

# DIN EN 13001-3-6:2023-09 (E)

## Cranes - General design - Part 3-6: Limit states and proof of competence of machinery - Hydraulic cylinders (includes Amendment 6:2021)

---

<b>Contents</b>		<b>Page</b>
European foreword .....		4
Introduction .....		5
<b>1</b>	<b>Scope .....</b>	<b>6</b>
<b>2</b>	<b>Normative references .....</b>	<b>6</b>
<b>3</b>	<b>Terms, definitions and symbols .....</b>	<b>7</b>
<b>3.1</b>	<b>Terms and definitions .....</b>	<b>7</b>
<b>3.2</b>	<b>Symbols and abbreviations .....</b>	<b>7</b>
<b>3.3</b>	<b>Terminology .....</b>	<b>10</b>
<b>4</b>	<b>General .....</b>	<b>12</b>
<b>4.1</b>	<b>Documentation .....</b>	<b>12</b>
<b>4.2</b>	<b>Materials for hydraulic cylinders .....</b>	<b>13</b>
<b>4.2.1</b>	<b>General requirements .....</b>	<b>13</b>
<b>4.2.2</b>	<b>Grades and qualities .....</b>	<b>14</b>
<b>5</b>	<b>Proof of static strength .....</b>	<b>14</b>
<b>5.1</b>	<b>General .....</b>	<b>14</b>
<b>5.2</b>	<b>Limit design stresses .....</b>	<b>16</b>
<b>5.2.1</b>	<b>General .....</b>	<b>16</b>
<b>5.2.2</b>	<b>Limit design stress in structural members .....</b>	<b>16</b>
<b>5.2.3</b>	<b>Limit design stresses in welded connections .....</b>	<b>17</b>
<b>5.3</b>	<b>Linear stress analysis .....</b>	<b>17</b>
<b>5.3.1</b>	<b>General .....</b>	<b>17</b>
<b>5.3.2</b>	<b>Typical load cases and boundary conditions .....</b>	<b>17</b>
<b>5.3.3</b>	<b>Cylinder tube .....</b>	<b>19</b>
<b>5.3.4</b>	<b>Cylinder bottom .....</b>	<b>20</b>
<b>5.3.5</b>	<b>Piston rod welds .....</b>	<b>21</b>
<b>5.3.6</b>	<b>Cylinder head .....</b>	<b>22</b>
<b>5.3.7</b>	<b>Cylinder tube and piston rod threads .....</b>	<b>22</b>
<b>5.3.8</b>	<b>Thread undercuts and locking wire grooves .....</b>	<b>22</b>
<b>5.3.9</b>	<b>Oil connector welds .....</b>	<b>23</b>
<b>5.3.10</b>	<b>Connecting interfaces to crane structure .....</b>	<b>23</b>
<b>5.4</b>	<b>Nonlinear stress analysis .....</b>	<b>24</b>
<b>5.4.1</b>	<b>General .....</b>	<b>24</b>
<b>5.4.2</b>	<b>Standard cylinder with end moments .....</b>	<b>24</b>
<b>5.4.3</b>	<b>Support leg .....</b>	<b>24</b>
<b>5.5</b>	<b>Execution of the proof .....</b>	<b>25</b>
<b>5.5.1</b>	<b>Proof for load bearing components .....</b>	<b>25</b>
<b>5.5.2</b>	<b>Proof for bolted connections .....</b>	<b>25</b>
<b>5.5.3</b>	<b>Proof for welded connections .....</b>	<b>26</b>
<b>6</b>	<b>Proof of fatigue strength .....</b>	<b>26</b>
<b>6.1</b>	<b>General .....</b>	<b>26</b>
<b>6.2</b>	<b>Stress histories .....</b>	<b>26</b>
<b>6.3</b>	<b>Execution of the proof .....</b>	<b>28</b>
<b>6.4</b>	<b>Limit design stress range .....</b>	<b>28</b>
<b>6.5</b>	<b>Details for consideration .....</b>	<b>28</b>

6.5.1	General .....	28
6.5.2	Bottom weld .....	29
6.5.3	Notch stress at oil connectors .....	31
6.5.4	Cylinder head .....	32
6.5.5	Piston rod .....	34
6.5.6	Cylinder head bolts .....	36
6.5.7	Cylinder head flange weld .....	36
6.5.8	Mechanical interfaces .....	39
7	Proof of elastic stability .....	39
7.1	General .....	39
7.2	Critical buckling load .....	39
7.3	Limit compressive design force .....	41
7.4	Execution of the proof .....	42
<b>Annex A (informative) Critical buckling load for common buckling cases .....</b>		<b>43</b>
A.1	General .....	43
A.2	Buckling case A .....	44
A.3	Buckling case B .....	44
A.4	Buckling case C .....	45
A.5	Buckling case D .....	45
A.6	Buckling case E .....	45
A.7	Buckling case F .....	46
A.8	Buckling case G .....	46
<b>Annex B (informative) Second order analysis of two important cases .....</b>		<b>47</b>
B.1	Compressed cylinder with end moments and angular misalignment .....	47
B.2	Compressed cylinder with lateral end force and angular misalignment .....	48
B.3	Axial stresses for cases in B.1 and B.2 .....	49
<b>Annex C (informative) Shell section forces and moments for cylinder bottom .....</b>		<b>50</b>
<b>Annex D (informative) Fatigue analysis of bottom weld for more complex cases .....</b>		<b>53</b>
<b>Annex E (informative) Selection of a suitable set of crane standards for a given application .....</b>		<b>56</b>
<b>Annex F (informative) List of hazards .....</b>		<b>58</b>
<b>Annex ZA (informative) Relationship between this European Standard and the essential requirements of Directive 2006/42/EC aimed to be covered .....</b>		<b>59</b>
<b>Bibliography .....</b>		<b>60</b>