# 6. Mechanical

## 6.1 Joint composition and the definition of the angle

This robot has a total of 28 joints in two arms of 6 flexibility, two legs of 6 flexibility, and the head of 3 flexibility and the body part of 1 flexibility. It is rotation flexibility altogether and a leg, an arm, and the waist are serial links. The name of a joint and flexibility distribution have become as it is shown in Fig. 6.1-1 and Table 6.1-1. in addition, [] of the joint name of front Naka -- an inside numerical value -- the order from 1 -- the machine from a root -- structural connection ranking is shown. Moreover, the joint angle which determines a robot's posture is defined by Fig. 6.1-2, 6.1.-3, the link parameter of Table 6.1-2, the joint coordinate system, and DH parameter, and **all joint instructions to a robot should follow this definition.**

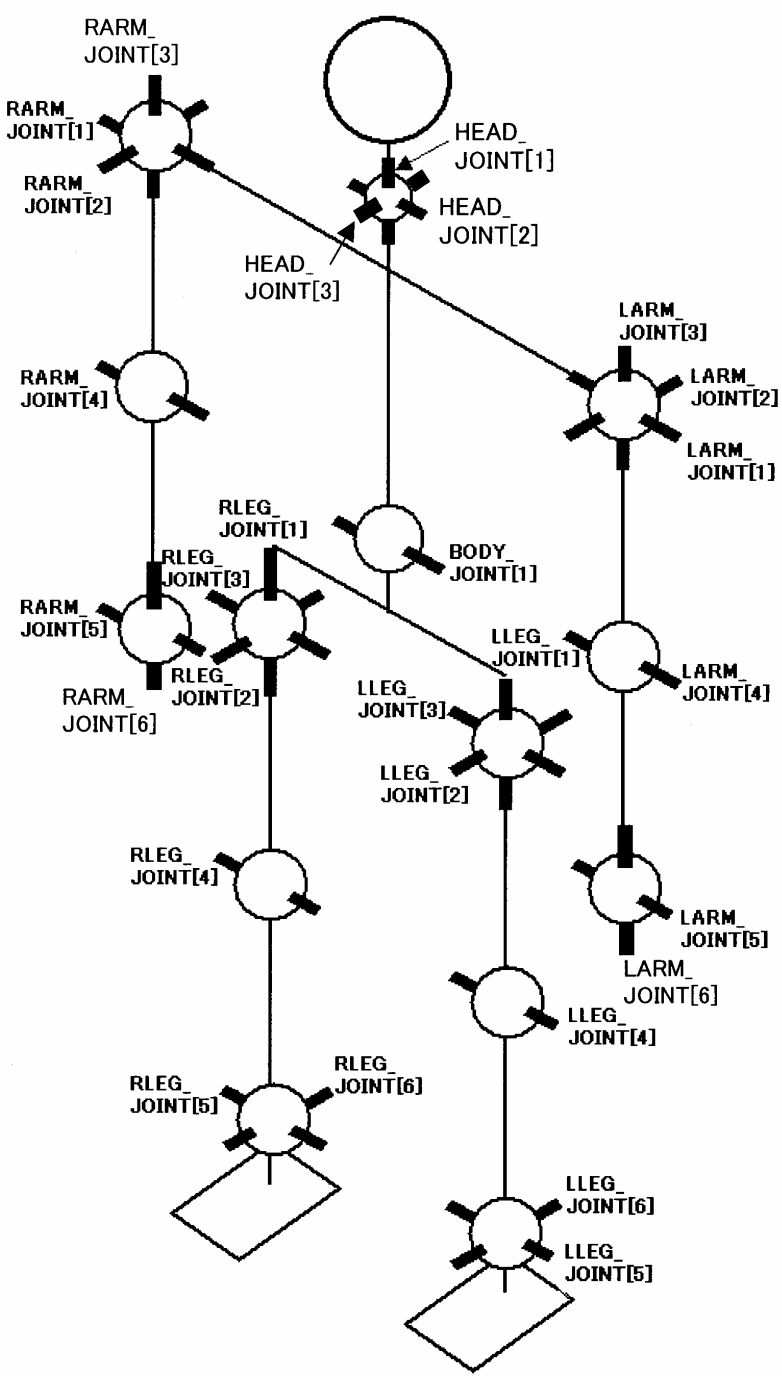



Fig. 6.1-1 Joint name

Table6.1-1　Joint name

| Joint name | Flexibility | Device ID |
|---|---|---|
| HEAD_JOINT[1] | Head torsion | 22 |
| HEAD_JOINT[2] | Head pitch | 22 |
| HEAD_JOINT[3] | Head roll | 22 |
| BODY_JOINT[1] | Waist pitch | 21 |
| RLEG_JOINT[1] | Right hip joint torsion | 1 |
| RLEG_JOINT[2] | Right hip joint roll | 2 |
| RLEG_JOINT[3] | Right hip joint pitch | 3 |
| RLEG_JOINT[4] | Right knee | 4 |
| RLEG_JOINT[5] | Right Ankle pitch | 5 |
| RLEG_JOINT[6] | Right Ankle roll | 6 |
| RARM_JOINT[1] | Right shoulder Pitch | 7 |
| RARM_JOINT[2] | Right shoulder roll | 8 |
| RARM_JOINT[3] | Right shoulder torsion | 9 |
| RARM_JOINT[4] | Right elbow | 10 |
| RARM_JOINT[5] | Right fingers open/close | 23 |
| RARM_JOINT[6] | Right hand torsion | 23 |
| LLEG_JOINT[1] | Left hip joint torsion | 11 |
| LLEG_JOINT[2] | Left hip joint roll | 12 |
| LLEG_JOINT[3] | Left hip joint pitch | 13 |
| LLEG_JOINT[4] | Left knee | 14 |
| LLEG_JOINT[5] | Left Ankle pitch | 15 |
| LLEG_JOINT[6] | Left Ankle roll | 16 |
| LARM_JOINT[1] | Left shoulder Pitch | 17 |
| LARM_JOINT[2] | Left shoulder roll | 18 |
| LARM_JOINT[3] | Left shoulder torsion | 19 |
| LARM_JOINT[4] | Left elbow | 20 |
| LARM_JOINT[5] | Left fingers open/close | 23 |
| LARM_JOINT[6] | Left hand torsion | 23 |

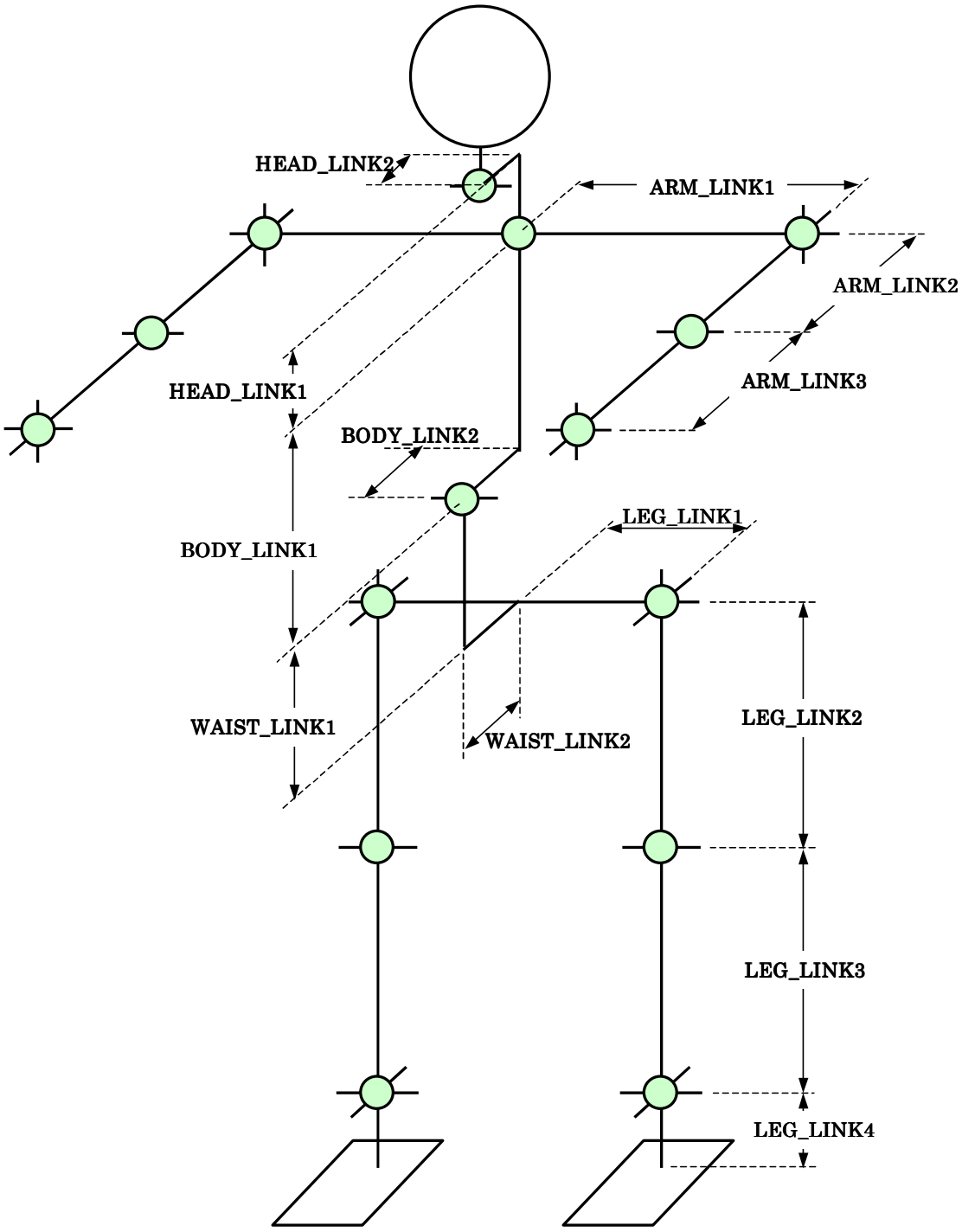



Fig.6.1-2　The parameter definition of the link length

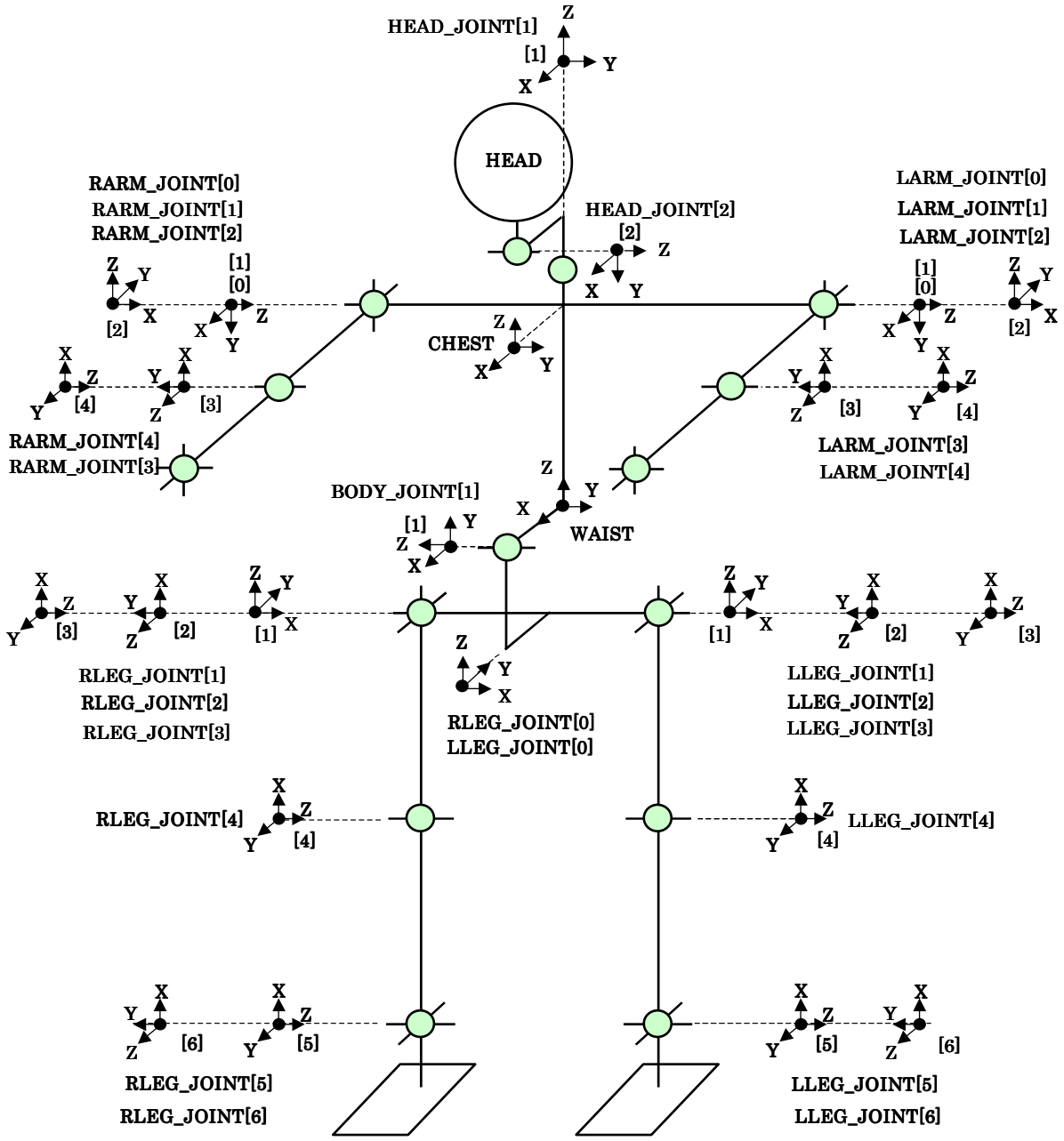


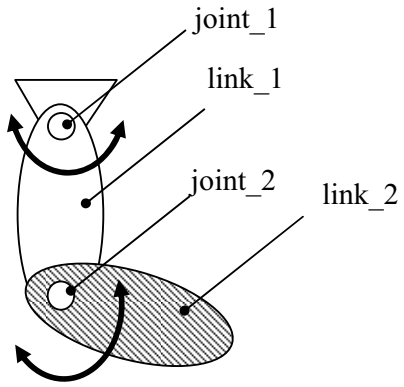

Fig.6.1-3　DH parameter definition coordinate（$\theta$ [i]=0 Posture）

Table.6.1-2 DH Parameter (theta[i] =0 is the posture of Fig.6.1-3

| | a[I-1] | α[I-1] | d[i] | θ[i] |
|---|---|---|---|---|
| | (m) | (deg) | (m) | (deg) |
| | | | | |
| CHEST | -BODY_LINK2 | 0 | BODY_LINK1 | 0 |
| HEAD_JOINT[1] | 0 | 0 | HEAD_LINK1 | 0 |
| HEAD_JOINT[2] | HEAD_LINK2 | -90 | 0 | 0 |
| ARM_JOINT[0] | 0 | -90 | (*)ARM_LINK1 | 0 |
| ARM_JOINT[1] | 0 | 0 | 0 | θ[1] |
| ARM_JOINT[2] | 0 | 90 | 0 | θ[2]+90 |
| ARM_JOINT[3] | 0 | 90 | ARM_LINK2 | θ[3]+90 |
| ARM_JOINT[4] | 0 | 90 | 0 | θ[4] |
| | | | | |
| BODY_JOINT[1] | 0 | 90 | 0 | 0 |
| LEG_JOINT[0] | -WAIST_LINK2 | -90 | -WAIST_LINK1 | 90 |
| LEG_JOINT[1] | (*)LEG_LINK1 | 0 | 0 | θ[1] |
| LEG_JOINT[2] | 0 | 90 | 0 | θ[2]+90 |
| LEG_JOINT[3] | 0 | 90 | 0 | θ[3] |
| LEG_JOINT[4] | -LEG_LINK2 | 0 | 0 | θ[4] |
| LEG_JOINT[5] | -LEG_LINK3 | 0 | 0 | θ[5] |
| LEG_JOINT[6] | 0 | -90 | 0 | θ[6] |
| | | | | |
| | (*)Please give as a negative value at the time of a right half the body. | | | |
| | | | | |
| | WAIST | ー＞ | CHEST | |
| | | | | |
| | | | | |
| ARM_LINK1 | 0.111 | m | | |
| ARM_LINK2 | 0.111 | m | | |
| ARM_LINK3 | 0.171 | m | | |
| LEG_LINK1 | 0.039 | m | | |
| LEG_LINK2 | 0.105 | m | | |
| LEG_LINK3 | 0.105 | m | | |
| LEG_LINK4 | 0.040 | m | | |
| BODY_LINK1 | 0.125 | m | | |
| BODY_LINK2 | 0.035 | m | | |
| HEAD_LINK1 | 0.103 | m | | |
| HEAD_LINK2 | 0.015 | m | | |
| WAIST_LINK1 | 0.055 | m | | |
| WAIST_LINK2 | 0.035 | m | | |
| | | | | |

## 6.2 Mass Property

mass property of the necessary link is in the attached sheet to simulate the dynamics of the robot. Mass property is defined in the link unit that it belongs to the degree of each joint freedom in accordance with the joint coordinate of the DH parameter .A link for example to belong to joint_1 in case as a ground plan becomes link_1, and mass property of link_1 by the coordinate of joint_1 is defined as it.




And, three kinds of mass property show it about the BODY link which is the body trunk of the robot by the difference in the loading thing of the cable mode and the wireless mode. Select and simulate mass property fitted to the configuration of an actual opportunity

## 6.3 Conversion of a joint angle and speed

Control of a robot's joint angle or speed uses as an instruction value what changed into the increase and decrease (speed) of a value of the pulse count value (position) of the encoder of a joint, or the pulse count value around time the position defined by DH parameter and speed. It is answered to all also of the position of the present joint, and the information on speed by the robot with this value. The incremental encoder is used for an encoder. Therefore, PURISETTO [ the counter used as a position instruction value / a joint angle / a known posture ] so that it can change into the joint angle absolute value defined by DH parameter (or reverse conversion). PURISETTO [ specifically / robot / an automatic starting point return program / a joint angle ] automatically. If PURISETTO completion is carried out, a joint angle and speed are convertible for the definition semi- じた value of DH parameter by the conversion formula of Table 6.3-1 and 6.3-2 (or reverse conversion).

Table 6.3-1 Conversion of DH parameter definition joint angle and position instruction value

| $\theta$ d | DH definition joint angle(deg) |
|---|---|
| P | Position instruction value(pulse) |
| A | Conversion factor(pulse/deg) |
| Note) | P is 2 bytes of integer with a mark |
| **Conversion type:** | **$P=A\times\theta d$** |
| Joint name | A(pulse/deg) |
| RLEG__JOINT[1] | 209 |
| RLEG__JOINT[2] | 209 |
| RLEG__JOINT[3] | -209 |
| RLEG__JOINT[4] | 209 |
| RLEG__JOINT[5] | 209 |
| RLEG__JOINT[6] | -209 |
| RARM__JOINT[1] | 209 |
| RARM__JOINT[2] | 209 |
| RARM__JOINT[3] | -209 |
| RARM__JOINT[4] | -209 |
| LLEG__JOINT[1] | 209 |
| LLEG__JOINT[2] | 209 |
| LLEG__JOINT[3] | 209 |
| LLEG__JOINT[4] | -209 |
| LLEG__JOINT[5] | -209 |
| LLEG__JOINT[6] | -209 |
| LARM__JOINT[1] | -209 |
| LARM__JOINT[2] | 209 |
| LARM__JOINT[3] | -209 |
| LARM__JOINT[4] | 209 |
| BODY__JOINT[1] | 209 |

Table 6.3-2 Conversion of DH parameter definition joint speed and speed instruction value

| ωd | DH definition joint speed (deg/s) |
|---|---|
| V | Speed instruction value(pulse/ms) |
| B | Conversion factor(pulse/ms/(deg/s)) |
| note) | V is 2 bytes of integer with a mark |
| **Conversion type:** | **V=B × ωd** |
| Joint name | B(pulse/ms/(deg/s)) |
| RLEG__JOINT[1] | 0.209 |
| RLEG__JOINT[2] | 0.209 |
| RLEG__JOINT[3] | −0.209 |
| RLEG__JOINT[4] | 0.209 |
| RLEG__JOINT[5] | 0.209 |
| RLEG__JOINT[6] | −0.209 |
| RARM__JOINT[1] | 0.209 |
| RARM__JOINT[2] | 0.209 |
| RARM__JOINT[3] | −0.209 |
| RARM__JOINT[4] | −0.209 |
| LLEG__JOINT[1] | 0.209 |
| LLEG__JOINT[2] | 0.209 |
| LLEG__JOINT[3] | 0.209 |
| LLEG__JOINT[4] | −0.209 |
| LLEG__JOINT[5] | −0.209 |
| LLEG__JOINT[6] | −0.209 |
| LARM__JOINT[1] | −0.209 |
| LARM__JOINT[2] | 0.209 |
| LARM__JOINT[3] | −0.209 |
| LARM__JOINT[4] | 0.209 |
| BODY__JOINT[1] | 0.209 |

## 6.4 Joint allowable movement range

The joint movement range (DH parameter angle minimum angle - a maximum angle) that it is permitted after pre- sets joint counter of the robot becomes a table 6.4-1. Software limit of movement range can be set up in the robot. Be sure to set up software limit in less than this movement range by counter value for the prevention of damage and the safety. And, software limit is set up by the maximum and minimum of counter value. Over shoot of the control to the range of a joint angle to use in the actual practical use, and take the inside of 1deg of the maximum-minimum value of the table 6.4-1.

Sample: The utility movement ranges of RLEG_JOINT [1] become -90 - 30deg.

Table 6.4-1 Joint allowable movement range

(counter value is value with a thing after the pre-set completion.)

| Joint name | Flexibility | DH parameter minimum | | DH parameter maximum | | Motor type | Device ID |
|---|---|---|---|---|---|---|---|
| | | DH angle (deg) | Counter value (Decimal) | DH angle (deg) | Counter value (Decimal) | | |
| RLEG_JOINT[1] | Right hip torsion | -91 | -19019 | 31 | 6479 | TYPE-2 | 1 |
| RLEG_JOINT[2] | Right hip roll | -31 | -6479 | 21 | 4389 | TYPE-3 | 2 |
| RLEG_JOINT[3] | Right hip pitch | -82 | 17138 | 71 | -14839 | TYPE-2 | 3 |
| RLEG_JOINT[4] | Right knee | -1 | -209 | 130 | 27170 | TYPE-3 | 4 |
| RLEG_JOINT[5] | Right ankle pitch | -61 | -12749 | 61 | 12749 | TYPE-3 | 5 |
| RLEG_JOINT[6] | Right ankle roll | -25 | 5225 | 25 | -5225 | TYPE-2 | 6 |
| RARM_JOINT[1] | Right shoulder pitch | -91 | -19019 | 151 | 31559 | TYPE-2 | 7 |
| RARM_JOINT[2] | Right shoulder roll | -96 | -20064 | 1 | 209 | TYPE-2 | 8 |
| RARM_JOINT[3] | Right shoulder | -91 | 19019 | 91 | -19019 | TYPE-2 | 9 |
| RARM_JOINT[4] | Right elbow | -115 | 24035 | 1 | -209 | TYPE-2 | 10 |
| LLEG_JOINT[1] | Left hip torsion | -31 | -6479 | 91 | 19019 | TYPE-2 | 11 |
| LLEG_JOINT[2] | Left hip roll | -21 | -4389 | 31 | 6479 | TYPE-3 | 12 |
| LLEG_JOINT[3] | Left hip pitch | -82 | -17138 | 71 | 14839 | TYPE-2 | 13 |
| LLEG_JOINT[4] | Left knee | -1 | 209 | 130 | -27170 | TYPE-3 | 14 |
| LLEG_JOINT[5] | Left ankle pitch | -61 | 12749 | 61 | -12749 | TYPE-3 | 15 |
| LLEG_JOINT[6] | Left ankle roll | -25 | 5225 | 25 | -5225 | TYPE-2 | 16 |
| LARM_JOINT[1] | Left shoulder pitch | -91 | 19019 | 151 | -31559 | TYPE-2 | 17 |
| LARM_JOINT[2] | Left shoulder roll | -1 | -209 | 96 | 20064 | TYPE-2 | 18 |
| LARM_JOINT[3] | Left shoulder torsion | -91 | 19019 | 91 | -19019 | TYPE-2 | 19 |
| LARM_JOINT[4] | Left elbow | -115 | -24035 | 1 | 209 | TYPE-2 | 20 |
| BODY_JOINT[1] | Waist pitch | -1 | 209 | 90 | -18810 | TYPE-3 | 21 |
| HEAD_JOINT[1] | Head torsion | -60 | - | 60 | - | RC-サーボ | 22 |
| HEAD_JOINT[2] | Head pitch | -45 | - | 15 | - | RC-サーボ | 22 |
| HEAD_JOINT[3] | Head roll | -15 | - | 15 | - | RC-サーボ | 22 |
| RARM_JOINT[5] | Right fingers | -60 | - | 60 | - | RC-サーボ | 23 |
| RARM_JOINT[6] | Right hand torsion | -90 | - | 90 | - | RC-サーボ | 23 |
| LARM_JOINT[5] | Left fingers | -60 | - | 60 | - | RC-サーボ | 23 |
| LARM_JOINT[6] | Left hand torsion | -90 | - | 90 | - | RC-サーボ | 23 |

※ The movement range of these joints may decrease, because of overlap.

## 6.5 Joint allowable torque

The allowable torque of the joint of the robot shows a table 6.5-1. Be careful not to exceed this value when the back drive operation of the joint by manual in direct acting servo off or the time of the movement of the robot.

Table 6.5-1 Joint Allowable torque

| item | joint Name | Flexibility | Joint Permission torque [N·m] | | Motor type |
|---|---|---|---|---|---|
| | | | Average | Peak | |
| 1 | RLEG_JOINT[1] | Right hip torsion | 1.5 | 3 | TYPE-2 |
| 2 | RLEG_JOINT[2] | Right hip roll | 2 | 4.5 | TYPE-3 |
| 3 | RLEG_JOINT[3] | Right hip pitch | 1.5 | 3 | TYPE-2 |
| 4 | RLEG_JOINT[4] | Right knee | 2 | 4.5 | TYPE-3 |
| 5 | RLEG_JOINT[5] | Right ankle pitch | 2 | 4.5 | TYPE-3 |
| 6 | RLEG_JOINT[6] | Right ankle roll | 1.5 | 3 | TYPE-2 |
| 7 | RARM_JOINT[1] | Right shoulder pitch | 1.5 | 3 | TYPE-2 |
| 8 | RARM_JOINT[2] | Right shoulder roll | 1.5 | 3 | TYPE-2 |
| 9 | RARM_JOINT[3] | Right shoulder | 1.5 | 3 | TYPE-2 |
| 10 | RARM_JOINT[4] | Right elbow | 1.5 | 3 | TYPE-2 |
| 11 | LLEG_JOINT[1] | Left hip torsion | 1.5 | 3 | TYPE-2 |
| 12 | LLEG_JOINT[2] | Left hip roll | 2 | 4.5 | TYPE-3 |
| 13 | LLEG_JOINT[3] | Left hip pitch | 1.5 | 3 | TYPE-2 |
| 14 | LLEG_JOINT[4] | Left knee | 2 | 4.5 | TYPE-3 |
| 15 | LLEG_JOINT[5] | Left ankle pitch | 2 | 4.5 | TYPE-3 |
| 16 | LLEG_JOINT[6] | Left ankle roll | 1.5 | 3 | TYPE-2 |
| 17 | LARM_JOINT[1] | Left shoulder pitch | 1.5 | 3 | TYPE-2 |
| 18 | LARM_JOINT[2] | Left shoulder roll | 1.5 | 3 | TYPE-2 |
| 19 | LARM_JOINT[3] | Left shoulder torsion | 1.5 | 3 | TYPE-2 |
| 20 | LARM_JOINT[4] | Left elbow | 1.5 | 3 | TYPE-2 |
| 21 | BODY_JOINT[1] | Waist pitch | 2 | 4.5 | TYPE-3 |
| 22 | HEAD_JOINT[1] | Head torsion | 0.87 | 1.12 | RCサーボ |
| 23 | HEAD_JOINT[2] | Head pitch | 0.87 | 1.12 | RCサーボ |
| 24 | HEAD_JOINT[3] | Head roll | 0.87 | 1.12 | RCサーボ |
| 25 | RARM_JOINT[5] | Right fingers | 0.28 | 0.36 | RCサーボ |
| 26 | RARM_JOINT[6] | Right hand torsion | 0.28 | 0.36 | RCサーボ |
| 27 | LARM_JOINT[5] | Left fingers | 0.28 | 0.36 | RCサーボ |
| 28 | LARM_JOINT[6] | Left hand torsion | 0.28 | 0.36 | RCサーボ |