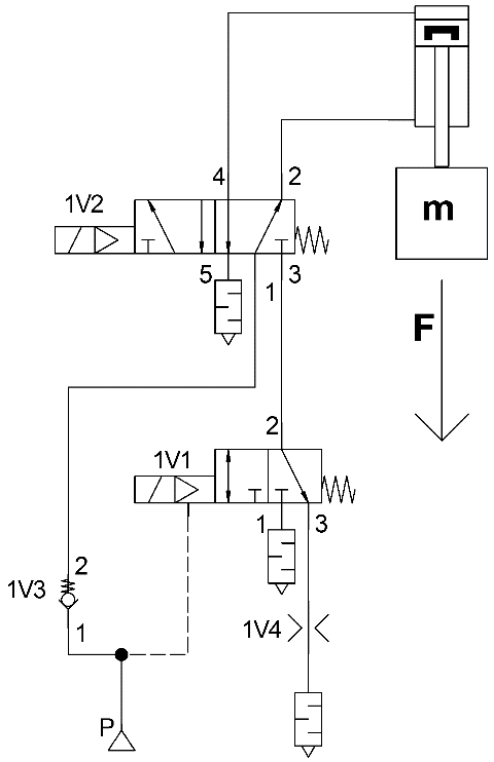

Figure 4: Pneumatic control system at reduced speed and selectable working speed in category 1 / PL c

The downward movement at working speed is performed by actuating 1V2 and the external pilot valve 1V1.

Only 1V2 is actuated for a speed-reduced downward movement, so that the volume flow is limited on the air discharge side by the fixed orifice 1V4.

The non-return valve 1V3 prevents a lowering of the load in case of a pneumatic power loss.

Provided that the valves are well-tried components which are suitable for this application, category 1 can be implemented for the following safety functions which may result in a PL c for the pneumatic part of the control system:

- prevention of leaving the speed-reduced movement,
- reversing or stopping a downward movement and
- protection against unexpected start-up of a downward movement

3.2 Pneumatic control system example 2

Figure 5 shows a pneumatic control system for which it is assumed that the cylinder is in the upper end position whilst the valves are in the rest position. Limit switches 1S1 and 1S2 indicate the end positions of the cylinder.

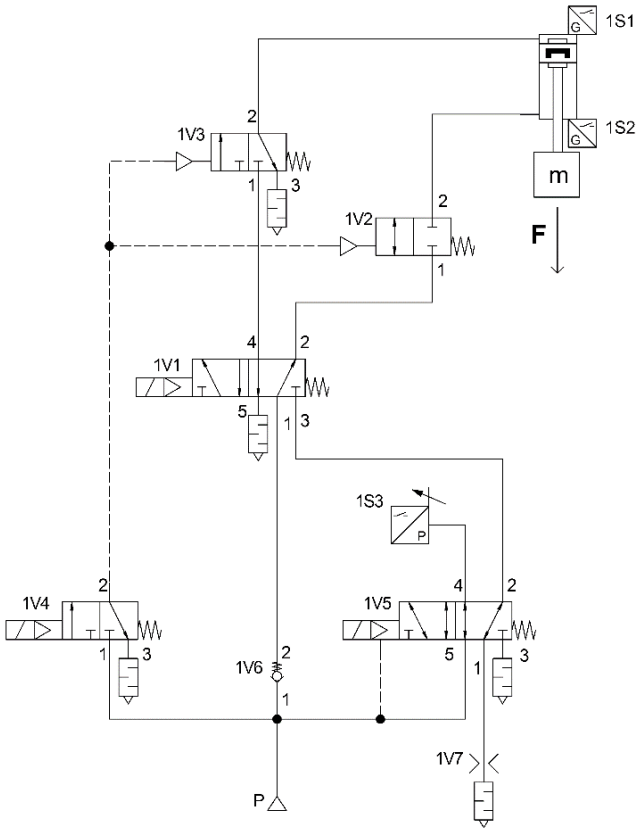

Figure 5: Pneumatic control system at reduced speed and selectable working speed in category 2 / PL d

The downward movement at working speed takes place by (electrical)

- actuation of valve 1V4 (which pneumatically actuates the valves 1V2 and 1V3),
- actuation of valve 1V1 and
- actuation of the external pilot valve 1V5.

Valve 1V4 and the directional control valve 1V1 are actuated for a speed-reduced downward movement so that the volume flow is limited on the air discharge side through the fixed orifice 1V7.

Example 2 mentions the implementation of a category 2 structure for the safety function

- prevention of leaving the speed-reduced movement.

In case of a detected implausibility of actuating the valve 1V5 and the output signal of the pressure switch 1S3, the downward movement must not be initiated by the higher-level shut-off path consisting of 1V2, 1V3 and 1V4 or the movement must be stopped. A possible overrun has to be taken into account.

An implementation of the aforementioned safety function with fault detection and higher-level shut-off path allows category 2 to be achieved with a PL d according to DIN EN ISO 13849-1.

For the safety functions,

- reversing or stopping a downward movement and
- protection against unexpected start-up of a downward movement

it results as follows:

The valves 1V2, 1V3 and 1V4 constitute the first channel of a two-channel control system in category 3 according to DIN EN ISO 13849-1. Valve 1V1 constitutes the second channel.

The following flow diagrams (figures 6 and 7) show a possible implementation of the fault detection for the individual valves for achieving a PL d in category 3 of the aforementioned safety functions.

3.3 Additional information

For the specific design of a machine control system, the impact of external forces has to be taken into account (e. g. layout of the fixed orifice, use of leakage-free stop valves).

If additional holding devices are used, it has to be ensured that these are only released when the cylinder is held in position by compressed air.

A standard setting of the cylinder working speed is not shown in the present examples. This is normally implemented by flow-control valves directly at both cylinder connections.

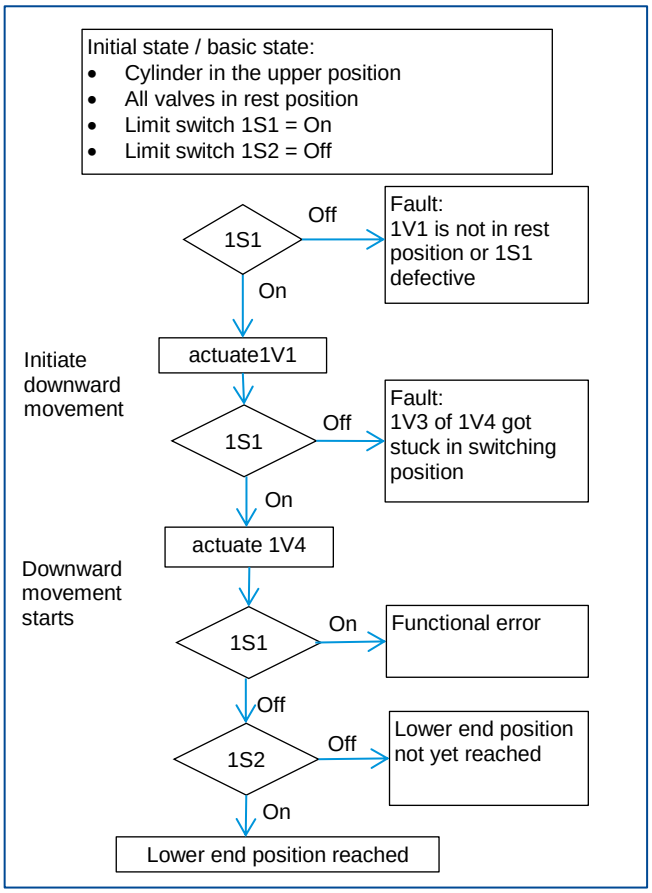

Figure 6: Flow diagram of fault detection for downward movement in category 3

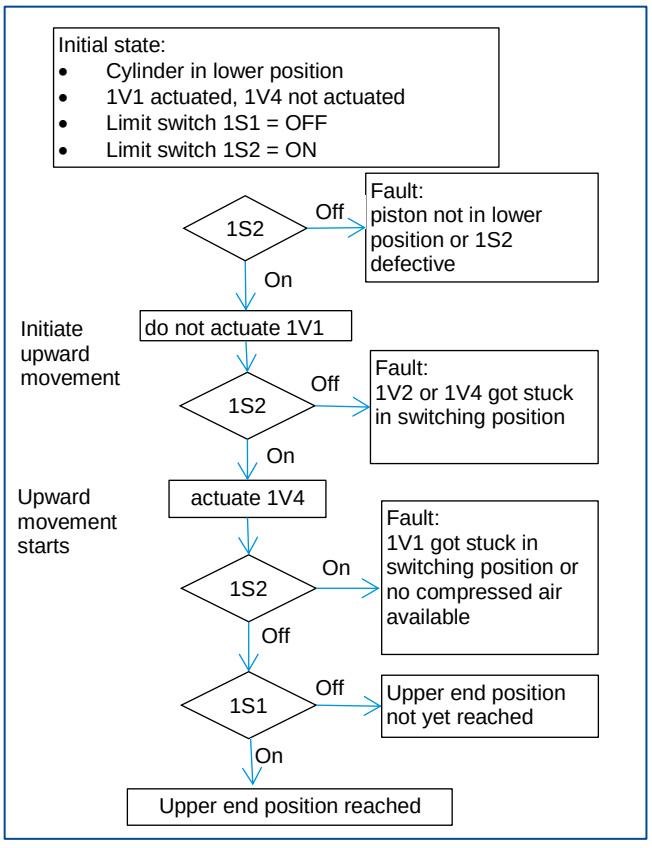

Figure 7: Flow diagram of fault detection for upward movement in category 3

4 Integration into machinery

Based on relevant company requests, it can be determined that reduced speed, e. g. for setting operation, has not (yet) been implemented in many cases.

As the examples in sections 2 and 3 show, a reduced speed in hydraulic and pneumatic control systems for linear axes can be achieved with little additional control engineering effort using commercially available fluid components. This also applies to the application of pneumatically driven linear axes, the physical condition of which (compressibility of the pressure medium) has to be taken into account for meeting the requirements of "reduced speed".

The further requirements for fluid power equipment according to DIN EN ISO 4413 Hydraulics [6] and DIN EN ISO 4414 Pneumatics [7] have to be taken into account.

The European Machinery Directive, the design principles according to DIN EN ISO 12100, the requirements of DIN EN ISO 13849-1 and -2 and further applicable standards have to be considered by the machine manufacturer in any case.

5 Summary and limits of application

This “Fachbereich AKTUELL” is based on expert knowledge gathered by the expert committee woodworking and metalworking, subcommittee machinery, robotics and automation of Deutsche Gesetzliche Unfallversicherung (DGUV) in the field of hydraulic equipment of machines and systems.

The present information has been developed in cooperation with the „Institut für Arbeitsschutz (IFA) of Deutsche Gesetzliche Unfallversicherung (DGUV). It is particularly intended as information to manufacturers and users of machinery in order to implement the requirement „reduced speed“ in specific modes of operation, such as e. g. setting, retooling, trouble-shooting, in fluid power control systems.

The particular provisions for other applications (in mining or similar) have to be taken into account.

The provisions according to individual laws and regulations remain unaffected by this “Fachbereich AKTUELL”. The requirements of the legal regulations apply in full. In order to get complete information, it is necessary to read the relevant regulation texts and the current standards.

The expert committee woodworking and metalworking is composed of representatives of the German Social Accident Insurance Institutions, federal authorities, social partners, manufacturers and users.

This “Fachbereich AKTUELL” replaces the information of the same title, issued as of 12/2018). An updating has become necessary due to editorial amendments.

This information is the English translation of the German issue “FBHM-058” of 11.10.2019.

Further information sheets of the expert committee woodworking and metalworking (Fachbereich Holz und Metall) or “Fachbereich AKTUELL” are available for download on the internet [8].

German Bibliography:

[1] Richtlinie 2006/42/EG des Europäischen Parlaments und des Rates vom 17. Mai 2006 über Maschinen (Maschinen-Richtlinie), Amtsblatt der Europäischen Union, Nr. L 157/24 vom 09.06.2006 mit Berichtigung im Amtsblatt L76/35 vom 16.03.2007.

[2] DIN EN ISO 12100 Sicherheit von Maschinen – Allgemeine Gestaltungsleitsätze – Risikobeurteilung und Risikominderung, Ausgabe 2011-03, mit Berichtigung vom 2013-08, Beuth-Verlag, Berlin.

[3] DIN EN ISO 13849-2 Sicherheit von Maschinen – Sicherheitsbezogene Teile von Steuerungen – Teil 2: Validierung, Ausgabe 2013-02, Beuth-Verlag, Berlin.

[4] IFA-Report 2/2017 Funktionale Sicherheit von Maschinensteuerungen – Anwendung der DIN EN ISO 13849, Deutsche Gesetzliche Unfallversicherung, Sankt Augustin

[5] DIN EN ISO 13849-1 Sicherheit von Maschinen – Sicherheitsbezogene Teile von Steuerungen – Teil 1: Allgemeine Gestaltungsleitsätze, Ausgabe 2016-06, Beuth-Verlag, Berlin.

[6] DIN EN ISO 4413, Fluidtechnik – Allgemeine Regeln und sicherheitstechnische Anforderungen an Hydraulikanlagen und deren Bauteile; Ausgabe 2011-04, Beuth Verlag, Berlin.

[7] DIN EN ISO 4414, Fluidtechnik – Allgemeine Regeln und sicherheitstechnische Anforderungen an Pneumatikanlagen und deren Bauteile; Ausgabe 2011-04, Beuth-Verlag, Berlin

[8] Internet: www.dguv.de/fb-holzundmetall Publikationen oder www.bghm.de Webcode: <626>

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