MITSUBISHI ELECTRIC

Mitsubishi Industrial Robot

CR750/CR751 series controller

Robot Safety Option Instruction Manual

4F-SF001-01

MELFA

BFP-A3372-C

⚠ Safety Precautions

Always read the following precautions and the separate "Safety Manual" before starting use of the robot to learn the required measures to be taken.

⚠CAUTION All teaching work must be carried out by an operator who has received special training.
(This also applies to maintenance work with the power source turned ON.)
→Enforcement of safety training

⚠CAUTION For teaching work, prepare a work plan related to the methods and procedures of operating the robot, and to the measures to be taken when an error occurs or when restarting. Carry out work following this plan.
(This also applies to maintenance work with the power source turned ON.)
→Preparation of work plan

⚠WARNING Prepare a device that allows operation to be stopped immediately during teaching work.
(This also applies to maintenance work with the power source turned ON.)
→Setting of emergency stop switch

⚠CAUTION During teaching work, place a sign indicating that teaching work is in progress on the start switch, etc.
(This also applies to maintenance work with the power source turned ON.)
→Indication of teaching work in progress

⚠DANGER Provide a fence or enclosure during operation to prevent contact of the operator and robot.
→Installation of safety fence

⚠CAUTION Establish a set signaling method to the related operators for starting work, and follow this method.
→Signaling of operation start

⚠CAUTION As a principle turn the power OFF during maintenance work. Place a sign indicating that maintenance work is in progress on the start switch, etc.
→Indication of maintenance work in progress

⚠CAUTION Before starting work, inspect the robot, emergency stop switch and other related devices, etc., and confirm that there are no errors.
→Inspection before starting work

The points of the precautions given in the separate "Safety Manual" are given below.
Refer to the actual "Safety Manual" for details.

⚠DANGER When automatic operation of the robot is performed using multiple control devices (GOT, programmable controller, push-button switch), the interlocking of operation rights of the devices, etc. must be designed by the customer.

⚠CAUTION Use the robot within the environment given in the specifications. Failure to do so could lead to faults or a drop of reliability.
(Temperature, humidity, atmosphere, noise environment, etc.)

⚠CAUTION Transport the robot with the designated transportation posture. Transporting the robot in a non-designated posture could lead to personal injuries or faults from dropping.

⚠CAUTION Always use the robot installed on a secure table. Use in an instable posture could lead to positional deviation and vibration.

⚠CAUTION Wire the cable as far away from noise sources as possible. If placed near a noise source, positional deviation or malfunction could occur.

⚠CAUTION Do not apply excessive force on the connector or excessively bend the cable. Failure to observe this could lead to contact defects or wire breakage.

⚠CAUTION Make sure that the workpiece weight, including the hand, does not exceed the rated load or tolerable torque. Exceeding these values could lead to alarms or faults.

⚠WARNING Securely install the hand and tool, and securely grasp the workpiece. Failure to observe this could lead to personal injuries or damage if the object comes off or flies off during operation.

⚠WARNING Securely ground the robot and controller. Failure to observe this could lead to malfunctioning by noise or to electric shock accidents.

⚠CAUTION Indicate the operation state during robot operation. Failure to indicate the state could lead to operators approaching the robot or to incorrect operation.

⚠WARNING When carrying out teaching work in the robot's movement range, always secure the priority right for the robot control. Failure to observe this could lead to personal injuries or damage if the robot is started with external commands.

⚠CAUTION Keep the jog speed as low as possible, and always watch the robot. Failure to do so could lead to interference with the workpiece or peripheral devices.

⚠CAUTION After editing the program, always confirm the operation with step operation before starting automatic operation. Failure to do so could lead to interference with peripheral devices because of programming mistakes, etc.

⚠CAUTION Make sure that if the safety fence entrance door is opened during automatic operation, the door is locked or that the robot will automatically stop. Failure to do so could lead to personal injuries.

⚠CAUTION Never carry out modifications based on personal judgments, non-designated maintenance parts. Failure to observe this could lead to faults or failures.

⚠WARNING When the robot arm has to be moved by hand from an external area, do not place hands or fingers in the openings. Failure to observe this could lead to hands or fingers catching depending on the posture.

⚠CAUTION Do not stop the robot or apply emergency stop by turning the robot controller's main power OFF. If the robot controller main power is turned OFF during automatic operation, the robot accuracy could be adversely affected. Also a dropped or coasted robot arm could collide with peripheral devices.

⚠CAUTION Do not turn OFF the robot controller's main power while rewriting the robot controller's internal information, such as a program and parameter. Turning OFF the robot controller's main power during automatic operation or program/parameter writing could break the internal information of the robot controller.

⚠DANGER Do not connect the Handy GOT when using the GOT direct connection function of this product. Failure to observe this may result in property damage or bodily injury because the Handy GOT can automatically operate the robot regardless of whether the operation rights are enabled or not.

⚠DANGER Do not connect the Handy GOT to a programmable controller when using an iQ Platform compatible product with the CR750-Q/CR751-Q controller. Failure to observe this may result in property damage or bodily injury because the Handy GOT can automatically operate the robot regardless of whether the operation rights are enabled or not.

⚠DANGER Do not remove the SSCNET III cable while power is supplied to the multiple CPU system or the servo amplifier. Do not look directly at light emitted from the tip of SSCNET III connectors or SSCNET III cables of the Motion CPU or the servo amplifier. Eye discomfort may be felt if exposed to the light.
(Reference: SSCNET III employs a Class 1 or equivalent light source as specified in JIS C 6802 and IEC60825-1 (domestic standards in Japan).)

⚠DANGER Do not remove the SSCNET III cable while power is supplied to the controller.
Do not look directly at light emitted from the tip of SSCNET III connectors or SSCNET III cables. Eye discomfort may be felt if exposed to the light.
(Reference: SSCNET III employs a Class 1 or equivalent light source as specified in JIS C 6802 and IEC60825-1 (domestic standards in Japan).)

DANGER Attach the cap to the SSCNET III connector after disconnecting the SSCNET III cable. If the cap is not attached, dirt or dust may adhere to the connector pins, resulting in deterioration connector properties, and leading to malfunction.

CAUTION Make sure there are no mistakes in the wiring. Connecting differently to the way specified in the manual can result in errors, such as the emergency stop not being released. In order to prevent errors occurring, please be sure to check that all functions (such as the teaching box emergency stop, customer emergency stop, and door switch) are working properly after the wiring setup is completed.

CAUTION Use the network equipments (personal computer, USB hub, LAN hub, etc.) confirmed by manufacturer. The thing unsuitable for the FA environment (related with conformity, temperature or noise) exists in the equipments connected to USB. When using network equipment, measures against the noise, such as measures against EMI and the addition of the ferrite core, may be necessary. Please fully confirm the operation by customer. Guarantee and maintenance of the equipment on the market (usual office automation equipment) cannot be performed.

■ Revision history

Date of print	Manual No.	Details of revisions
2015-02-06	BFP-A3372	・ First print
2015-02-13	BFP-A3372-A	・ The safety performance items in "Table 1-2 List of specifications" was added. ・ The risk matters (7)(8) in "Chapter 1.5.1 residual risk (Common)" was added.
2015-04-09	BFP-A3372-B	・ The name of “Wiring unit” was changed to “Extended safety unit”. ・ The chapter 8 was added. ・ The Table in the section 4.3.3 was removed.
2015-06-04	BFP-A3372-C	・ "1.2.1 Combination of software version" is added. ・ Figures "Enable/disable setting", "Speed monitoring setting" are modified in "Fig. 4.1 Parameter editing screen for the parameters" ・ Specifications in the Version Combination B is added to “SLS function” in “Table 4-2 Correspondence of the monitoring mode to the contents of monitoring” ・ Specifications in the Version Combination B is added to the "4.3.4 SLS function (Speed monitoring function)" ・ The parameters SFPFCSIG, SLSMONSP, SLSLMTOV, SLSCOMP are added to "5.1.1 Parameter List" ・ The figure of “(1) Enable/disable setting screen” in “5.1.2 Parameter details” is changed. ・ The parameter SFPFCSIG is added to "Table 5.2 Safety monitoring function parameters in the Enable/disable setting screen" ・ The screen image for Version Combination B is added to "(4) Speed monitoring setting screen" in "5.1.2 Parameter details". ・ The parameters SLSMONSP, SLSLMTOV, SLSCOMP are added to "Table 5-5 Safety monitoring function parameters in the speed monitoring setting screen" ・ "5.1.3 CRC output for the parameter file." is added. ・ Descriptions are added to the countermeasure column for H2370 error in "6.1 List of errors related to the safety monitoring function"

■ Introduction

Thank you for purchasing an industrial robot from Mitsubishi Electric Corporation. The "robot safety option", used together with external devices such as a safety switch or light curtain, enhances the robot safety function.
Before using the "robot safety option", make sure to read and fully understand the contents of this manual.

The manual is intended for use on the assumption that you understand basic operations and functions of the Mitsubishi industrial robot. For the basic operation of the robot, refer to the separate "Instruction Manual/Detailed explanations of functions and operations".

■Symbols in this manual

⚠ **Danger**	Incorrect handling may result in imminent danger, leading to death or serious injury.
⚠ **Warning**	Incorrect handling may lead to death or serious injury.
⚠ **Caution**	Incorrect handling may result in property damage, or danger leading to impairment of the user.

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1 Function and configuration

1.1 Overview

This manual provides descriptions on the robot safety option. For the robot arm or robot controller, refer to the corresponding manuals.
Using the robot safety option extends the safety monitoring function of robots. The option can be used with safety switches, light curtains, etc. connected.

1.2 System configuration

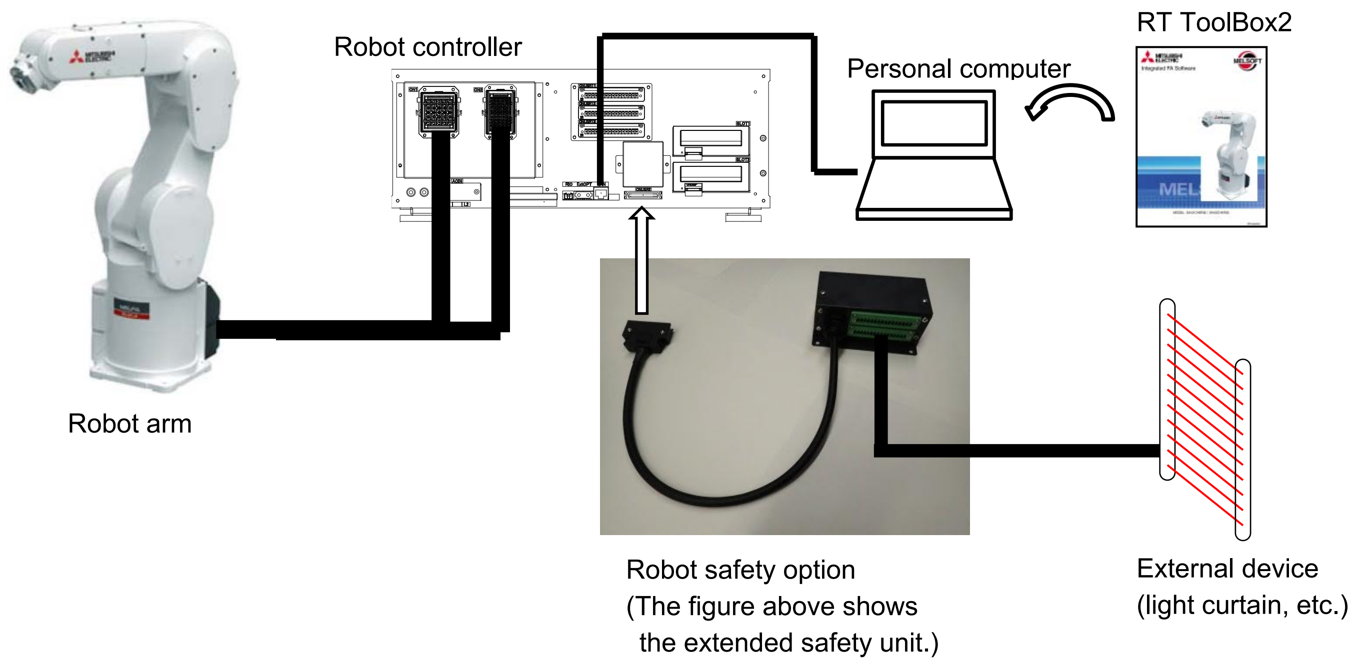


Fig.1-1 System configuration

Table 1-1 System configuration

Item	Details		Remarks
Robot arm	Vertical multiple-joint type RV-F series	RV-2F, RV-4F, RV-4FL, RV-4FJL, RV-7F, RV-7FL, RV-7FLL, RV-13F, RV-13FL, RV-20F	Additional axes and user mechanisms are not included in the system.
	Horizontal multiple-joint type RH-F series	RH-3FH, RH-6FH, RH-12FH, RH-20FH, RH-3FHR, RH-1FHR	
Robot controller	CR750-Q/CR751-Q	Ver.R6 or later(*)	
	CR750-D/CR751-D	Ver.S6 or later(*)	
MELSOFT RT ToolBox2	3D-11C-WINJ 3D-11C-WINE	Ver.3.30G or later(*)	Install the software to a personal computer. The software is used to enable the safety monitoring function. Separate purchase is required.
MELSOFT RT ToolBox2 mini	3D-12C-WINJ 3D-12C-WINE	Ver.3.30G or later(*)	
Robot safety option	4F-SF001-01		The option explained in this instruction manual.
External device	Light curtain, safety switch, etc.		To be prepared by the customer according to the system configuration.

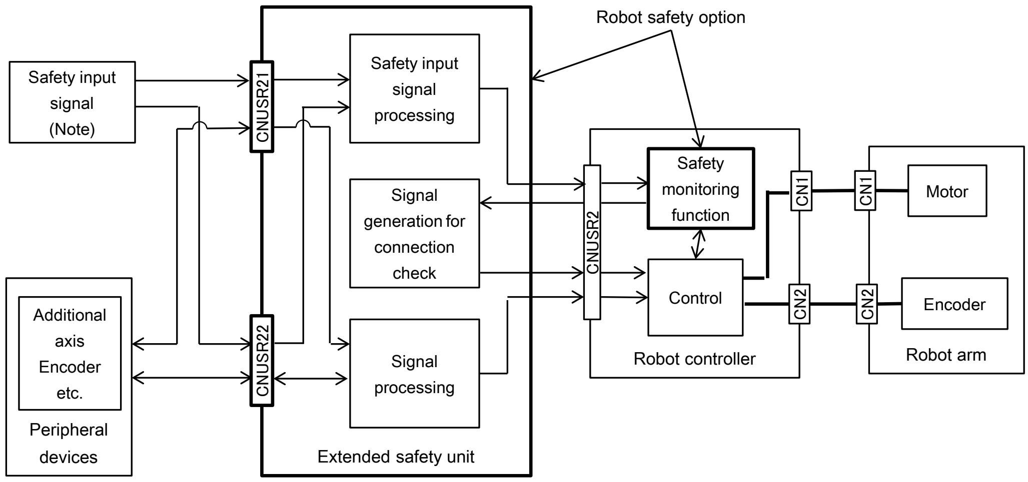
(*) Refer to “1.2.1 Combination of software version.”

1.2.1 Combination of software version

Depending on the combination of versions of Robot Controller and RT ToolBox2, features are partially modified or added in the safety monitoring function. In this document, the combination is described as shown in the following table.

Software Version Combination		Description in this document
Robot Controller	RT ToolBox2 / RT ToolBox2 mini	
Ver.R6b or later(CR750-Q/CR751-Q) Ver.S6b or later (CR750-D/CR751-D)	Ver.3.40S or later	Version Combination B
Combination except for "Version Combination B"		Version Combination A

1.3 Functional block diagram



Note: Safety switch, light curtain, etc.

Fig. 1-2 Functional Block Diagram

1.4 Specifications

Table 1-2 List of specifications

Item			Details	Remarks
Safety function	STO		The function to electrically block the driving energy to the motor of the robot arm	Corresponds to stop category 0 of IEC 60204-1
	SS1		The function to control the motor speed of the robot to decelerate	Corresponds to stop category 1 of IEC 60204-1
	SLS		The function to monitor whether the TCP speed does not exceed the monitoring speed	EN61800-5-2 compliant
	SLP		The function to monitor whether a fixed monitoring position does not exceed the position monitoring plane	EN61800-5-2 compliant
	STR		The function to monitor whether the torque feedback does not exceed the allowable torque width	EN61800-5-2 compliant
Safety performance	Related standart		ENISO10218-1(2011) EN62061(2006) ENISO13849-1(2008) IEC61508 (2010) EN61800-5-1 , EN61800-5-2 IEC61326-3-1 ,EN60204	
	Performance		SIL 2,　Category 3　PL d	
	Mean time to the occurrence of a dangerous failure		MTTFd ≧ 100 [year]	
	Diagnostic coverage		DC≧90[%]	
	Average probability of dangerous failure per hour	SLS,SLP	PFH = 3.37×10-7 [1/h]	
		STR	PFH = 3.48×10-7 [1/h]	
		STO	PFH = 3.84×10-8 [1/h]	
Extended safety unit	Structure (IP rating)		IP20	
	Environment	Operating temperature range	0 to 40°C	It must be kept away from heat appliances and other heat sources.
		Relative humidity	45 to 85%	Non-condensing
		Vibration	During transportation: 34 m/s^2 During operation: 5 m/s^2 or lower	
		Atmosphere	No corrosive gas / flammable gas / oil mist / dust	
		Installation environment	Indoors. Place where no intense electromagnetic is generated. No roughness or tilt on the installation surface.	No direct sunlight Do not install the unit on surfaces with high roughness.
	Input signal	Dedicated stop input (SKIP)	One channel	The function is installed to the robot controller as standard.
		Encoder input for tracking	For one robot	The function is installed to the robot controller as standard.
		Safety input	Two channels (duplex)	It is a unique signal for the robot safety option.
	Output signal	Contactor control output for the additional axis	2 bits	The function is installed to the robot controller as standard.
		Robot error output	2 bits	The function is installed to the robot controller as standard.
	Mass		About 600 g	Mass of the extended safety unit

1.5 Risk assessment

To ensure safety, the user needs to assess all the risks and determines residual risks for the mechanical system as a whole. Companies or individuals who configure the system will accept full responsibility for installation and authorization of the safety system. Assessment for all risks and safety level certification are required for the equipment/system as a whole. The following shows residual risks related to the safety monitoring function of this product.

1.5.1 Residual risks (common)

(1) If the origin settings or parameter settings or programs of a robot controller are incorrect, unexpected operation may occur and safety cannot be ensured. Fully check whether operations are as intended.
(2) Until correct installation, wiring, and adjustment are achieved, safety cannot be ensured.
(3) Only a qualified person is given the authority to install, start, repair, adjust, etc. the equipment to which devices are installed. Installing or operating the equipment should be done by a trained engineer.
(4) For the safety monitoring function, perform the wiring separately from other signal wirings.
(5) Protect cables by appropriate means (installing inside the control panel, using a cable guard, etc.).
(6) It is recommended to use switches, relays, sensors, etc. conforming to safety standards. For using switches, relays, sensors, etc. not conforming to safety standards, sufficient verification of safety is necessary on the customer side.
(7) The safety functions targets only the Robot controller and the robot arm.The safety functions not contain the additional axis (robot additional axis and user mechanism). When the customer uses the additional axis, the customer shall do ensure and the evaluation of the safety of the additional axis and the robot.
(8) In order to diagnose the failure of the controller, at least once every six months, please turn off the robot controller’s power. The controller executes the fault diagnosis of the hardware when the power is turned on.

1.5.2 Residual risk (for each function)

(1) STO function

This function interrupts transmission of power to the motor installed in the robot arm, and may bring variation to a posture of robot arms due to mechanical factors, such as break of timing belts or brake wear, etc. of the robot arm. Periodic maintenance of the robot arm is required.

(2) SS1 function

This function controls and decelerates the motor speed installed to a robot arm. The movement cannot be stopped immediately after deceleration is started.

(3) SLS function

This function monitors the TCP speed of the robot, not each part of the robot arm. Depending on the robot posture, some parts of the robot arm may move at the speed higher than the monitoring speed.
As this function is activated only when the robot servo is turned ON, this function does not monitor the TCP speed while the robot servo is turned OFF.

(4) SLP function

In the following cases, the monitoring position may exceed the position monitoring plane. The following shows some concrete examples.

- At the moment the position monitoring plane is applied, the robot position is beyond the plane.
- At the moment the position monitoring plane is applied, the robot is moving near the plane at high speed.
- The robot posture changes with the robot brake released.

(5) STR function

This function monitors the motor torque for each axis of the robot, not the power generated at each part of the robot.

(6) Duplex input monitoring function

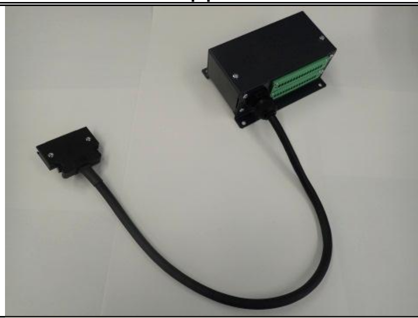
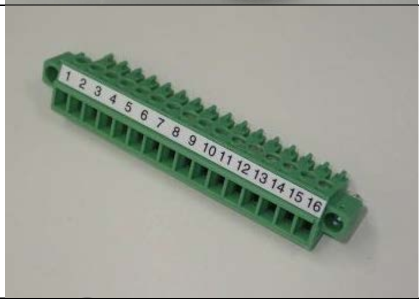
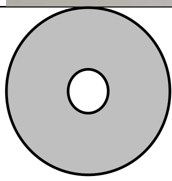
This function only monitors whether the duplexed input signals match each other, and does not detect malfunction or misconnection of the connected devices. The robot detects the mismatched signal when a signal mismatch for 0.2 seconds or more occurs.

2 Installation

2.1 Confirming the product

Please check to see if the package has all the necessary parts before use.

Table 2-1 List of items included in the package

Number	Item	Quantity	Outer appearance	Model name
1	Extended safety unit	1		U770B068G001
2	Connector for wiring	2		U770D007G51
3	Instruction manual	1	 CD-ROM	BFP-A3374

2.2 Installation and connection

⚠CAUTION Make sure the power of the robot controller is turned OFF before fixing the extended safety unit, connecting the robot controller and the extended safety unit, or installing the connector to the extended safety unit.

⚠CAUTION Please pay attention to the orientation of insertion of the connector. The connector may be broken if it is forcibly inserted in an incorrect orientation.

⚠CAUTION When an operator with static electricity installs/connects the product, the robot controller or the extended safety unit may be broken. Start the work after all the charged static electricity is removed.

2.2.1 Fixing of the extended safety unit

Fix the extended safety unit on the place with no vibration using the hole shown in the dimensional outline drawing *1 (Fig. 7-1) with a screw M4.

2.2.2 Connecting with the robot controller

Connect the cable connector installed to the extended safety unit to CNUSR2 of the robot controller.

⚠CAUTION Be careful in inserting the connector to the CR751 controller because CNUSR1 and CNUSR2 have the same shape. Inserting an incorrect connector may lead to malfunction of the controller.

(1) CR750 controller

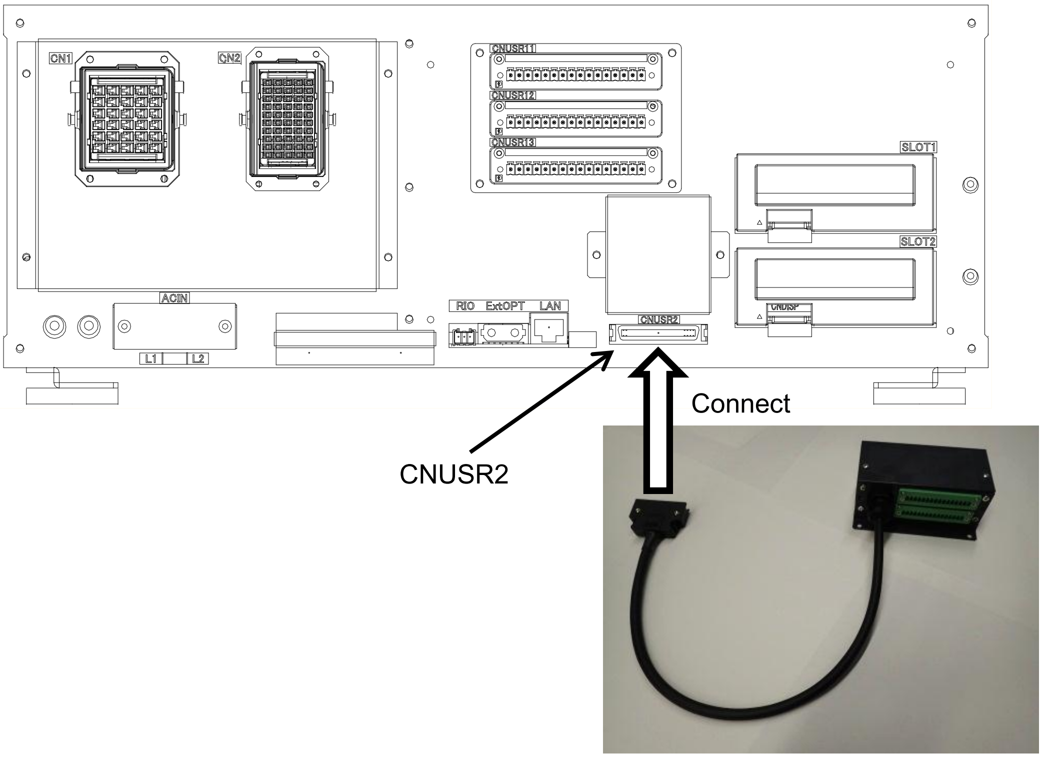
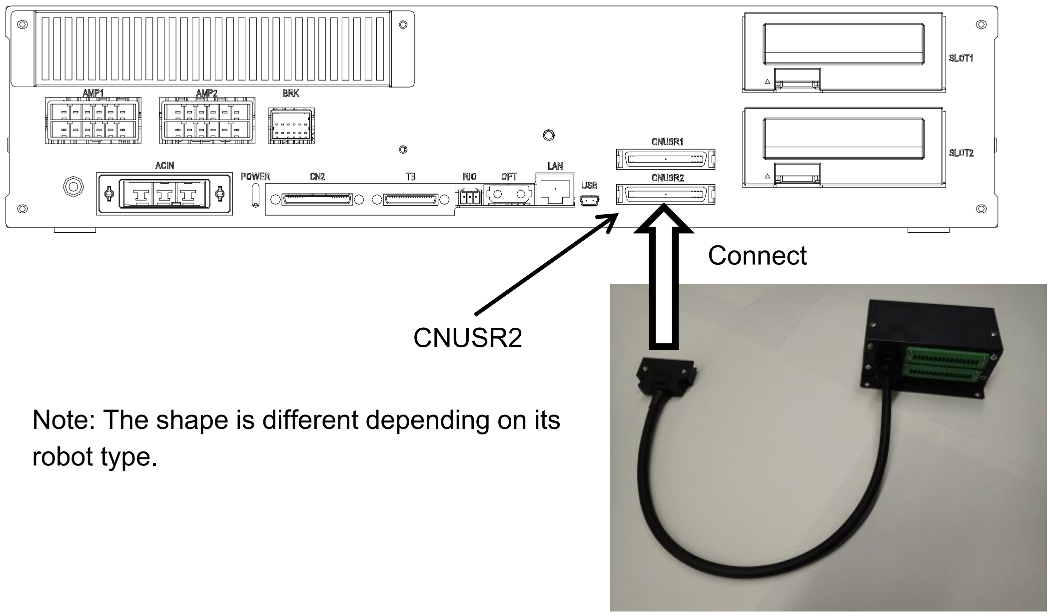


Fig. 2-1 Connection to the CR750 controller

(2) CR751 controller



Note: The shape is different depending on its robot type.

Fig. 2-2 Connection to the CR751 controller

2.2.3 Connecting cables to the wiring connector

⚠CAUTION Misconnection of the cables to the wiring connector may lead to malfunction or abnormal behavior of the robot. Be careful in connecting the cables to the wiring connector.

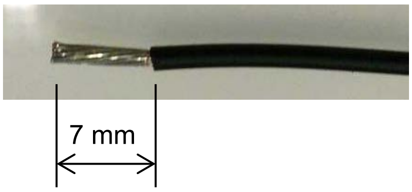
The following shows how to connect cables to the wiring connector. Use the cable of AWG#26 to 16 (0.15 to 1.5 mm^2). And also use cables with shield to avoid influence of noise.

■ Tools

DIN standard flat head screwdriver (thickness: 0.4 mm, width: 2.5 mm)

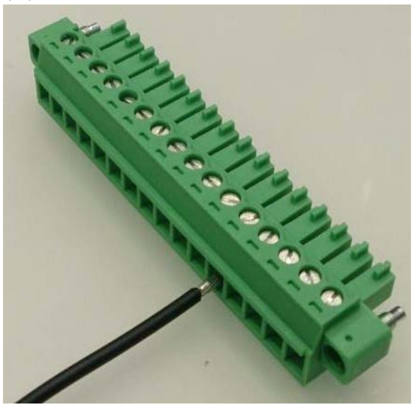
Recommended tools: SZS 0-0.4x2.5 (Phoenix contact)
SZF 0-0.4x2.5 (Phoenix contact)

(1) Strip off the sheath of the cable.

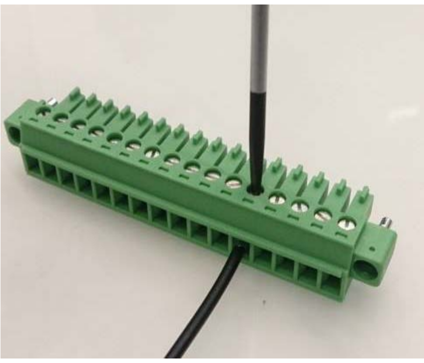


(2) Loosen the screw.

(3) Insert the cable to the insertion port.



(4) Tighten the screw.



Tightening torque: 0.22 to 0.25 Nm

2.2.4 Connecting the wiring connector to the extended safety unit

Insert the wiring connector to CNUSR21 or CNUSR22 of the extended safety unit. Tighten and fix securely two connector fixing screws mounted on the both sides of the connector using the tool used in wiring operation. (Tightening torque: 0.22 to 0.25 Nm)
After fixing is completed, refer to "4.2.5 Test operation" and perform the operation check for the signals specific to the robot safety option. For the other signals, refer to specifications / instruction manual that comes with the robot and perform the operation check.

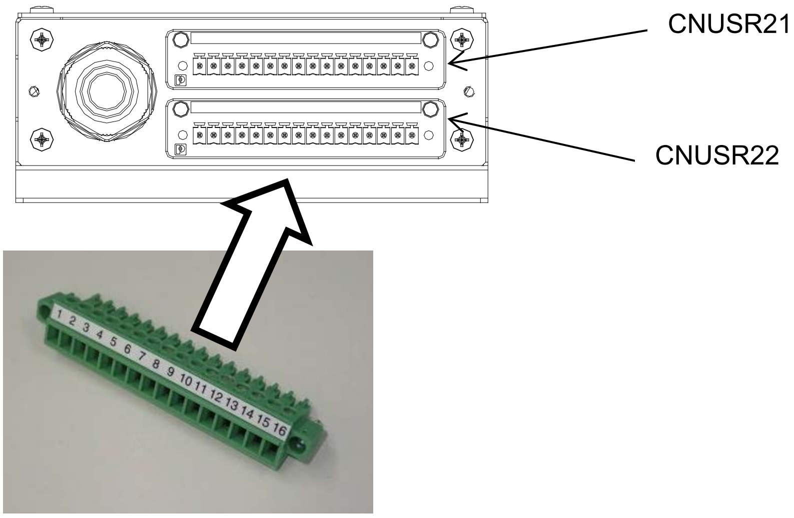


Fig. 2-3 Connecting the connector to the extended safety unit

2.3 Check items

Check the following items periodically.

(1) Make sure the connector is securely fixed to the extended safety unit.
(2) Make sure the electric wire does not come off from the wiring connector.
(3) Make sure the screw fixing the electric wire to the wiring connector is not loosened. If it is loosened, make sure the electric wire is inserted securely and retighten the screw.
(4) Make sure the screw fixing the extended safety unit is not loosened.
(5) Make sure the connector inserted to CNUSR2 is securely inserted.

2.4 Long life parts

The robot safety option does not have any long life parts.

2.5 Maintenance

In case of malfunction of the extended safety unit, the extended safety unit needs to be replaced. Please contact your service provider.

3 Signals and wiring

3.1 Description of signals

3.1.1 Electrical specifications

This manual only explains signals specific to the robot safety option. Please refer to the robot specifications for the electrical specifications of the signals not explained in this manual.

Fig. 3-1 Electrical specifications (MPI1*/MPICOM1)

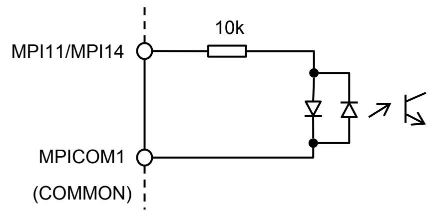
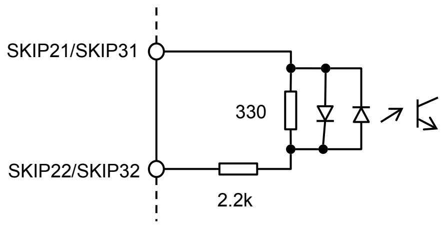
Item	Specifications	Internal circuit
Type	DC input	
Input point	2	
Insulation type	Photocoupler insulation	
Input voltage	24 V±10%	
Input resistor	About 10 kΩ	
Input current	About 2mA	
Common type	2 points / 1 common	

Fig. 3-2 Electrical specifications (SKIP*1/SKIP*2)

Item	Specifications	Internal circuit
Type	DC input	
Input point	2	
Insulation type	Photocoupler insulation	
Input voltage	24 V±10%	
Input resistor	About 2.5 kΩ	
Input current	About 9 mA	
Common type	1 point / 1 common	

3.1.2 Signal operation

DSI1/DSI2 signals are used to switch monitoring contents of the safety monitoring function. Each of the signals is duplex and the state of two input signals need to match. If the state of two input signals does not match, an error occurs.

Fig. 3-3 DSI1 operation

Input state		DSI1 state
DSI1-A (SKIP21-SKIP22)	DSI1-B (MPI11-MPICOM1)	
ON	ON	ON
OFF	OFF	OFF
ON	OFF	Error H2221 occurs. It is treated as ON in the process.
OFF	ON	Error H2221 occurs. It is treated as OFF in the process.

Fig. 3-4 DSI2 operation

Input state		DSI2 state
DSI2-A (SKIP31-SKIP32)	DSI2-B (MPI14-MPICOM1)	
ON	ON	ON
OFF	OFF	OFF
ON	OFF	Error H2222 occurs. It is treated as ON in the process.
OFF	ON	Error H2222 occurs. It is treated as OFF in the process.

3.2 Connectors and signal assignment

Fig. 3-5 Signal assignment of CNUSR21

Pin No.	Signal name	Function	Remarks
1	AXMC11	Additional axis contactor control output	The function is the standard function of the robot. For details, refer to specifications or instruction manual that comes with the robot.
2	AXMC12	Additional axis contactor control output	
3	LAH2	Differential encoder A phase signal + side CH2	
4	LBH2	Differential encoder B phase signal + side CH2	
5	LZH2	Differential encoder Z phase signal + side CH2	
6	SG	Common pin	
7	ROBOTERR11	Robot error output	
8	ROBOTERR12	Robot error output	
9	NC	Reserved	Unused
10	SKIP11	Dedicated stop input common (COM)	The function is the standard function of the robot. For details, refer to specifications or instruction manual that comes with the robot.
11	SKIP12	Dedicated stop input	
12	MPI11	Safety input CH1-B	DSI1-B
13	MPI14	Safety input CH2-B	DSI2-B
14	MPICOM1	Safety input common	Common to MPI11 and MPI14
15	NC	Reserved	Unused
16	NC	Reserved	

Fig. 3-6signal assignment of CNUSR22

Pin No.	Signal name	Function	Remarks
1	AXMC21	Additional axis contactor control output	The function is the standard function of the robot. For details, refer to specifications or instruction manual that comes with the robot.
2	AXMC22	Additional axis contactor control output	
3	LAL2	Differential encoder A phase signal - side CH2	
4	LBL2	Differential encoder B phase signal - side CH2	
5	LZL2	Differential encoder Z phase signal - side CH2	
6	SG	Common pin	
7	ROBOTERR21	Robot error output	
8	ROBOTERR22	Robot error output	
9	NC	Reserved	Unused
10	SKIP21	Safety input CH2-A	DSI1-A
11	SKIP22	Safety input common	Common to SKIP21
12	SKIP31	Safety input CH2-A	DSI2-A
13	SKIP32	Safety input common	Common to SKIP31
14	NC	Reserved	Unused
15	NC	Reserved	
16	NC	Reserved	

3.3 Input signal connection example

Fig. 3-1 shows a signal connection example. Devices to be connected depend on the user's system configuration.

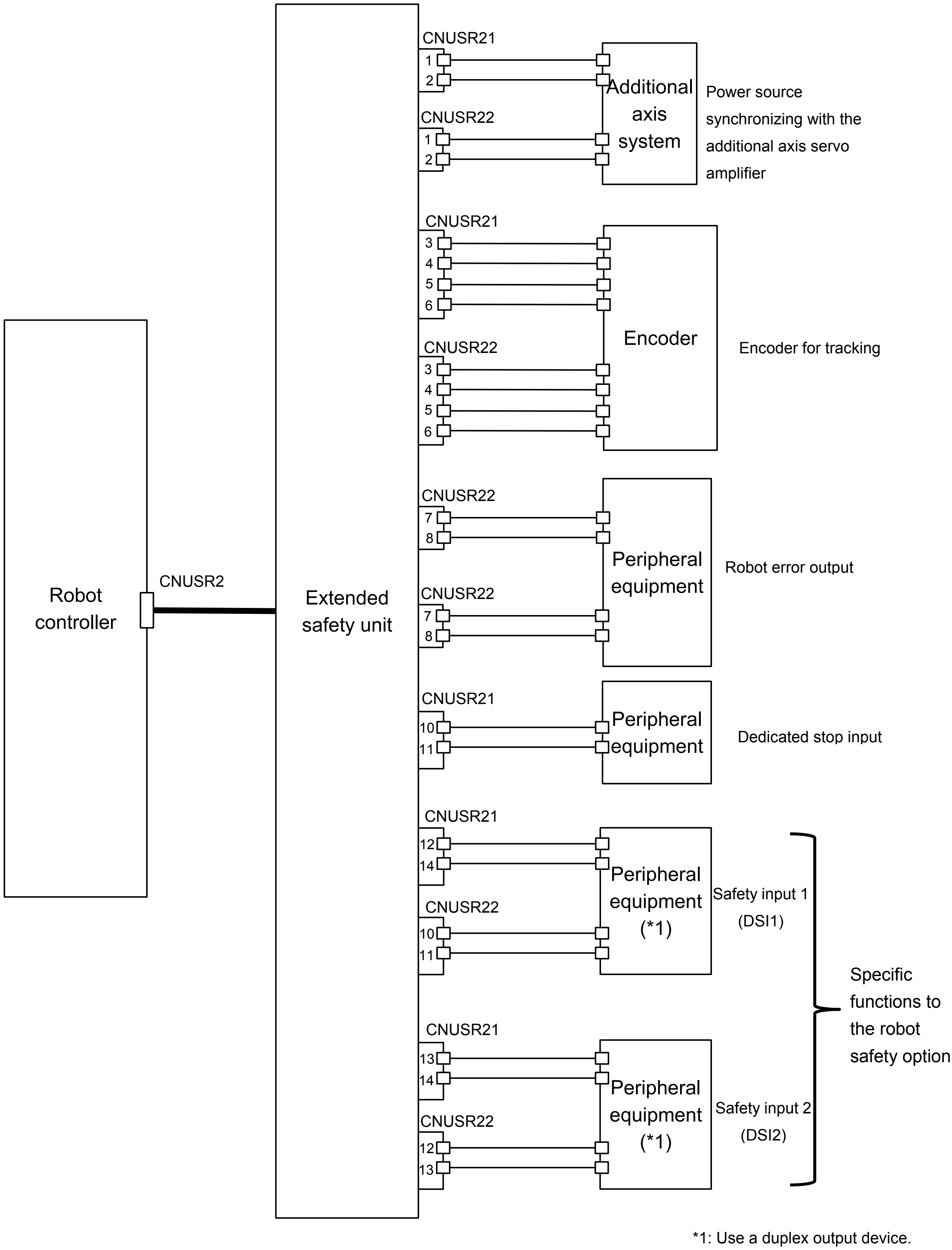


Fig. 3-2 Input signal connection example

3.4 Measures against static electricity / noise

Use a shielded wire to avoid influence of noise. Perform wiring through the shortest path so that the cable length can become shorter. In case of malfunction, etc. due to static electricity or noise, ground the extended safety unit using the terminal for grounding shown in the dimensional outline drawing *2 (Fig. 7-1). Use an M3 screw with a length of 8 mm for grounding.
An operator with static electricity should not touch CNUSR21 or CNUSR22. Malfunction may occur due to the static electricity. If there is a possibility of accidental touch, use the electrostatic protection cover shown in Fig. 3-3 to prevent accidental touching of CNUSR21 or CNUSR22. Fix the cover to the extended safety unit using the screw hole shown in Fig. 7-1 *3.
Screw to be used: M3, 6 mm long
Tightening torque: 0.63 Nm

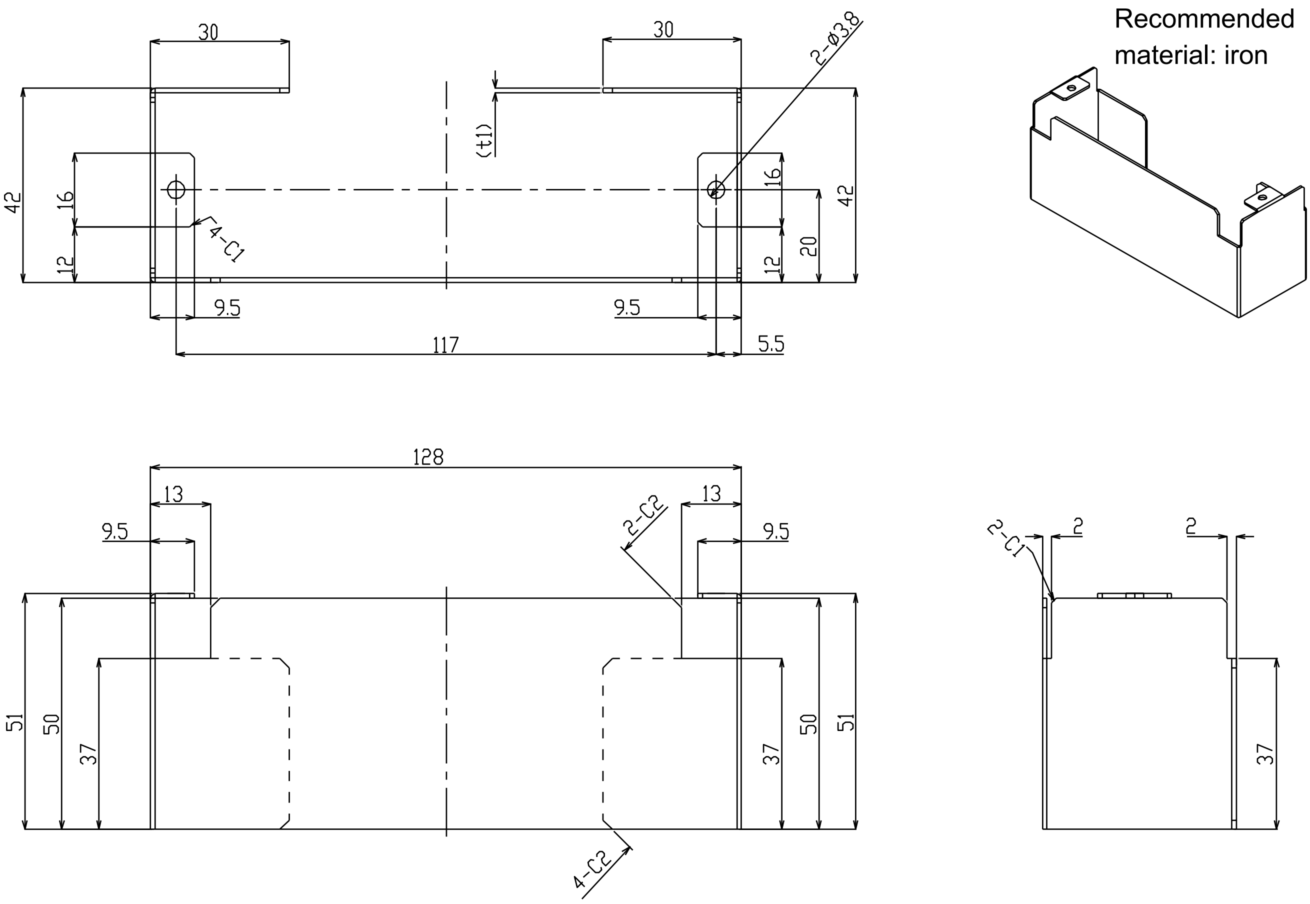


Fig. 3-3 Electrostatic protection cover

4 Safety monitoring function

4.1 Safety monitoring function overview

The following functions are available on the robot safety option.

(1) STO function(Safe torque off)
The function electrically blocks the driving energy to the motor of a robot arm.

(2) SS1 function(Safe stop 1)
The function controls and decelerates the motor speed of a robot. The STO function is executed when the stop is conformed.

(3) SLS function(Safe limited speed):Speed monitoring function
The function monitors whether the TCP speed does not exceed the monitoring speed. When it exceeds the monitoring speed, the robot generates an error and turns the servo OFF to stop.

(4) SLP function(Safe limited position):Position monitoring function
The function monitors whether the fixed position does not exceed the position monitoring plane. When it exceeds the position monitoring plane, the robot generates an error and turns the servo OFF to stop.

(5) STR function(Safe torque range):Torque width monitoring
The function monitors whether the torque feedback does not exceed the allowable torque width. When it exceeds the allowable torque width, the robot generates an error and turns the servo OFF to stop.

(6) Duplex input monitoring function
The system monitors whether the status of the duplex input signals is consistent. The function monitors the DSI signals, DSI1 and DSI2. When the function detects difference, the robot generates an error and turns the servo OFF to stop.

4.2 Startup

The safety monitoring function is disabled in the factory default setting. To use the safety monitoring function, refer to the following explanation and enable the function. Separately prepare RT ToolBox2 / RT ToolBox2 mini version 3.30G or later, which is required to enable the safety monitoring function.

4.2.1 Connecting RT ToolBox2

For setting the safety monitoring function, connect RT ToolBox2 to the controller and perform setting online. For information on how to connect RT ToolBox2 to the controller, refer to the separate "RT ToolBox2 / RT ToolBox2 mini Instruction manual".

4.2.2 Password setting

⚠CAUTION The safety monitoring function can not be used unless changing the password from the factory default setting

A password is set for the parameters related to the safety monitoring function to prevent unintended change of the setting. To use the safety monitoring function, change the factory default password to new one at first.
(To confirm the parameter setting, the password is not required.)

(1) Factory default password

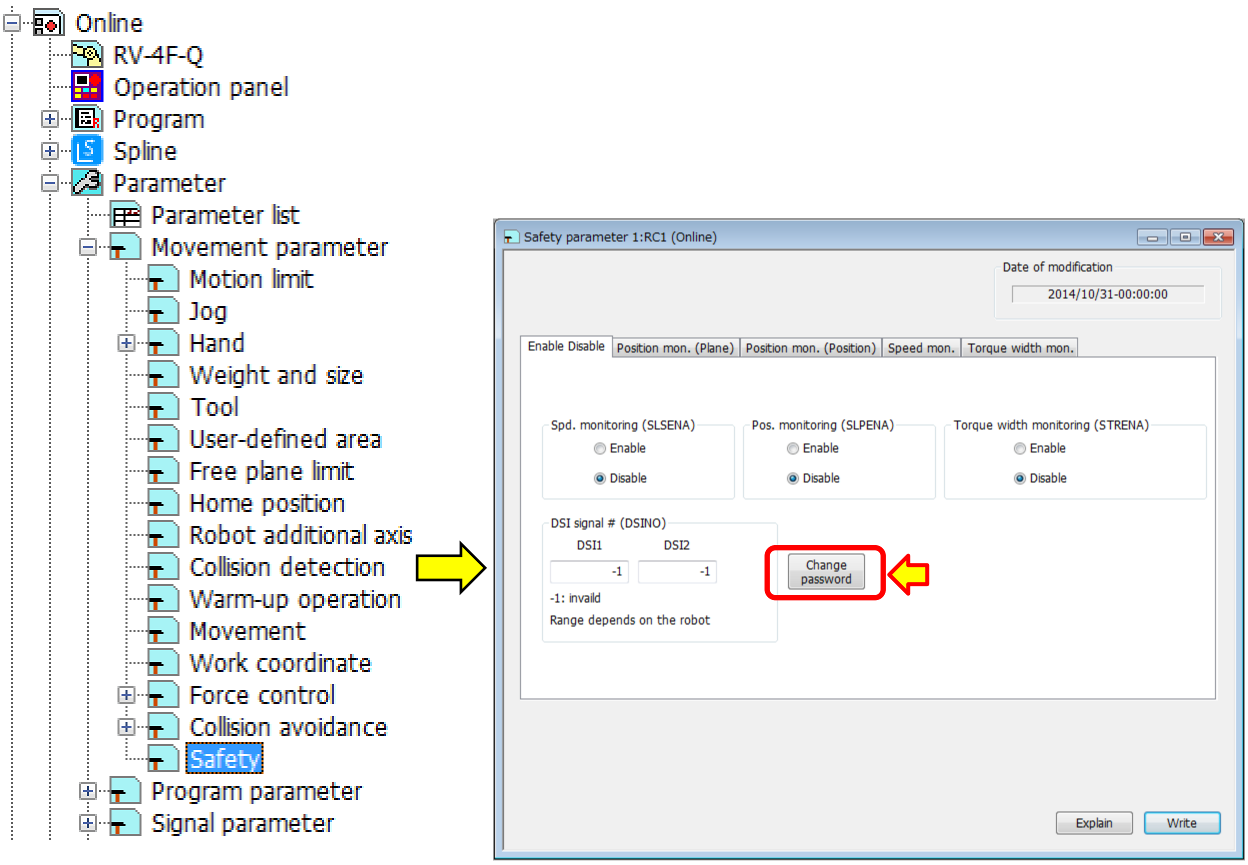
The factory default password is "MELFASafetyPSWD". Unless the password is changed, error L7378 (Change password) occurs when a parameter change is attempted for a parameter related to the safety monitoring function, and the parameter cannot be changed.

(2) Password change

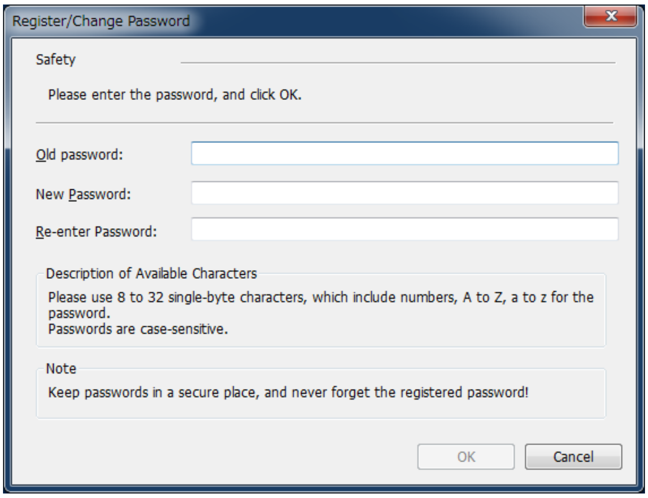
The password is changed on the RT ToolBox2 editing screen for parameters related to the safety monitoring function.

The editing screen for parameters related to the safety monitoring function is displayed by selecting [Online]→[Parameter]→[Movement parameter]→[Safety] of the workspace.

(If the robot is not compatible with the safety monitoring function, [Safety] is not displayed on the [Movement parameter] tree and the editing screen for parameters related to the safety monitoring function cannot be displayed.)



Press the [Change password] button on the bottom of the editing screen for parameters related to the safety monitoring function to display [Register/Change Password]. Enter new and old passwords and change the password.



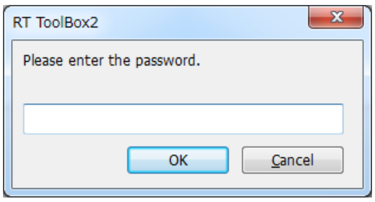
Use 8 to 32 single-byte characters for the password. Available characters are alphanumeric characters (0 to 9, A to Z, and a to z), and they are case-sensitive.

⚠CAUTION If you forget the password, parameters related to the safety monitoring function cannot be changed. Never forget the registered password. If you forgot the password, the memory in the controller needs to be initialized to the factory default setting by robot type resetting operation. For details about the robot type resetting operation, refer to the "Instruction manual/Detailed explanations of functions and operations" supplied with the robot arm.

⚠CAUTION To prevent unintended change of parameters, keep passwords in a secure place without leakage of the invention to a third party.

(3) Entering password

When an attempt is made to write a parameter on the editing screen for parameters related to the safety monitoring function, the screen for entering the password appears.



Enter a correct password and press the [OK] button to write the parameter to the controller. If the password is incorrect, writing the parameter is not executed. After the error dialog is displayed, the screen for entering passwords appears again.

Entering passwords is required for the first attempt to write a parameter after the editing screen for parameters related to the safety monitoring function is displayed. When writing parameters is continued without closing the editing screen for parameters related to the safety monitoring function, it is not necessary to enter the password again.

4.2.3 Enable/disable

The safety monitoring function is disabled in the factory default setting. To use the safety monitoring function, change the setting of the target parameter to "Enable" on the RT ToolBox2 editing screen for parameters related to the safety monitoring function. Target parameters are as follows.

Safety monitoring function	Target parameter name
Speed monitoring (SLS function)	SLSENA
Position monitoring (SLP function)	SLPENA
Torque width monitoring (STR function)	STRENA
DSI signal	DSINO

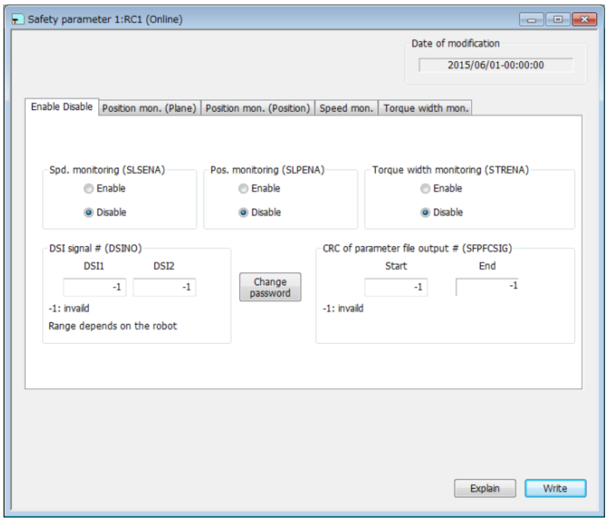
⚠CAUTION To enable the safety monitoring function, connect the extended safety unit to the CNUSR2 connector of the controller in advance. If the safety monitoring function is enabled without connecting the extended safety unit, error H2260 (No extended safety unit) occurs.

⚠CAUTION When the origin of the robot is not set, the safety monitoring function cannot be activated even when the function is enabled. Set the origin of the robot before enabling the safety monitoring function.

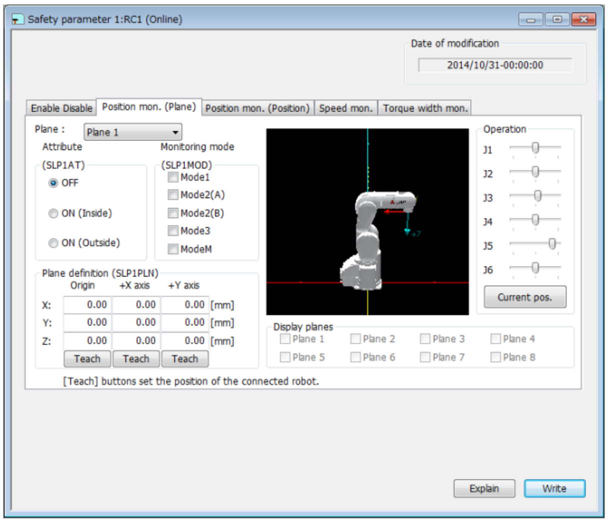
4.2.4 Parameter setting

Set the parameters related to the safety monitor function on the RT ToolBox2 editing screen for parameters related to the safety monitoring function.

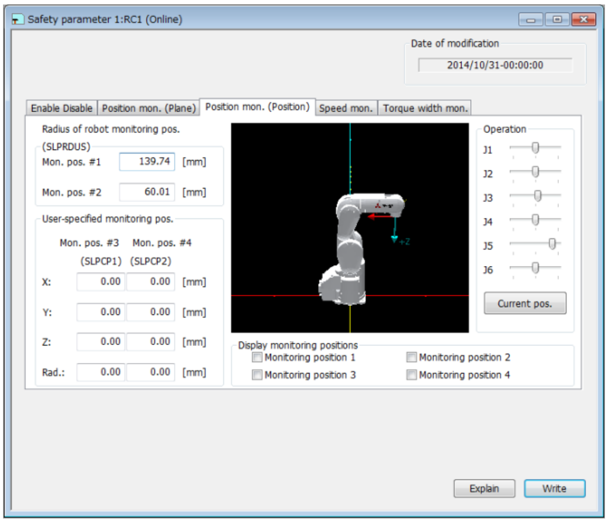
(1) Editing screen for parameters related to the safety monitoring function
The editing screen for parameters related to the safety monitoring function is displayed by selecting [Online]→[Parameter]→[Movement parameter]→[Safety] of the workspace. The setting of the parameters related to the safety monitoring function can be confirmed/changed on this screen.
Parameters are classified under five tabs as shown below. When a parameter setting is changed and the tab change is attempted before writing the parameter to the controller, the dialog for attracting attention appears.



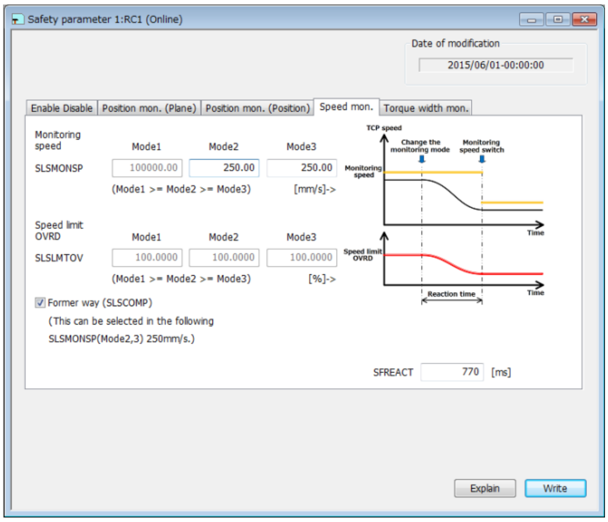
Enable/disable setting (*)



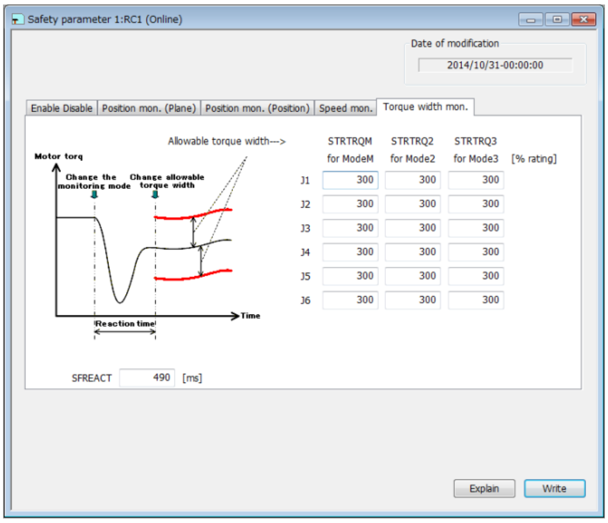
Position monitoring (plane) setting



Position monitoring (position) setting



Speed monitoring setting(*)



Torque width monitoring setting

(*) These samples show the images in the case of "Version Combination B" for the robot controller and RT ToolBox2.

Fig. 4-1 Parameter editing screen for the parameters related to the safety monitoring function

⚠CAUTION The setting of the parameters displayed on the editing screen for parameters related to the safety monitoring function can be confirmed or changed only through this screen. The setting cannot be confirmed or changed on the parameter list screen of RT ToolBox2 or the parameter editing screen of the teaching pendant.

(2) Parameter setting procedure

Set the parameter in the following steps.

Connecting RT ToolBox2	Connect RT ToolBox2 to the controller and put it in the online state.
Parameter setting	Display the editing screen for parameters related to the safety monitoring function, and set each parameter. Enter the password when you write the setting to the controller.
Parameter verification	Read each parameter and confirm that it is set correctly.
Turn ON the power supply again	The parameter setting takes effect after the power supply of the controller is turned OFF once, and then turned ON again.

4.2.5 Test operation

(1) Debugging operation

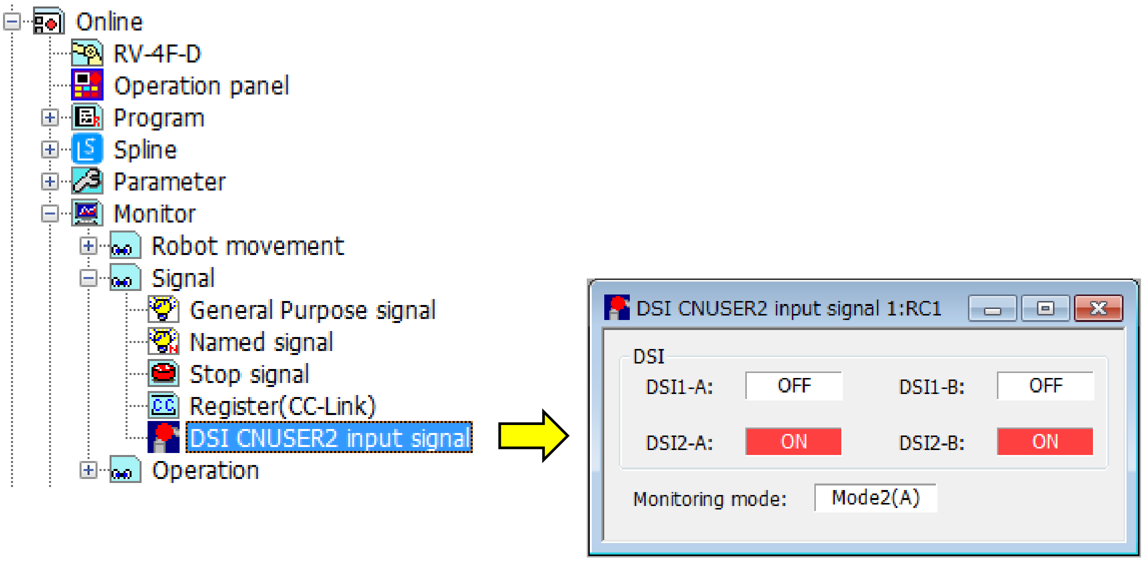
Perform the debugging operation (step feed, etc.) to confirm if the created program operates correctly. (For the debugging operation, refer to the separate "Instruction manual/Detailed explanations of functions and operations" supplied with the robot arm.)

The safety monitoring function is effective during the debugging operation too. However, note that the robot operation speed or monitoring state of the safety monitoring function may differ from its actual operation.

(2) Confirmation of DSI signal

The input state of DSI signal can be confirmed on the "DSI CNUSER2 input signal" screen of RT2 ToolBox2. Input the DSI signal individually from the peripheral devices and test to see if ON/OFF state of the signal or wiring is correct.

The "DSI CNUSER2 input signal" screen is displayed by selecting [Online]→[Monitor]→[Signal]→[DSI CNUSER2 input signal] of the workspace.



4.3 Safety monitoring function

4.3.1 Monitoring mode

(1) Overview
The monitoring mode defines the details of monitoring for the safety monitoring function (SLS/SLP/STR). Specify the mode using the controller mode and the DSI signals.

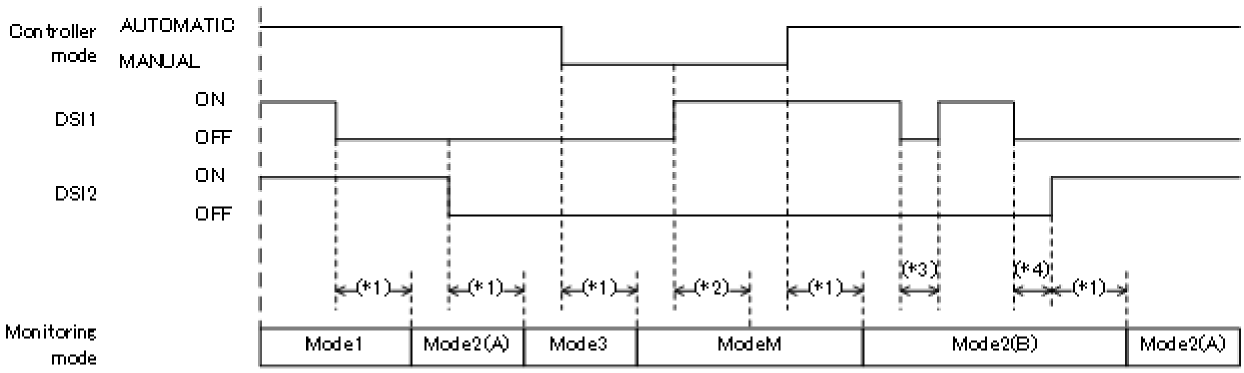
(2) Specifying the monitoring mode
The monitoring mode is specified by a state of the controller mode (AUTOMATIC/MANUAL) and ON/OFF of the DSI signals. The correspondence of the state of the controller mode and DSI signals to the monitoring mode is specified as shown below.

Table 4-1 Correspondence of the state of the controller mode and DSI signals to the monitoring mode

Monitoring mode		Controller mode	DSI signal	
			DSI1	DSI2
Mode 1		AUTOMATIC	ON	ON
			ON	Disable *1)
			Disable *1)	ON
			Disable *1)	Disable *1)
Mode 2	Mode 2 (A)		OFF	ON
			OFF	Disable *1)
	Mode 2 (B)		ON	OFF
			Disable *1)	OFF
Mode 3			OFF	OFF
Mode M		MANUAL	- *2)	- *2)

*1) When "-1" is specified for the input signal number of DSI signal, the DSI signal is disabled.
*2) When the controller mode is set to MANUAL, the state of DSI signals are not referred to.

The following illustration shows an example of monitoring mode changes due to the state changes of the controller mode and DSI signals.



(*1) After the state of the controller mode and a DSI signal changes and the reaction time specified by the parameter SFREACT passes, the monitoring mode is changed to the specified one.
(*2) When the controller mode is set to MANUAL, the monitoring mode is not changed from Mode M even if the state of DSI signal changes and the reaction time passes.
(*3) When the state of a DSI signal changes and returns to the former state before the reaction time passes, the monitoring mode is not changed.
(*4) When the state of a DSI signal changes and another DSI signal changes before the reaction time passes, the elapsed time until then is reset, and the monitoring mode is changed after the new reaction time passes.

(3) Switching the monitoring content by the monitoring mode
The monitoring content of SLS function/SLP function/STR function is switched according to the monitoring mode as shown below.

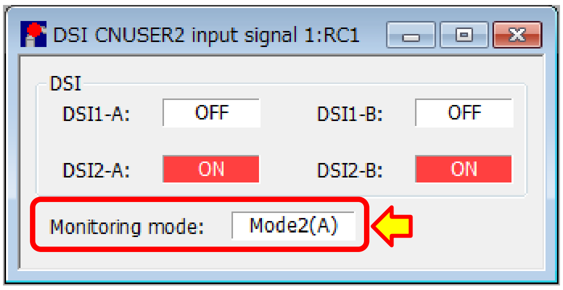
Table 4-2 Correspondence of the monitoring mode to the contents of monitoring

Monitoring mode		SLS function		SLP function	STR function
		Version Combination A	Version Combination B		
Mode 1		No speed monitoring	Monitors the speed in the setting value of the first element in the parameter “SLSMONSP”	Monitors the position in the plane where Mode 1 is specified as the applicable monitoring mode in parameter SLPnMOD (n = 1 to 8).	No torque width monitoring
Mode 2	Mode 2(A)	Monitors the speed in the setting value of the first element in the parameter SLSSPD	Monitors the speed in the setting value of the second element in the parameter “SLSMONSP”	Monitors the position in the plane where Mode 2(A) is specified as the applicable monitoring mode in parameter SLPnMOD.	Monitors the torque width using the setting value of parameter STRTRQ2.
	Mode 2(B)			Monitors the position in the plane where Mode 2(B) is specified as the applicable monitoring mode in parameter SLPnMOD.	
Mode 3		Monitors the speed in the setting value of the second element in the parameter SLSSPD.	Monitors the speed in the setting value of the third element in the parameter “SLSMONSP”	Monitors the position in the plane where Mode 3 is specified as the applicable monitoring mode in parameter SLPnMOD.	Monitors the torque width using the setting value of parameter STRTRQ3.
Mode M		Monitors the speed in the setting value of the parameter JOGSPMX.		Monitors the position in the plane where Mode M is specified as the applicable monitoring mode in parameter SLPnMOD.	Monitors the torque width using the setting value of parameter STRTRQM.

The distinction between (A) and (B) for Mode 2 applies to SLP function only. It does not apply to SLS function and STR function.

(4) How to confirm the monitoring mode
The state of the monitoring mode is confirmed in the following way.

(a) Signal monitor screen
The current state of the monitoring mode is displayed on the "DSI CNUSER2 input signal" screen of RT ToolBox2.



(b) Dedicated output signal
The state of the monitoring mode can be output to the dedicated output signal SFMODE. The following table shows the correspondence of the output signal value to the state of the monitoring mode.

Safety monitoring function	Monitoring mode	Value of dedicated output signal SFMODE
Enabled	Mode M	1
	Mode 1	2
	Mode 2(A)	3
	Mode 2(B)	4
	Mode 3	5
Disabled	—	0

(c) Robot status variable
The state of the monitoring mode can be confirmed in the robot status variable M_SfMode.

M_SfMode

[Function]

The variable returns a current state of the monitoring mode for the safety monitoring function.

[Format]

```
Example) <Numerical variables> = M_SfMode
```

[Terminology]

<Numerical variables>   A current state of the monitoring mode is returned.

[Reference Program]

```
M_Outb(100) = M_SfMode        'The variable outputs a current state of the monitoring mode
                              from the output signal 100 using 8-bit data.
```

[Explanation]

(1) The variable returns a current state of the monitoring mode for the safety monitoring function.
(2) The variable returns the following value depending on the state of the monitoring mode.

Safety monitoring function	Monitoring mode	M_SfMode value
Enabled	Mode M	1
	Mode 1	2
	Mode 2(A)	3
	Mode 2(B)	4
	Mode 3	5
Disabled	—	0

(3) The variable is read-only.

4.3.2 STO function

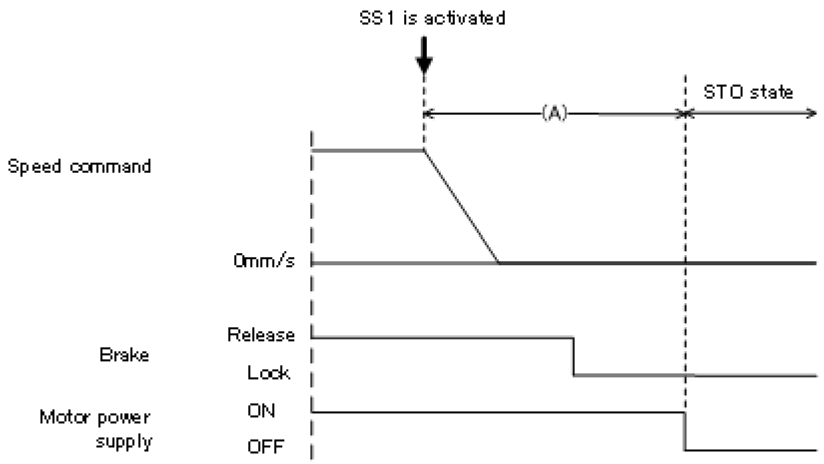
(1) Overview
Emergency stop input electrically blocks the driving energy to the motor.

(2) Sequence overview
STO function is activated by the emergency stop input. When the robot is moving, STO function starts after deceleration by SS1 function.

4.3.3 SS1 function

(1) Overview
During the robot operation, the function starts the deceleration by the emergency stop input or when an H level error occurs. After the speed command becomes zero, the STO function is executed.

(2) Sequence overview
The operation sequence of the SS1 function is as follows. The SS1 function is activated when one of the following situations occurs during the robot operation.
・Input the emergency stop.
・An H level error occurs.
When the SS1 function is activated, the deceleration starts at the designated deceleration speed. After the speed command becomes zero, the brake is locked and the power supply to the servo motor is blocked.



For the value of the elapsed time and the motion angle until the power supply to the motor is blocked after SS1 function is activated, please refer to “8 Maximum elapsed time/maximum motion angle”.

4.3.4 SLS function (Speed monitoring function)

The behavior of SLS function depends on the version combination, “Version Combination A” or “Version Combination B” for the software version on the controller and RT ToolBox2.

Table 4-1 Differences in the SLS function dependent on the version combination

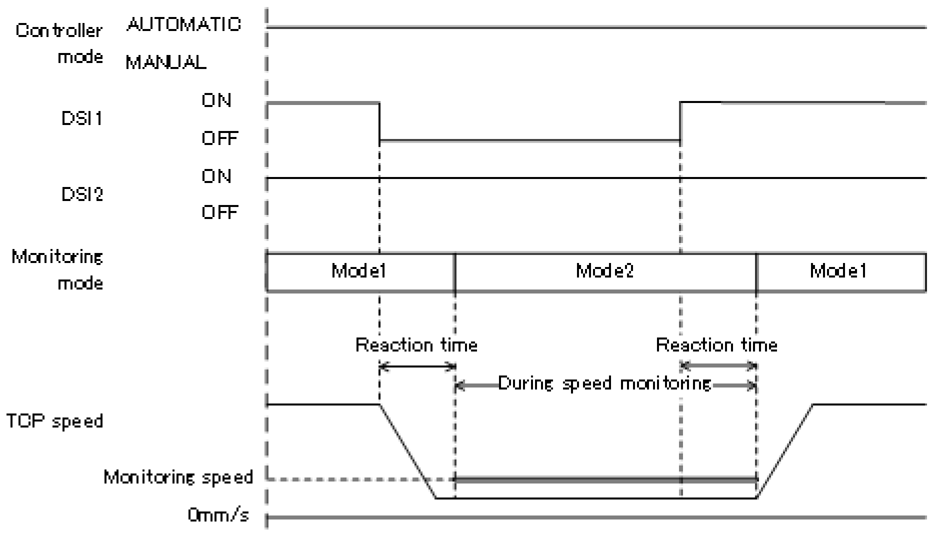
Item	Version Combination A	Version Combination B
Behavior in Mode 1	Speed Monitoring is not performed.	Speed Monitoring is performed.
Setting range of monitoring speed	Speed above 250mm/s cannot be specified.	Speed above 250mm/s can be specified.
Operation speed restriction	Operation speed is restricted in accordance with the setting value of monitoring speed.	The behavior does not depend on the monitoring speed. Specify the speed limit OVRD (parameter SLSMTOV) for restricting the operation speed.

Please note that even if the software combination corresponds to the “Version Combination B” in your system, this function can be operated in the equivalent behavior as in the “Version Combination A”.

4.3.4.1 SLS function in the “Version Combination A”

(1) Overview
The function specifies the monitoring speed for the robot TCP speed to restrain the speed command below the monitoring speed, and monitors the actual TCP speed (command/feedback) does not exceed the monitoring speed. If the actual TCP speed exceeds the monitoring speed, error H2300 (detected by the speed feedback) or H2310 (detected by the speed command) occurs and the robot turns the servo OFF to stop.

(2) Starting the SLS function
The SLS function is activated when the monitoring mode is switched from Mode 1 to Mode 2/3/M.
For example, the speed monitoring is started when the DSI1 signal is turned OFF and the monitoring mode is switched from Mode 1 to Mode 2 after the reaction time passes. During the speed monitoring, the function monitors the TCP speed to see if it is below the monitoring speed. When the DSI1 signal is turned ON, the monitoring mode returns to Mode 1 and the speed monitoring is ended after the reaction time passes.



⚠CAUTION If the reaction time is changed by the parameter SFREACT, the time required for the deceleration of the robot when the monitoring mode is switched does not change. Therefore, if the reaction time is shorter, an error may occur because the deceleration of the robot is not completed when the monitoring speed is switched depending on the operation.

(3) Switching the monitoring speed

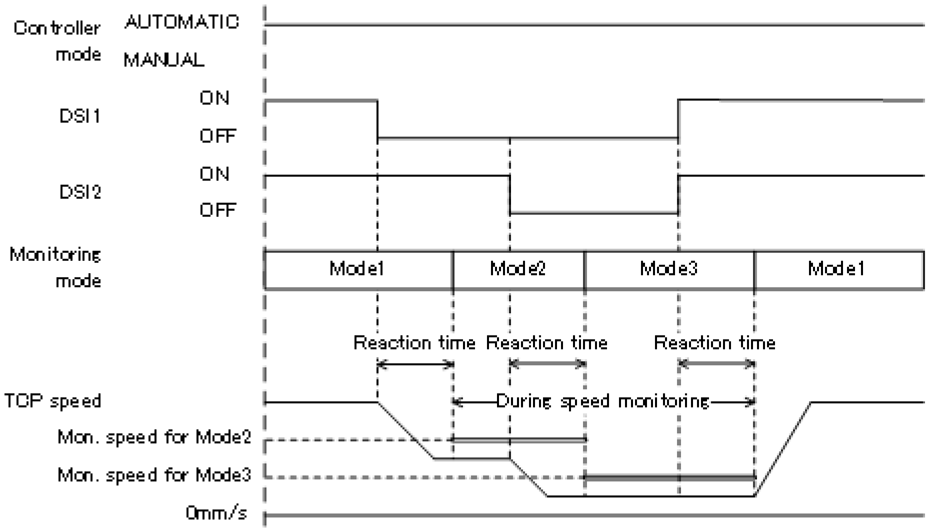
The monitoring speed can be set for each monitoring mode. When the monitoring mode is switched, the monitoring speed is switched accordingly. Set the monitoring speed in the parameter SLSSPD and JOGSPMX.

Monitoring mode	Monitoring speed setting parameter
Mode 2	SLSSPD 1st element
Mode 3	SLSSPD 2nd element
Mode M	JOGSPMX

Besides, the Mode 2 and Mode 3 should satisfy the following conditions.

(Mode 2 monitoring speed) ≥ (Mode 3 monitoring speed)

The following shows the situation of monitoring speed by switching the monitoring speed.
When the DSI1 signal is turned OFF and the monitoring mode is switched from Mode 1 to Mode 2, the speed monitoring at the monitoring speed for Mode 2 is started. After that, when the DSI2 signal is turned OFF and the monitoring mode is switched to Mode 3, the monitoring speed is switched to the monitoring speed for Mode 3 and the speed monitoring is continued.

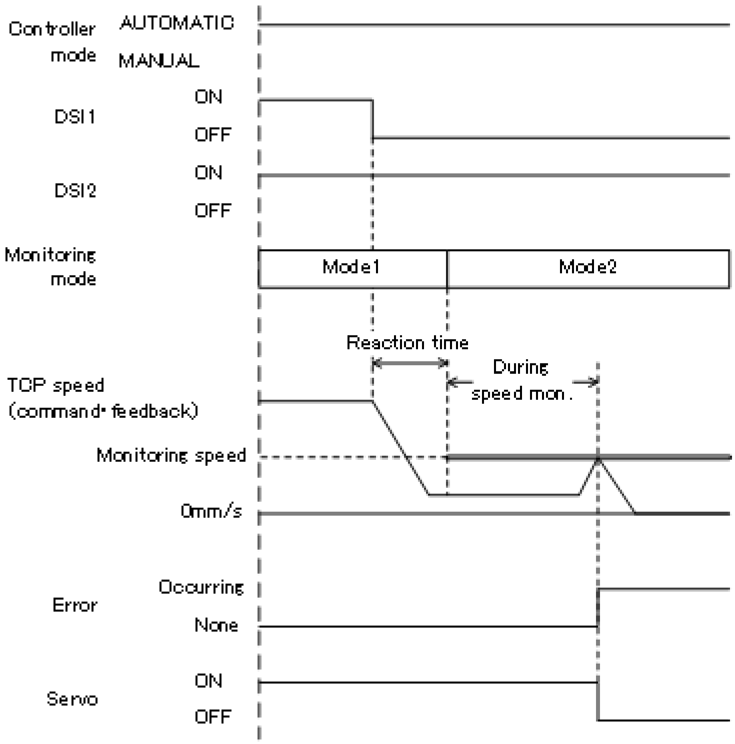


⚠CAUTION Switching the monitoring mode may lead to the change in motion speed of the robot. Be careful in changing the monitoring mode.

(4) Speed monitoring

(a) Monitoring the speed command / speed feedback

The function monitors the speed command / speed feedback to see if it does not exceed the monitoring speed during the speed monitoring. If the function detects the speed command or speed feedback exceeds the monitoring speed, error H2300 (detected by the speed feedback) or H2310 (detected by the speed command) occurs and the robot turns the servo OFF to stop.



⚠CAUTION While the robot servo is turned OFF, the speed monitoring is not performed even if the monitoring mode is Mode 2, Mode 3, or Mode M.

(b) Restricting the operation speed

The function restricts the speed of the movement performed by the interpolation command or the jog operation so that the TCP speed may not exceed the monitoring speed during the speed monitoring.

Even if the speed exceeding the monitoring speed is specified by the Spd command, in the override setting, or as the jog feed speed, the robot moves so that the speed may not exceed the monitoring speed.

⚠CAUTION Restriction on the commanded speed is effective for the movement speed set by the interpolation command or for the jog operation. The restriction is not effective for the correction speed generated by the compliance control, force sense control, or tracking function.

Therefore, when the speed monitoring is started while these functions are executed, an error may occur depending on the settings of the operation content or monitoring speed.

⚠CAUTION The movement speed under real-time external control (Mxt command) is not restricted. Correct the commanded position according to the monitoring speed on the commanded position generation side.

4.3.4.2 SLS function in the “Version Combination B”

(1) Selection of speed monitoring method

Even if the software version combination of the controller and RT ToolBox2 corresponds to the “Version Combination B”, by setting the parameter SLSCOMP, the SLS function equivalent to the “Version Combination A” can be selected. In such a case, the parameter for specifying the monitoring speed in mode 2/3 is different. In the “Version Combination B”, the parameter SLSSPD should not be used, but the parameter SLSMONSP should be used instead.

Monitoring mode	Specification of the monitoring speed	
	Version Combination A	Version Combination B
Mode 2	The first element in SLSSPD	The second element in SLSMONSP
Mode 3	The second element in SLSSPD	The third element in SLSMONSP

For the details of function, refer to “4.3.4.1 “SLS function in the “Version Combination A”.

(2) Overview

Specifying the monitoring speed for the TCP speed of robot, this function monitors to see if the actual TCP speed (command, feedback) does not exceed the monitoring speed. In the case TCP speed exceeds the monitoring speed, the error H2300(detected to the speed feedback) / H2310(detected to the speed command) occurs, and the robot stops after turning the servo off.

(3) Starting the SLS function

SLS function starts operation by enabling the function in the parameter SLSENA. Speed monitoring is performed in all monitoring modes.

(4) Switching the monitoring speed/speed limit OVRD

Monitoring speed can be set for each monitoring mode. By switching the monitoring mode, in accordance with the mode change, monitoring speed is also switched. Monitoring speed is set to the parameter SLSMONSP, JOGSPMX.

Monitoring mode	Parameter for setting the monitoring speed
Mode 1	The first element in SLSMONSP
Mode 2	The second element in SLSMONSP
Mode 3	The third element in SLSMONSP
Mode M	JOGSPMX

In addition, please note that the monitoring speed settings for mode 1, mode 2 and mode 3 should satisfy the following condition.

(Monitoring Speed for mode 1) ≥ (Monitoring Speed for mode 2) ≥ (Monitoring Speed for mode 3)

For restricting the motion speed in accordance with the monitoring mode, set the speed limit OVRD.
When the speed limit function is enabled, speed limit OVRD has an effect on the operation speed of robot as shown in the following equation.

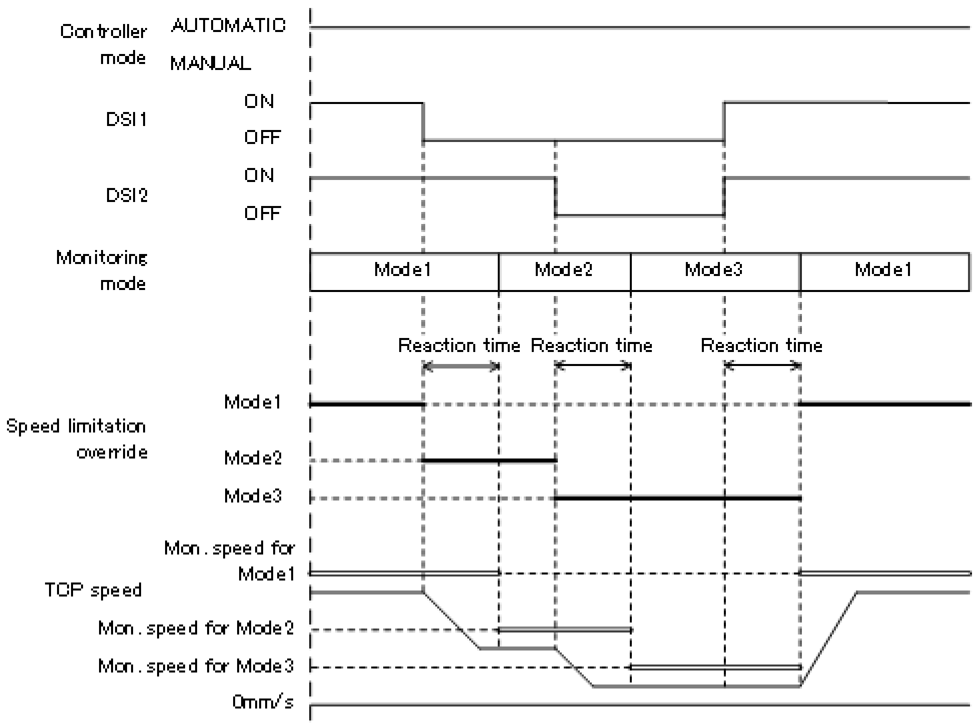
Robot operation speed = (Commanded speed in the program, etc.)x(Speed Limit OVRD[%])/100

Speed limit override is set to the parameter SLSLMTOV.

Monitoring mode	Parameters for setting the speed limit OVRD
Mode 1	The first element in SLSLMTOV
Mode 2	The second element in SLSLMTOV
Mode 3	The third element in SLSLMTOV

In addition, please note that the following condition must be satisfied for speed limit OVRD settings in mode 1, mode 2 and mode 3.
(Speed limit OVRD in mode 1) ≥ (Speed limit OVRD in mode 2) ≥ (Speed limit OVRD in mode 3)

The following chart shows the behavior of monitoring speed and speed limit OVRD dependent on transition of monitoring mode.
In the state monitoring mode is selected as mode1, if the DSI1 signal is turned off, then mode 2 speed limit OVRD is applied. After the reaction time is elapsed, if the mode is switched to mode 2, then the speed monitoring operation is performed with the mode 2 monitoring speed. After then, if the DSI2 signal is turned off, mode 3 speed limit OVRD is applied, and when the mode is switched to mode 3, the monitoring speed is switched to the mode 3 monitoring speed and speed monitoring operation continues.



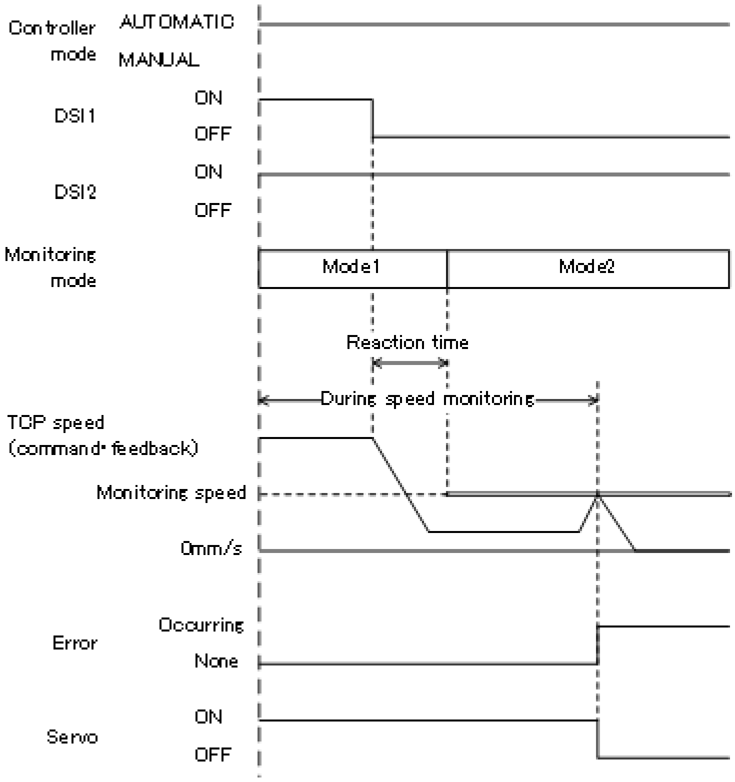
⚠CAUTION Even if the reaction time is changed by setting SFREACT, the time required for deceleration of robot operation speed when the monitoring mode is switched does not change. Therefore, if the reaction time setting is too short, in some motion patterns, because the deceleration of robot may not be completed when the monitoring speed is changed, error may occur.

⚠CAUTION Switching monitoring mode may cause the change of robot operation speed.
Be careful in changing the monitoring mode.

(5) Speed Monitoring

(a) Monitoring speed command/speed feedback

During speed monitoring, this function monitors to see if the speed command/speed feedback does not exceed the monitoring speed. If the function detects the speed command or speed feedback exceeding the monitoring speed, error H2300 (detected by the speed feedback) or H2310 (detected by the speed command) occurs and the robot turns the servo OFF to stop.



⚠CAUTION While the robot servo is turned OFF, the speed monitoring is not performed.

(b) Operation speed restriction

While monitoring speed, robot operation speed during execution of interpolation commands/jog operation is restricted by speed limit OVRD. However, in the case like the speed after being applied the speed limit OVRD exceeds the monitoring speed, error H2300(detected to speed feedback) / H2310(detected to speed command) occurs and the robot turns off the servo to stop. In such a case, please revise the setting values for monitoring speed/speed limit OVRD or the speed value specified on the robot (Spd command, override, etc.) so that the errors can be avoided.

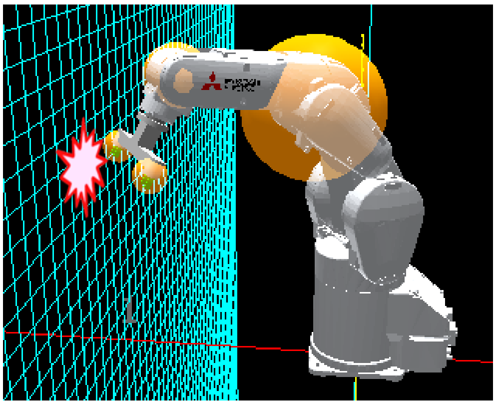
⚠CAUTION Speed restriction by the speed limit OVRD is effective on the operation speed set by interpolation commands/jog operation. This restriction has no effect on the corrected speed generated by the compliance control, force sense control, or tracking function.
For this reason, during execution of these functions, an error may occur depending on the settings of the operation contents or monitoring speed.

⚠CAUTION Speed limit OVRD has no effect on the speed command under real-time external control (Mxt control). Correct the command position according to the monitoring speed on the command position generating side.

4.3.5 SLP function (Position monitoring function)

(1) Overview

The function defines a plane (position monitoring plane) around the robot to restrict intrusion, and monitors the monitoring positions set for the robot do not exceed the plane. When a monitoring position approaches the position monitoring plane during the operation, the robot stops its operation. Besides, if the monitoring position enters a restricted area beyond the position monitoring plane, error H220m (m is a plane number) occurs and the robot turns the servo OFF to stop.

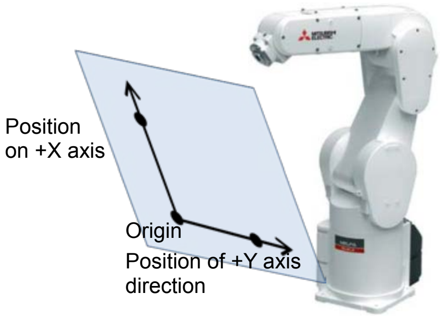


(2) Setting the position monitoring plane

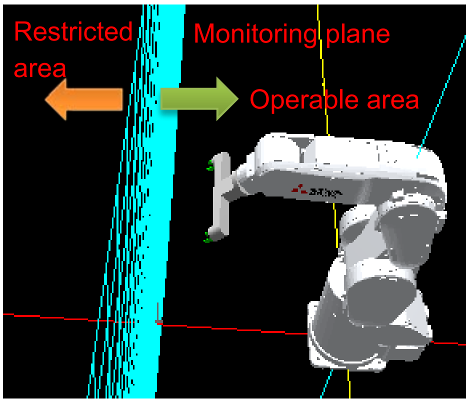
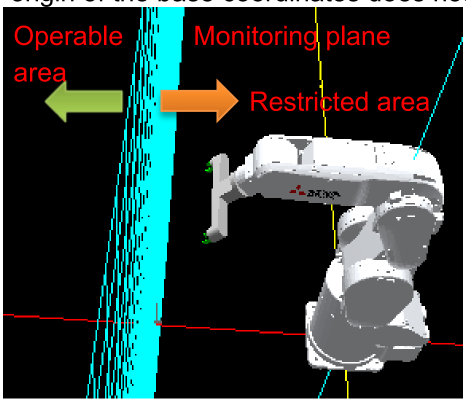
Up to eight planes can be set as the position monitoring plane.
Set each plane using the following parameters.

(a) Parameter SLPmPLN (m = 1 to 8)

Specify X, Y, and Z coordinate values [mm] of three points (origin, position on +X axis, and position of +Y axis direction) to set the plane.
Besides, even if a base conversion is performed, the relative positional relationship between the robot arm and the position monitoring plane does not change for the position monitoring of the SLP function. Use coordinate values in the base coordinate system for setting the parameters.



(b) Parameter SLPmAT (m = 1 to 8)
Specify whether the position monitoring plane is enabled (ON) or disabled (OFF).

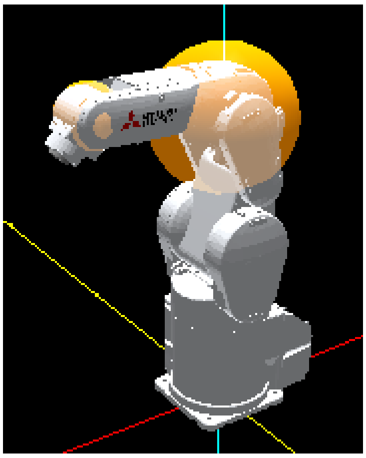
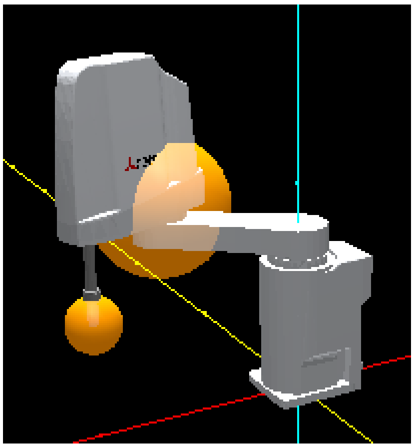
<table>
<tr><th>Specification</th><th>Description</th></tr>
<tr><td>OFF</td><td>Not used for position monitoring.</td></tr>
<tr><td>ON (Inside)</td><td>Used for position monitoring.
Using the relevant plane as a reference, the operable area of the robot is on the side where the origin of the base coordinates exists.

</td></tr>
<tr><td>ON
(Outside)</td><td>Used for position monitoring.
Using the relevant plane as a reference, the operable area of the robot is on side where the origin of the base coordinates does not exist.

</td></tr>
</table>

(c) Parameter SLPmMOD (n = 1 to 8)
Select the monitoring mode to be applied to the position monitoring plane from the following modes. Multiple monitoring modes can be selected.
Monitoring modes to be selected: Mode 1, Mode 2(A), Mode 2(B), Mode 3, and Mode M

(3) Setting the monitoring positions
The monitoring position is set as a sphere around the designated position.
There are four monitoring positions (two positions on the robot arm and two user-specified positions).

(a) Monitoring positions on the robot arm

The center of the sphere for the monitoring positions on the robot arm is specified depending on the robot type as follows.

RV-F series	RH-F series
 Monitoring position 1: J3 axis rotation center position Monitoring position 2: J5 axis rotation center position	 Monitoring position 1: J2 axis rotation center position Monitoring position 2: Lower end of the J3 axis

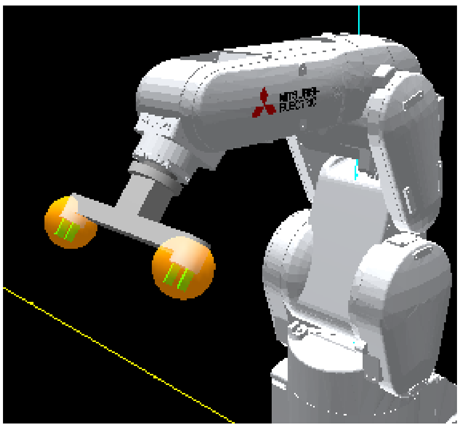
The center position cannot be changed, but the radius value can be changed in parameter SLPRDUS.

(b) User-specified monitoring positions

The user can specify two monitoring positions separately from those on the robot arm. Each of the monitoring position is specified in parameter SLPCP1/SLPCP2.

Setting item	Description
X, Y, Z	Specify the center position of the monitoring position. Set coordinate values [mm] of the X, Y, Z axes along the TOOL coordinate system from the center of the mechanical interface.
Radius	Specify the radius [mm] of the sphere for the monitoring position.

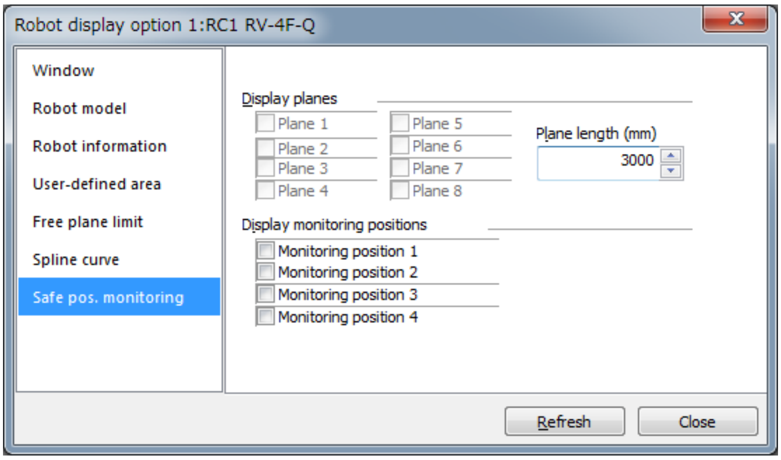
For initial values of parameter SLPCP1/SLPCP2, the center position of the mechanical interface is regarded as the monitoring position.



(4) 3D monitor display

The position monitoring planes and the monitoring positions can be displayed on the 3D monitor of RT ToolBox2. This enables you to monitor the position monitoring planes / monitoring positions.

To display the planes/positions on the 3D monitor, select the item(s) to be displayed in [Safe pos. monitoring] on the [Robot display option] screen. To display the [Robot display option] screen, select [3D View]→[Robot display option] on the menu bar.



Select the item(s) to be displayed and press the [Refresh] button to display them on the 3D monitor. Position monitoring planes can be selected only when they are set as enabled.

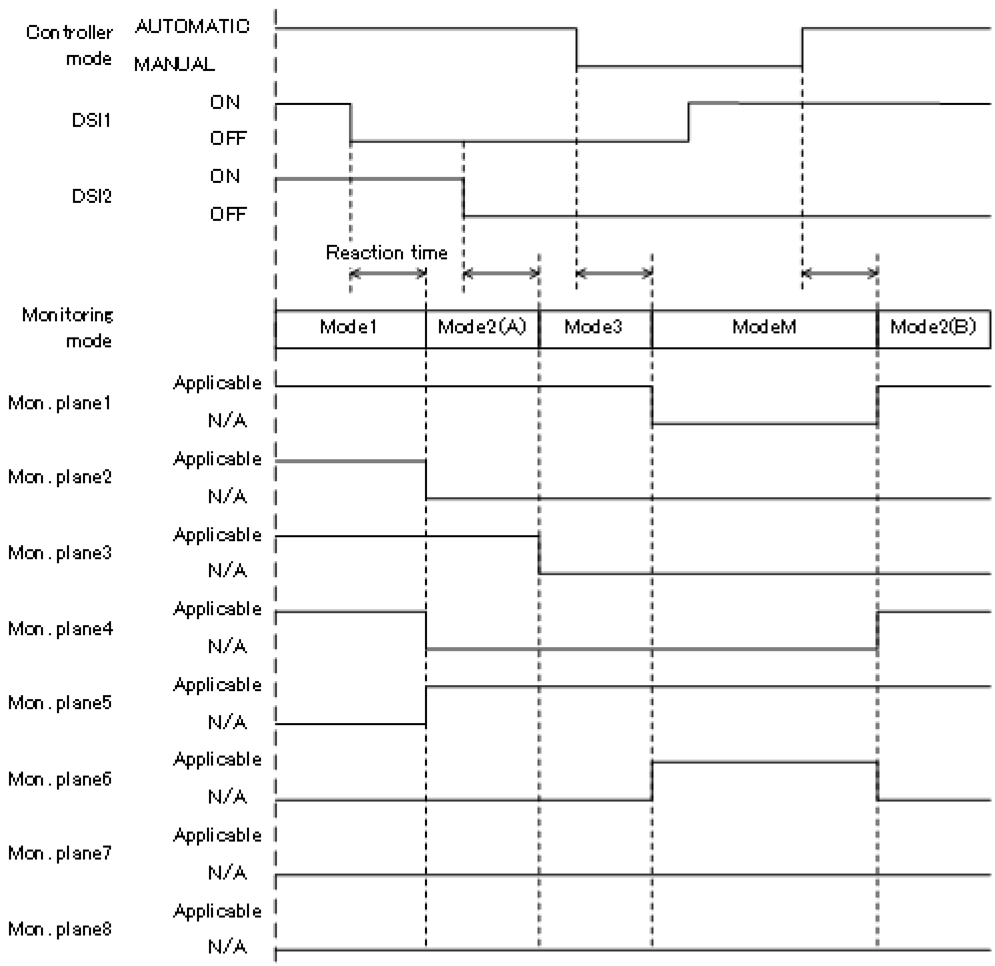
(5) Starting the SLP function

The SLP function is constantly being executed. The planes subject to the position monitoring are switched based on the current state of the monitoring mode and the setting of each monitoring plane (enable/disable and applicable monitoring mode).

For example, in the case each plane is set as shown in the table below, monitoring planes applied/not applied to this function are changed by monitoring mode switching.

Table 4-3 An example of setting for each monitoring plane.

Monitoring plane	Enable/Disable	Applicable monitoring mode				
		Mode 1	Mode 2(A)	Mode 2(B)	Mode 3	Mode M
Plane1	Enabled	✓	✓	✓	✓	
Plane2	Enabled	✓				
Plane3	Enabled	✓	✓			
Plane4	Enabled	✓		✓		
Plane5	Enabled		✓	✓	✓	✓
Plane6	Enabled					✓
Plane7	Disabled	✓				
Plane8	Disabled					



(6) Position monitoring

During the position monitoring, the function monitors four monitoring positions to see if they do not exceed the position monitoring plane applied at that time.

If a monitoring position approaches the position monitoring plane during the operation performed by the interpolation command or for the jog operation, the robot stops its operation (SLP pre-stop status). The behaviors at the stop near the position monitoring plane are as follows.

(a) During the operation performed by the interpolation command

The [RUN] state is maintained for the automatic operation of the program. The robot operation is stopped, and the execution does not proceed and stops at the line of the interpolation command, but the state does not change to [STOP].

If the target position monitoring plane does not exist in the vicinity due to the monitoring mode change to disable the target position monitoring plane, the SLP pre-stop status is reset and the operation resumes.

Besides, when the automatic operation enters the [STOP] state due to a stop input or error occurrence, the SLP pre-stop status is also reset.

⚠CAUTION When the monitoring mode is switched, the robot may start motion.
Be careful in changing the monitoring mode.

(b) During the operation performed for the jog operation

A buzzer goes off from the teaching pendant to notify that the position monitoring plane is accessed, and the robot stops.

Besides, if the function detects that any one of the monitoring positions exceeds the plane, error H220 m (m is a plane number) occurs and the robot turns the servo OFF to stop. The position monitoring is performed for three types of positions (position command, position feedback, and servo position). The error message of error H220 m changes according to the detected position.

⚠CAUTION The function to stop the movement at the position near the position monitoring plane is activated against a motion command by the interpolation command or for the jog operation. The function is not activated against a correction command of the compliance control, force sense control, or tracking function.
Therefore, even if the motion command is stopped near the position monitoring plane during operation of such functions operation, the target position may reach the position monitoring plane to cause an error.

⚠CAUTION The function to stop the movement near the position monitoring plane is not activated against the real-time external control (Mxt command).

(7) How to confirm the SLP pre-stop status
When the robot is stopped during the automatic operation, confirm whether the operation is in the SLP pre-stop status as followings.

(a) Operation panel in the front of the controller
When the operation is in the SLP pre-stop status, the start button LED lamp on the operation panel blinks.

(b) Dedicated output signal
The present SLP pre-stop status can be output to the dedicated output signal SLPPRSTP. The following table shows the correspondence of the output signal value to the SLP pre-stop status.

SLP pre-stop status	Value of the dedicated output signal SLPPRSTP
During pre-stop	1 to 8 (Numbers of the position monitoring plane for the stop are output.)
Not in pre-stop status	0

(c) Robot status variable
The SLP pre-stop status can be confirmed in the robot status variable M_SlpPreStp.

M_SlpPreStp

[Function]
The variable returns the present SLP pre-stop status.

[Format]

```
Example) <Numerical variables>=M_SlpPreStp
```

[Terminology]
<Numerical variables> The current SLP pre-stop status is returned.
Not in pre-stop status: 0 / During pre-stop: 1 to 8 (number of the applicable position monitoring plane)

[Reference Program]
M_Outb(100) = M_SlpPreStp 'The variable outputs the present SLP pre-stop status from the output signal 100 using 8-bit data.

[Explanation]
(1) The variable returns the present SLP pre-stop status.
(2) While the robot is stopped in the SLP pre-stop status, the number (1 to 8) of the applicable position monitoring plane is returned. Otherwise, 0 is returned.
(3) When the position monitoring (SLP function) is disabled, 0 is always returned.
(4) The variable is read-only.

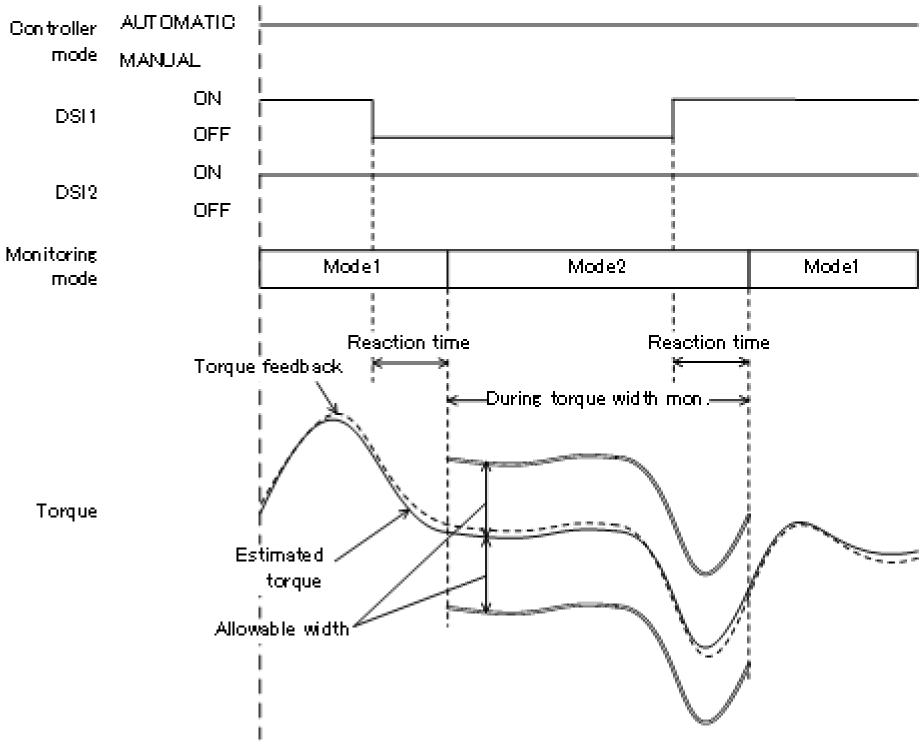
(8) Restoration after the position monitoring plane is exceeded
When the robot is stopped beyond the position monitoring plane, the robot cannot be moved because the error cannot be reset. In such a case, disable or change the mode of the applicable monitoring plane to exclude from the application, and reset the error and retract the robot. Alternatively, release the brake and move the robot to the position where the position monitoring plane is not exceeded, and reset the error.

⚠CAUTION While no error exists, if the position monitoring plane is exceeded during the robot movement by the brake release operation, error H220m occurs and the brake is applied at the same time. While the error is occurring, the brake is not applied even if another error occurs while the brake is released.

4.3.6 STR function (Torque monitoring function)

(1) Overview
The function calculates a presumed torque based on the robot movement, defines an allowable torque width around the presumed torque, and monitors whether the actual torque (torque feedback) is within the allowable width. If the torque feedback exceeds the allowable torque width, error H221n (n is a joint axis number) occurs and the robot turns the servo OFF to stop.

(2) Starting the STR function
The STR function is started when the monitoring mode is switched from Mode1 to Mode 2/3/M.
For example, when the DSI1 signal is turned OFF in Mode 1 and the mode is switched to Mode 2 after the reaction time passes, the torque width monitoring is started. During the torque width monitoring, the function monitors the difference between the presumed torque and the torque feedback to see if it is within the allowable torque width. When the DSI1 signal is turned ON, the mode is returned to Mode 1 after the reaction time passes and the torque width monitoring is ended.

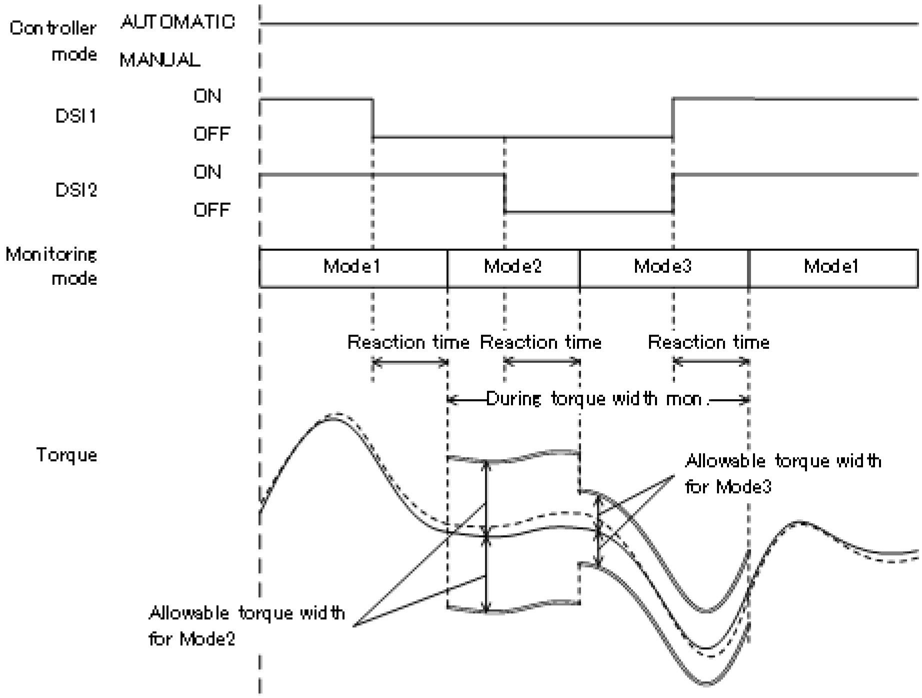


(3) Switching the allowable toque width
An allowable torque width can be set for each monitoring mode. When the monitoring mode is switched, the allowable width is switched accordingly. Set the allowable width in the parameter STRTRQ2/STRTRQ3/STRTRQM.

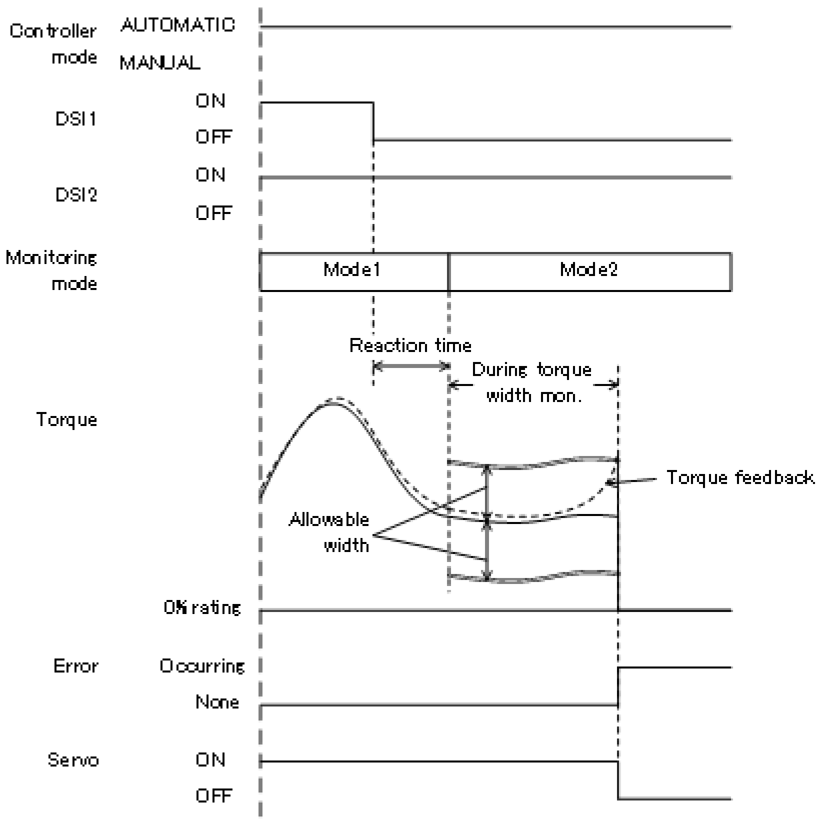
Monitoring mode	Parameter for the setting of the allowable torque width
Mode 2	STRTRQ2
Mode 3	STRTRQ3
Mode M	STRTRQM

The allowable torque width monitoring is performed by switching the monitoring mode as follows.
When the DSI1 signal is turned OFF in Mode 1 and the mode is switched to Mode 2, the allowable torque

width monitoring is started with the allowable torque width for Mode 2. After that, when the DSI2 signal is turned OFF and the mode is switched to Mode 3, the allowable width is switched to the allowable torque width for Mode 3 and the torque width monitoring is continued.



(4) Torque width monitoring
During the torque width monitoring, the function monitors the difference between the presumed torque and torque feedback to see if it is within the allowable torque. If the torque feedback exceeds the allowable torque, error H221n (n is a joint axis number) occurs and the robot turns the servo OFF to stop.



⚠CAUTION When the robot servo is turned OFF, the allowable torque width monitoring is not executed even if the monitoring mode is Mode 2, Mode 3, or Mode M.

⚠CAUTION For calculating the presumed torque, the hand/workpiece condition (parameter HNDDATn and WRKDATn (n=0 to 8)) settings are referenced. For precise calculation, set accurate hand/workpiece condition values. For the hand/workpiece condition, refer to the separate "Instruction manual/Detailed explanations of functions and operations" supplied with the robot arm.

(5) Confirming the torque width
Set the communication setting of the oscillograph function of RT ToolBox2 as shown below to display a graph showing the difference between the presumed torque and torque feedback (error of presumed torque, unit: % rating).

Communication setting	Setting value
Communication method	Real time monitor
Request data selection	Error of presumed torque

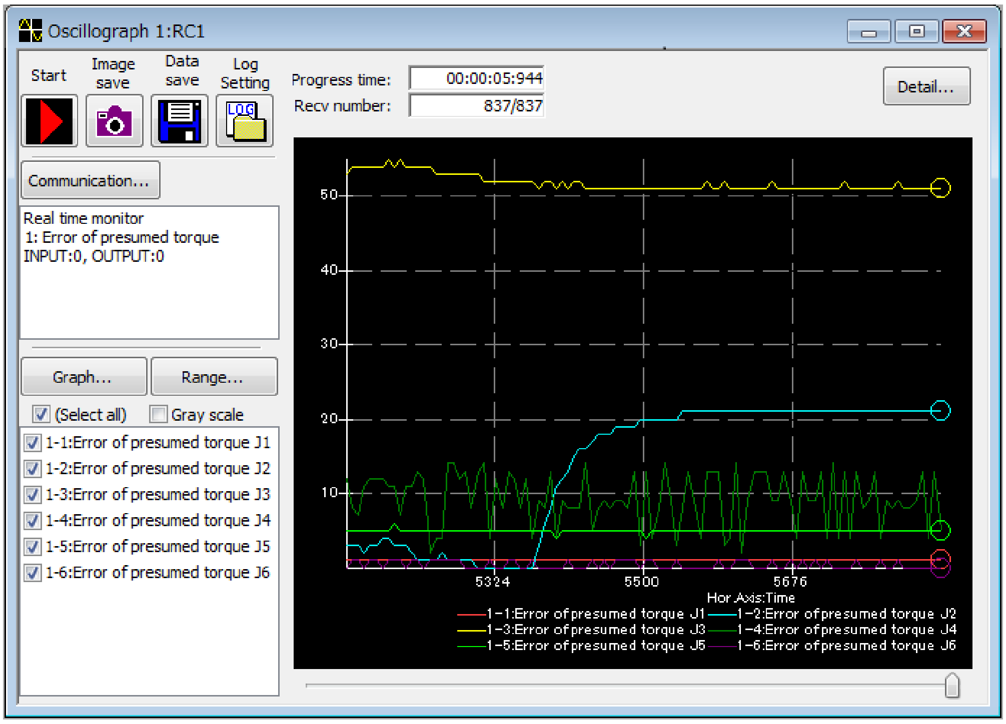


Fig 4-2 Graphical display of the presumed torque error

An error of the presumed torque is calculated when all of the following conditions are satisfied.

- Torque width monitoring (STR) is enabled.
- The monitoring mode is any of Mode 2, Mode 3, or Mode M.
- Robot servo is turned ON.

For setting the allowable torque width, actually move the robot and reference the presumed torque error displayed in the graph. For the oscillograph function, refer to the separate "RT ToolBox2 / RT ToolBox2 mini Instruction manual" supplied with the RT ToolBox2.

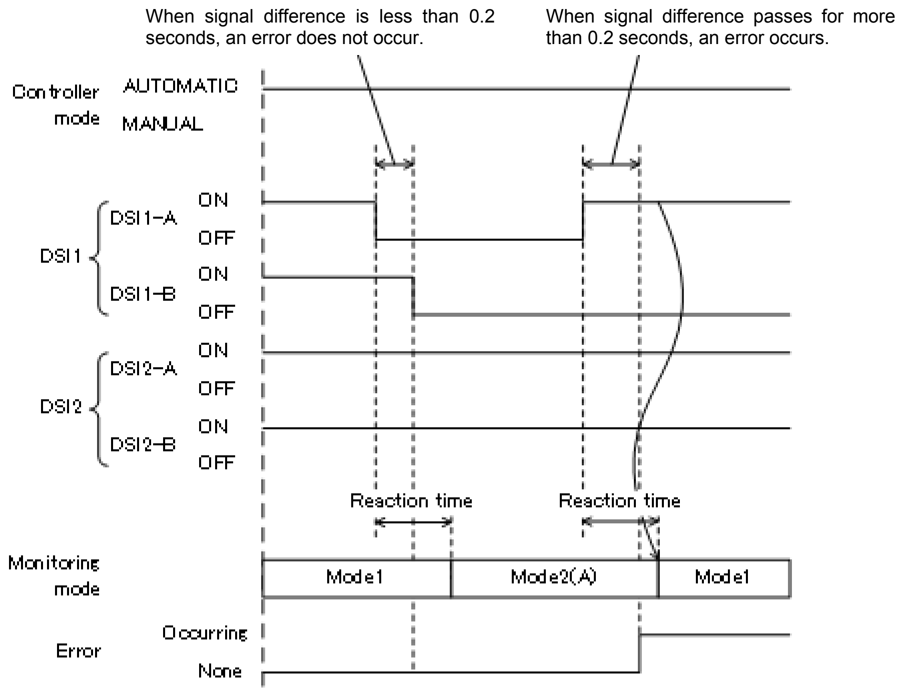
4.3.7 Duplex input monitoring function

(1) Overview
The DSI signals specifying the monitoring mode status are duplex input signals, and the function always monitors consistency of the status. When the function detects that the input signals do not match, error H222m (m = 1 or 2: DSI signal number) occurs and the robot turns the servo OFF to stop.

(2) Duplex input monitoring
The DSI signals, DSI1 and DSI2, are both duplex input signals.

DSI signal	Corresponding duplex input
DSI1	DSI1-A, DSI1-B
DSI2	DSI2-A, DSI2-B

The function always monitors the status of the duplex input to see if it is consistent, and when the status is not consistent for 0.2 seconds or more, error H222m occurs. If the inconsistency does not continue for 0.2 seconds or more, no error occurs.
When the status of the duplex input is inconsistent, the input signal status specified in parameter DSINO is used for specifying the monitoring mode.
For the input signal number of DSI signal (parameter DSINO) for which “-1” (Disabled) is set, the duplex input signal monitoring is not executed.



5 Parameters

5.1 Safety monitoring function parameters

5.1.1 Parameter List

To allow parameter changes to take effect, turn OFF the controller power supply once, and turn it ON again.

Table 5-1 Parameters related to the safety monitoring function

Setting screen	Parameter	Parameter name
Enable Disable	Enable/disable setting for speed monitoring	SLSENA
	Enable/disable setting for position monitoring	SLPENA
	Enable/disable designation for torque width monitoring	STRENA
	DSI signal number	DSINO
	Parameter file CRC output number	SFPFCSIG (*1)
Position monitoring (plane setting)	Definition of position monitoring plane	SLPmPLN (m = 1 to 8)
	Attribute of position monitoring plane	SLPmAT (m = 1 to 8)
	Applicable monitoring mode for position monitoring plane	SLPmMOD (m = 1 to 8)
Position monitoring (position setting)	Radius of robot monitoring position	SLPRDUS
	User-specified monitoring position 1	SLPCP1
	User-specified monitoring position 2	SLPCP2
Speed monitoring	Monitoring speed	SLSMONSP(*1) SLSSPD(*2)
	Speed limit OVRD	SLSLMTOV(*1)
	Existing method	SLSCOMP(*1)
	Reaction time for monitoring mode change	SFREACT
Torque width monitoring	Allowable torque width applied when the monitoring mode is Mode M	STRTRQM
	Allowable torque width applied when the monitoring mode is Mode 2	STRTRQ2
	Allowable torque width applied when the monitoring mode is Mode 3	STRTRQ3
	Reaction time for monitoring mode change	SFREACT
Parameter list screen (RT ToolBox2) Parameter editing screen (teaching pendant)	Monitoring mode output (dedicated output)	SFMODE
	SLP pre-stop status output (dedicated output)	SLPPRSTP

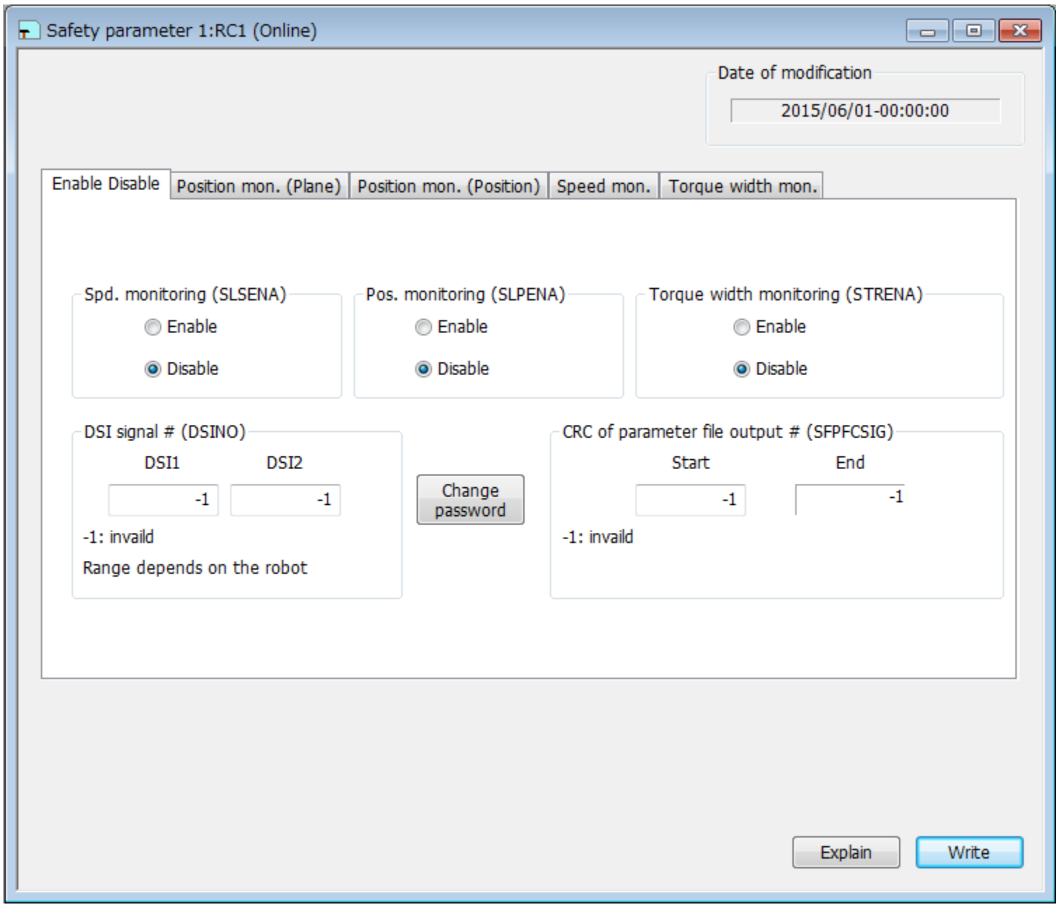
(*1) Available in the “Version Combination B”.

(*2) In the “Version Combination B”, SLSSPD is not used.

5.1.2 Parameter details

The following describes the parameters in each of the safety monitoring function parameter setting screens of RT ToolBox2.

(1) Enable/disable setting screen



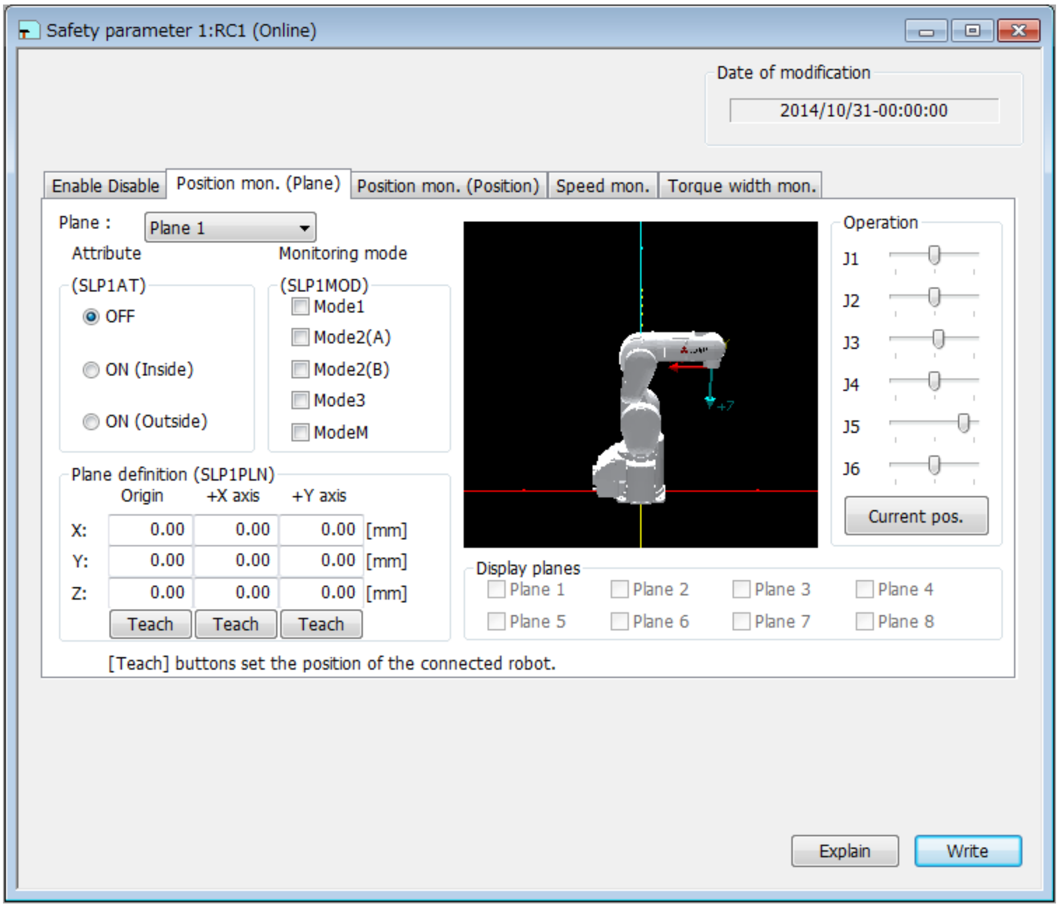
※ "CRC of parameter file output" is shown when the software version combination of controller and RT ToolBox2 corresponds to the "Version Combination B"

Table 5-2 Safety monitoring function parameters in the Enable/disable setting screen

Parameter name	Parameter	Description	Factory default setting
SLSENA	Enable/disable setting for speed monitoring	Specify enable/disable of the speed monitoring function (SLS).	Disabled
SLPENA	Enable/disable setting for position monitoring	Specify enable/disable setting of the position monitoring function (SLP).	Disabled
STRENA	Enable/disable designation for torque width monitoring	Specify enable/disable setting of the torque width monitoring function (STR).	Disabled
DSINO	DSI signal number	Specify the number of the input signal used as DSI. ・When DSI is not used, set "-1" (disabled). ・The same value cannot be set in both DSI1 and DSI2. (Except for "-1") ・Set the following values for using DSI1-A/DSI2-A of the extended safety unit. DSI = 801, DSI2 = 802 Setting range D series: -1, 0 to 255, 801, 802 Q series: -1, 801, 802	DSI1: -1 DSI2: -1

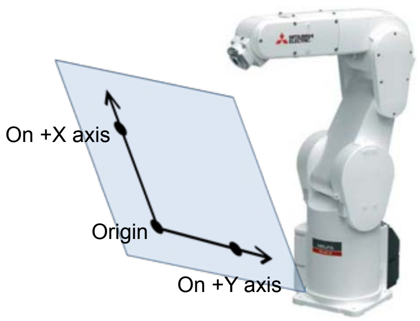
Parameter name	Parameter	Description	Factory default setting
SFPFCSIG	CRC of parameter file output（valid only in the “Version Combination B”）	Start address and end address of the dedicated signal for the output of CRC of parameter file for the Safety Monitoring Function is specified. ・Output signal width is fixed to 16bits. ・When the start address is specified, the end address is set automatically. ・If this function needs to be disabled, set “-1” to the starting address. (Then, the end address is set to “-1” automatically) Setting range: -1,0 to 19999 ※ For the CRC output of parameter file, refer to “5.1.3 CRC output of parameter file”.	Start：-1 End：-1

(2) Position monitoring (plane) setting screen



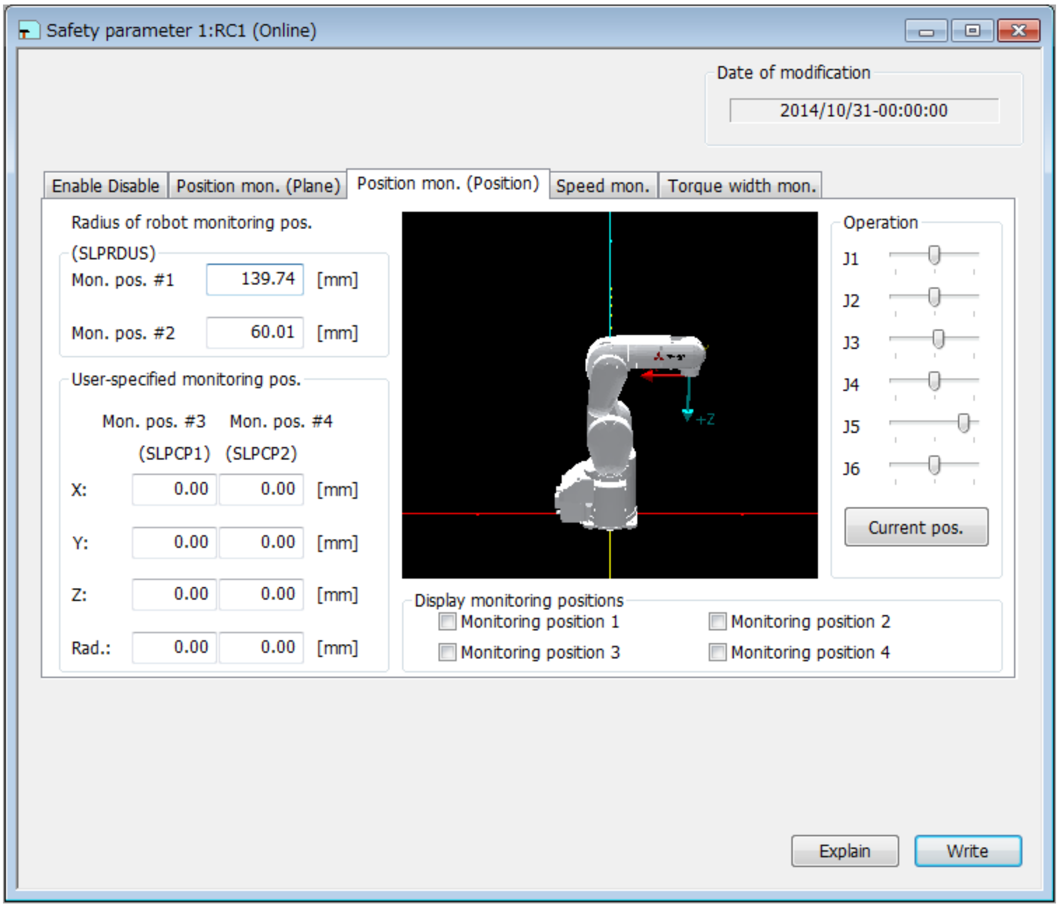
* When the plane for which "Attribute" is ON (enabled) is selected in the "Display planes" section, it is displayed in the graphics display section and its positional relationship with the robot can be checked. Note that the graphics display section is not linked with the 3D monitor.

Table 5-3 Safety monitoring function parameters in the Position monitoring (plane) setting screen

Parameter name	Parameter	Description	Factory default setting
SLPmPLN (m = 1 to 8)	Definition of position monitoring plane	Set the X-, Y-, and Z-axis coordinate values of the three positions (origin, on +X axis, on +Y axis) to define the position monitoring plane. ・Up to eight planes can be set. ・For position monitoring, positions in the base coordinate system is used. For defining planes, also use coordinate values in the base coordinate system. ・When coordinate values that cannot form a plane are specified, error H0230 (Parameter error) occurs at power-ON even when the plane is specified to be enabled. Unit: mm (The two digits after the decimal points are significant.) 	Origin : (0.0, 0.0, 0.0) On +X axis : (0.0, 0.0, 0.0) On +Y axis : (0.0, 0.0, 0.0)

<table>
<tr><th>Parameter name</th><th>Parameter</th><th>Description</th><th>Factory default setting</th></tr>
<tr><td>SLPmAT
(m = 1 to 8)</td><td>Attribute of position monitoring plane</td><td>Specify whether the set position monitoring plane is ON (enabled) or OFF (disabled).
<table>
<tr><th>Specification</th><th>Description</th></tr>
<tr><td>OFF</td><td>Not used for position monitoring.</td></tr>
<tr><td>ON
(Inside)</td><td>Used for position monitoring.
Using the relevant plane as a reference, the operable area of the robot is on the side where the origin of the base coordinates exists.</td></tr>
<tr><td>ON
(Outside)</td><td>Used for position monitoring.
Using the relevant plane as a reference, the operable area of the robot is on side where the origin of the base coordinates does not exist.</td></tr>
</table></td><td>Disabled</td></tr>
<tr><td>SLPmMOD
(m = 1 to 8)</td><td>Applicable monitoring mode for position monitoring plane</td><td>Specify the monitoring mode to be applied to the position monitoring plane.
･Select the checkbox of the applicable monitoring mode.
･Multiple monitoring modes can be selected.</td><td>All disabled</td></tr>
</table>

(3) Position monitoring (position) setting screen



* When a checkbox in the "Display monitoring positions" section is selected, a sphere indicating the monitoring position is displayed in the graphics display section, and its positional relationship with the robot and the sphere size can be checked. Note that the graphics display section is not linked with the 3D monitor.

Table 5-4 Safety monitoring function parameters in the position monitoring (position) setting screen

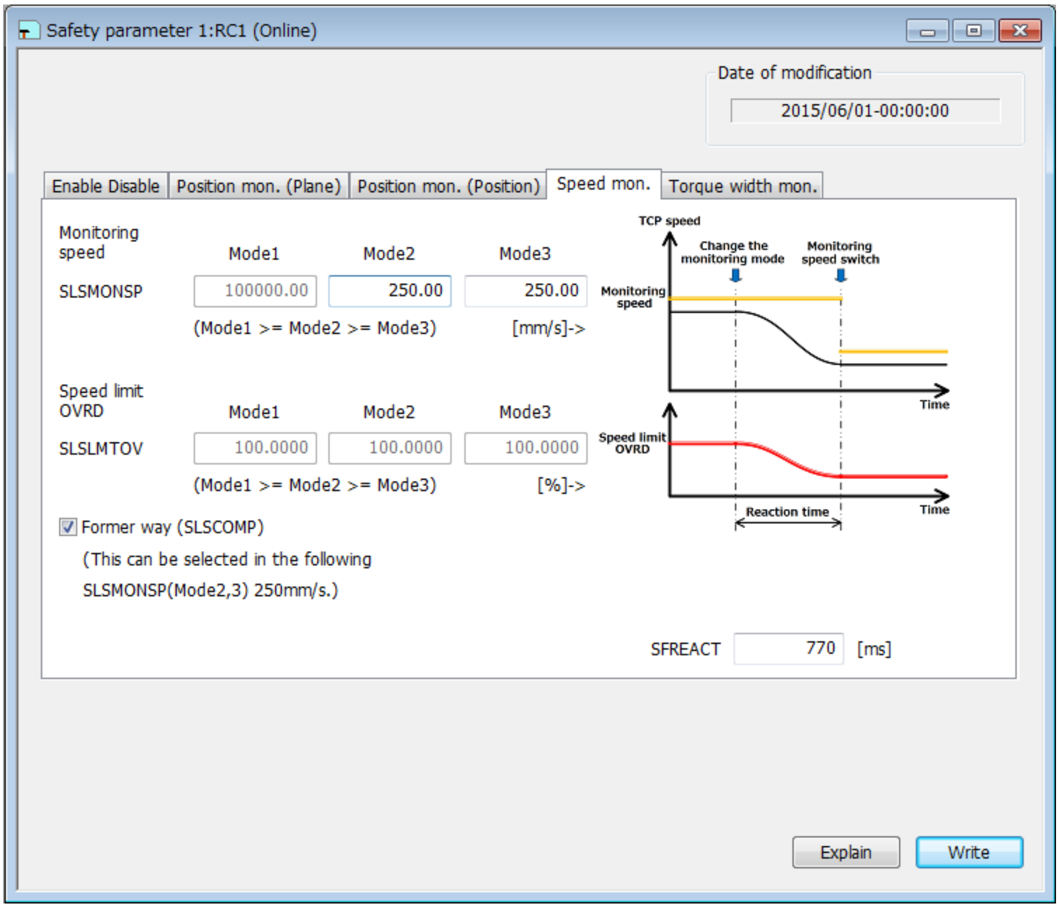
<table>
<tr><th>Parameter name</th><th>Parameter</th><th>Description</th><th>Factory default setting</th></tr>
<tr><td>SLPRDUS</td><td>Radius of robot monitoring position</td><td>Specify the radius of the sphere to be used for monitoring position of the robot arm.
The center of the sphere is as shown in the table below.
<table><tr><th>Monitoring position</th><th>RV-F/FL series
RV-FJ series</th><th>RH-FH series
RH-FHR series</th></tr><tr><td>Monitoring position 1</td><td>J3 axis rotation center</td><td>J2 axis rotation center</td></tr><tr><td>Monitoring position 2</td><td>J5 axis rotation center</td><td>Lower end of the ball screw</td></tr></table>
· The minimum setting value differs according to the model. When the value lower than the minimum value is set, the setting is changed to the minimum value at power-ON.

Setting range: Minimum value for each model to 3276.7
Unit: mm (The two digits after the decimal points are significant.)</td><td>Monitoring position 1: Minimum value
Monitoring position 2: Minimum value
(The minimum value differs according to the model.)</td></tr>
<tr><td>SLPCP1</td><td>User-specified monitoring position 1</td><td rowspan="2">Set the monitoring position (coordinate values and radius) to be used for monitoring position.
· X, Y, Z
Specify the coordinate values of the center position of the sphere placed at the monitoring position.
Specify the values on the X, Y, and Z axes of the TOOL coordinate system that has its origin on the mechanical interface.

· Radius
Specify the radius of the sphere placed at the monitoring position.

Setting range
X, Y, Z: -32767.0 to 32767.0
Radius: 0.0 to 3276.7
Unit: mm (The two digits after the decimal points are significant.)</td><td rowspan="2">X, Y, Z: (0.0, 0.0, 0.0)
Radius: 0.0</td></tr>
<tr><td>SLPCP2</td><td>User-specified monitoring position 2</td></tr>
</table>

(4) Speed monitoring setting screen



※ Above figure shows the image in the case software version combination of controller and RT ToolBox2 corresponds to the "Version Combination B". The image for "Version Combination A" is shown in the figure below.

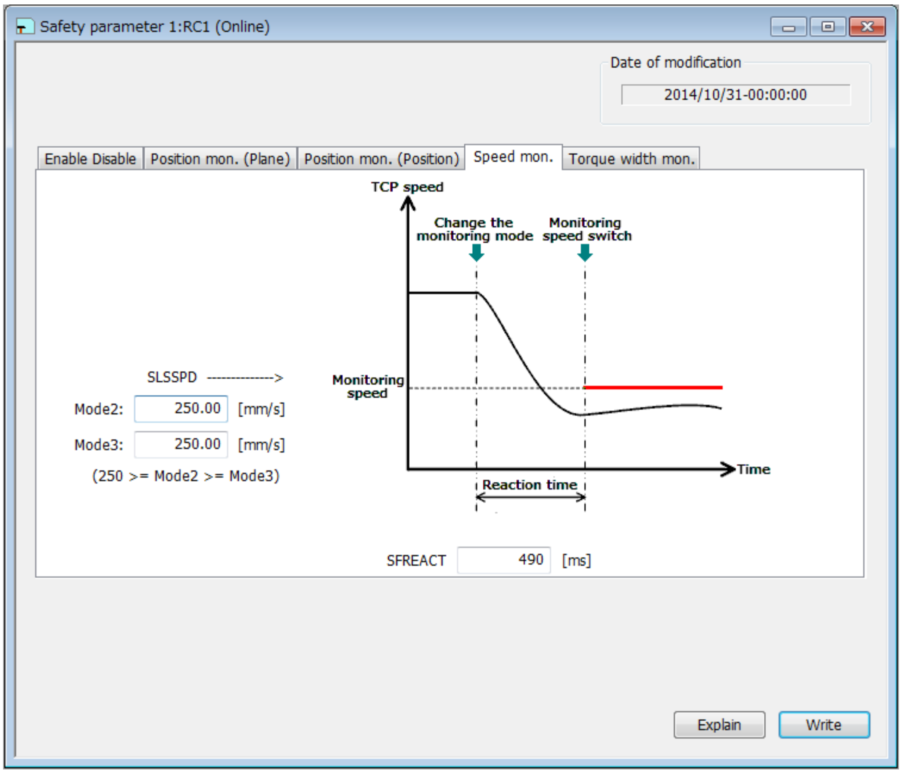


Table 5-5 Safety monitoring function parameters in the speed monitoring setting screen

Parameter name	Parameter	Description	Factory default setting
SLSMONSP	Monitoring speed (Valid only in the “Version Combination B”)	In each mode of mode1, mode2, mode3, the monitoring speed applied for each monitoring mode is specified. ・A check mark for the ”Existing method(SLSCOMP)” should be removed for setting the monitoring speed for mode 1. Setting Range: 0.0 or above Note that the following condition must be fulfilled. Mode 1 monitoring speed ≥ Mode 2 monitoring speed ≥ Mode 3 monitoring speed. Unit: mm/s (The two digits after the decimal points are significant.)	Mode 1: 100000.0 Mode 2: 250.0 Mode 3: 250.0
SLSSPD	Monitoring speed (Valid only in the “Version Combination A”)	Specify the monitoring speed applied when the monitoring mode is Mode 2 or Mode 3. Setting range: 0.0 to 250.0 However, the following conditions must be satisfied. Mode 2 monitoring speed ≥ Mode 3 monitoring speed Unit: mm/s (The two digits after the decimal points are significant.)	Mode 2: 250.0 Mode 3: 250.0
SLSLMTOV	Speed Limit OVRD (Valid only in the “Version Combination B”)	In each mode of mode1, mode2, mode3, the speed limit override applied for each monitoring mode is specified. ・A check mark for the ”Existing method(SLSCOMP)” should be removed for setting the speed limit override. Setting Range: 0.0 to 100.0 Note that the following condition must be satisfied. Mode 1 value ≥ Mode 2 value ≥ Mode 3 value. Unit: % (The four digits after the decimal points are significant.)	Mode 1: 100.0 Mode 2: 100.0 Mode 3: 100.0
SLSCOMP	Existing method (Valid only in the “Version Combination B”)	Speed monitoring method by the SLS function is specified. ・Check this parameter when the method the same as in the “Version Combination A”(Existing method) is needed to be applied. ・If this parameter is checked, the settings for “Monitoring speed (SLSMONSP)” for mode 1 and “Speed limit OVRD(SLSLMTOV)” are disabled. ・In the case the speed needs to be limited by the speed limit OVRD Setting range: Checked(Existing method) Unchecked(New method) ※ For checking this parameter, the setting values of “Monitoring speed(SLSMONSP)” for mode 2 and mode 3 must be equal to or below 250.0.	Checked (Existing method)
SFREACT	Reaction time for monitoring mode change	Specify the time after the DSI signal changes until the monitoring mode and the monitoring speed are switched to new ones. ・Even when the setting of this parameter is changed, the time required for deceleration when the monitoring mode is switched does not change. Therefore, if the reaction time setting is too short, the speed may reach the monitoring speed during deceleration, and an error may occur. ・Same as "SFREACT" in the torque width monitoring setting screen. Setting range: 0 to 10000 Unit: ms	Differs according to the model.

(5) Torque width monitoring setting screen

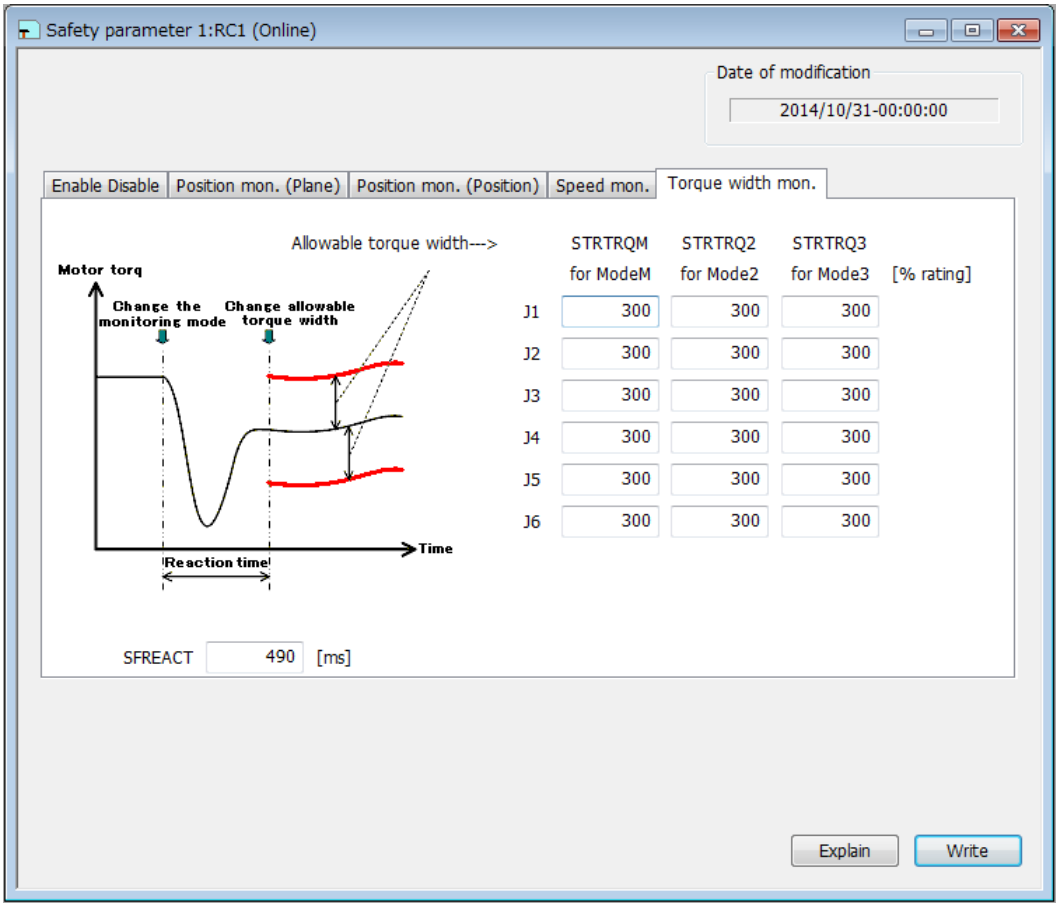


Table 5-6 Safety monitoring function parameters in the torque width monitoring setting screen

Parameter name	Parameter	Description	Factory default setting
STRTRQM	Allowable torque width applied when the monitoring mode is Mode M	Specify the allowable torque width applied in the corresponding monitoring mode for each joint axis. · The difference between the presumed torque calculated based on the robot movement and the actual torque feedback is monitored. The torque width monitoring error occurs when the setting of this parameter is exceeded. Therefore, the smaller the setting value is, the more likely the error occurs. Use the oscillograph function of RT ToolBox2 to monitor the error of the presumed torque, and set an appropriate value. Setting range: 0 to 300 Unit: % rating	300 for all axes
STRTRQ2	Allowable torque width applied when the monitoring mode is Mode 2		
STRTRQ3	Allowable torque width applied when the monitoring mode is Mode 3		
SFREACT	Reaction time for monitoring mode change	Specify the time after the DSI signal changes until the monitoring mode and the allowable torque width are switched to new ones. · Same as "SFREACT" in the speed monitoring setting screen. Setting range: 0 to 10000 Unit: ms	Differs according to the model.

(6) Dedicated output signals

No dedicated parameter setting screen is available for the dedicated output signals SFMODE and SLPPRSTP. Enter the parameter name on the parameter list screen of RT ToolBox2 or the parameter editing screen of the teaching pendant to confirm or change the parameter setting.

Fig 5-7 Dedicated output signals for the safety monitoring function

<table>
<tr><th>Parameter name</th><th>Name</th><th>Function</th><th>Factory default setting</th></tr>
<tr><td>SFMODE</td><td>Monitoring mode output</td><td>The present value of the monitoring mode is output to the specified signal.
· The output value is as follows.
<table>
<tr><th>Monitoring mode</th><th>Value</th></tr>
<tr><td>Safety monitoring function disabled</td><td>0</td></tr>
<tr><td>Mode M</td><td>1</td></tr>
<tr><td>Mode 1</td><td>2</td></tr>
<tr><td>Mode 2(A)</td><td>3</td></tr>
<tr><td>Mode 2(B)</td><td>4</td></tr>
<tr><td>Mode 3</td><td>5</td></tr>
</table>
Element 1: Specify the starting number of the output destination.
Element 2: Specify the ending number of the output destination.
Setting range: -1 to 19999
However, the following conditions must be satisfied.
Element 1 ≤ Element 2
Output signal range: 3 to 16 bits
To set "-1" (invalid), set "-1" in both of the 1st. and 2nd element.</td><td>-1, -1</td></tr>
<tr><td>SLPPRSTP</td><td>SLP pre-stop status output</td><td>The present SLP pre-stop status is output to the specified signal.
- The output value is as follows.
<table>
<tr><th>SLP pre-stop status</th><th>Value</th></tr>
<tr><td>Pre-stop status</td><td>1 to 8</td></tr>
<tr><td>Not in pre-stop status</td><td>0</td></tr>
</table>
The number 1 to 8 indicates the position monitoring plane which is subject to stopping.

Element 1: Specify the starting number of the output destination.
Element 2: Specify the ending number of the output destination.
Setting range: -1 to 19999
However, the following conditions must be satisfied.
Element 1 ≤ Element 2
Output signal range: 4 to 16 bits
To set "-1" (invalid), set "-1" in both of the 1st. and 2nd element.</td><td>-1, -1</td></tr>
</table>

5.1.3 CRC output of the parameter file

(1) Overview

The CRC value of the parameter file in which the parameters for Safety Monitoring Function are stored can be calculated, and the value can be output externally by the dedicated output signal. The peripheral instruments can detect the modification of parameters for Safety Monitoring Function by monitoring this signal.

Please note that the software version combination of controller and RT ToolBox2 must correspond to the "Version Combination B" for using this function

(2) Timings of calculation of CRC

The CRC for the parameter file is calculated in the following timings.

・Just after the Power-on of the controller.

・When the controller completes writing operation of the parameters, after modification of the parameters for Safety Monitoring Function.

※ Even if the Safety Monitoring Function is disabled, the CRC is calculated and output to the dedicated output signal.

※ When the parameters are written to the controller by means of the restore function in RT ToolBox2, the CRC is calculated when the power is turned on in the next time. The CRC has the same value as in the case when the written parameter file is backed-up.

(3) Dedicated output signal

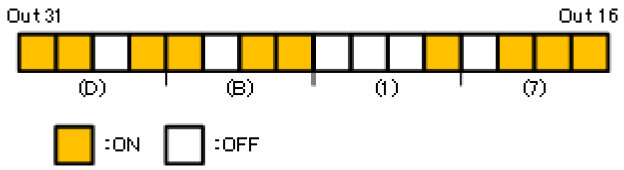
The CRC for the parameters is output to the dedicated signal, SFPFCSIG. The width of output signal is fixed to 16 bits.

For example,

・ SFPFCSIG setting: Start = 16, End = 31

・ CRC value： DB17(in the hexadecimal)

In the settings shown above, the signal is output as follows.



6 Troubleshooting

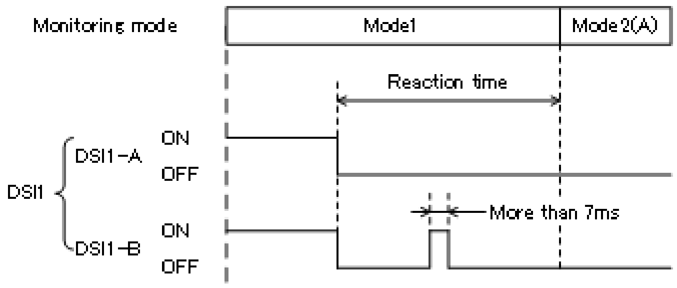
6.1 List of errors related to the safety monitoring function

The table below shows the list of errors related to the safety monitoring function.
For details about errors not mentioned in the list, refer to the separate "Instruction manual/ Troubleshooting" supplied with the robot arm.
(For errors with numbers suffixed with "*", reset the power supply.)

Table 6-1 List of errors related to the safety monitoring function

Error number	Causes of the error and its countermeasures	
H0097 *	Error message	Abnormal MC status
	Cause	The duplex magnetic contactor status signal status is not consistent.
	Countermeasure	The status of the duplex system for the magnetic contactor (MC) is not consistent. After turning OFF the power, turn ON the power again to reset the error. If the same error recurs, contact the manufacturer.
H0098 *	Error message	Abnormal SR status
	Cause	The duplex safety relay status signal status is not consistent.
	Countermeasure	The status of the duplex system for the safety relay (SR) is not consistent. After turning OFF the power, turn ON the power again to reset the error. If the same error recurs, contact the manufacturer.
H0210 *	Error message	Power supply fault (5V)
	Cause	The power supply output voltage is out of the specified range.
	Countermeasure	The output voltage of the 5V power supply is the specified value or higher/lower. After turning OFF the power, turn ON the power again to reset the error. If the same error recurs, contact the manufacturer.
H0211 *	Error message	Power supply fault (3.3V)
	Cause	The power supply output voltage is out of the specified range.
	Countermeasure	The output voltage of the 3.3V power supply is the specified value or higher/lower. After turning OFF the power, turn ON the power again to reset the error. If the same error recurs, contact the manufacturer.
H0212 *	Error message	Power supply fault (2.5V)
	Cause	The power supply output voltage is out of the specified range.
	Countermeasure	The output voltage of the 2.5V power supply is the specified value or higher/lower. After turning OFF the power, turn ON the power again to reset the error. If the same error recurs, contact the manufacturer.
H0213 *	Error message	Power supply fault (1.3V)
	Cause	The power supply output voltage is out of the specified range.
	Countermeasure	The output voltage of the 1.3V power supply is the specified value or higher/lower. After turning OFF the power, turn ON the power again to reset the error. If the same error recurs, contact the manufacturer.
H0220 *	Error message	Memory fault (main CPU)
	Cause	A memory fault is detected.
	Countermeasure	A fault (inconsistent data between writing/reading, broken retention data) is detected for the memory (DRAM) to which the main CPU has access. After turning OFF the power, turn ON the power again to reset the error. If the same error recurs, contact the manufacturer.
H0230 *	Error message	Parameter error (xxxxx)
	Cause	The parameter setting is illegal.
	Countermeasure	The parameter setting is not correct. Check the parameter setting shown in the "(xxxxx)" part of the error message, and set an appropriate value.
H0240 *	Error message	Inconsistent safety function setting
	Cause	The enable/disable setting of the safety function is not consistent.
	Countermeasure	Inconsistency is detected in the enable/disable setting check of the safety monitoring function. After turning OFF the power, turn ON the power again to reset the error. Then, check the enable/disable setting of the safety monitoring function. When the applicable robot is not compatible with the safety monitoring function, disable all the settings of the safety monitoring function.
H220m (The letter "m" indicates the monitoring plane number 1 to 8.)	Error message	SLP robot position error (command)
	Cause	A position in excess of the limit is detected by the position monitoring function.
	Countermeasure	The monitoring position calculated based on the robot position command exceeds the operable area limit defined by the plane of the position monitoring function. Check the relevant parameter setting such as details of the robot movement or the definition of the plane.
	Error message	SLP robot position error (FB)
	Cause	A position in excess of the limit is detected by the position monitoring function.

Error number	Causes of the error and its countermeasures	
	Countermeasure	The monitoring position calculated based on the robot feedback position exceeds the operable area limit defined by the plane of the position monitoring function. Check the relevant parameter setting such as details of the robot movement or the definition of the plane.
	Error message	SLP robot position error (SCPU)
	Cause	A position in excess of the limit is detected by the position monitoring function.
	Countermeasure	The monitoring position calculated by the servo CPU exceeds the operable area limit defined by the plane of the position monitoring function. Check the relevant parameter setting such as details of the robot movement or the definition of the plane.
H221n (The letter "n" indicates the axis number 1 to 8.)	Error message	STR robot torque error (MCPU)
	Cause	A torque error is detected by the torque width monitoring function.
	Countermeasure	A feedback torque in excess of the predetermined allowable torque width is detected by the torque width monitoring function of the main CPU. Check the relevant parameter setting such as details of the robot movement, interference with the peripheral equipment, or the allowable torque width / terminal load setting.
	Error message	STR robot torque error (SCPU)
	Cause	A torque error is detected by the torque width monitoring function.
	Countermeasure	A feedback torque in excess of the predetermined allowable torque width is detected by the torque width monitoring function of the servo CPU. Check the relevant parameter setting such as details of the robot movement, interference with the peripheral equipment, or the allowable torque width / terminal load setting.
H222m * (The letter "m" indicates the DSI number 1 or 2.)	Error message	DSI inconsistency
	Cause	The duplex DSI status is not consistent.
	Countermeasure	The duplex DSI signal ON/OFF status is not consistent. Check the following for the DSI. ・DSI wiring ・Duplex signal ON/OFF status ・ON/OFF status switching timing (The error occurs when the ON/OFF status remains inconsistent between the duplex signals for about 0.2 seconds or more.) ・Parameter DSINO setting
H2240 *	Error message	Origin data change
	Cause	The origin data is changed during execution of the position monitoring function.
	Countermeasure	The error occurs when the origin data is changed by setting the origin during execution of the position monitoring function. After turning OFF the power, turn ON the power again to reset the error.
C2250	Error message	Safety function execution disabled (No origin setting)
	Cause	The safety function cannot be executed because the origin is not set.
	Countermeasure	The safety monitoring function is not activated when the origin is not set. Set the origin.
H2260 *	Error message	Safety function execution disabled (No extended safety unit)
	Cause	The extended safety unit of the robot safety option is not connected.
	Countermeasure	To use the safety monitoring function, it is necessary to connect the extended safety unit of the robot safety option to the controller. Connect the extended safety unit. If the error occurs even if the extended safety unit is connected, the extended safety unit may be faulty. Contact your service provider.
H2300	Error message	SLS TCP speed F/B error
	Cause	An excessive speed feedback is detected by the speed monitoring function.
	Countermeasure	A speed feedback exceeding the predetermined speed is detected by the speed monitoring function. Check the robot movement or the monitoring speed setting. Or else, check that the reaction time (parameter SFREACT) setting is not too short.
H2310	Error message	SLS TCP speed command error
	Cause	An excessive speed command is detected by the speed monitoring function.
	Countermeasure	A speed command exceeding the predetermined speed is detected by the speed monitoring function. Check the robot movement or the monitoring speed setting. Or else, check that the reaction time (parameter SFREACT) setting is not too short.
H2320	Error message	SF robot control error
	Cause	The robot motion command and the feedback are inconsistent.
	Countermeasure	The robot position command and the feedback position are inconsistent. Check the details of the robot movement, the terminal load setting, or interference with the peripheral equipment.
H2340 *	Error message	SF motion command error
	Cause	A robot motion command error is detected.
	Countermeasure	An error is detected in the conversion process of the robot motion command. After turning OFF the power, turn ON the power again to reset the error. If the same error recurs, contact the manufacturer.

Error number	Causes of the error and its countermeasures	
H2370 *	Error message	SF monitoring mode inconsistency
	Cause	The monitoring mode is inconsistent between the main CPU and the servo CPU.
	Countermeasure	The monitoring mode status of the functional safety is inconsistent between the main CPU and the servo CPU. After turning OFF the power, turn ON the power again to reset the error. If the same error recurs, contact the manufacturer. And, this error can be generated in the case the pulse with the width above 7ms is input to a counterpart of the duplex inputs within the period form the change of DSI signal state to the change of monitoring mode(within the reaction time), as shown in the chart below. In such a case, remove the cause of such a pulse and prevent such a pulse input. 
	Error message	SF process error (MCPU)
	Cause	The safety function of the servo CPU is not executed properly.
	Countermeasure	Improper operation of the servo CPU safety function is detected. After turning OFF the power, turn ON the power again to reset the error. If the same error recurs, contact the manufacturer. If CR750-Q/CR751-Q/CRnQ-700 robot controller is used, this error is generated when the power is turned off only on the drive unit side. In such a case, turn on the drive unit and reset the error.
	Error message	SF process error (MCPU)
	Cause	A safety function error is detected.
	Countermeasure	A process error of the safety function is detected for the main CPU. After turning OFF the power, turn ON the power again to reset the error. If the same error recurs, contact the manufacturer.
	Error message	Enable/disable setting inconsistency (xxx)
	Cause	The enable/disable setting of the safety monitoring function is inconsistent between the main CPU and the servo CPU.
	Countermeasure	The enable/disable status of the function displayed in the "(xxx)" part of the error message is inconsistent between the main CPU and the servo CPU. Check the relevant parameter setting, turn OFF the power, and turn it ON again. * One of the following is displayed in "(xxx)". DSI, SLS, SLP, or STR
H238n * (The letter "n" indicates the axis number 1 to 8.)	Error message	SF process error (SCPU)
	Cause	A safety function error is detected.
	Countermeasure	A process error of the safety monitoring function is detected for the servo CPU. After turning OFF the power, turn ON the power again to reset the error. If the same error recurs, contact the manufacturer.
H6640 * (Detail number = 85000)	Error message	Illegal setting of the dedicated signal parameter SFMODE
	Cause	The setting of the dedicated signal parameter SFMODE (safety mode output) is illegal.
	Countermeasure	An error (output bit width of the output signal is less than 3 bits) exists in the dedicated output SFMODE setting. Correct the parameter setting.
C7081 (Detail number = 05000)	Error message	Illegal CRC during parameter writing
	Cause	The parameter CRC value is illegal.
	Countermeasure	An error is detected in the CRC check in the writing process of a parameter related to the safety monitoring function. Check the communication environment between the robot controller and the personal computer, and perform the writing operation again.
L7378	Error message	Change password
	Cause	The password has not been changed from the initial value.
	Countermeasure	The password to change functional safety related parameters has not been changed from the initial value. Change the password to new one, and perform parameter setting. The factory default password is “MELFASafetyPSWD”.

6.2 Errors involving change in specification

The specification of the following errors changes when the safety monitoring function is enabled.

(1) To reset the following errors while the safety monitoring function is enabled, reset the power supply.

Error number	Error message
H0039	Door switch open signal wiring fault
H0044	Operation panel mode key line fault
H0045	T/B enable switch line fault
H0046	Enabling device wiring fault
H0051	External emergency stop wiring fault
H0061	Operation panel emergency stop line fault
H0071	T/B emergency stop line fault
H0074	T/B enable/disable switch line fault
H1680	Servo ON timeout
H1681	Unexpected servo OFF
H1682	Servo ON timeout (safety relay)
H1683	Servo ON timeout (contactor welded)

(2) When the emergency stop button on the operation panel is pressed while the safety monitoring function is enabled, as well as H0060 (Operation panel emergency stop being input), H0050 (External emergency stop signal being input) occurs.

7 Dimensional outline drawings

7.1 Dimensional outline of the extended safety unit

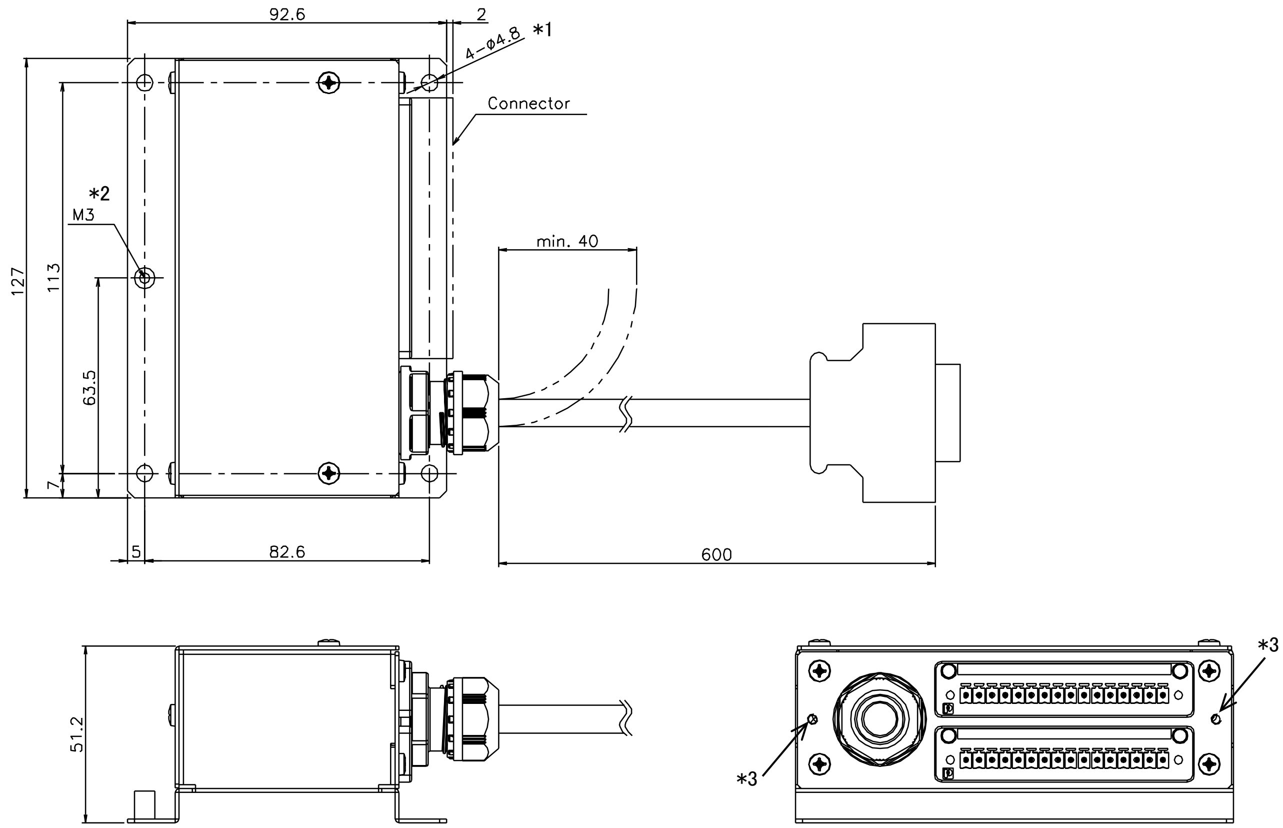


Fig. 7-1 Dimensional outline drawings

8 Maximum elapsed time/maximum motion angle

8.1 Overview

The values in this chapter shows the elapsed time and motion angle until the power supply to the motor is blocked after SS1 function is activated. When the motion speed is lower, as the time needed for deceleration gets shorter, the processing is executed in shorter elapsed time and in less motion angle than the values shown in this chapter. If the robot is not used properly, the maximum elapsed time and maximum motion angle may be larger than the values in this chapter.

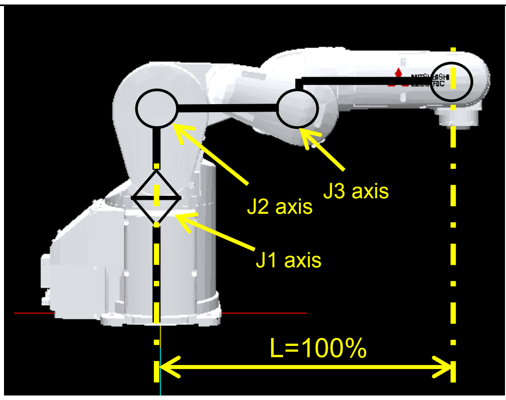
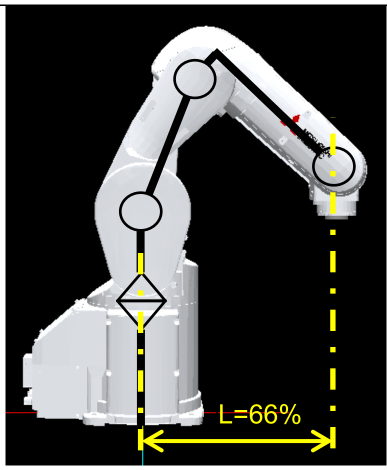
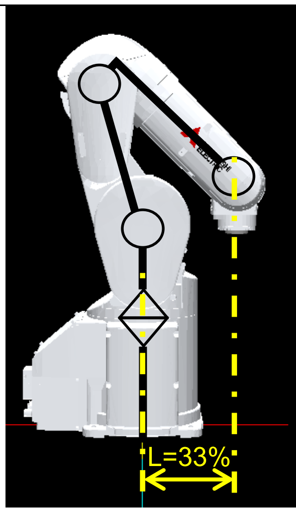
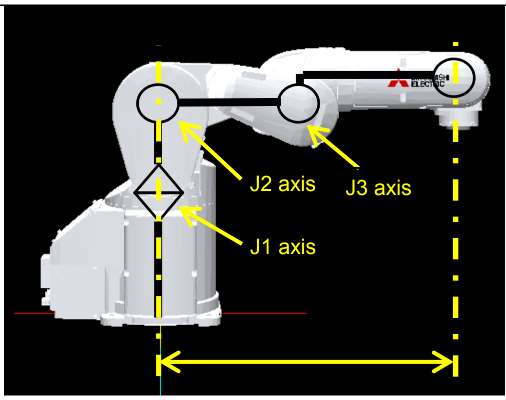
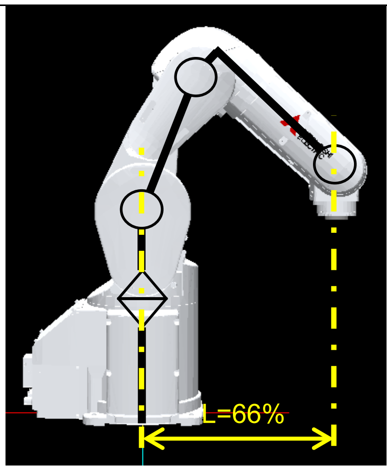
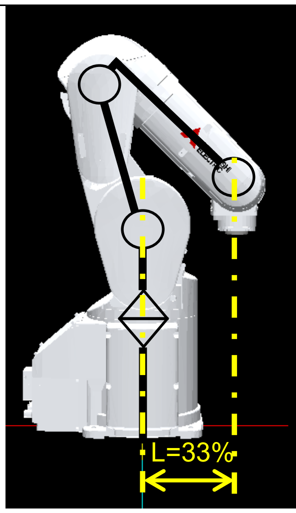
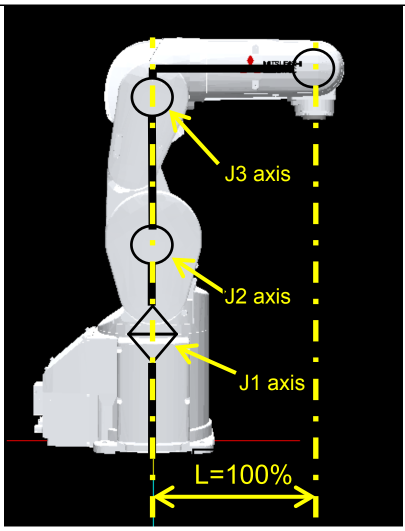
8.2 Symbol definition

The symbols in this section are defined as the table below.

Symbol	Unit	Meaning	Details
L	mm	Robot arm extention rate	Rate of robot arm extension for each axis of rotation. Please refer to “8.3 Robot arm extention rate” for details.
M	%	Load rate	Rate of robot load against maximum load. For example, M=66% means that the robot load is 2.64kg for the robot whose maximum load is 4kg.
OVRD	%	Over	The speed of robot movement.
t	s(second)	Stopping time	Maximum elapsed time until the power supply to the motor is blocked after SS1 function is activated.
deg	° (degree)	Stopping angle	Maximum motion angle until the power supply to the motor is blocked after SS1 function is activated.
d	mm	Stopping distance	Maximum motion distance until the power supply to the motor is blocked after SS1 function is activated. (only for J3 axis of RH-FH series)

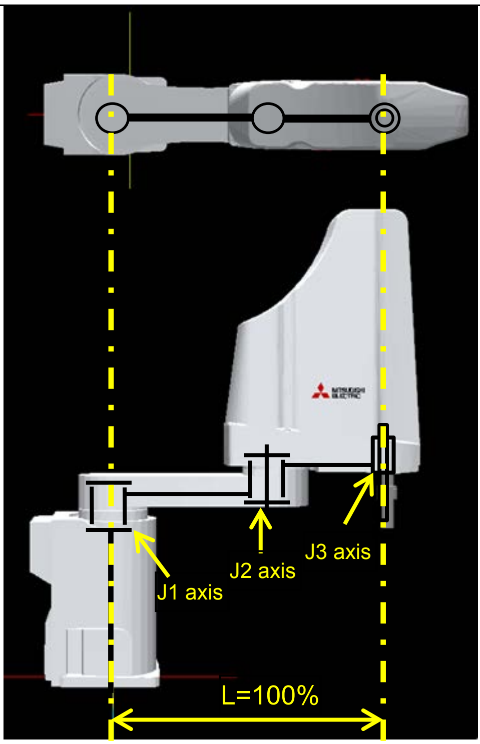
8.3 Robot arm extention rate

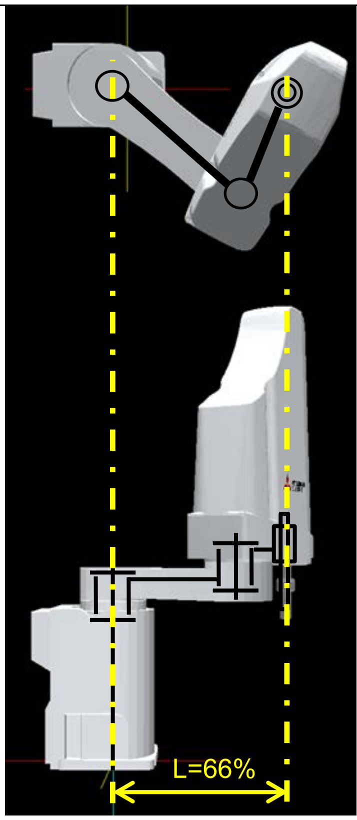
8.3.1 RV-F series

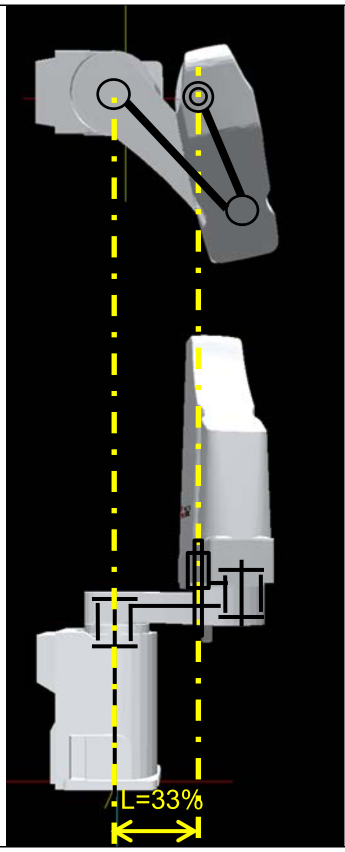
Axis	L=100%	L=66%	L=33%
J1			
J2			
J3			

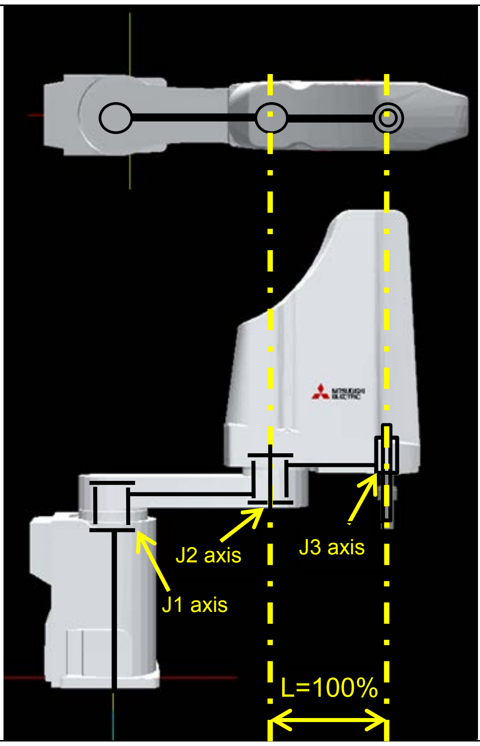
Note: The robot model in the figure is RV−4F.

8.3.2 RH-FH series

<table>
<tr><td>Axis</td><td>L=100%</td><td>L=66%</td><td>L=33%</td></tr>
<tr><td>J1</td><td>


</td><td>


</td><td>


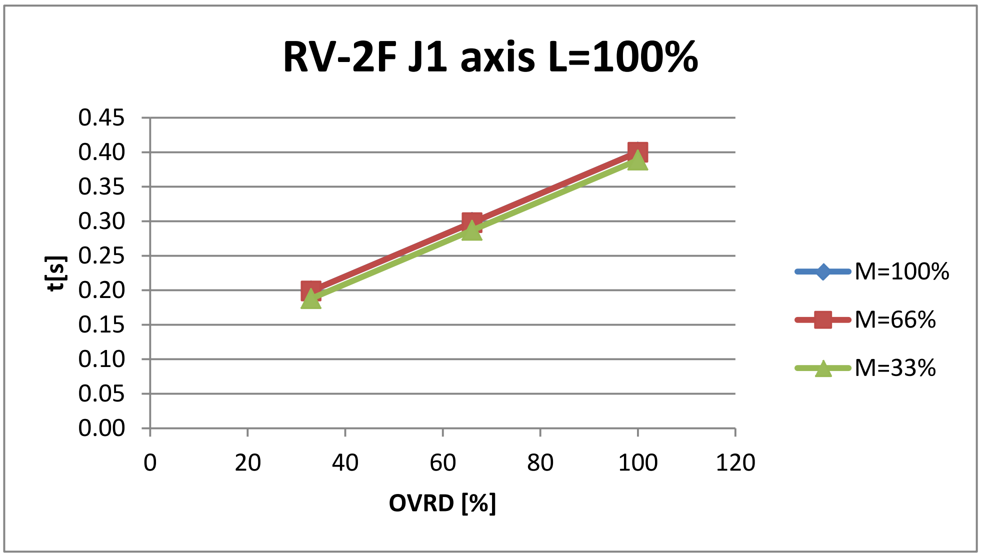
</td></tr>
<tr><td>J2</td><td>


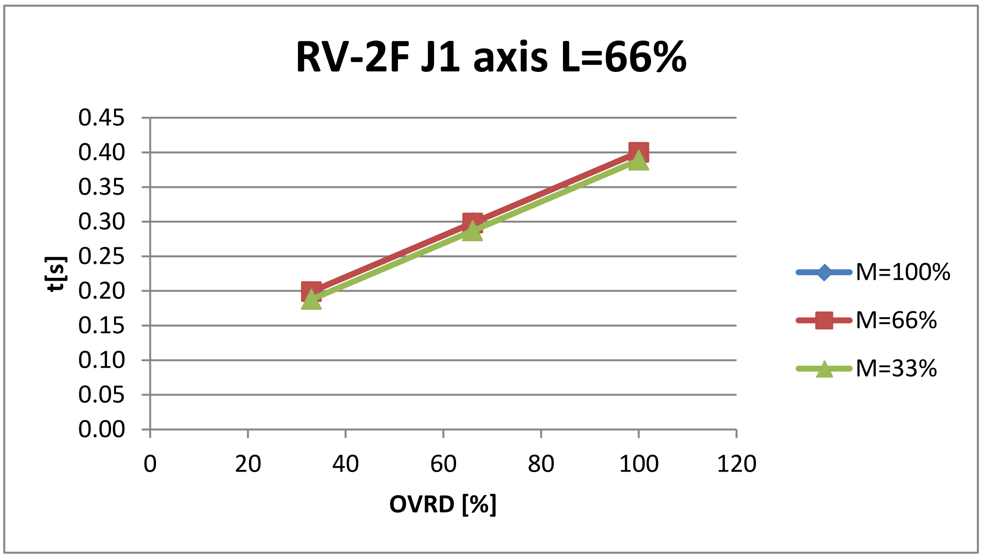
</td><td></td><td></td></tr>
</table>

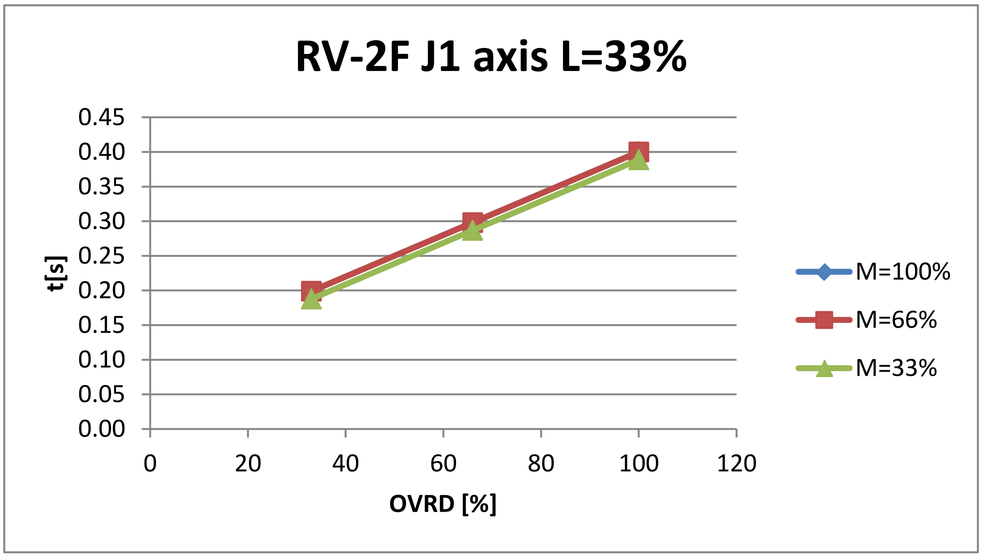
8.4 Stopping time/stopping angle

8.4.1 RV-2F

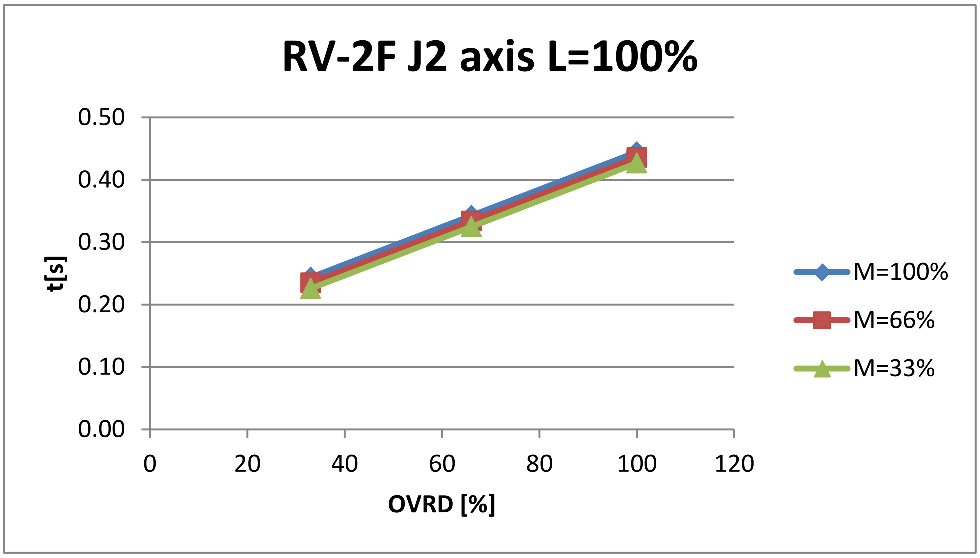
(1) Stopping time of J1 axis

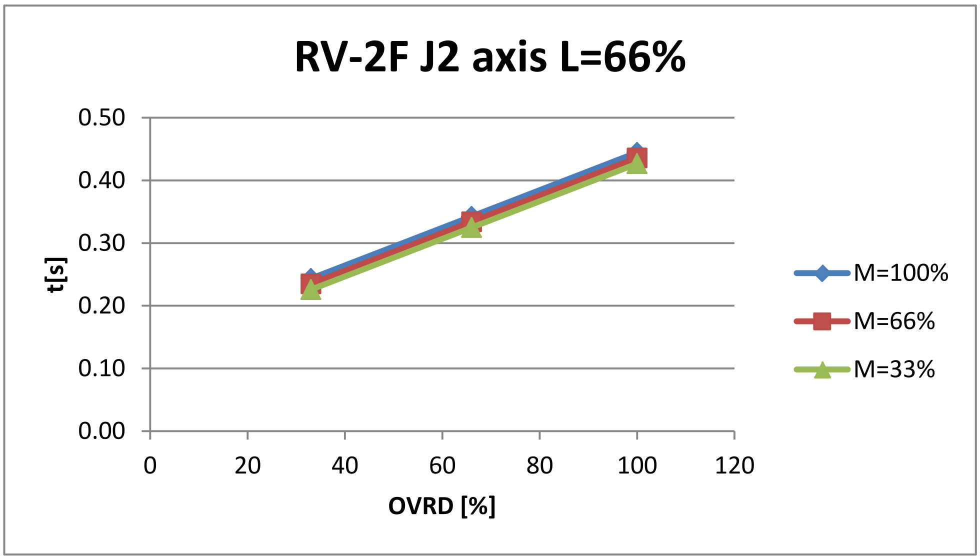


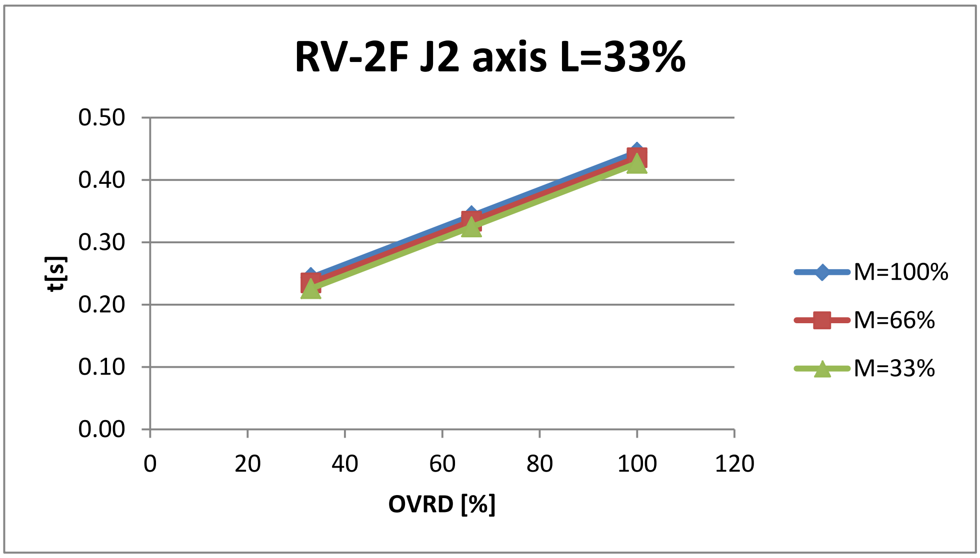




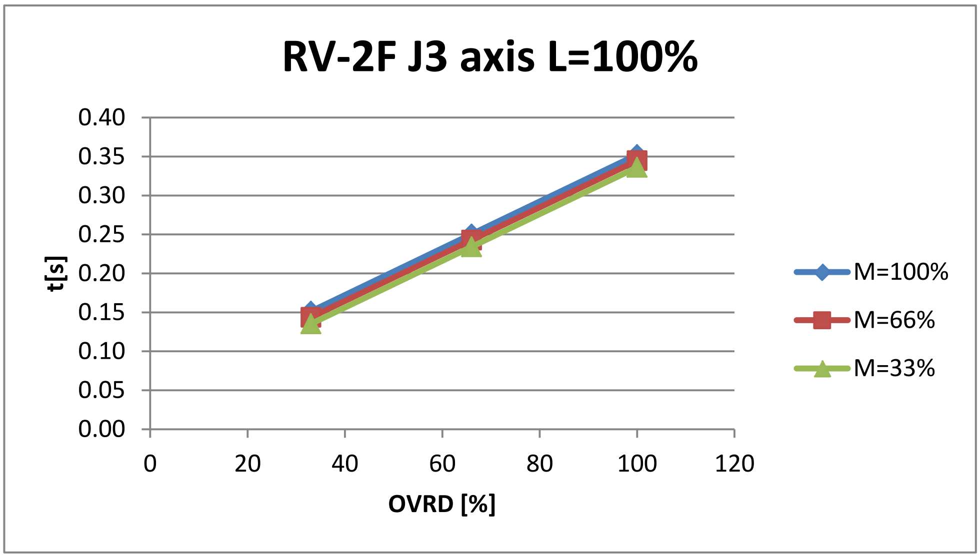
(2) Stopping time of J2 axis



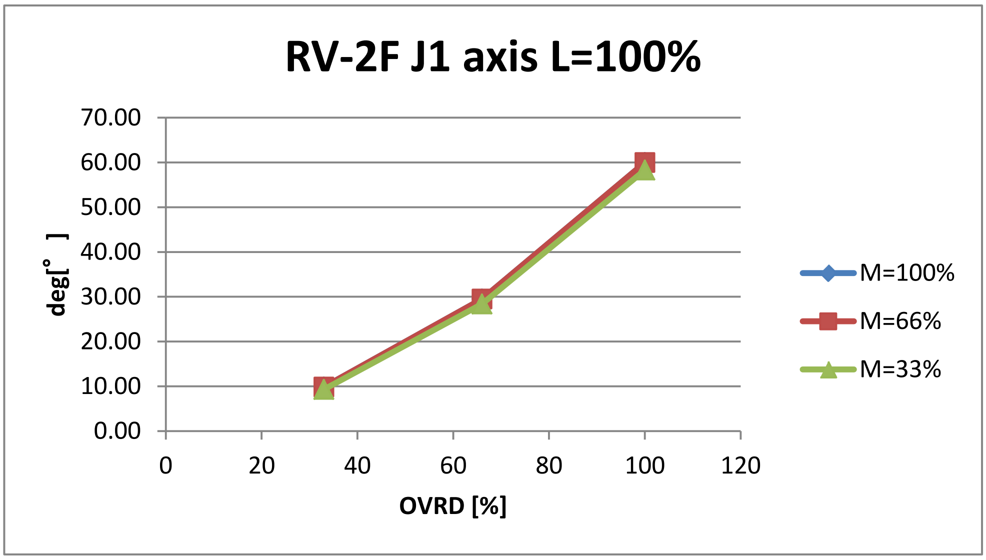


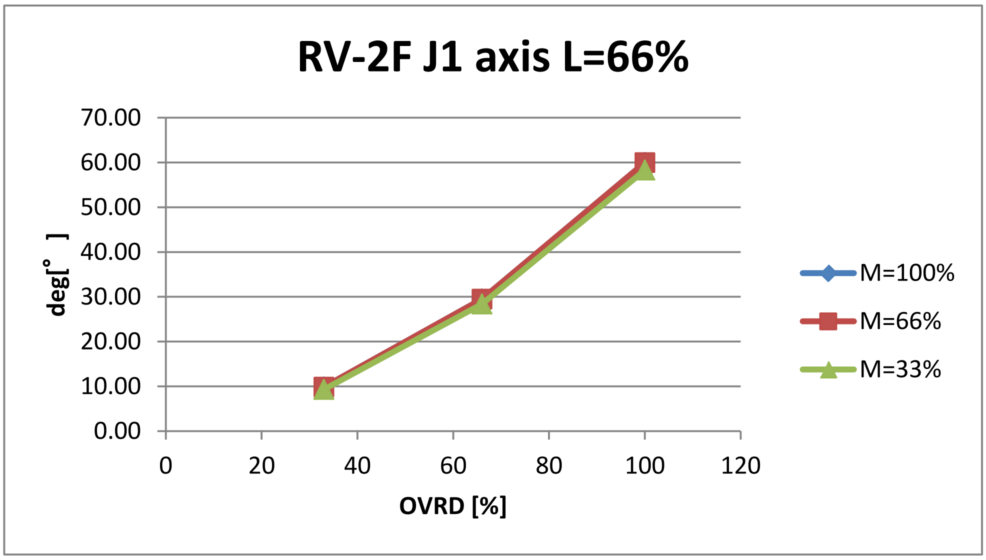


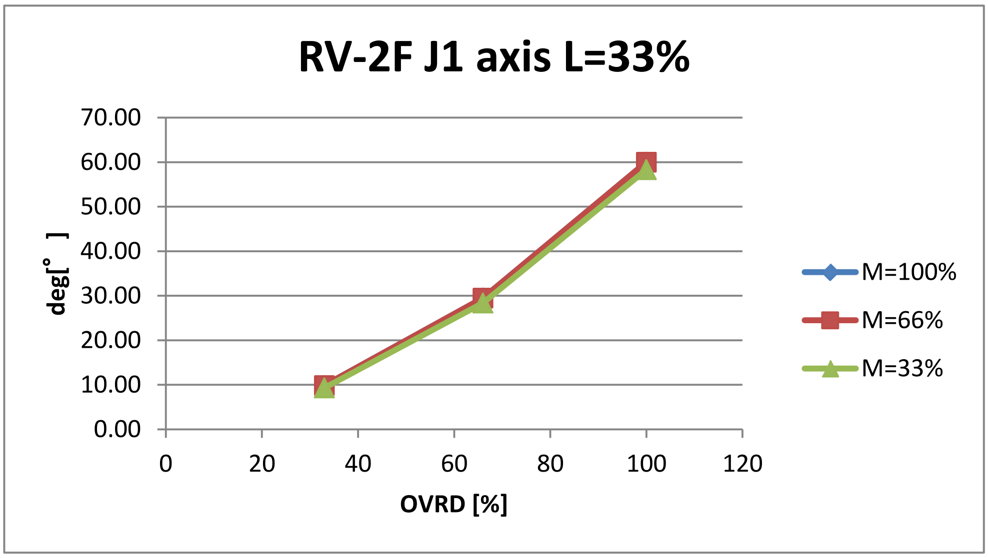
(3) Stopping time of J3 axis



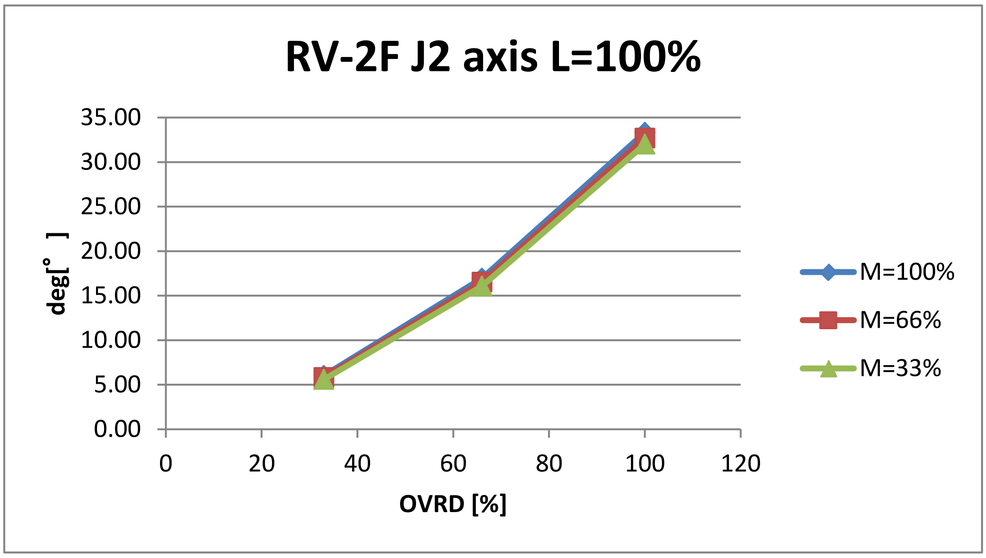
(4) Stopping angle of J1 axis

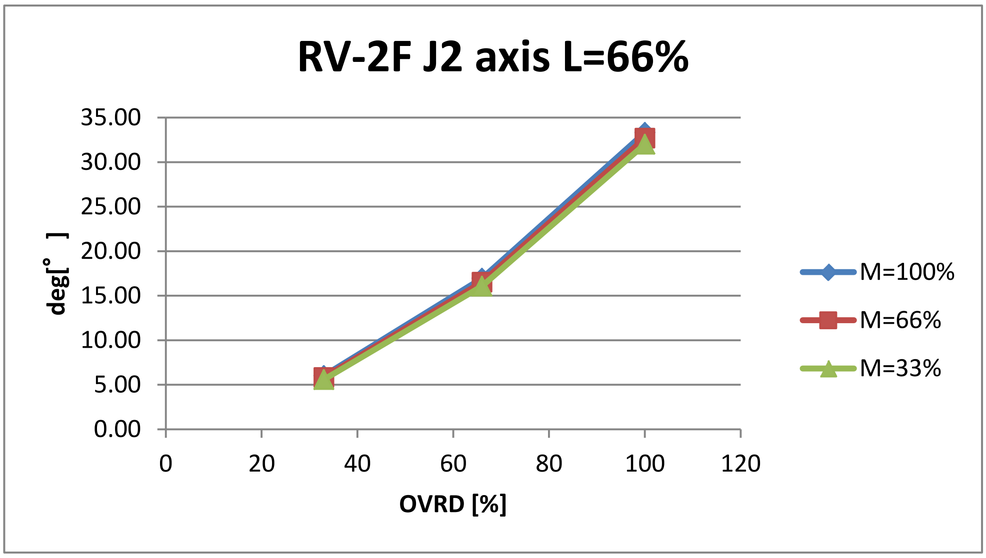


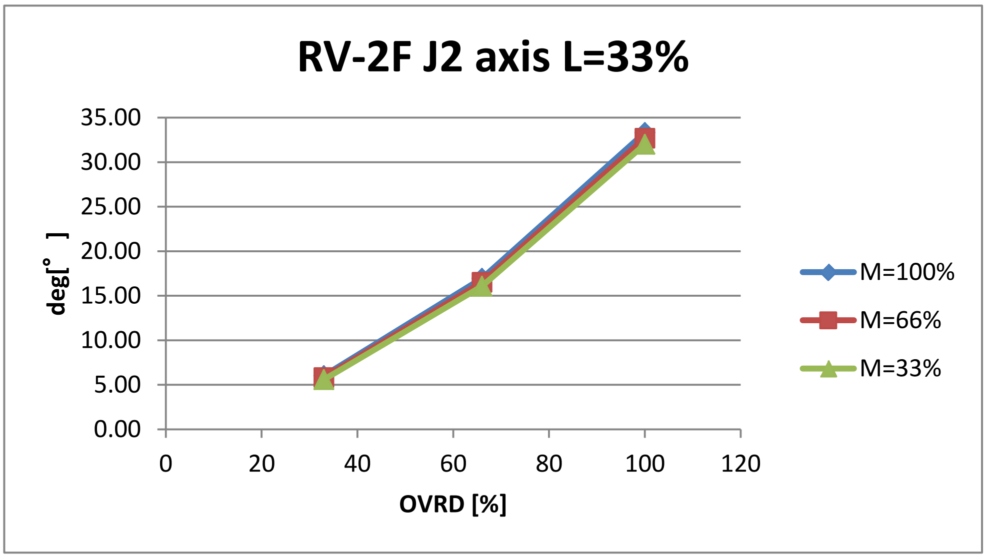




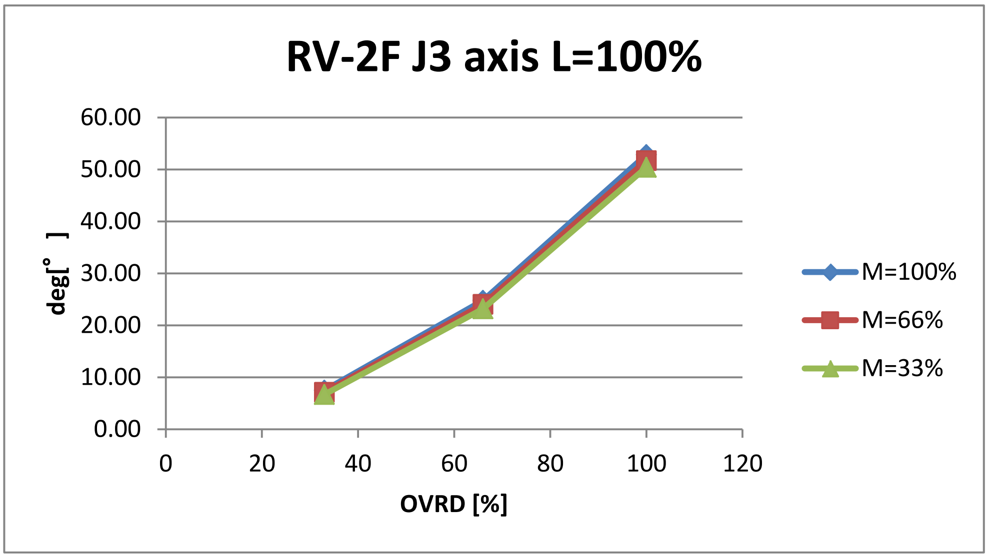
(5) Stopping angle of J2 axis





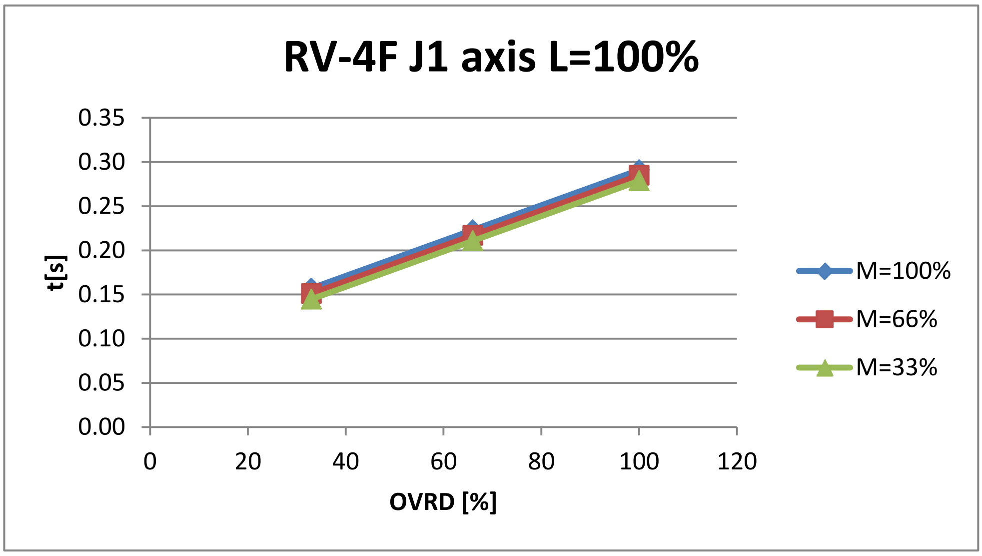


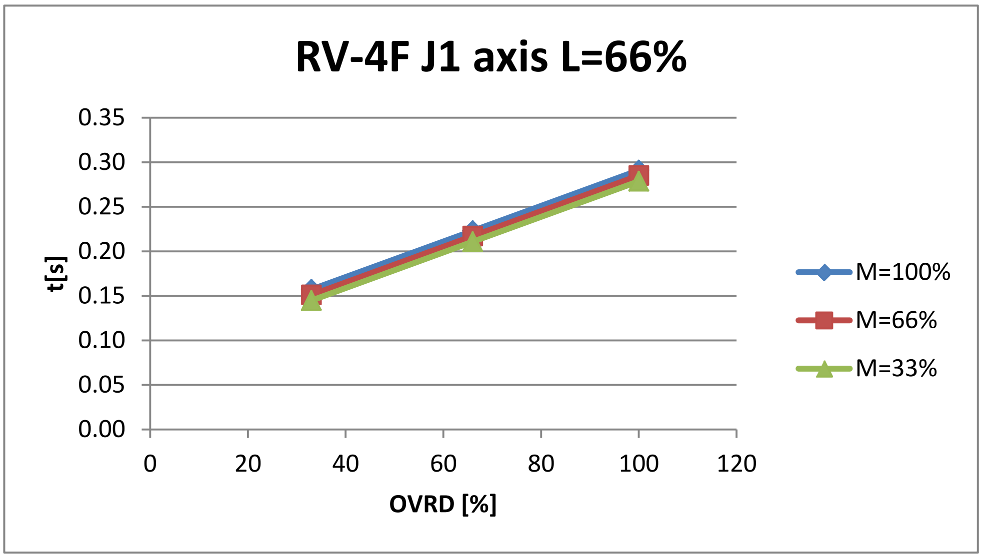
(6) Stopping angle of J3 axis

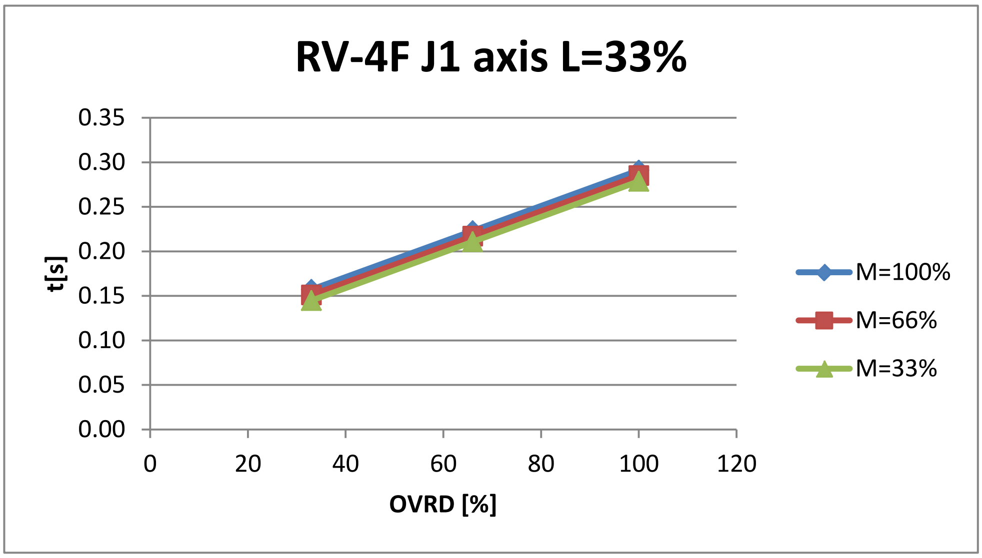


8.4.2 RV-4F

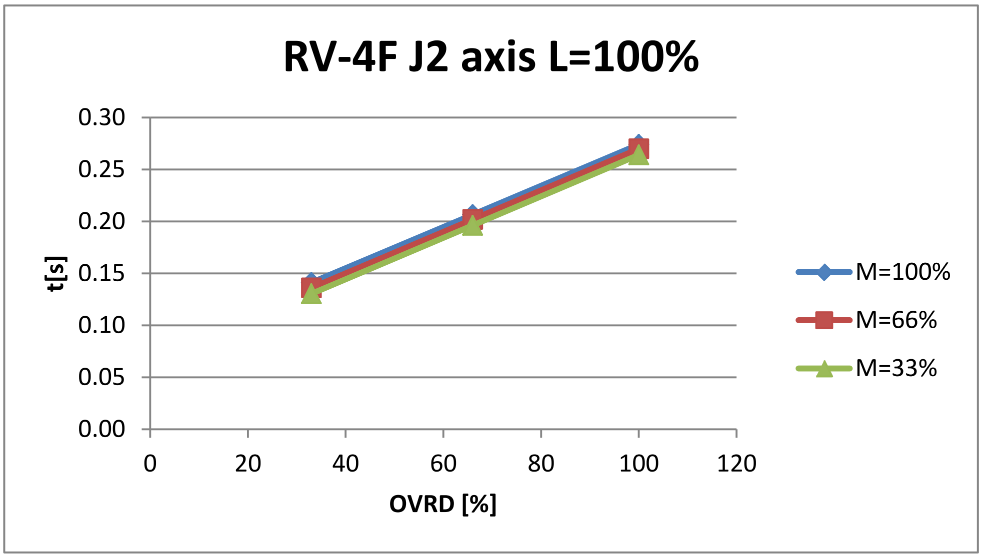
(1) Stopping time of J1 axis

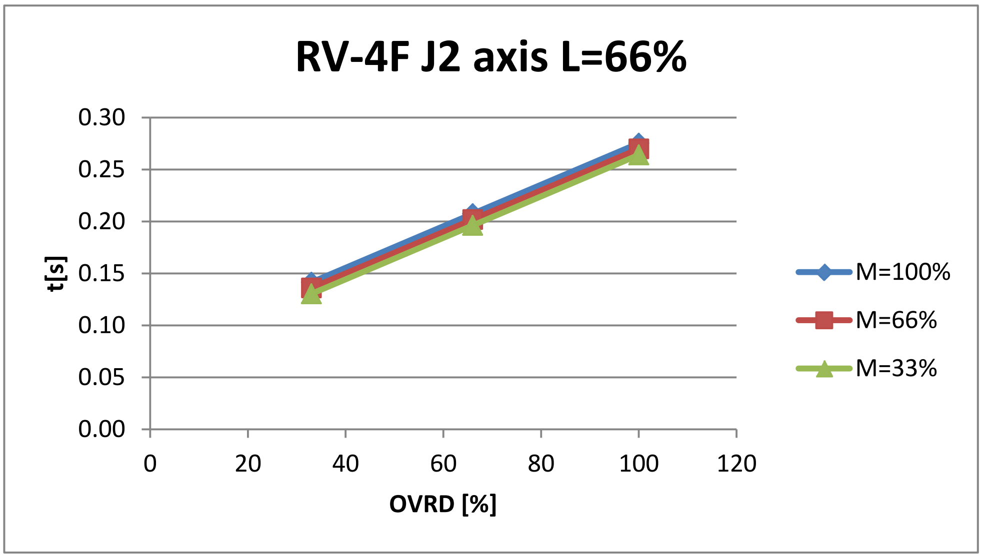


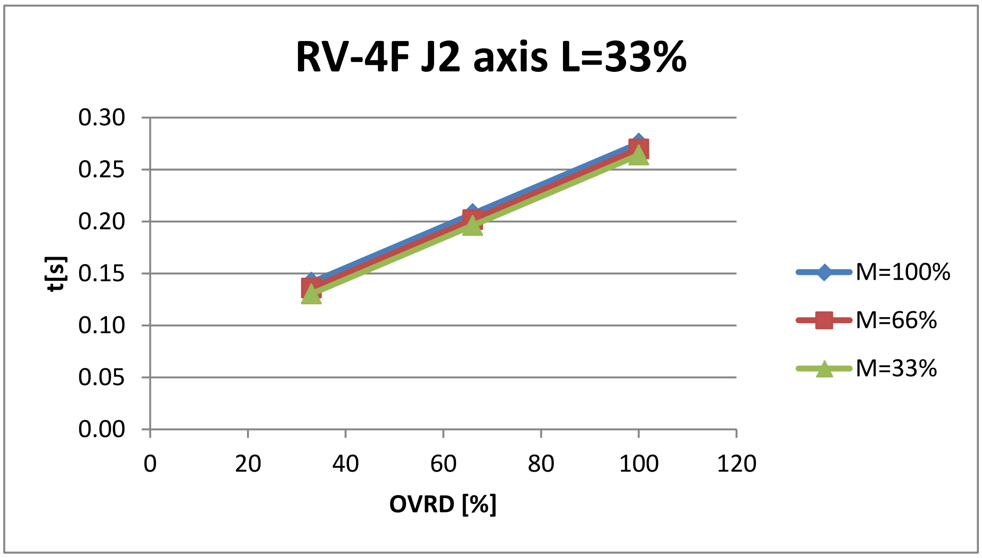




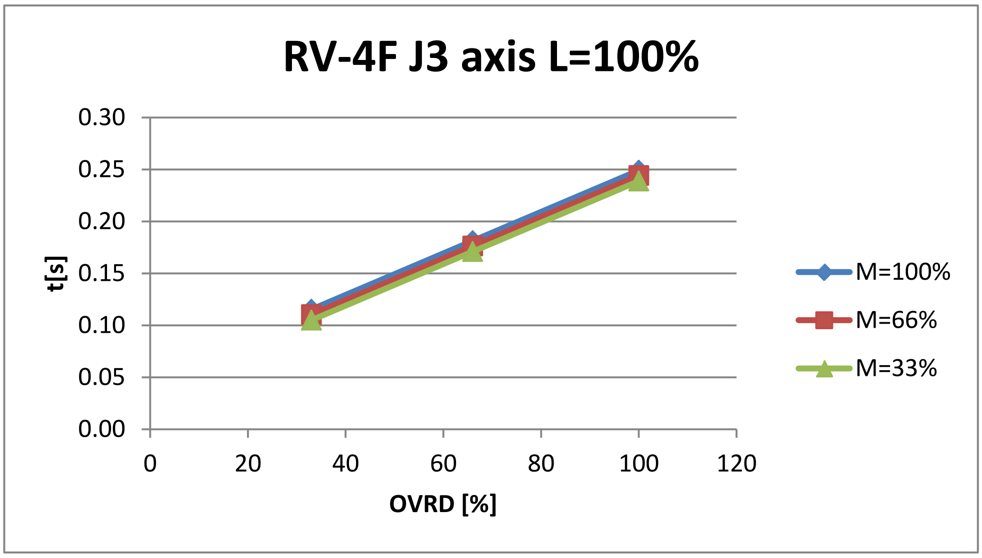
(2) Stopping time of J2 axis



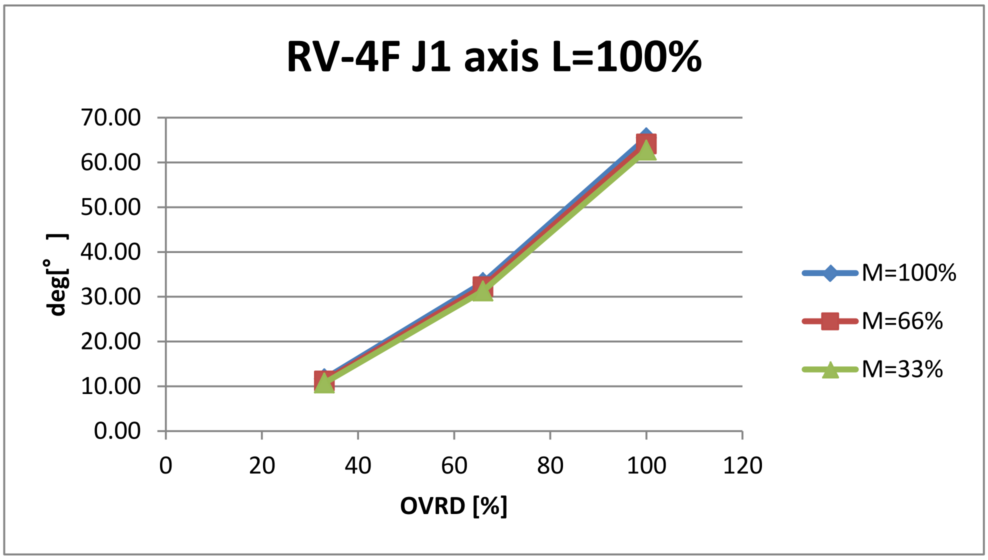


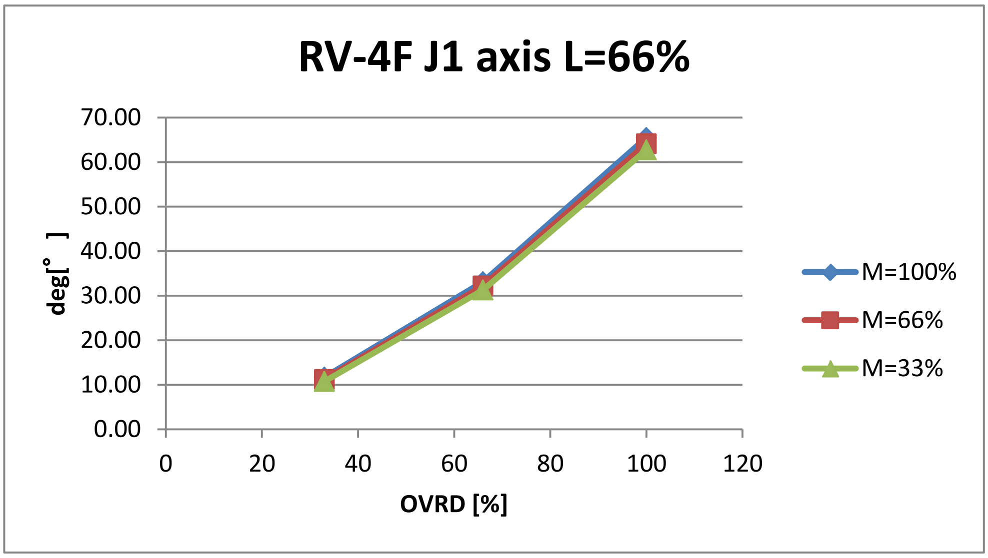


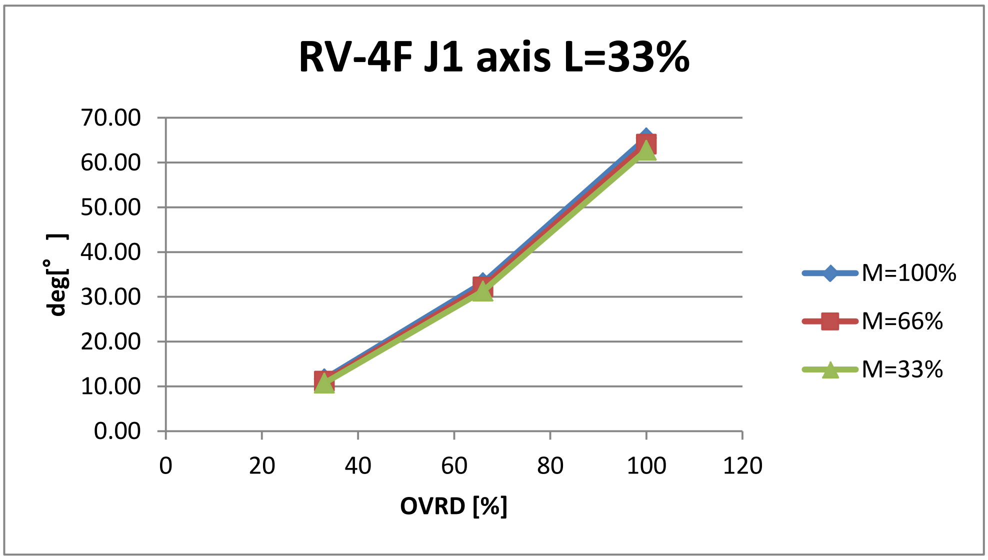
(3) Stopping time of J3 axis



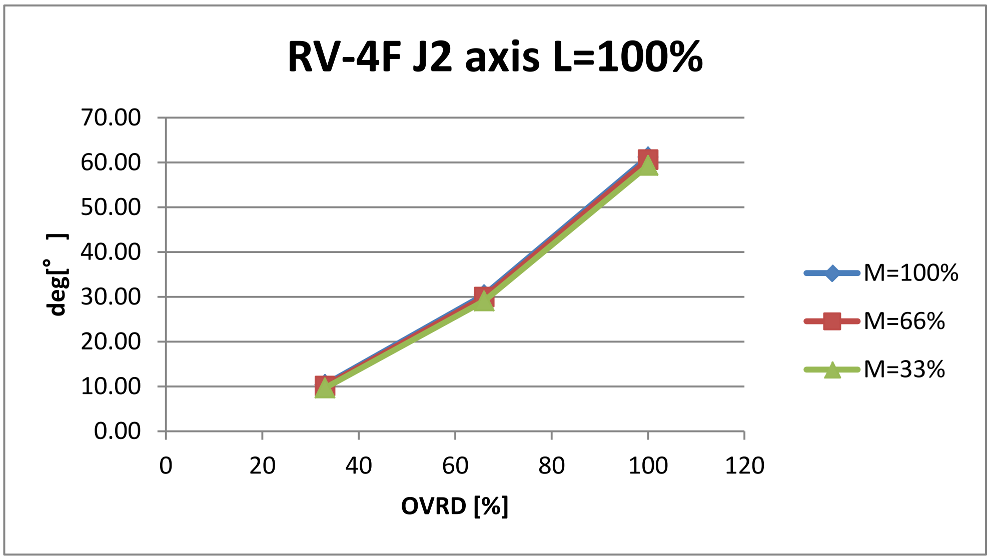
(4) Stopping angle of J1 axis

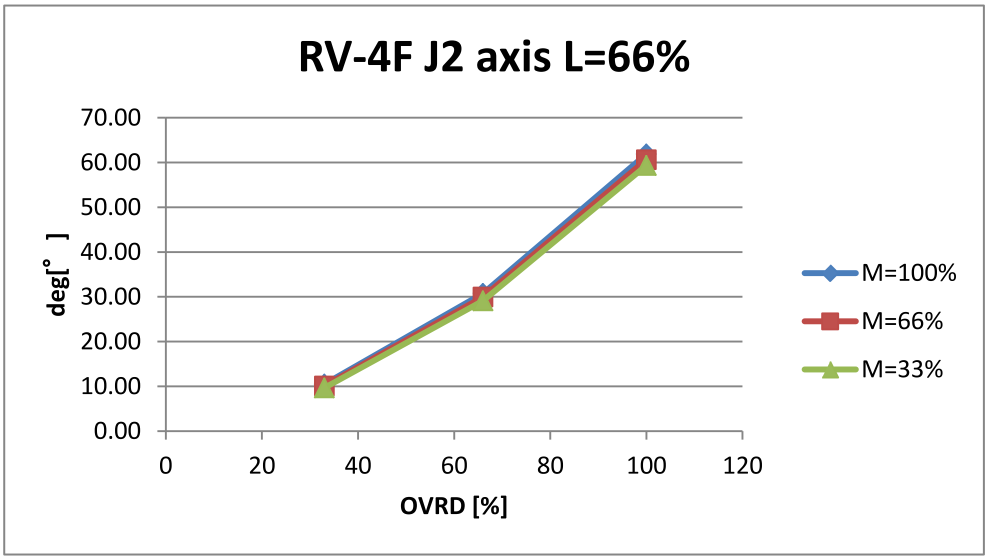


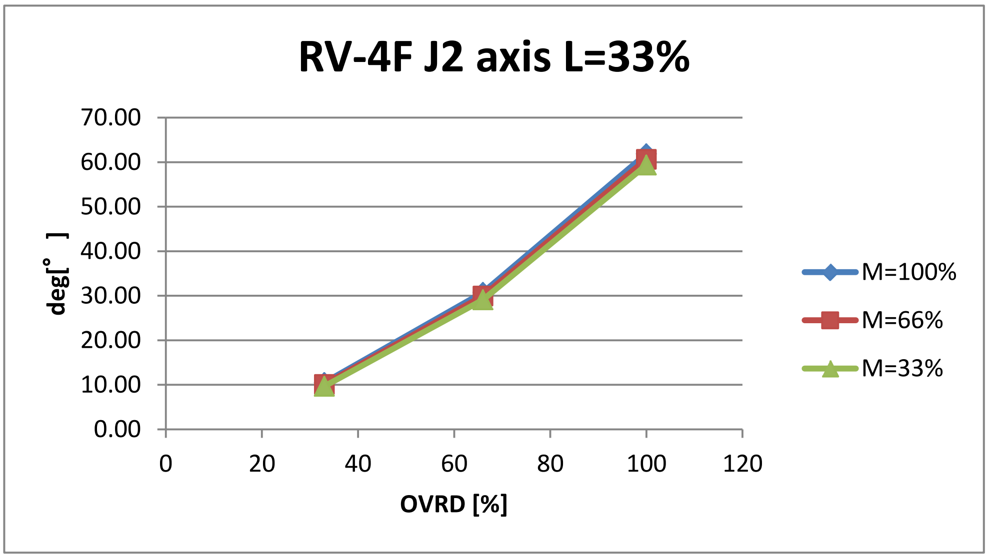




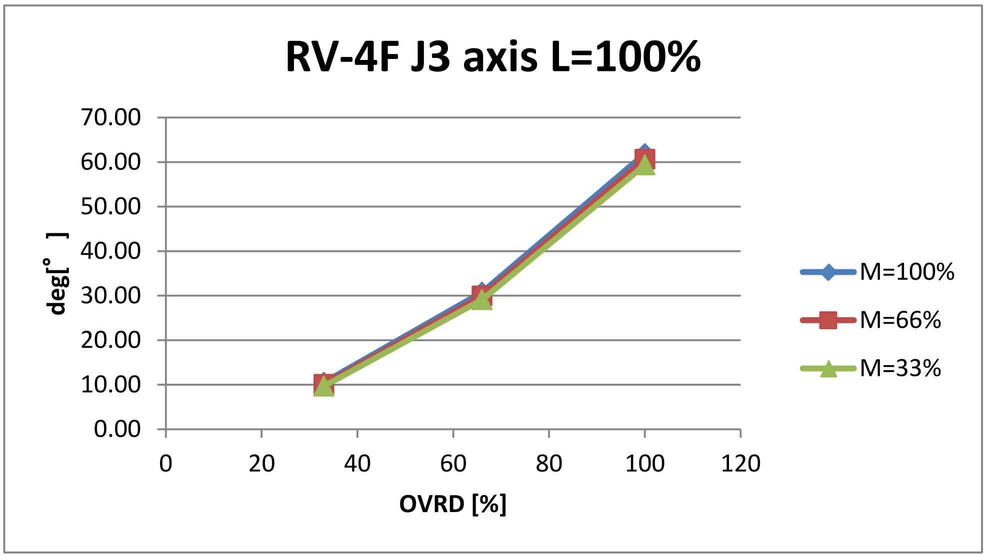
(5) Stopping angle of J2 axis





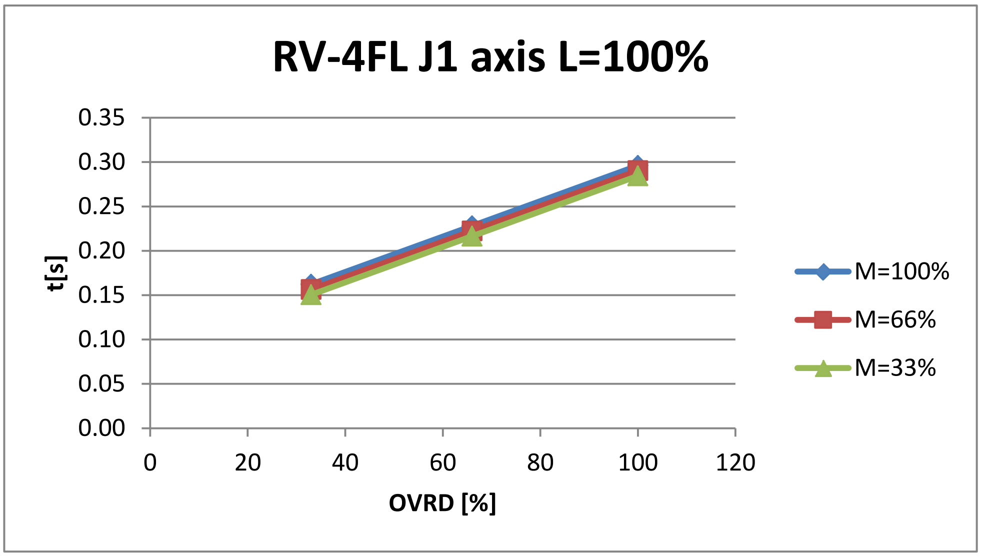


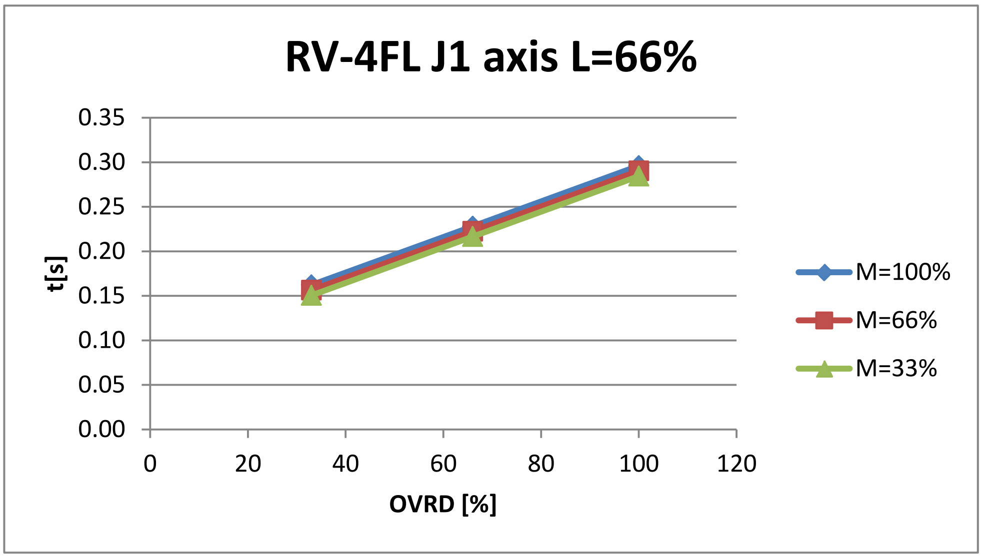
(6) Stopping angle of J3 axis

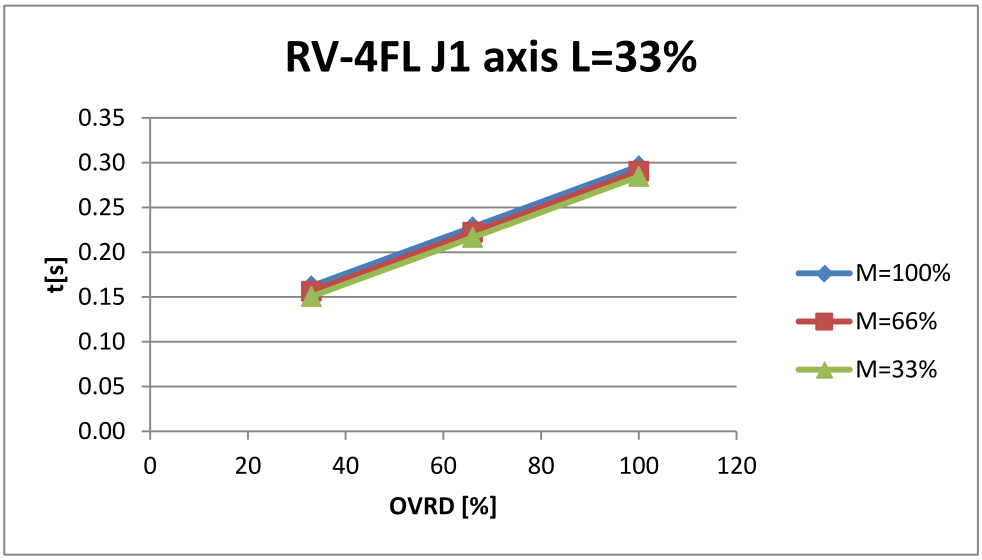


8.4.3 RV-4FL

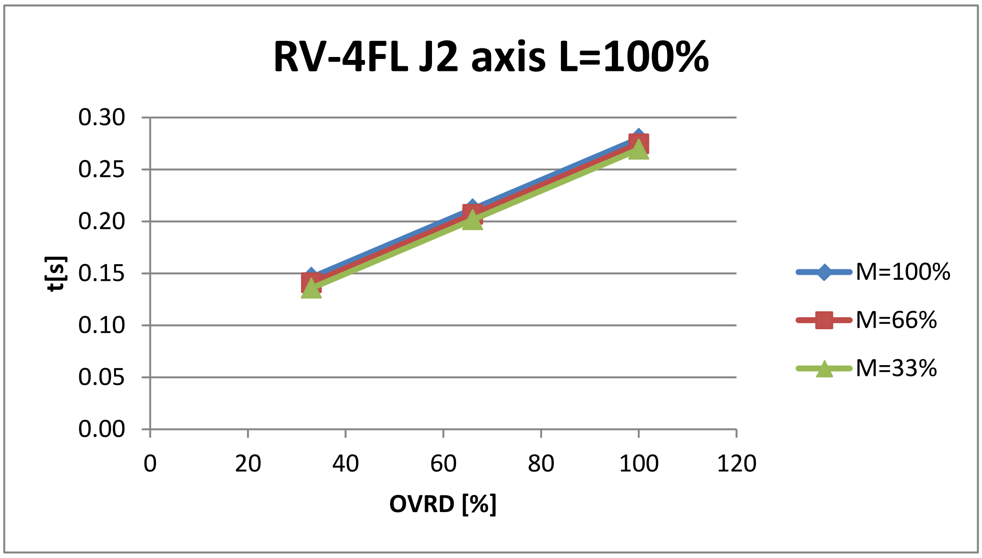
(1) Stopping time of J1 axis

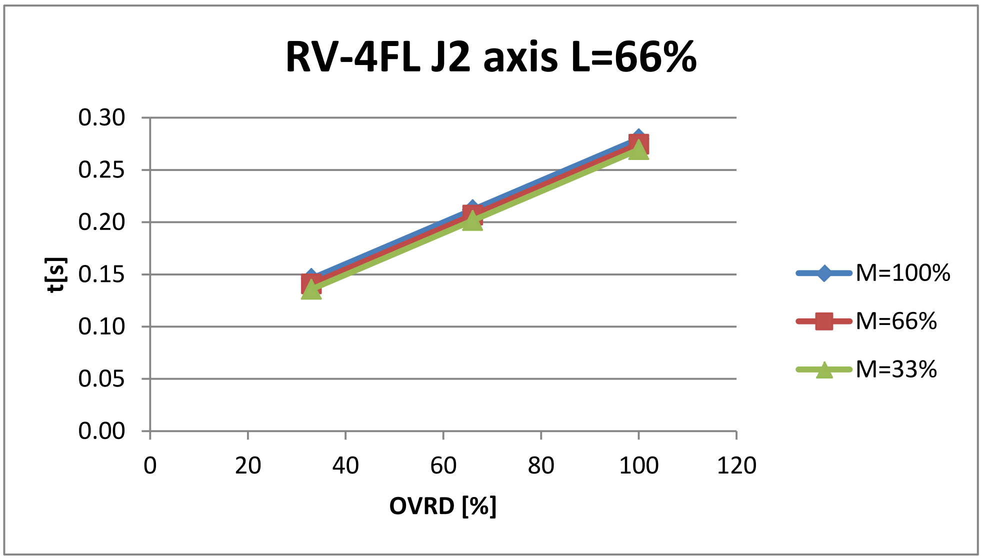


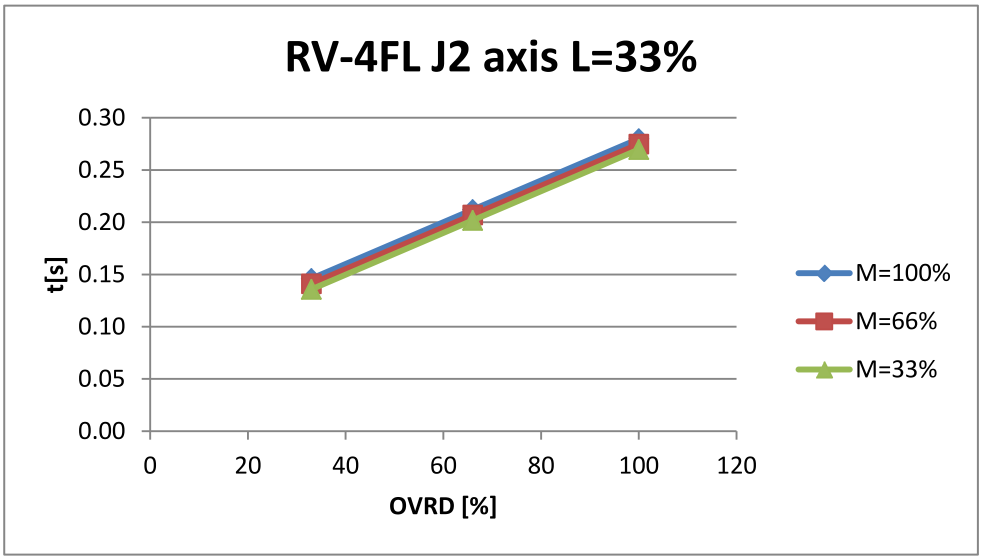




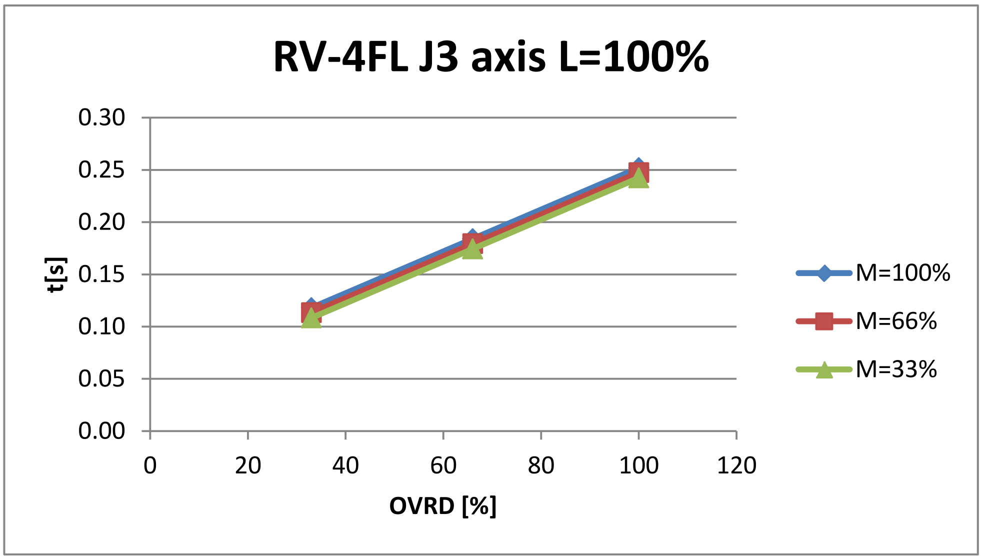
(2) Stopping time of J2 axis



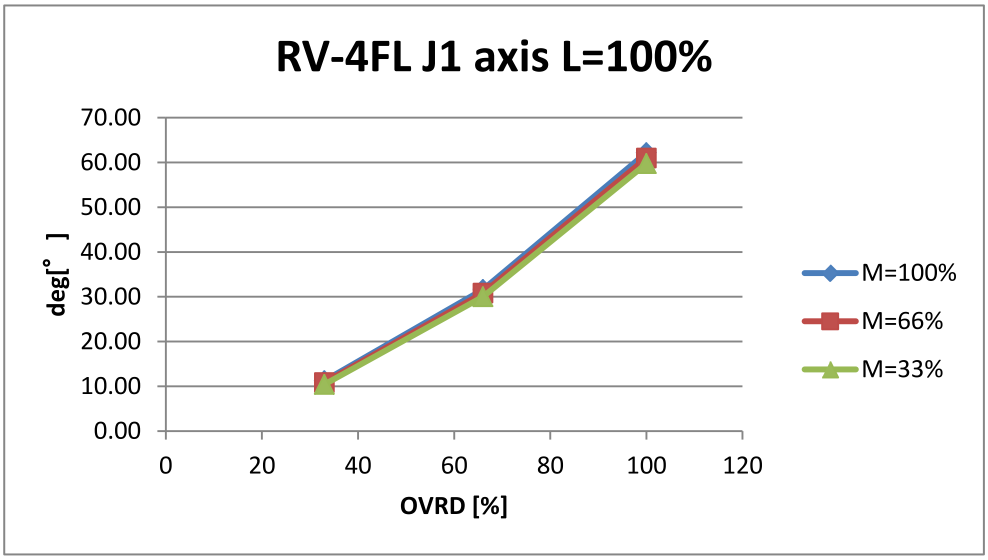


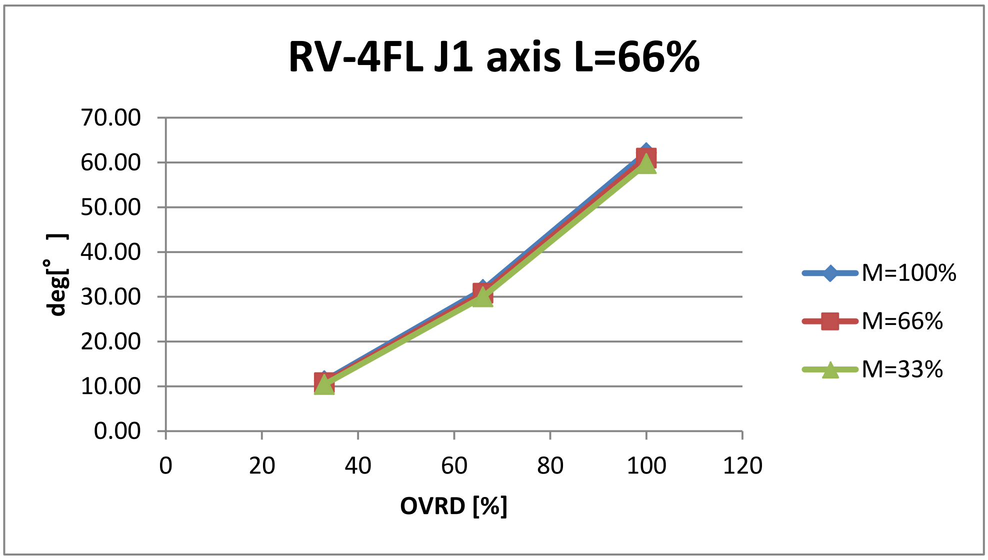


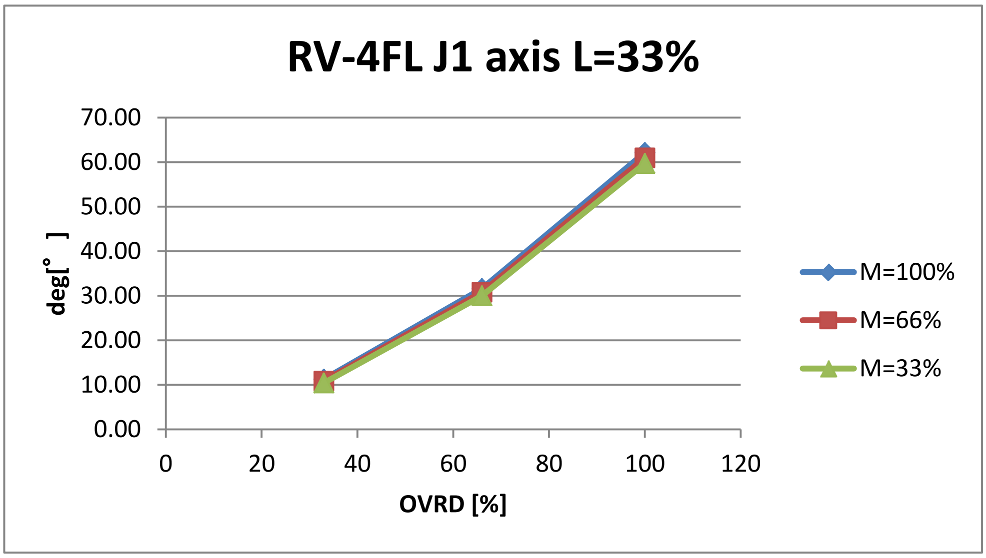
(3) Stopping time of J3 axis



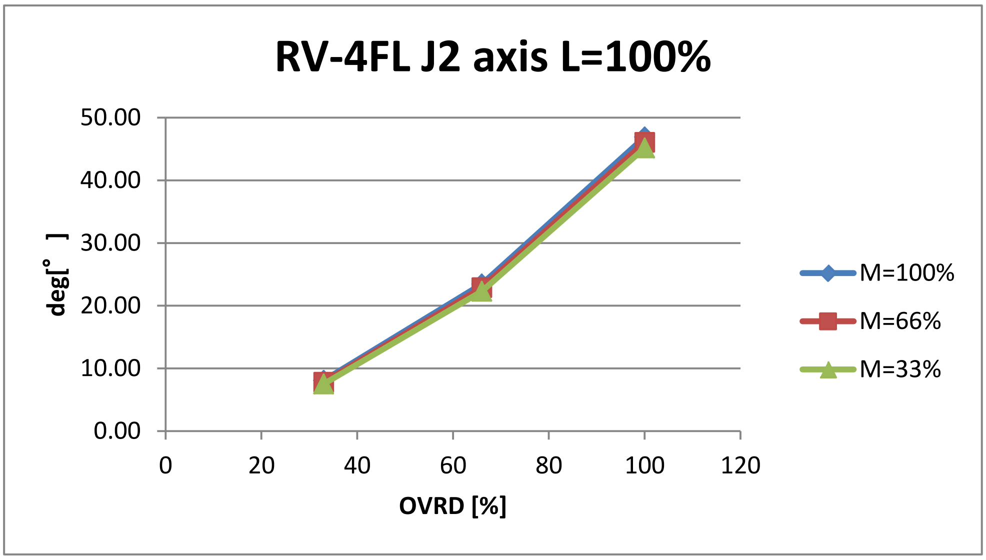
(4) Stopping angle of J1 axis

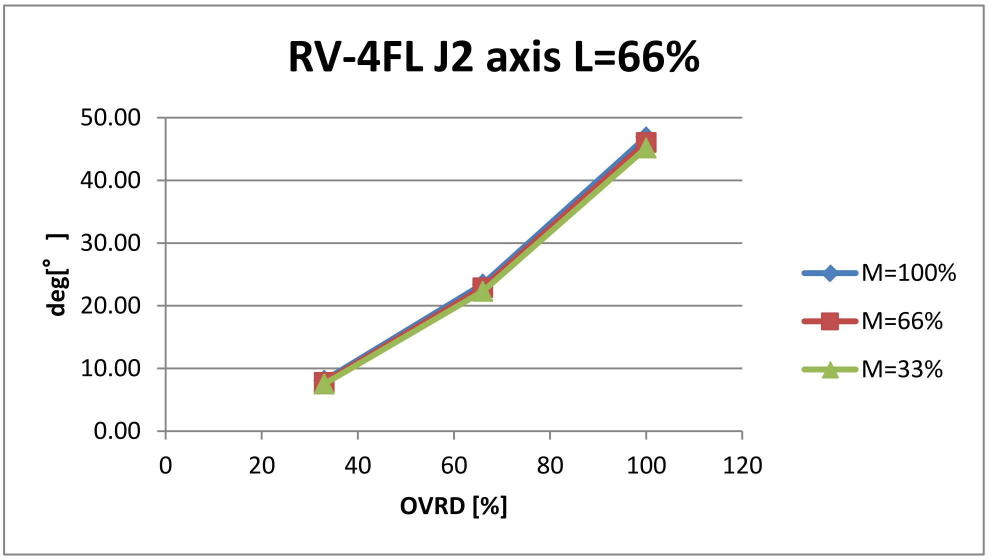


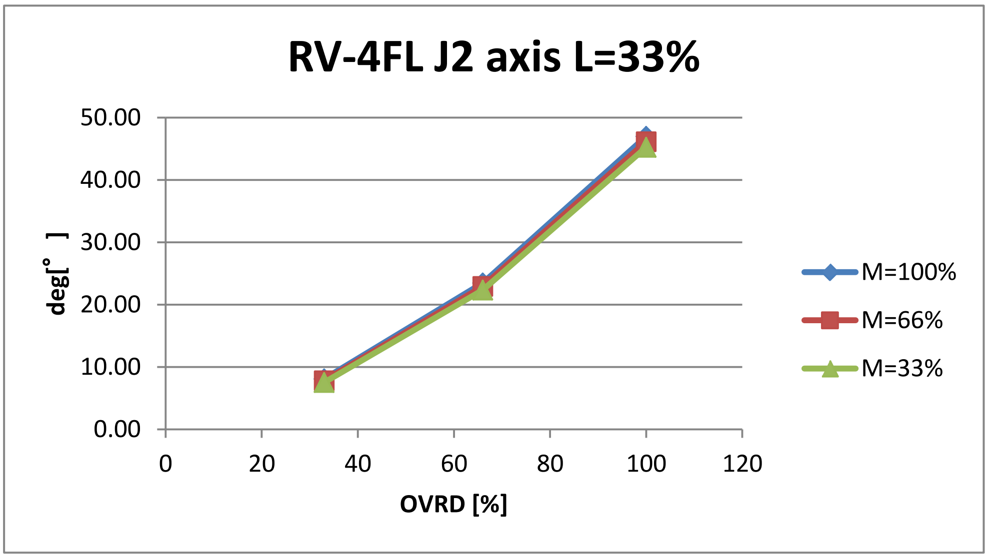




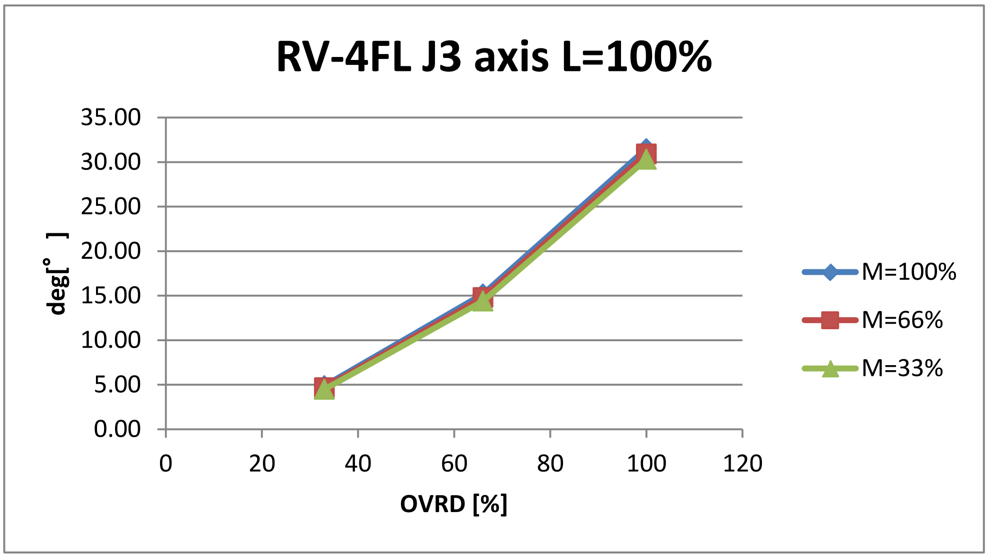
(5) Stopping angle of J2 axis





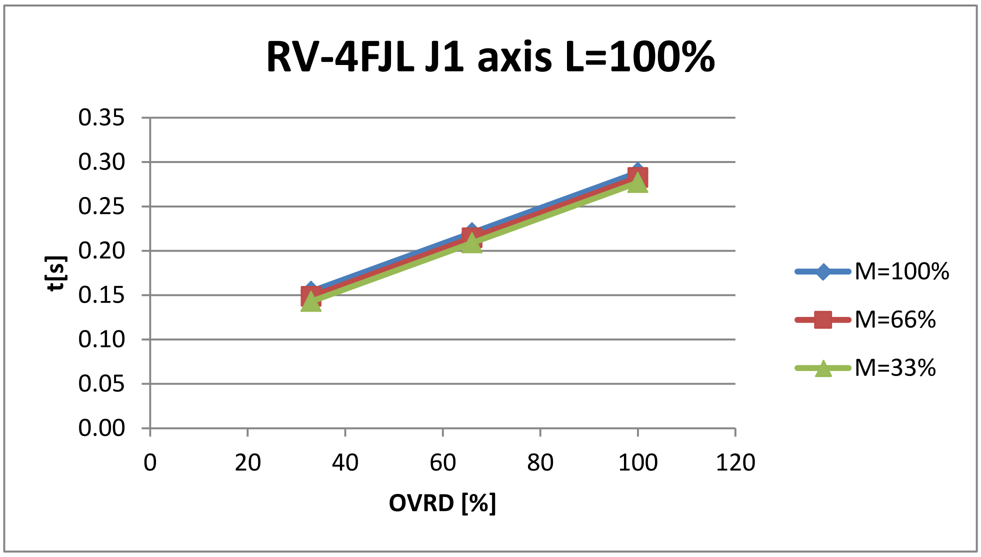


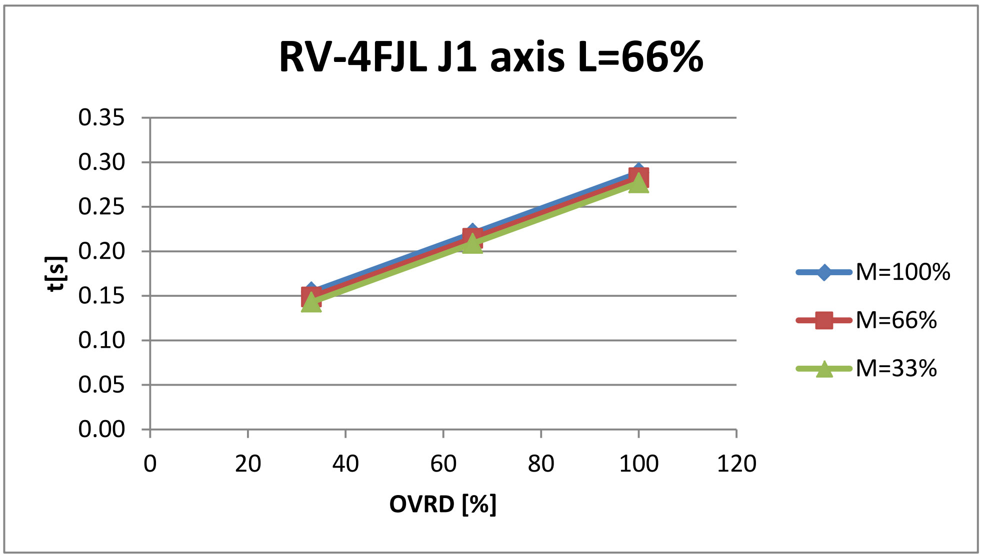
(6) Stopping angle of J3 axis

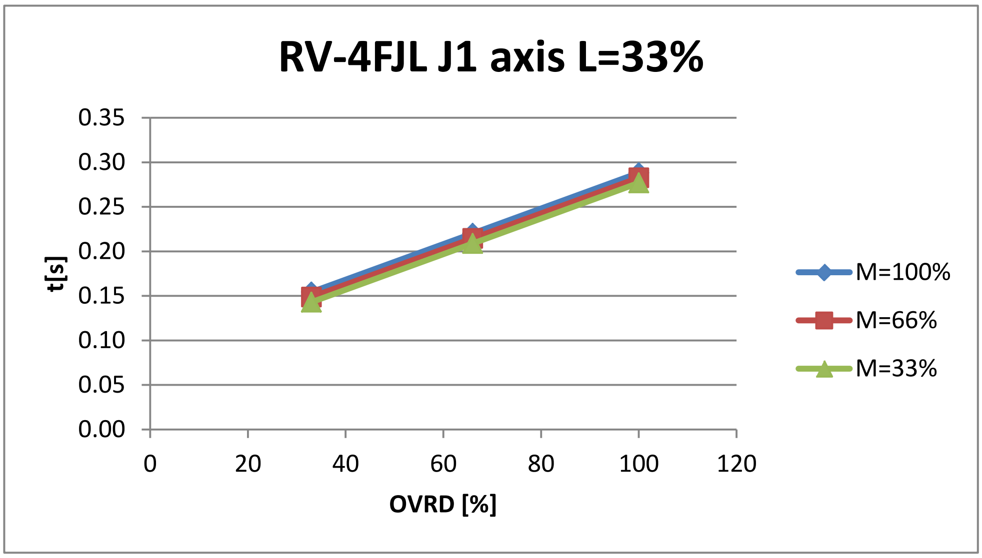


8.4.4 RV-4FJL

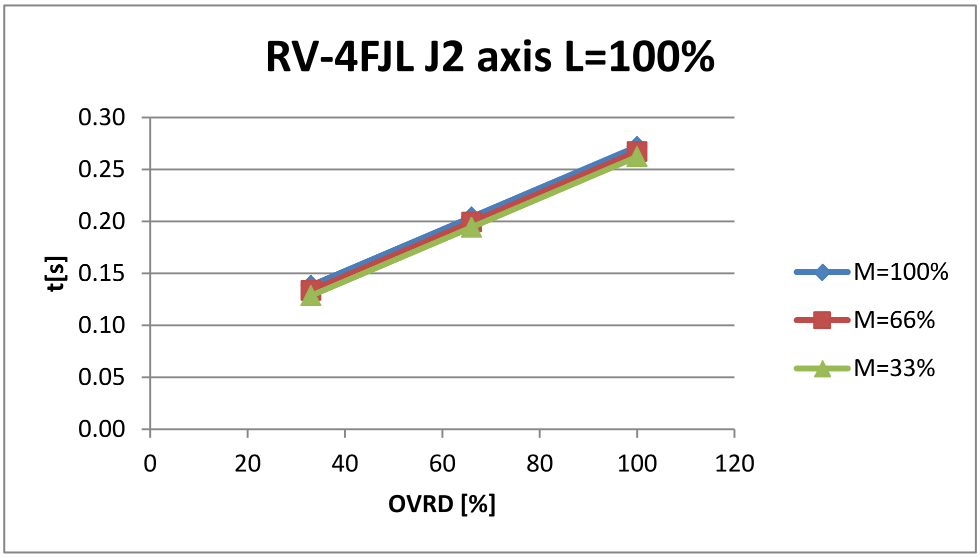
(1) Stopping time of J1 axis

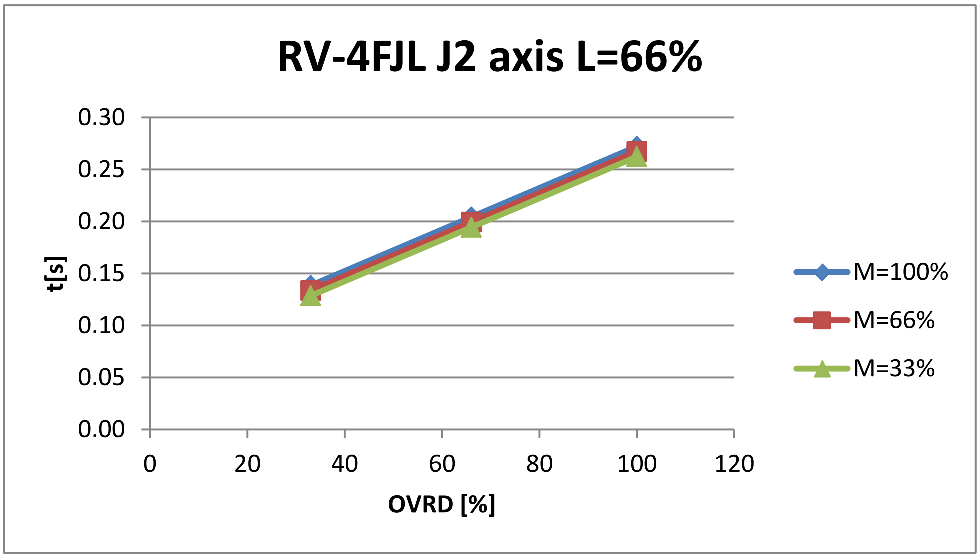


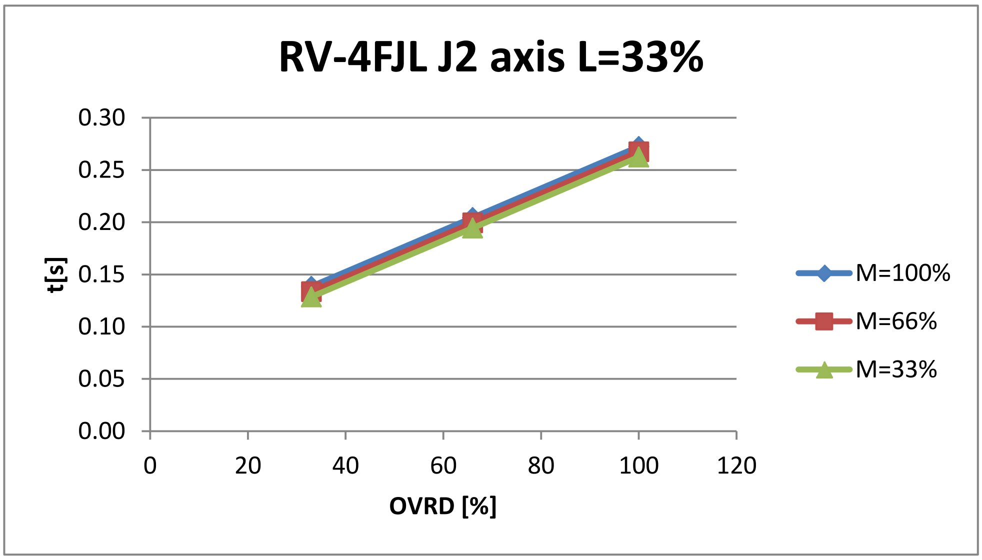




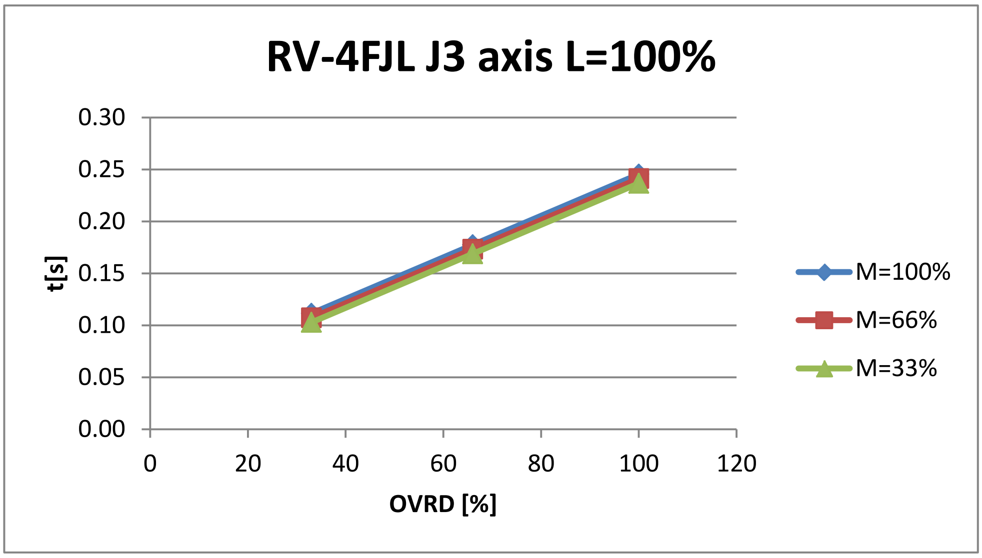
(2) Stopping time of J2 axis



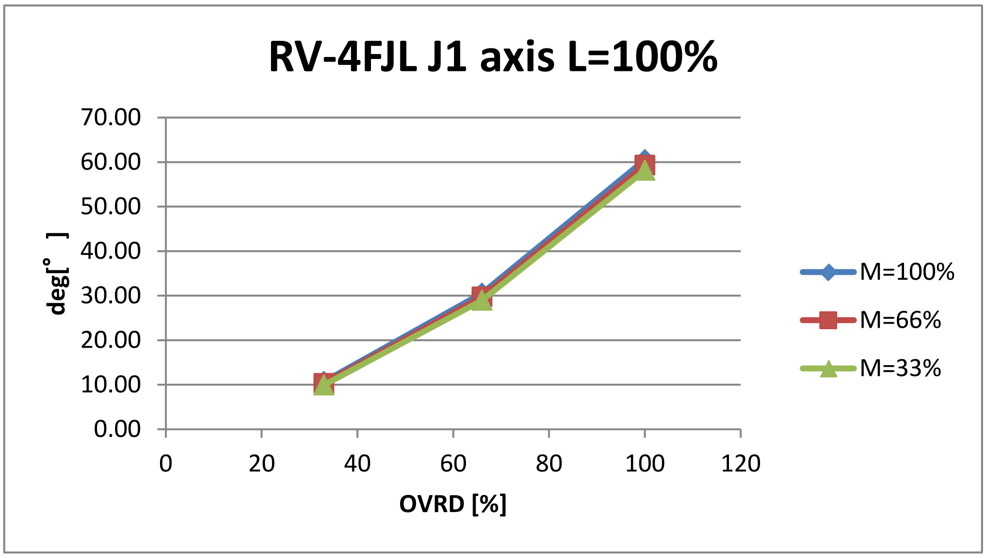


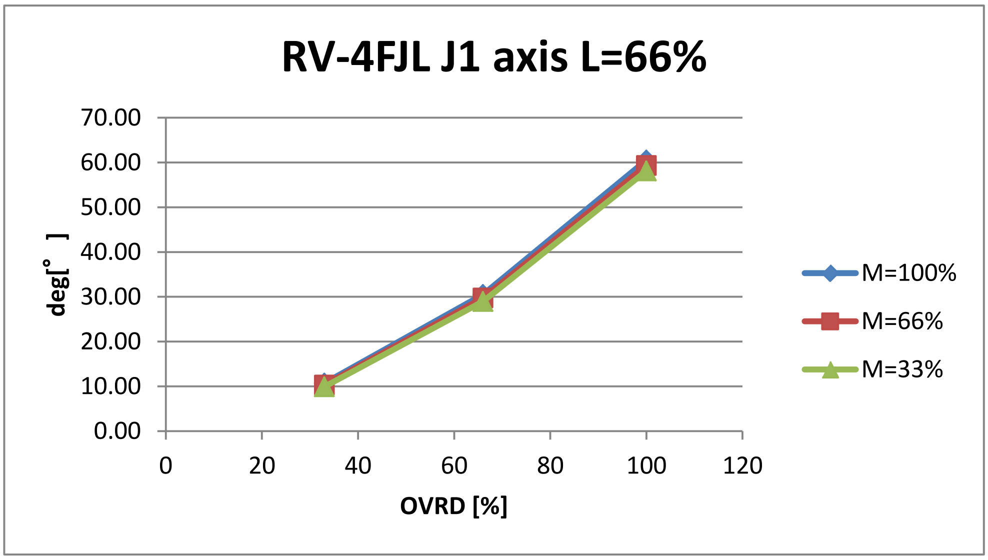


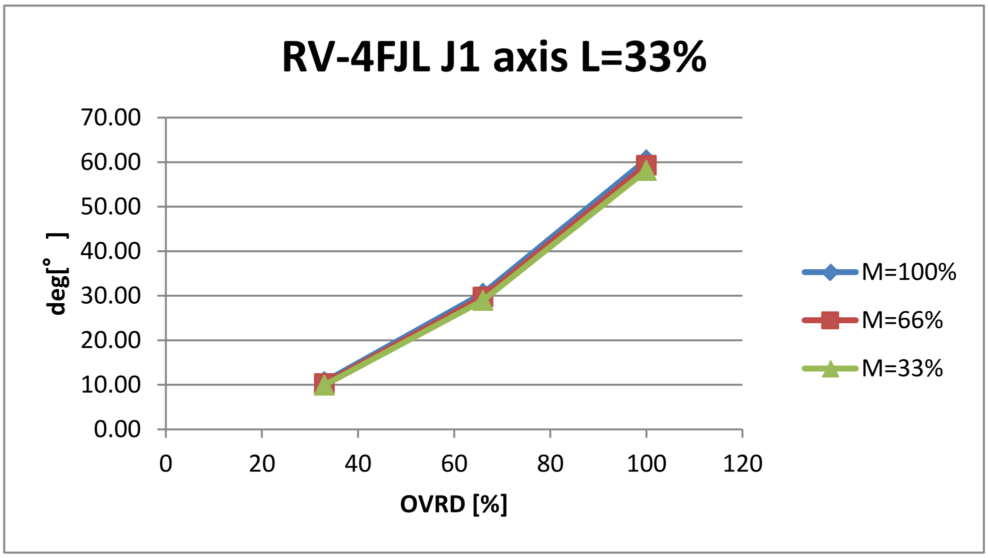
(3) Stopping time of J3 axis



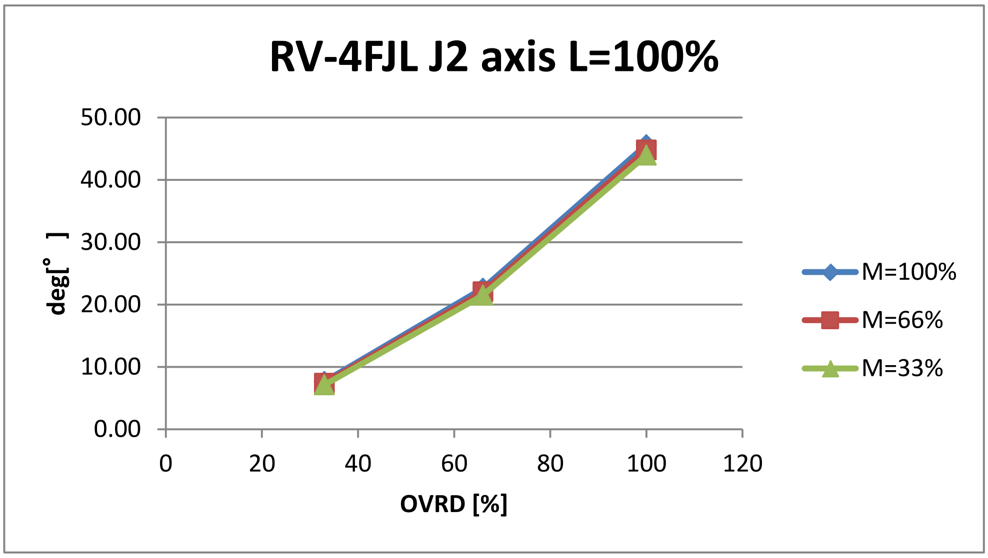
(4) Stopping angle of J1 axis

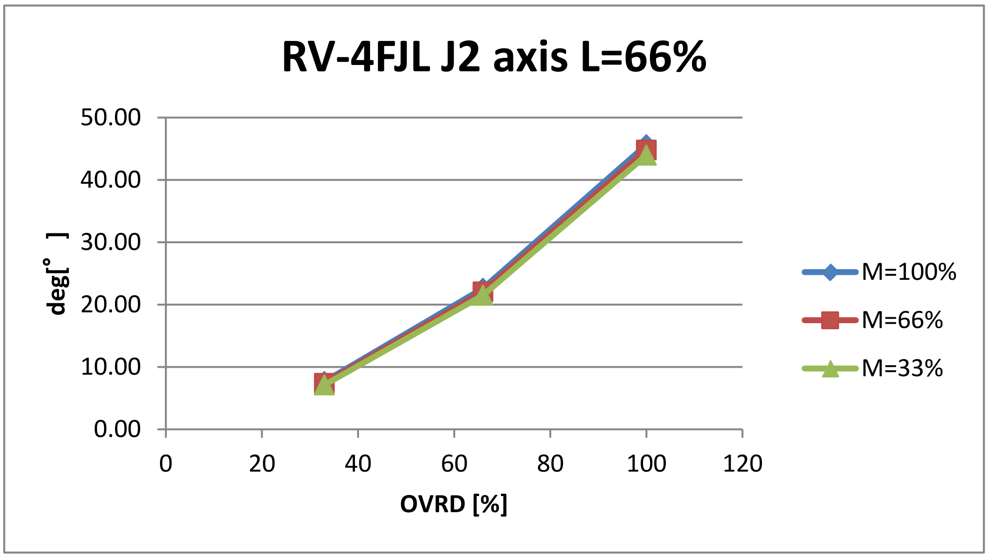


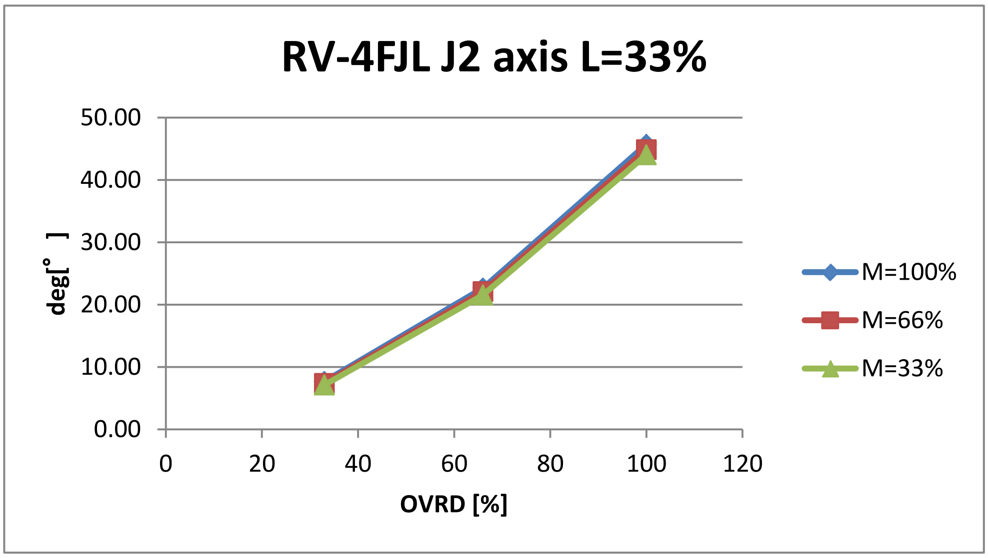




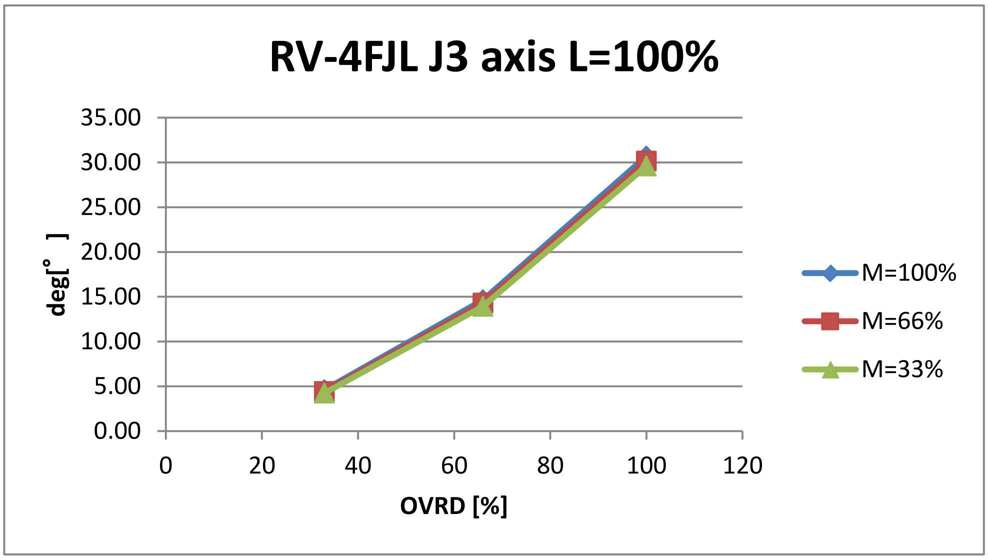
(5) Stopping angle of J2 axis





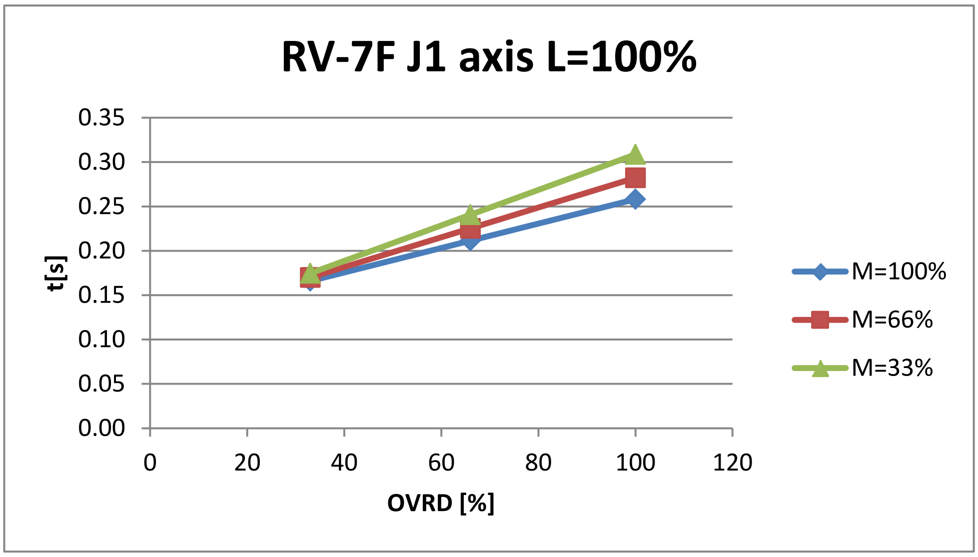


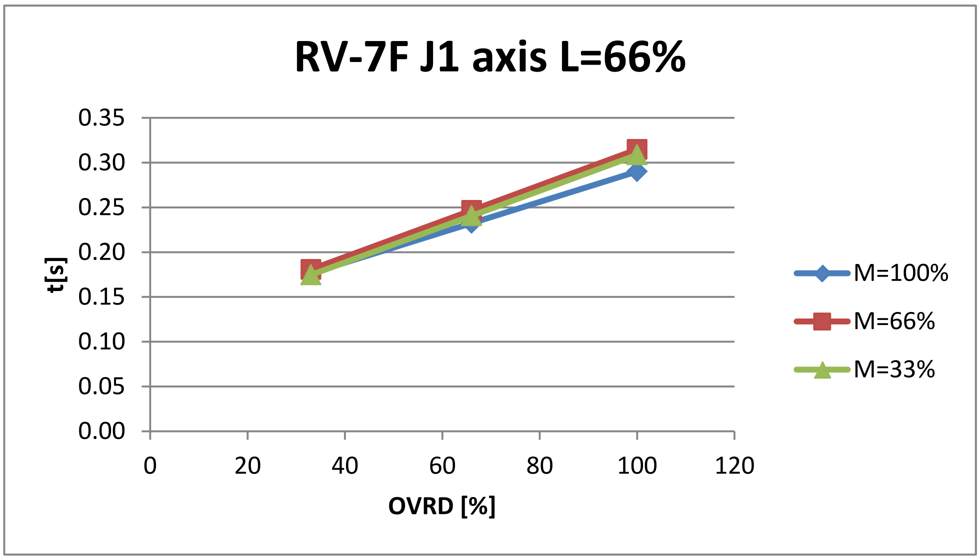
(6) Stopping angle of J3 axis

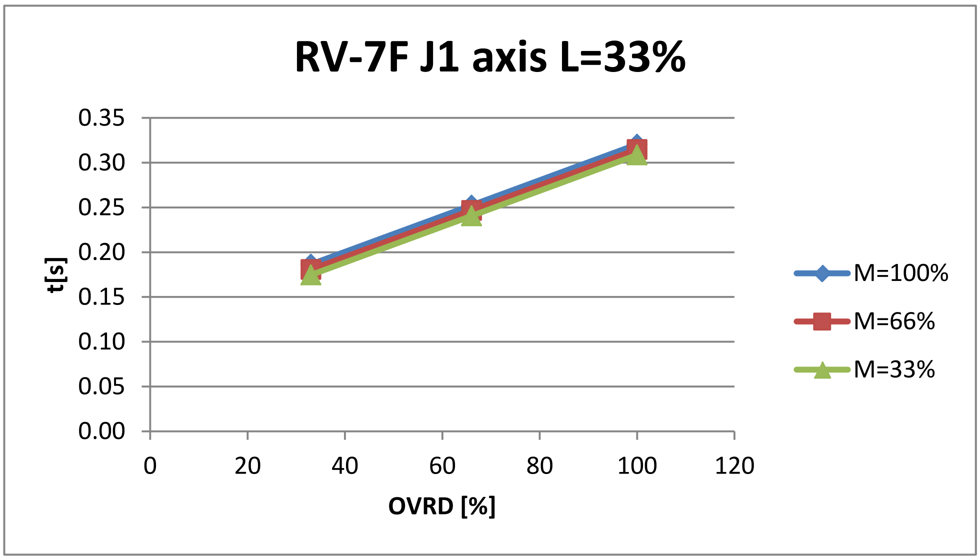


8.4.5 RV-7F

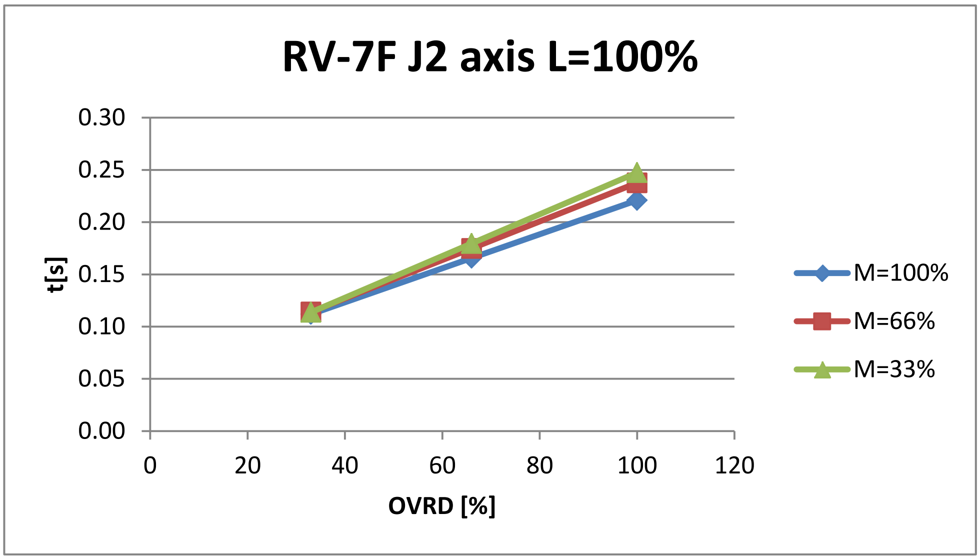
(1) Stopping time of J1 axis

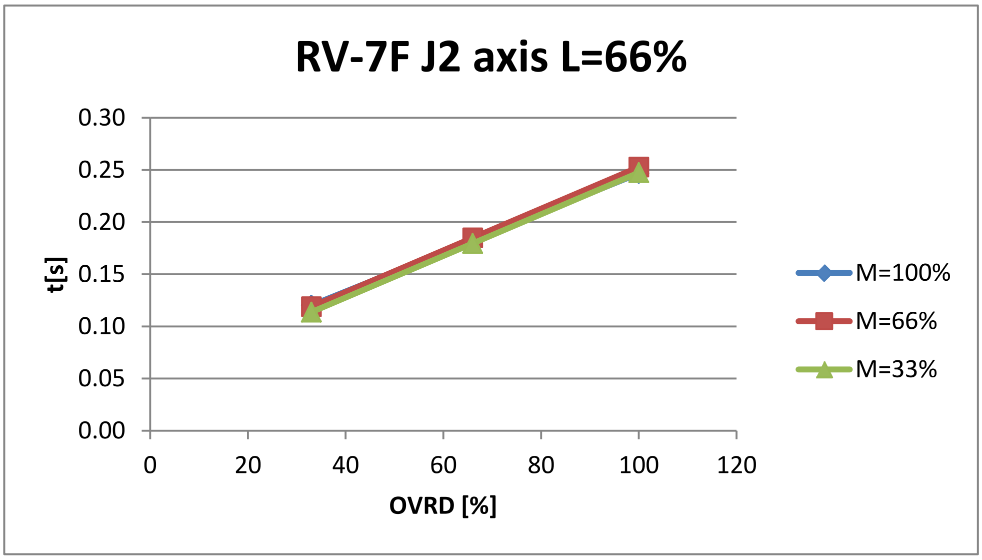


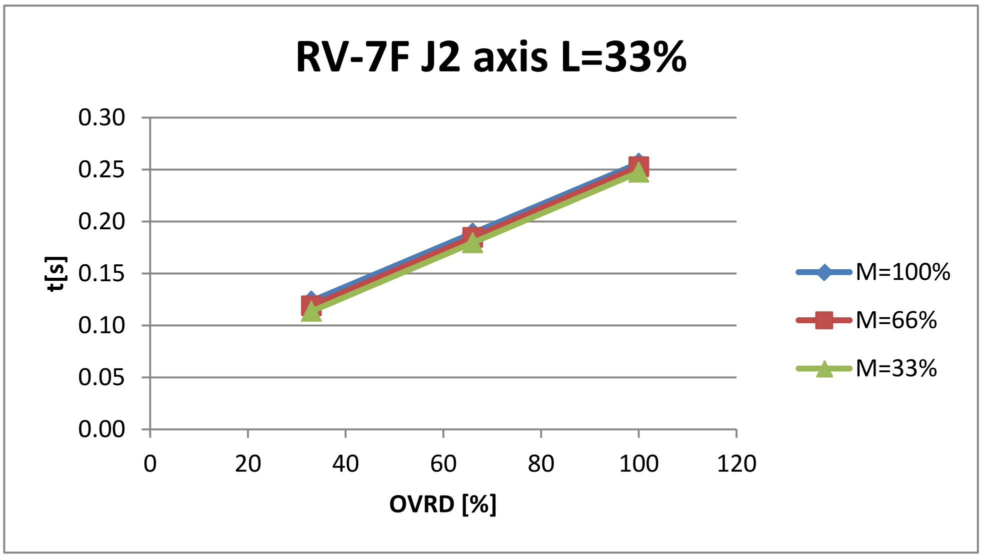




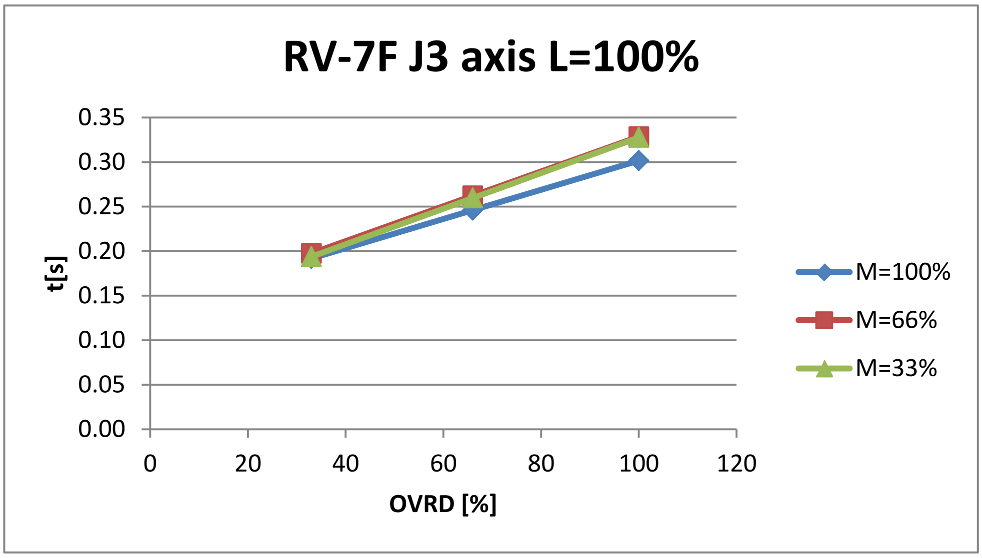
(2) Stopping time of J2 axis



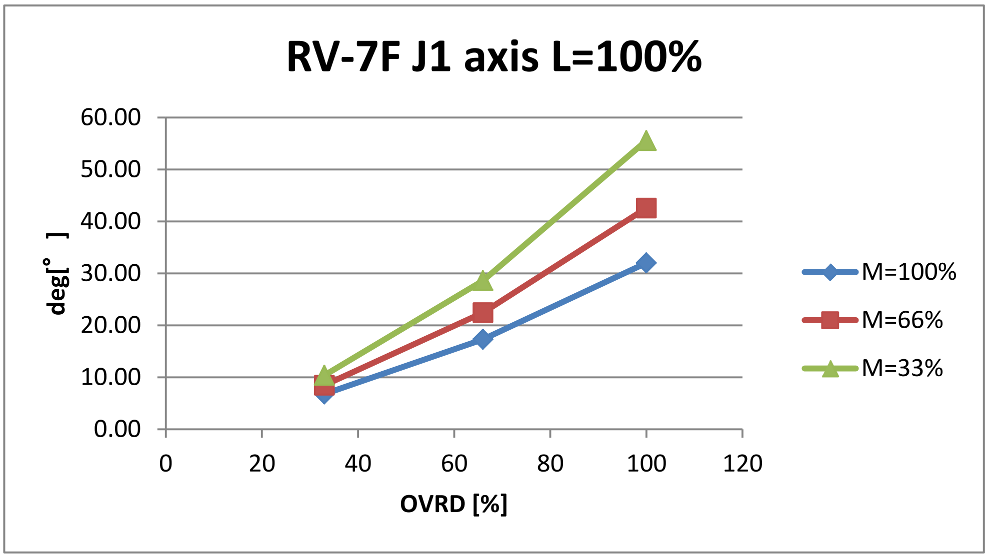


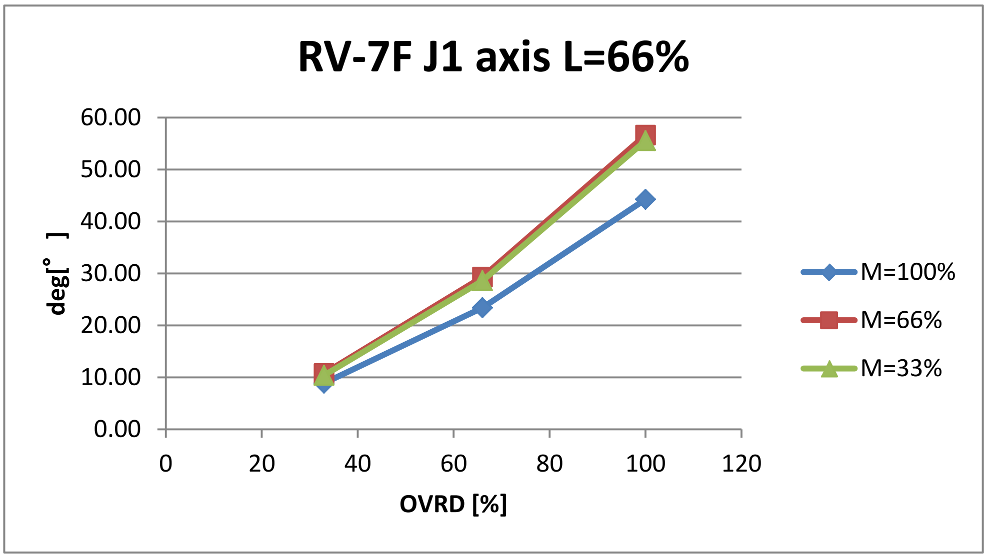


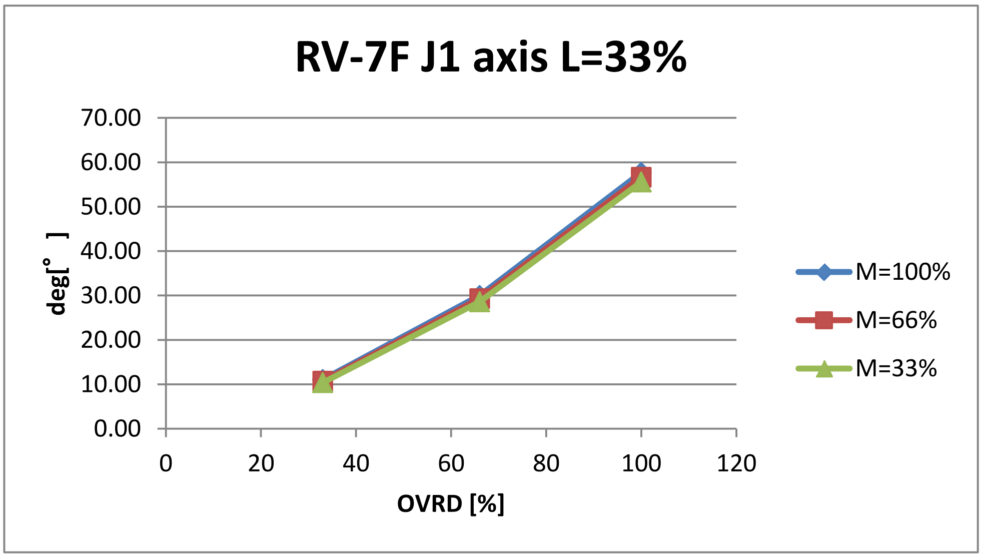
(3) Stopping time of J3 axis



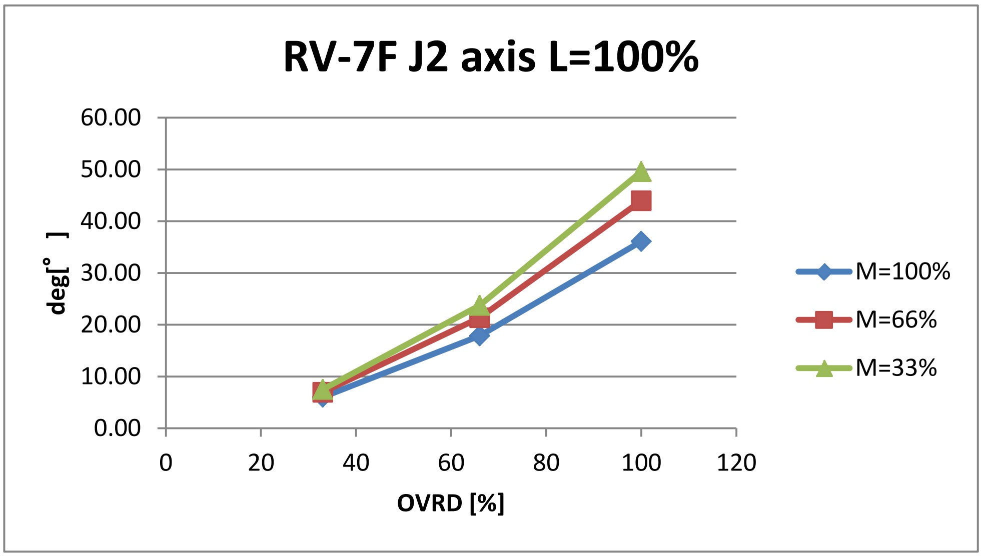
(4) Stopping angle of J1 axis

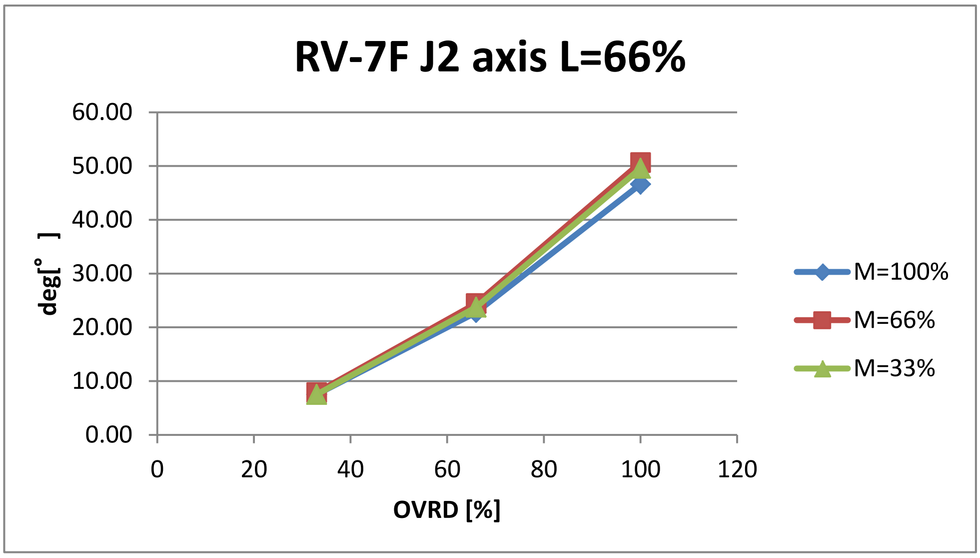


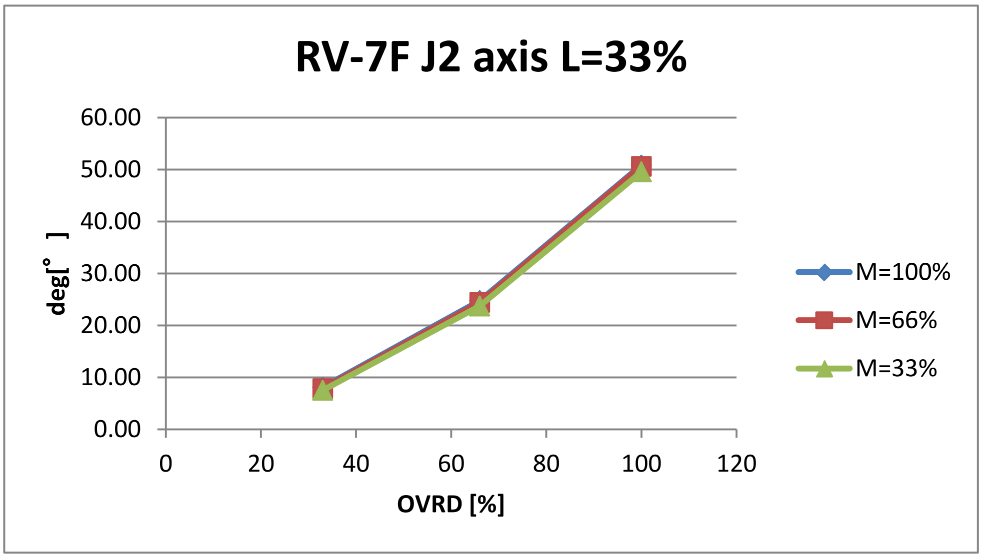




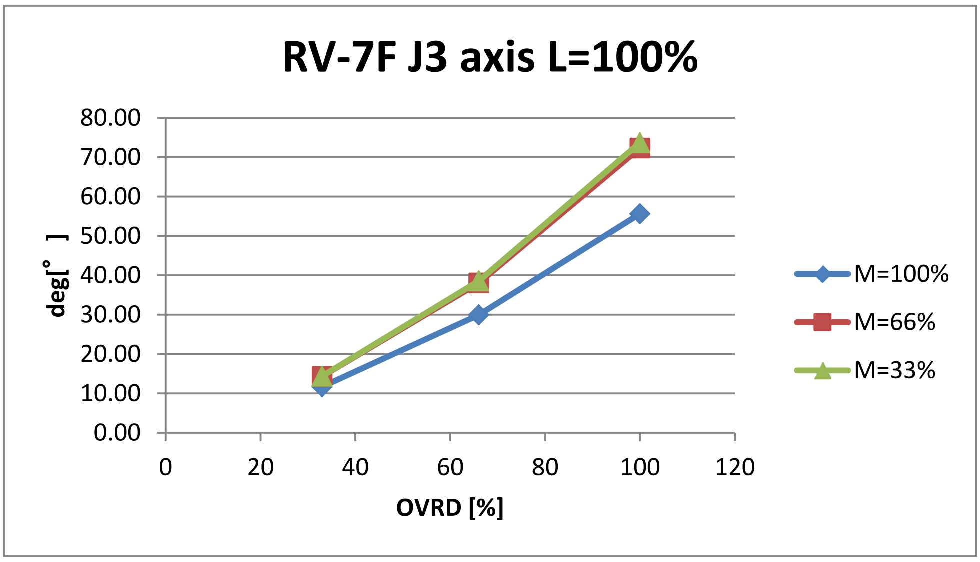
(5) Stopping angle of J2 axis





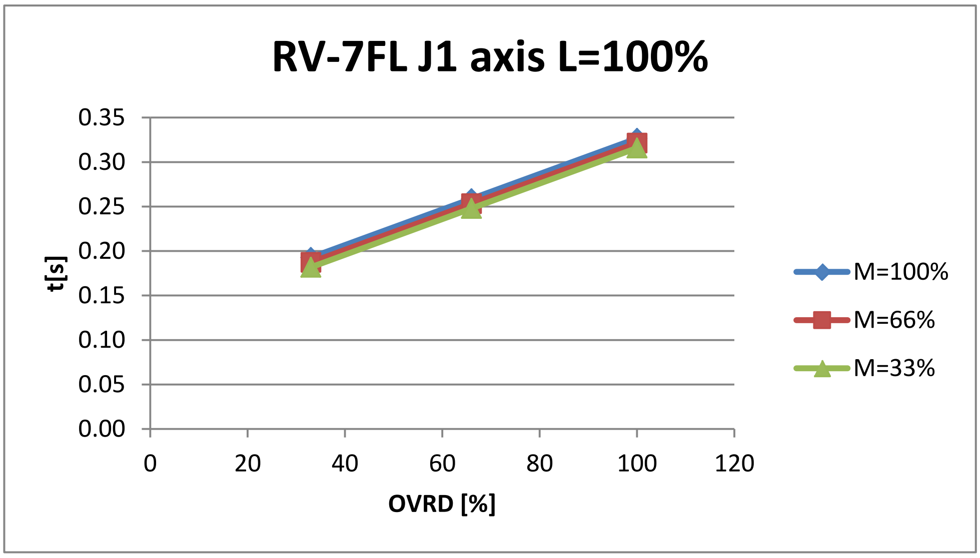


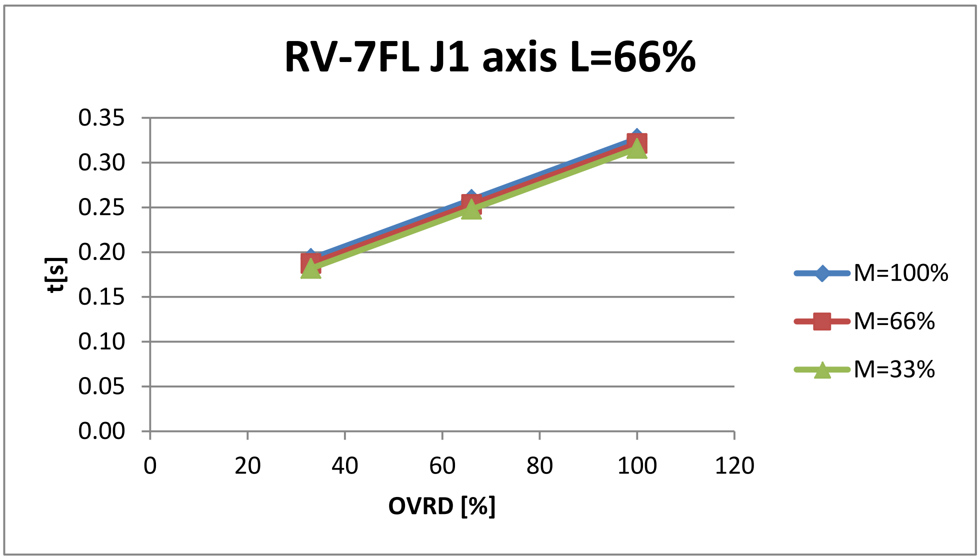
(6) Stopping angle of J3 axis

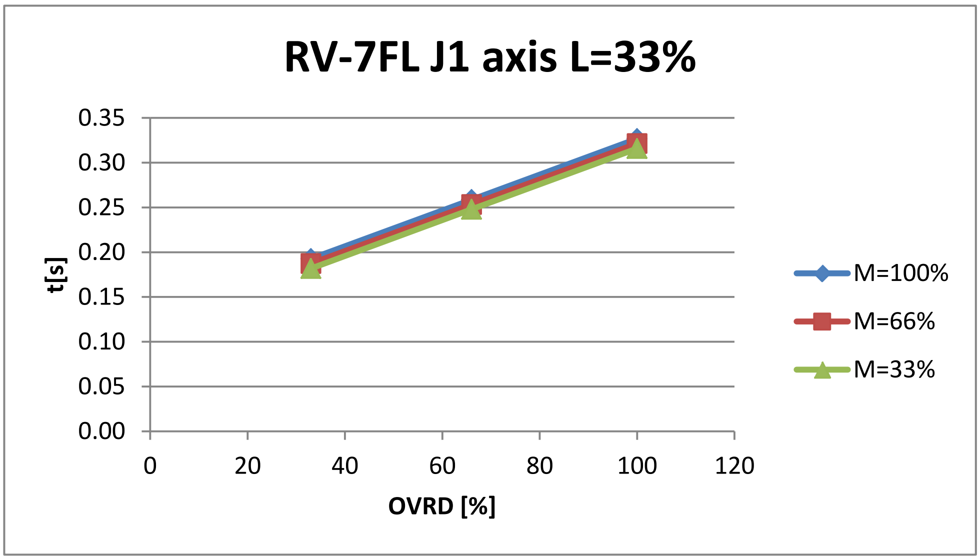


8.4.6 RV-7FL

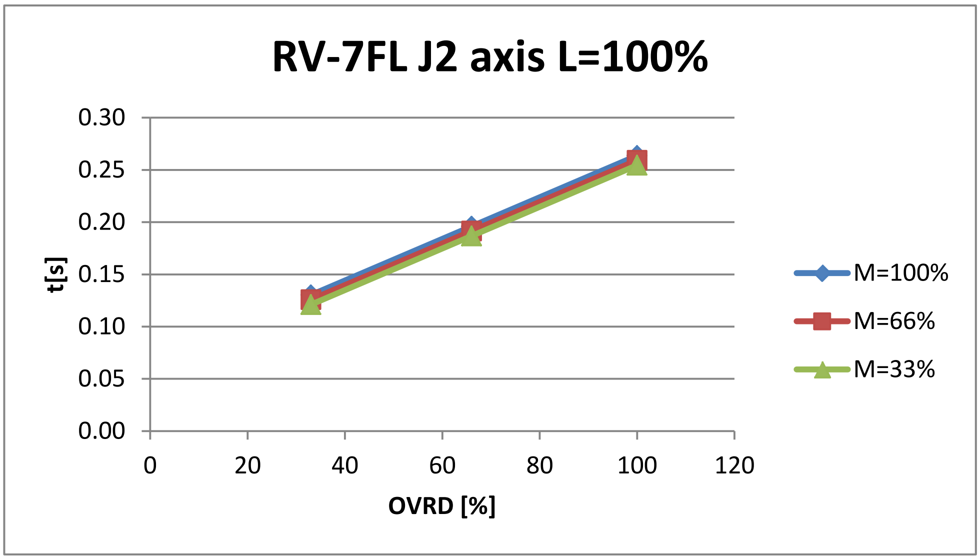
(1) Stopping time of J1 axis

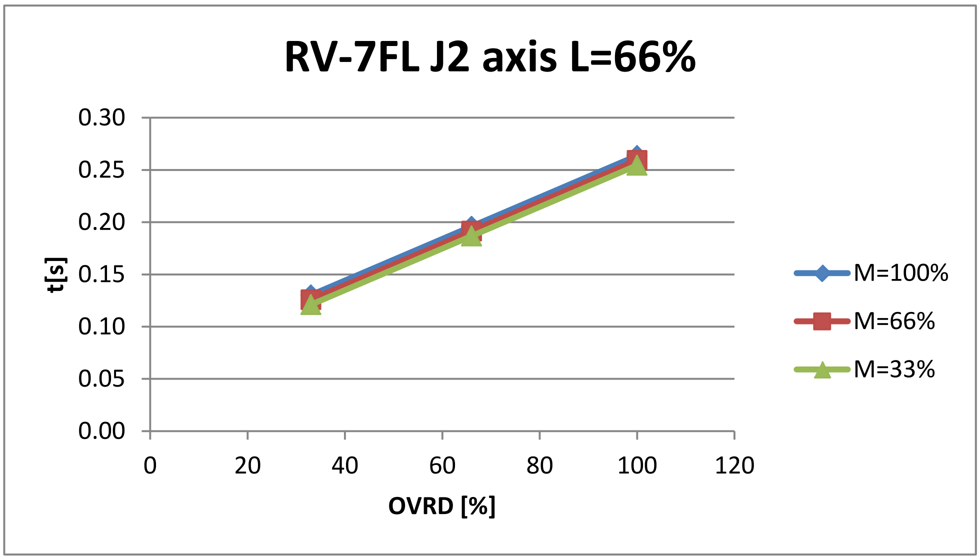


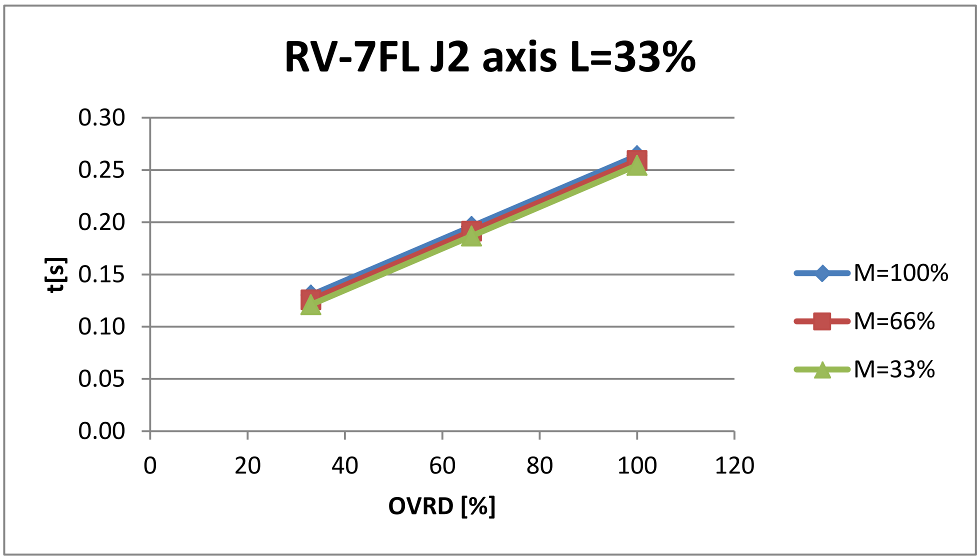




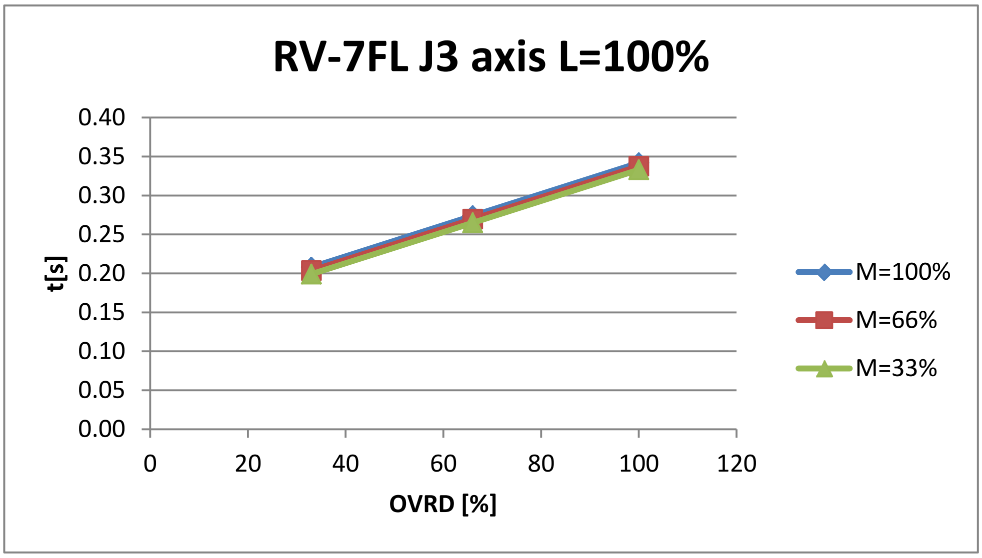
(2) Stopping time of J2 axis



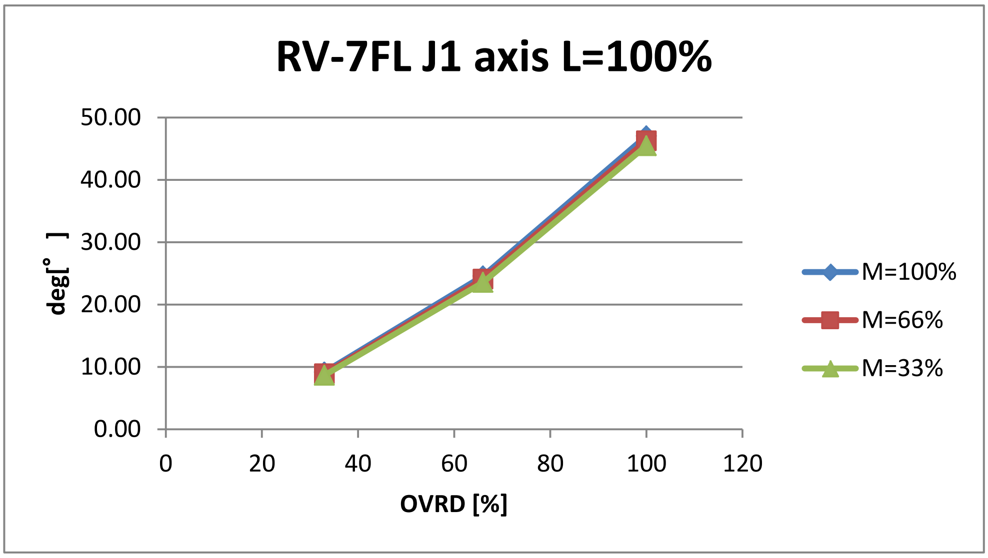


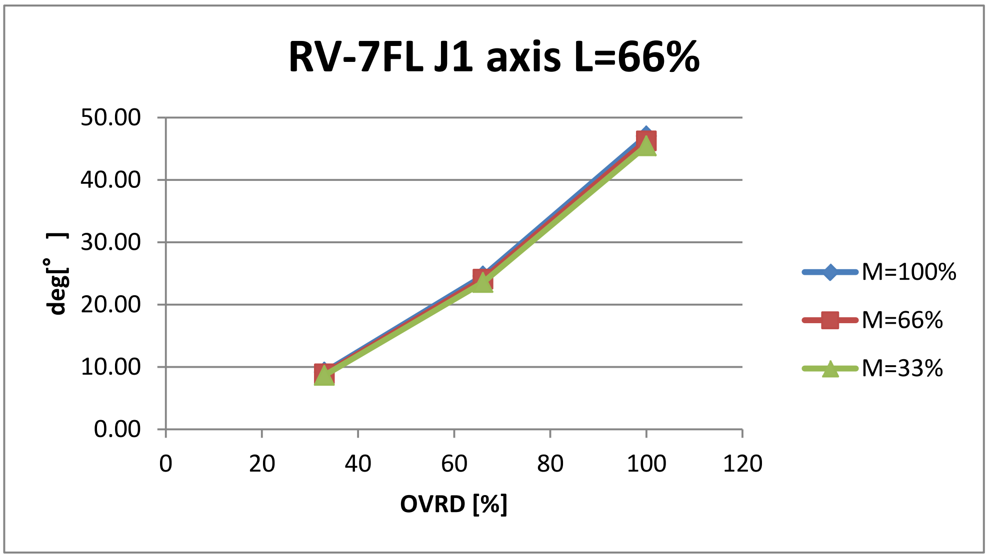


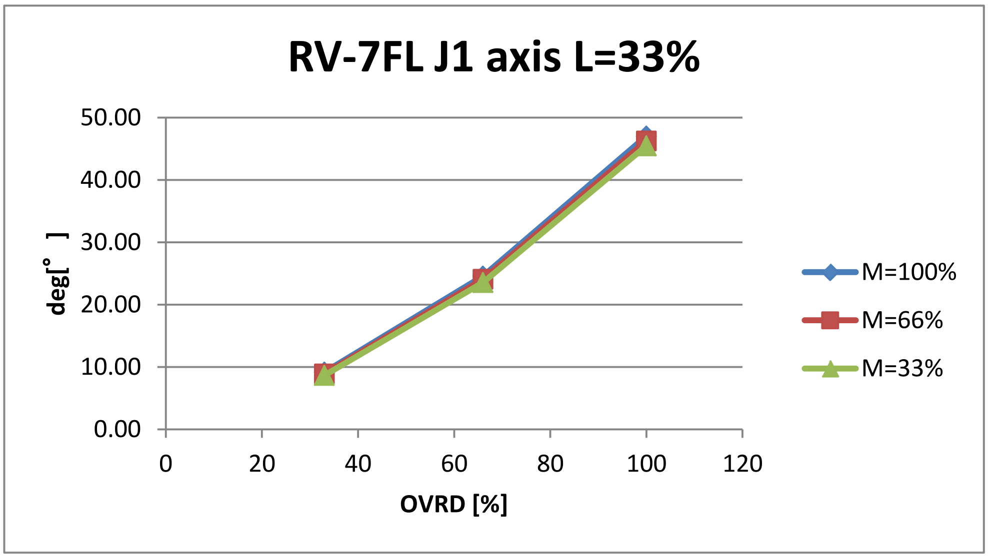
(3) Stopping time of J3 axis



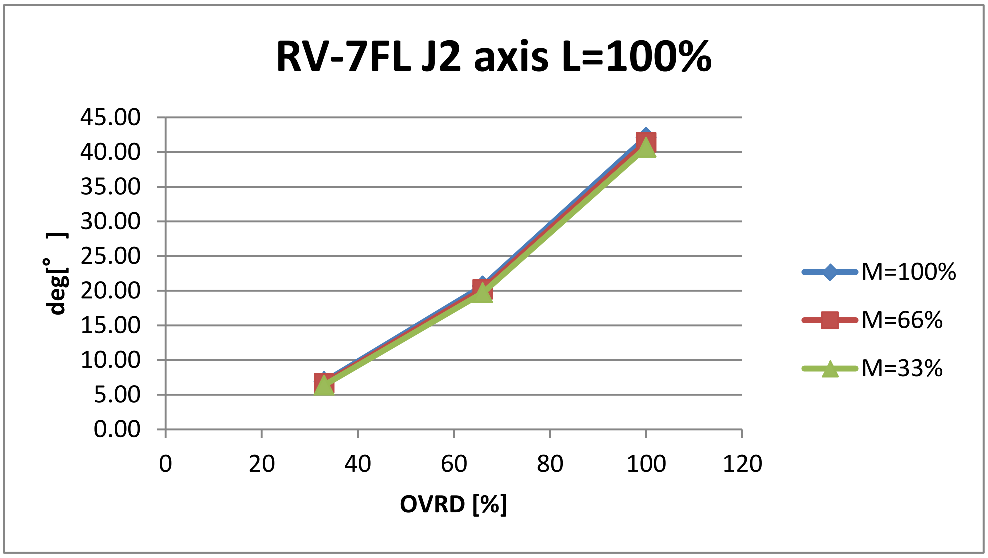
(4) Stopping angle of J1 axis

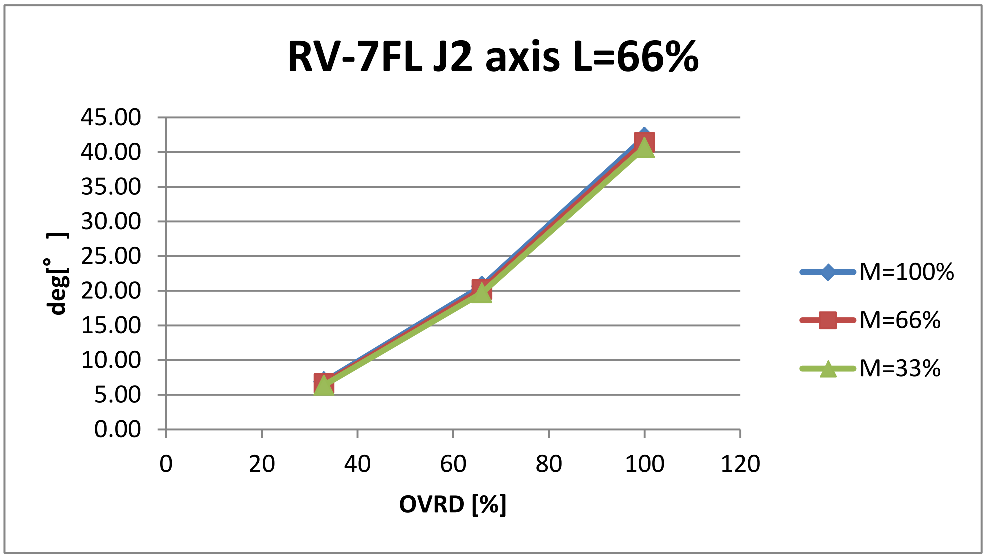


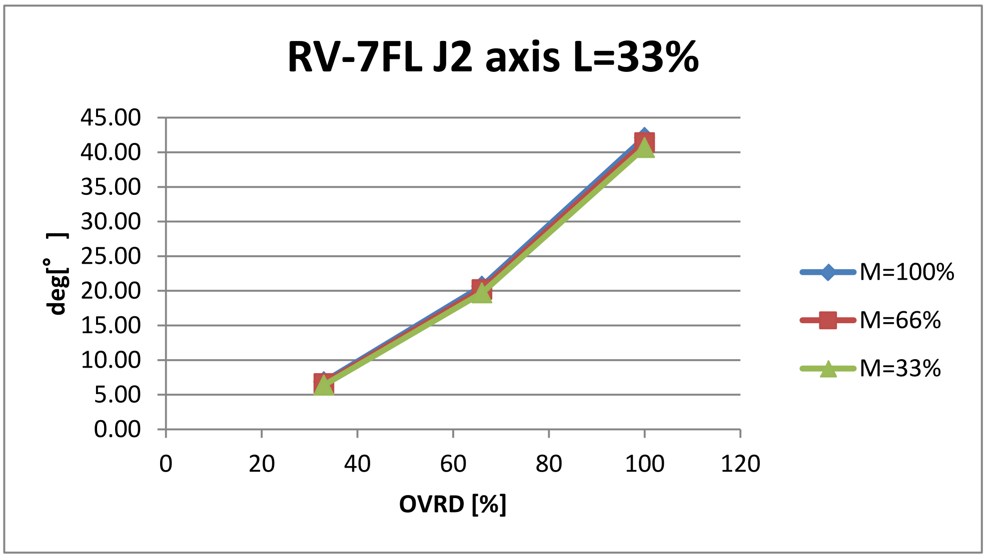




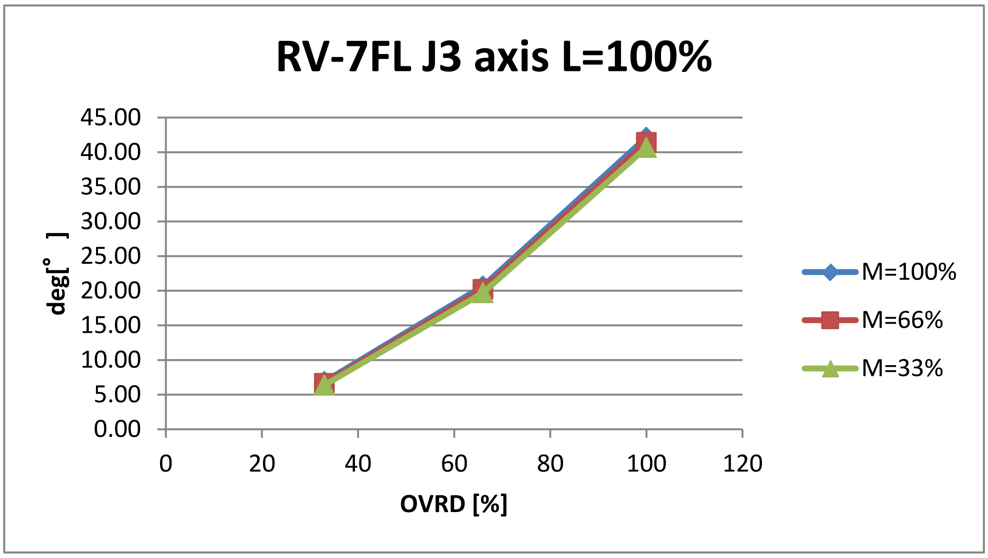
(5) Stopping angle of J2 axis





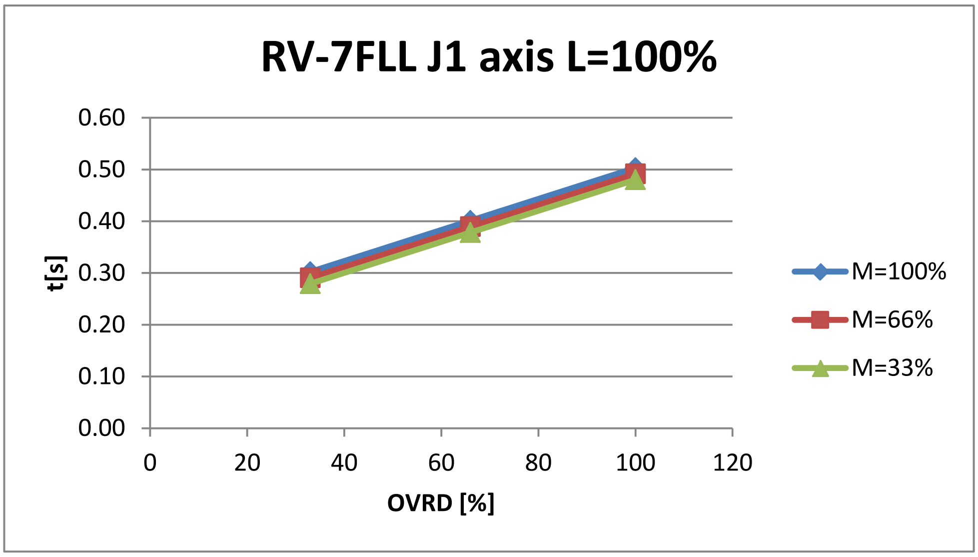


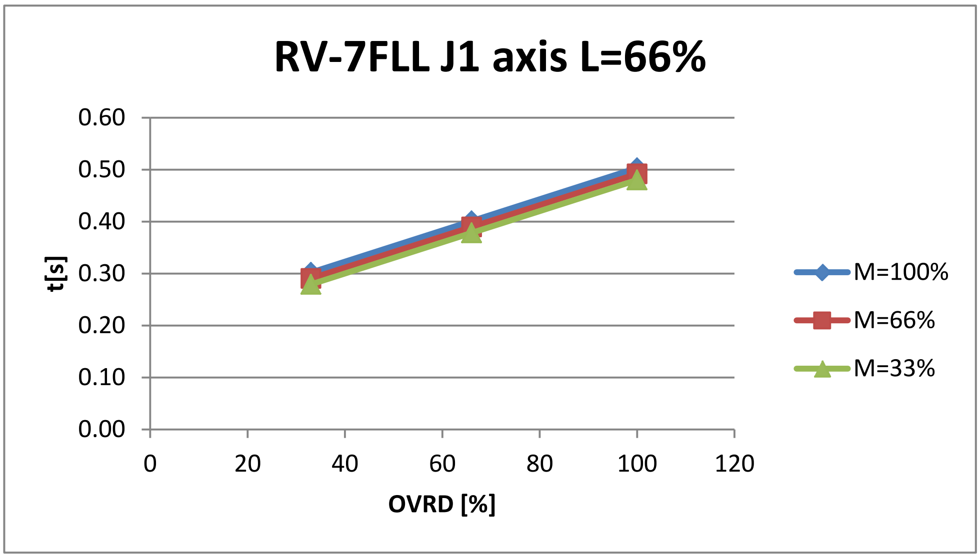
(6) Stopping angle of J3 axis

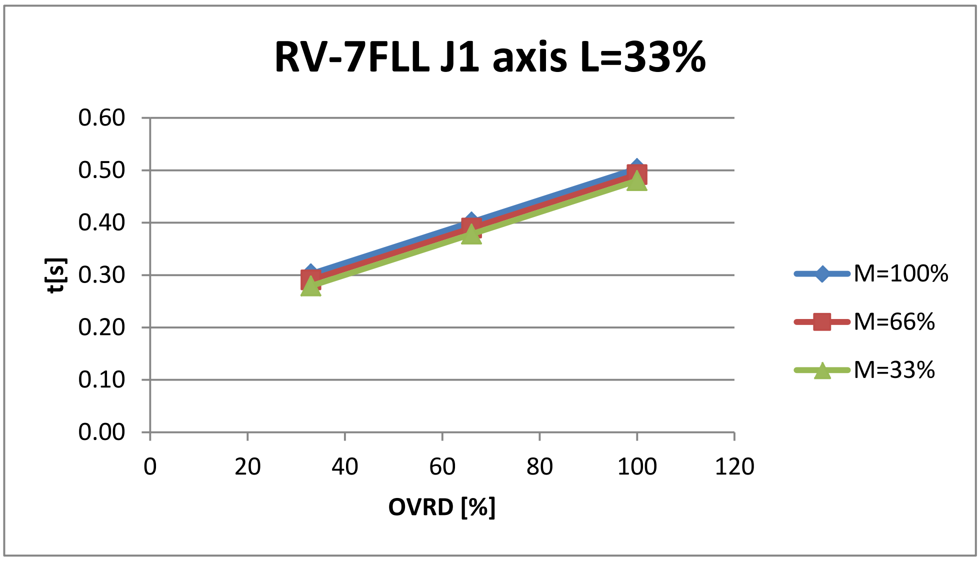


8.4.7 RV-7FLL

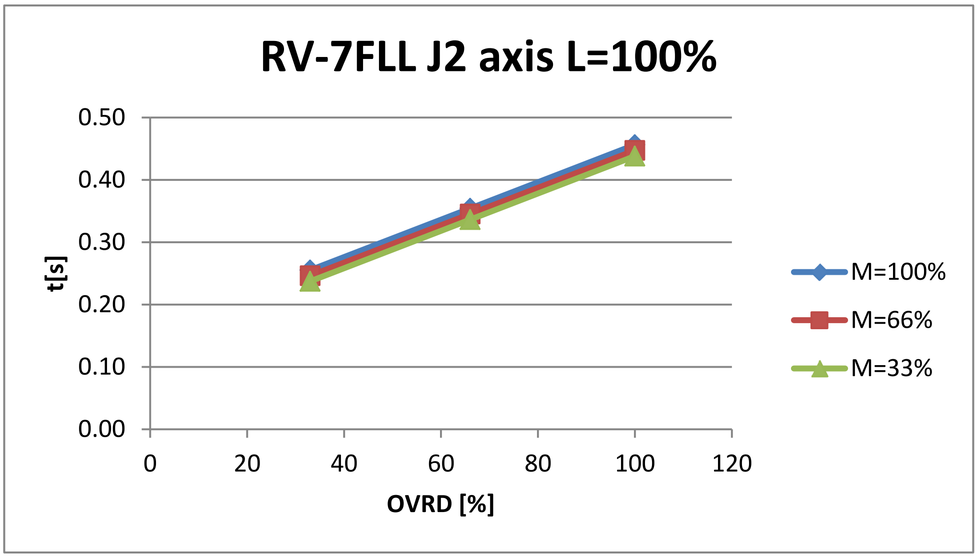
(1) Stopping time of J1 axis

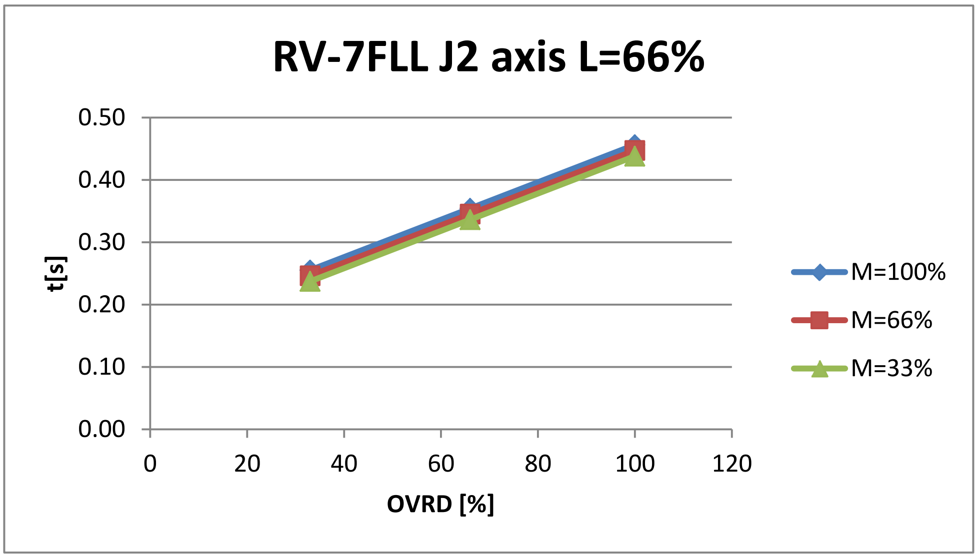


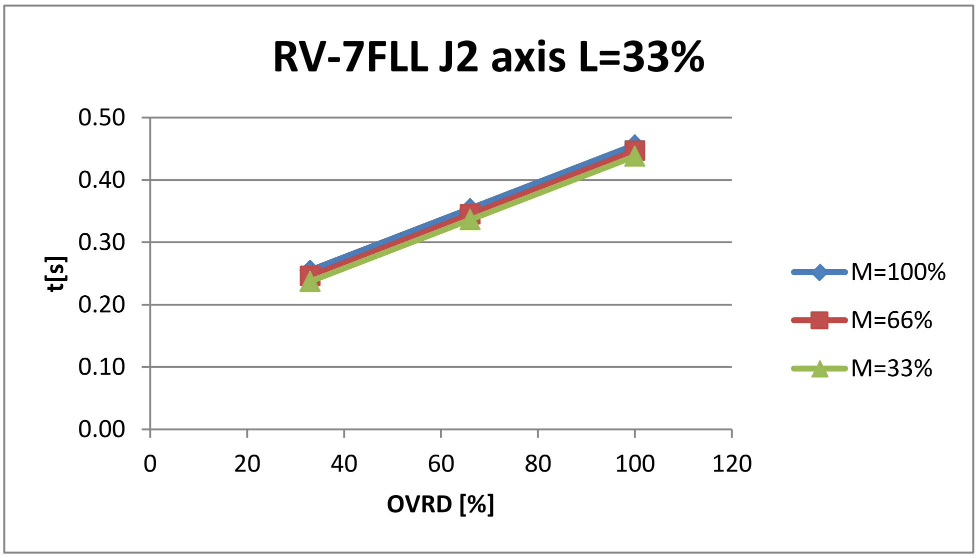




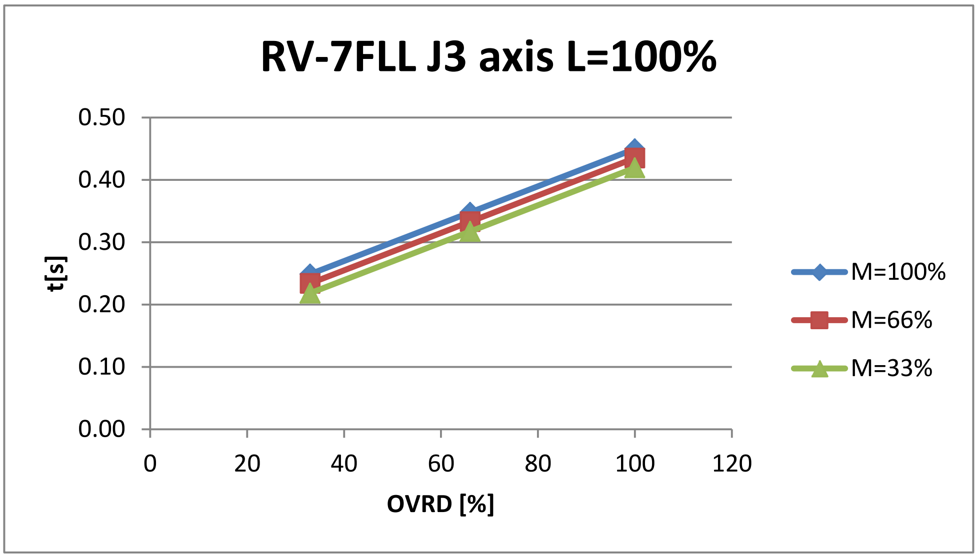
(2) Stopping time of J2 axis



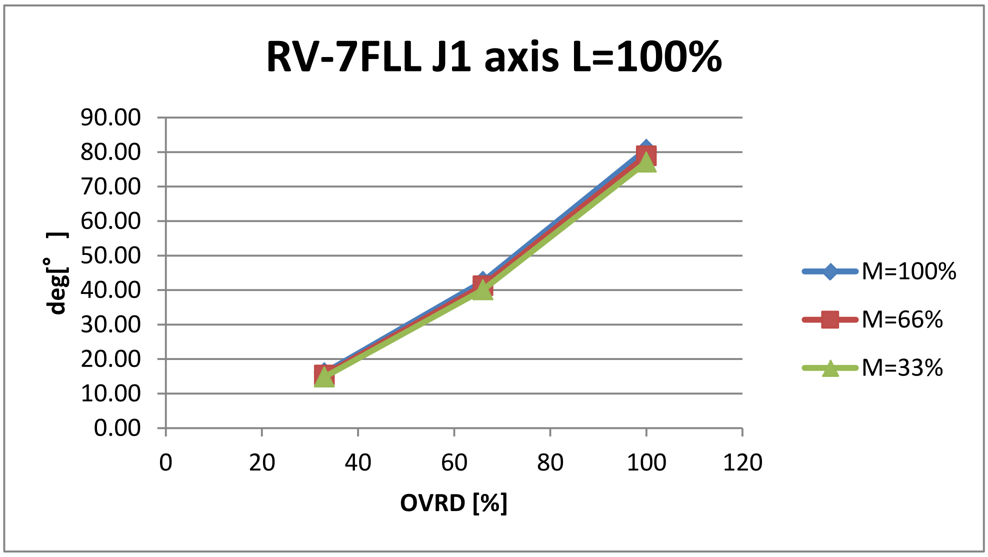


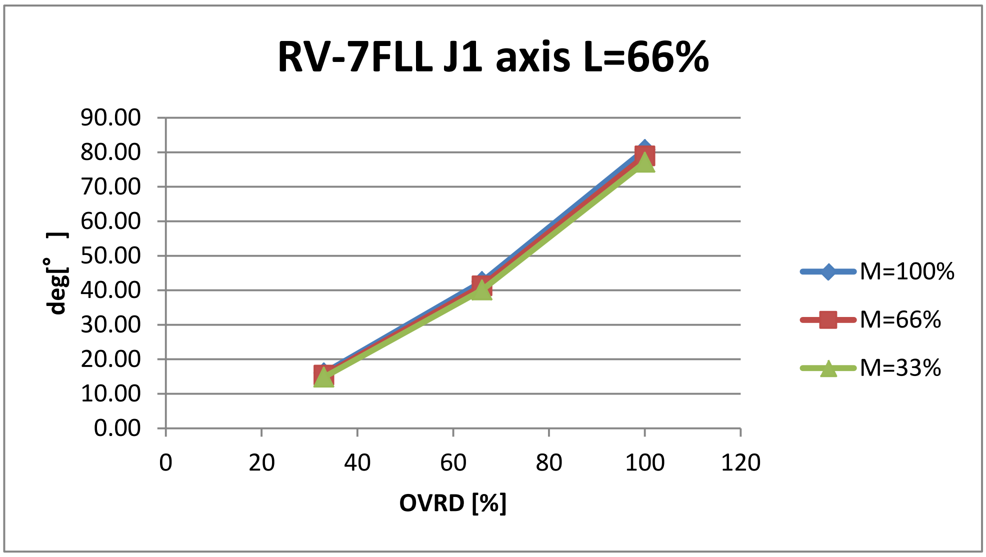


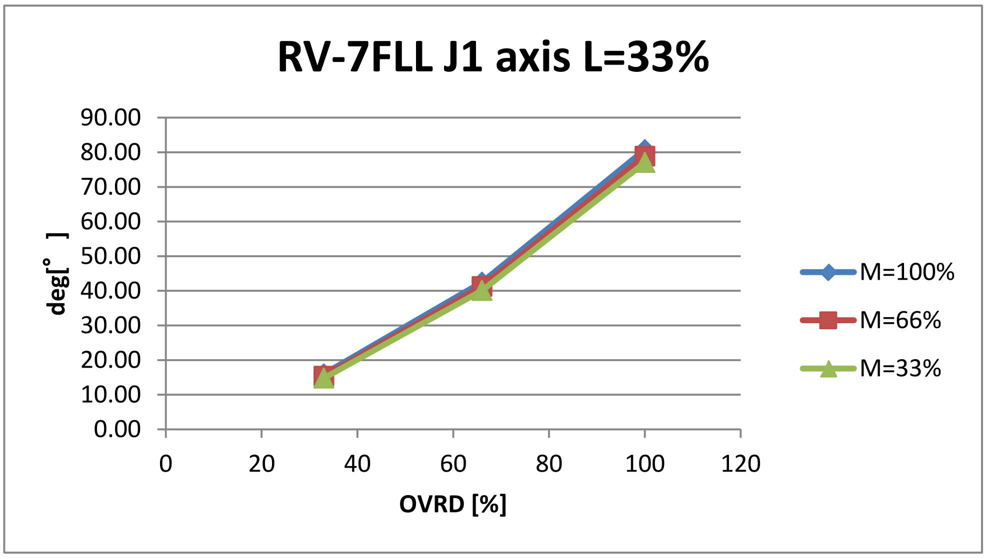
(3) Stopping time of J3 axis



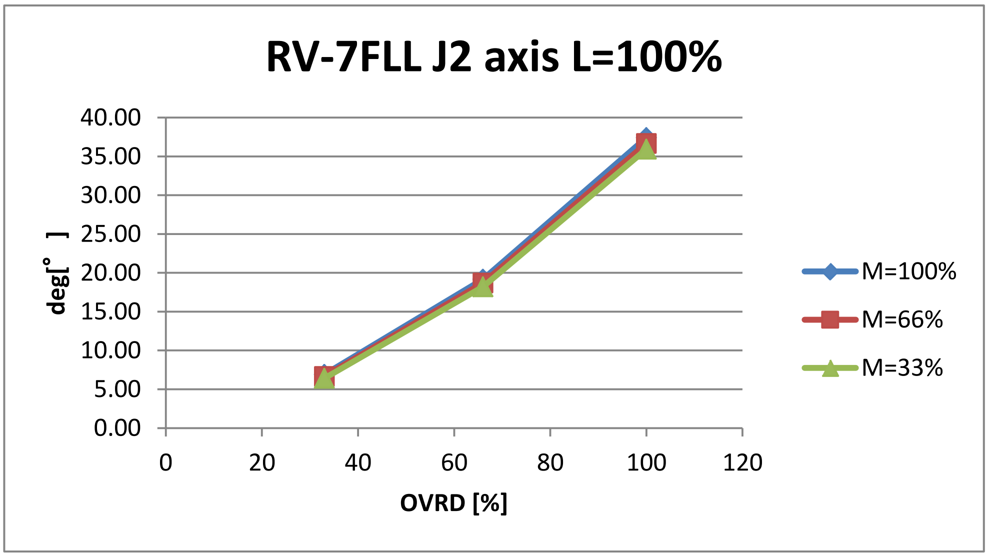
(4) Stopping angle of J1 axis

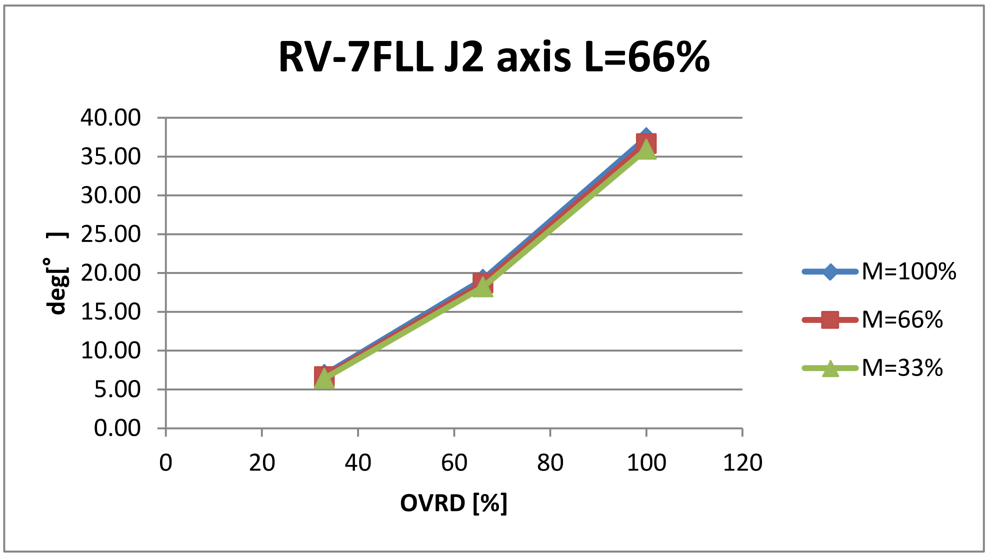


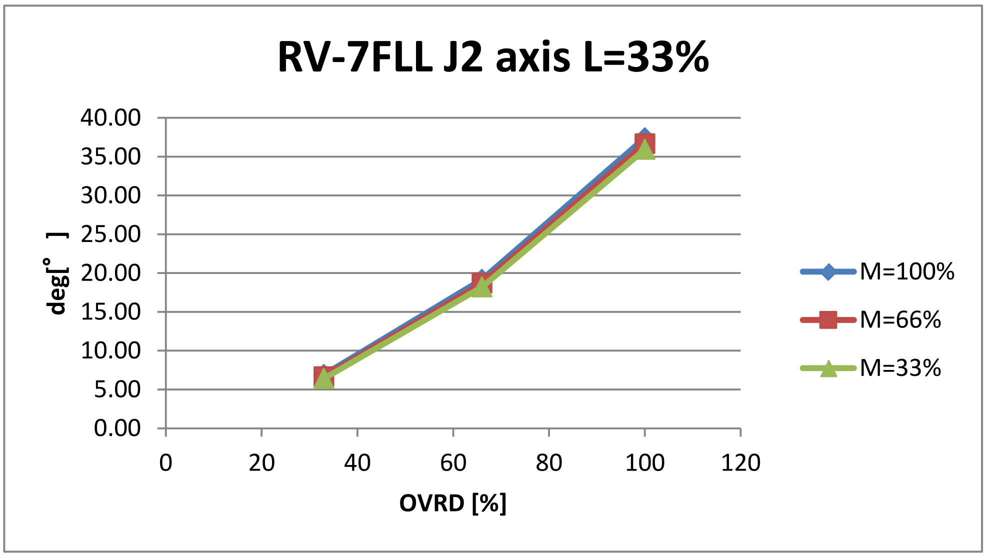




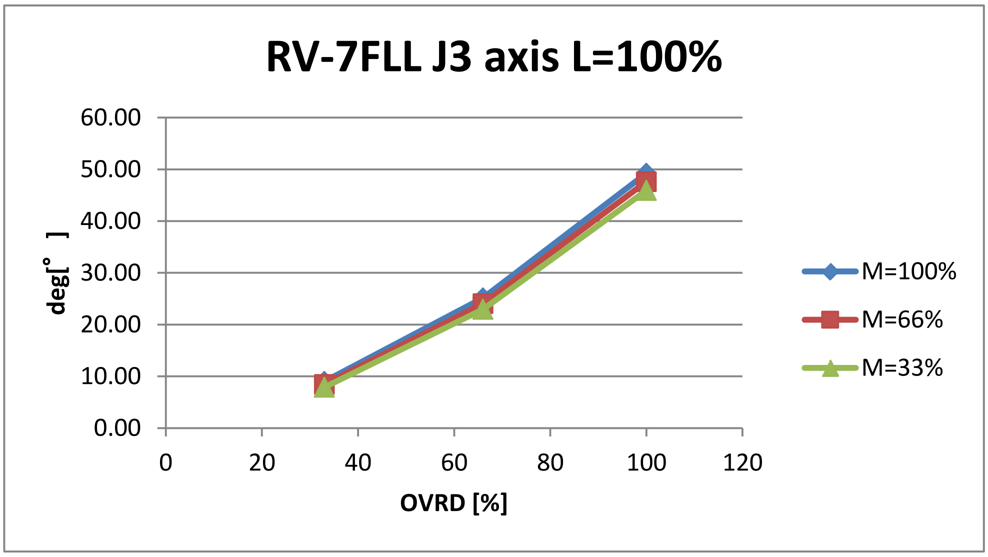
(5) Stopping angle of J2 axis





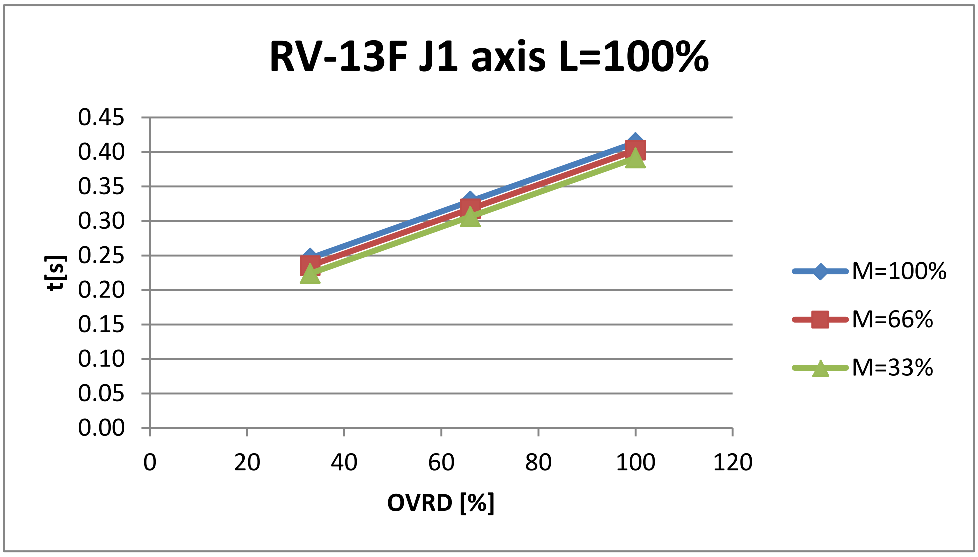


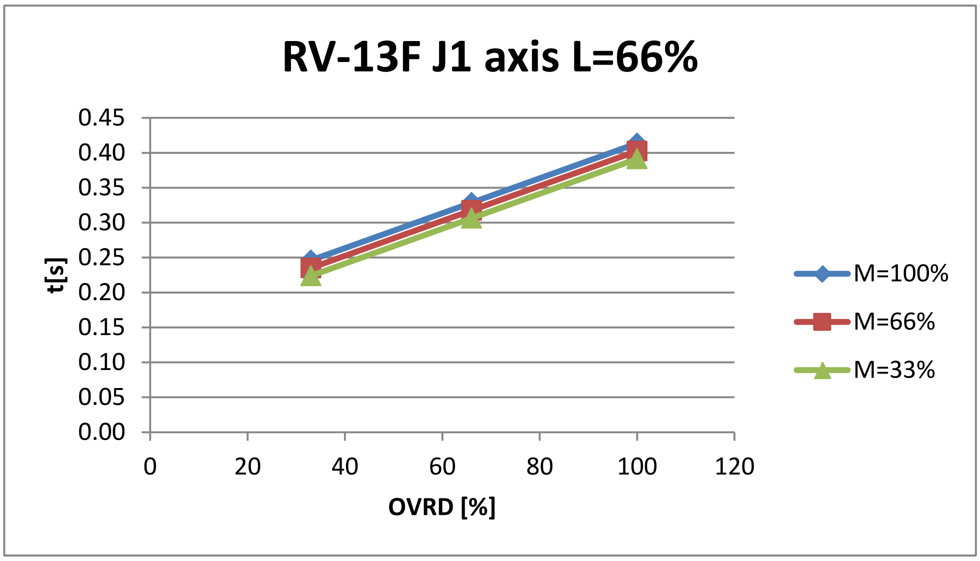
(6) Stopping angle of J3 axis

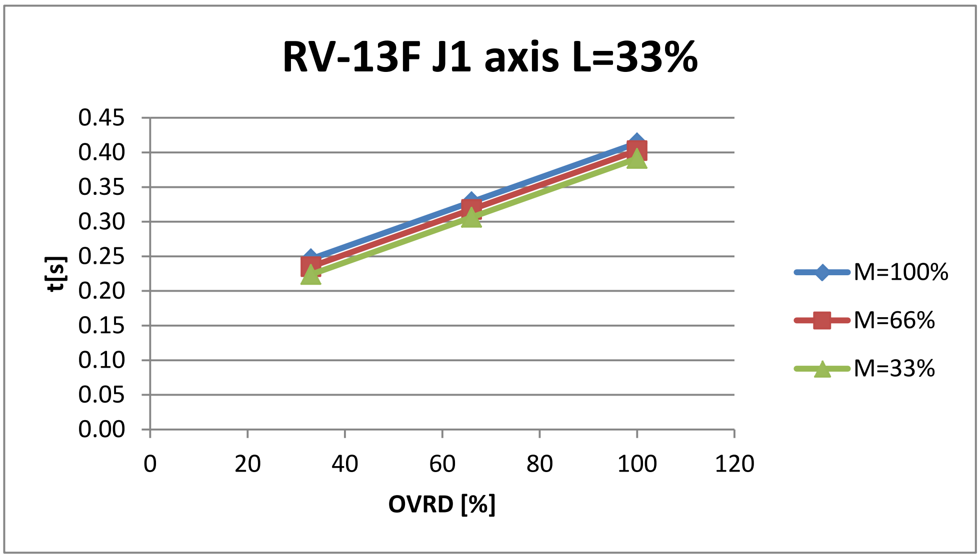


8.4.8 RV-13F

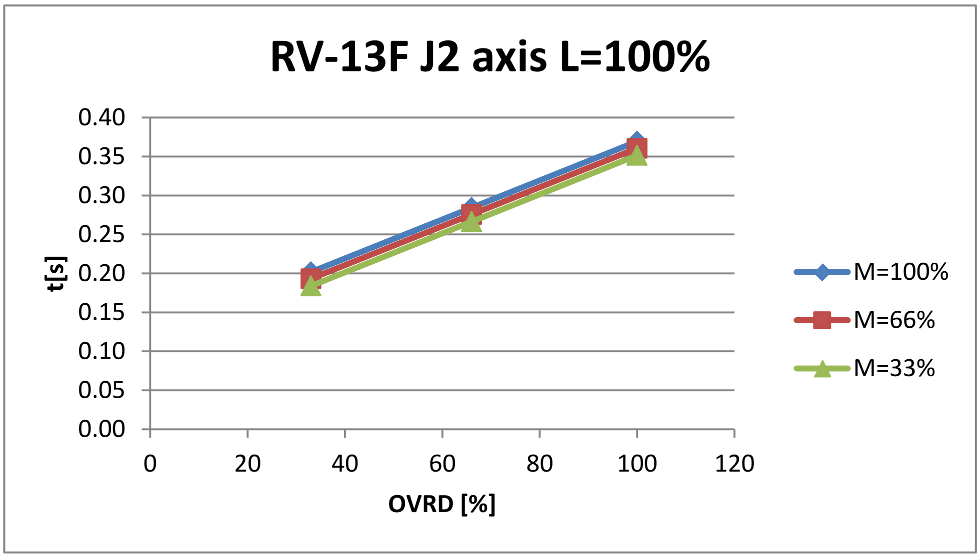
(1) Stopping time of J1 axis

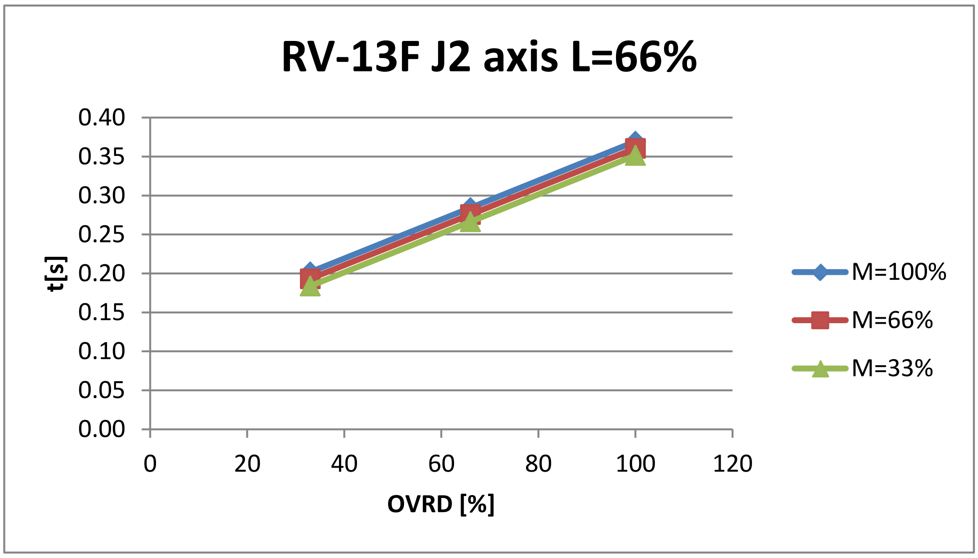


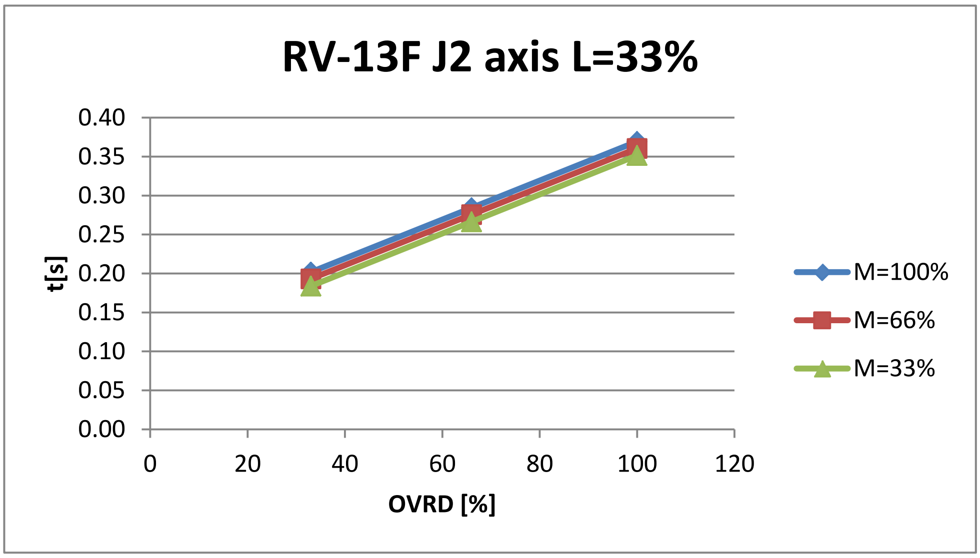




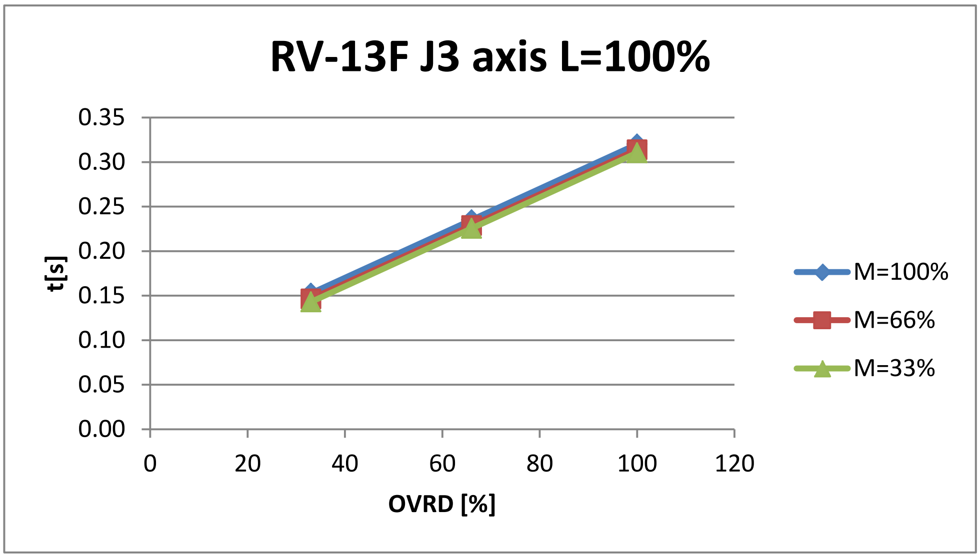
(2) Stopping time of J2 axis



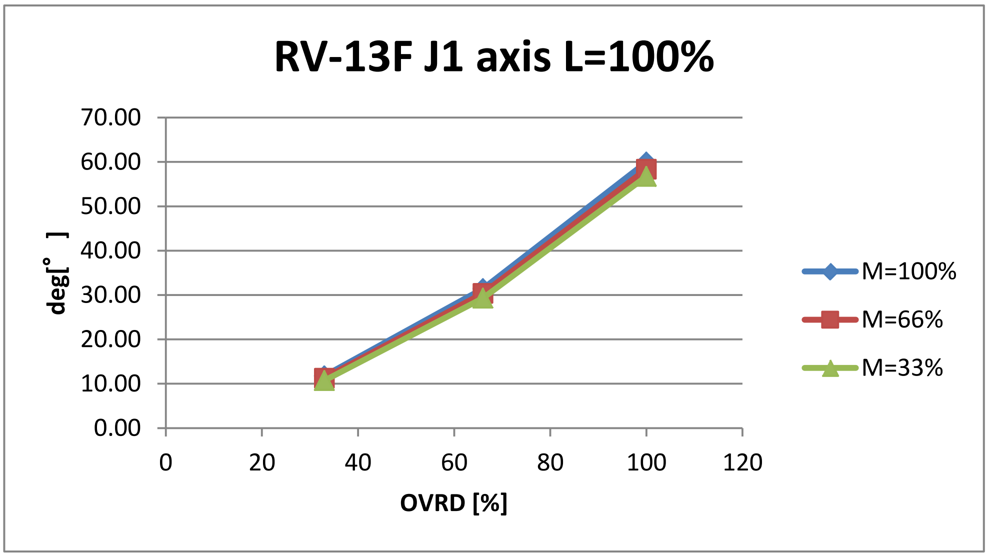


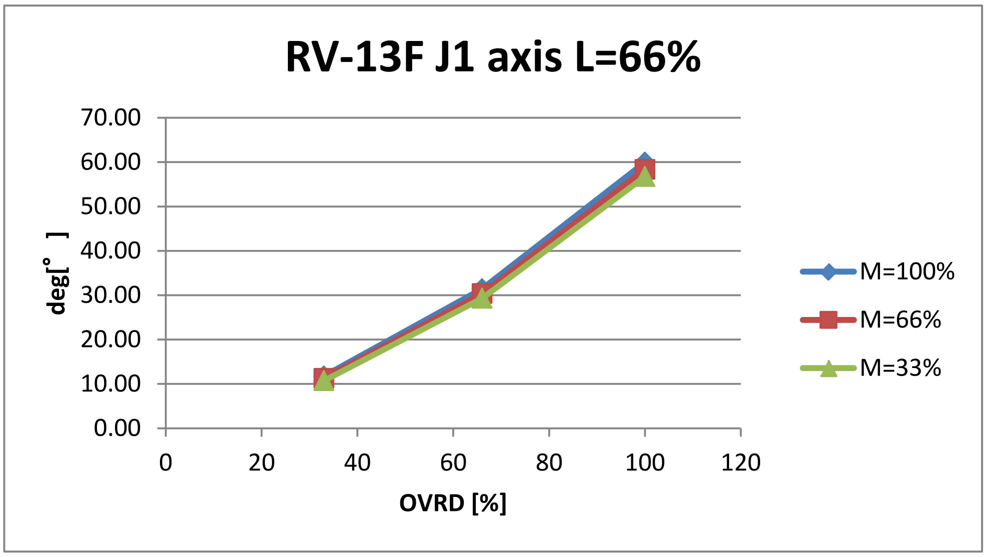


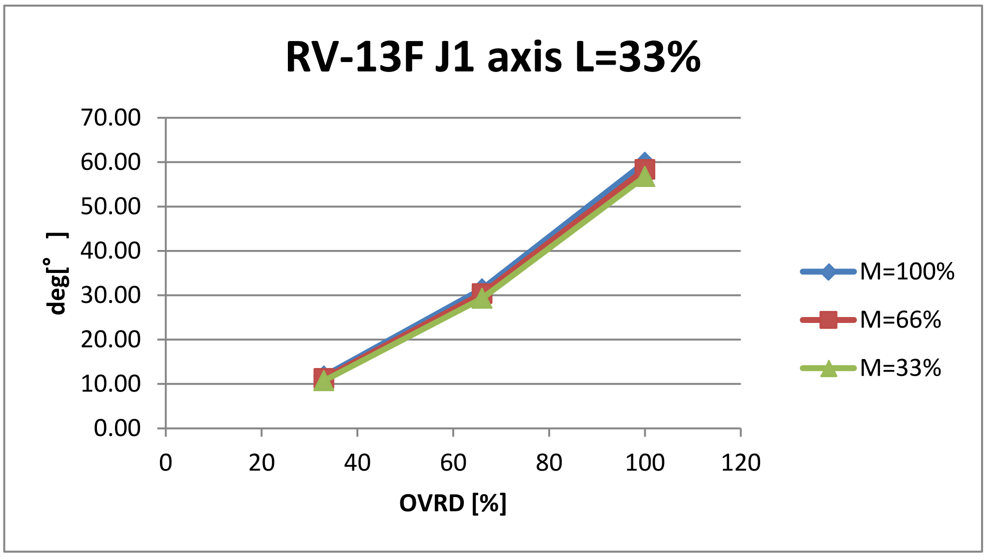
(3) Stopping time of J3 axis



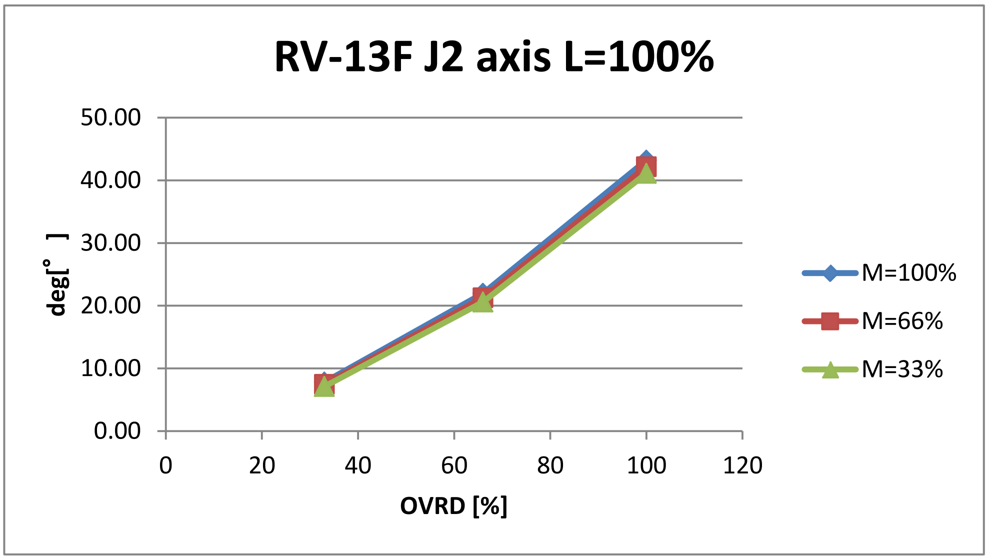
(4) Stopping angle of J1 axis

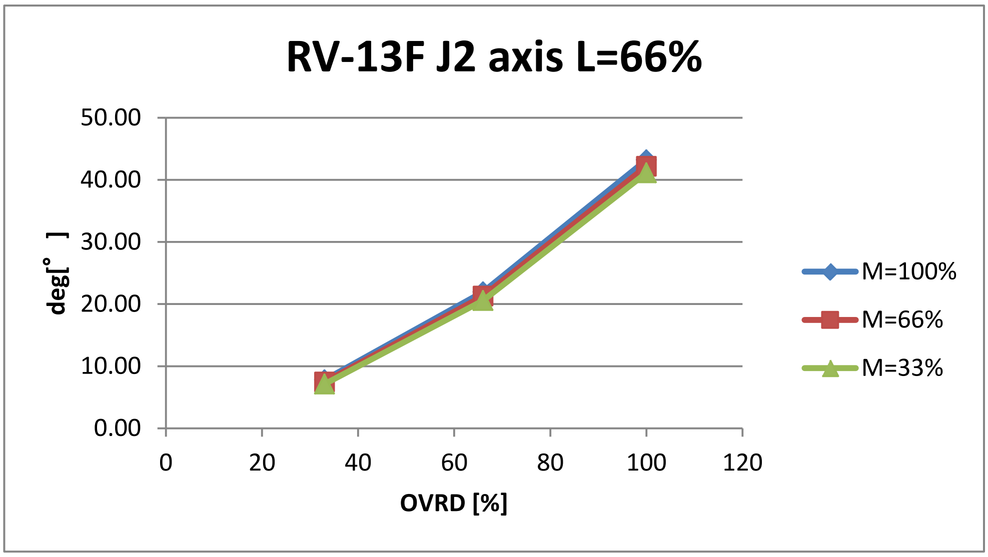


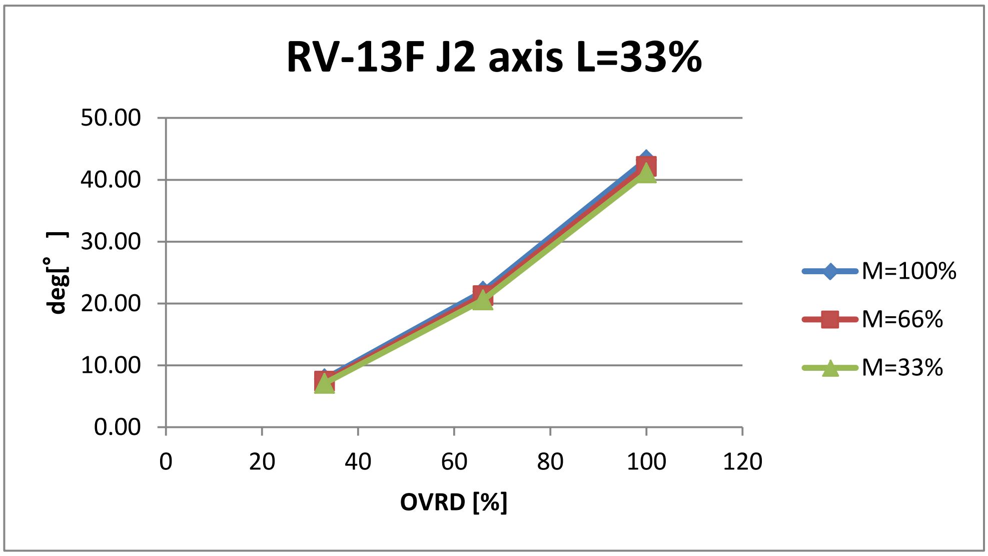




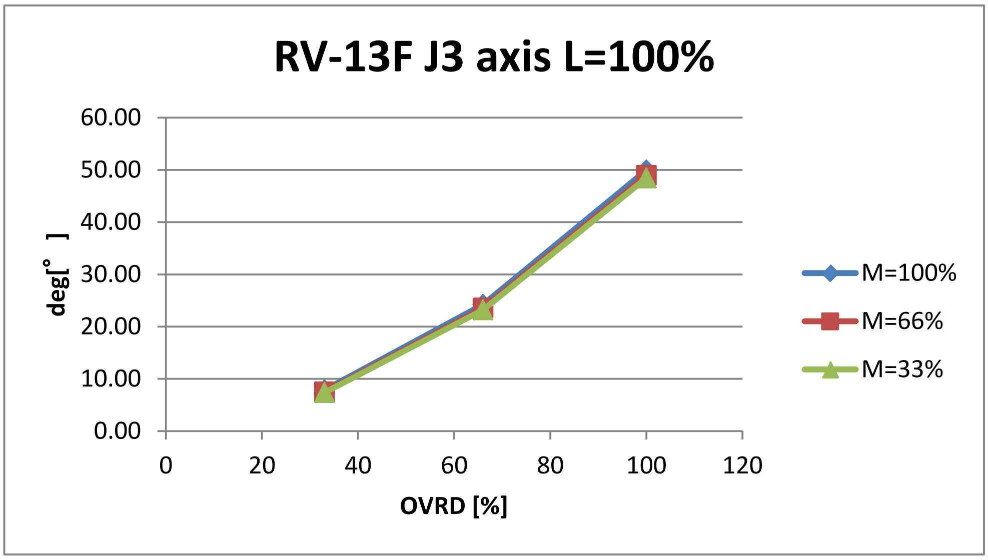
(5) Stopping angle of J2 axis





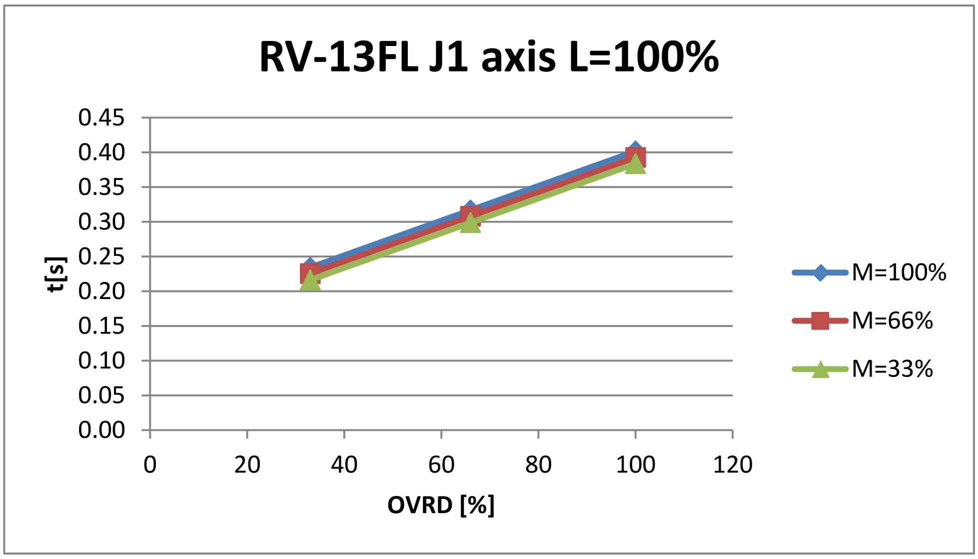


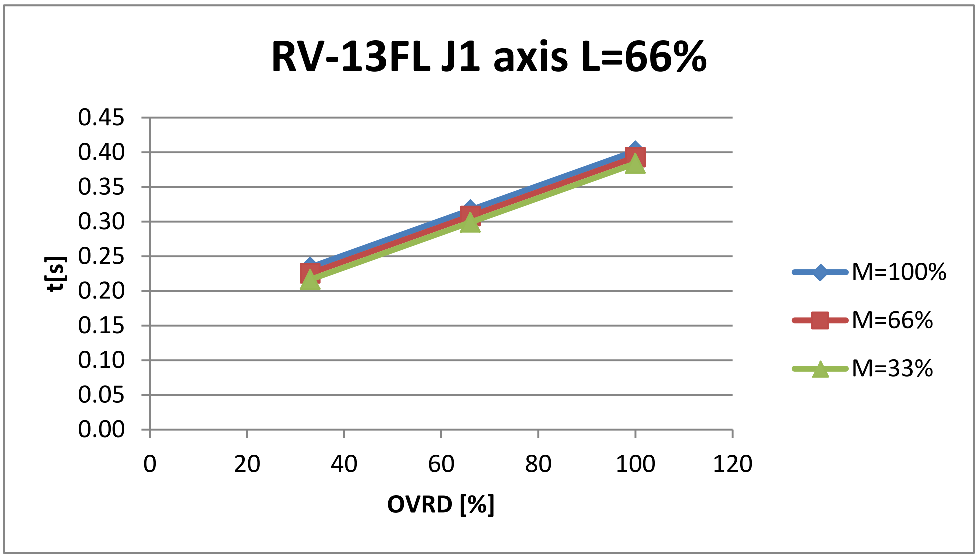
(6) Stopping angle of J3 axis

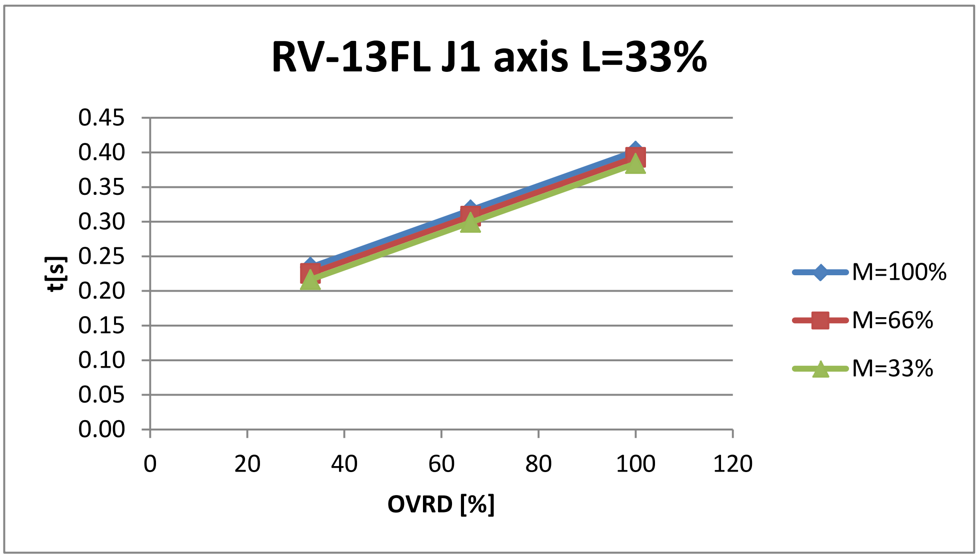


8.4.9 RV-13FL

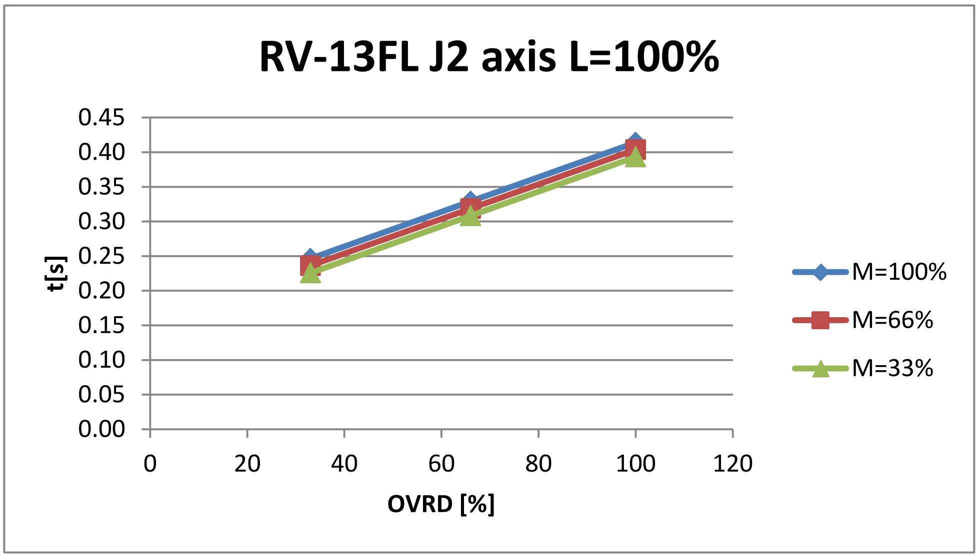
(1) Stopping time of J1 axis

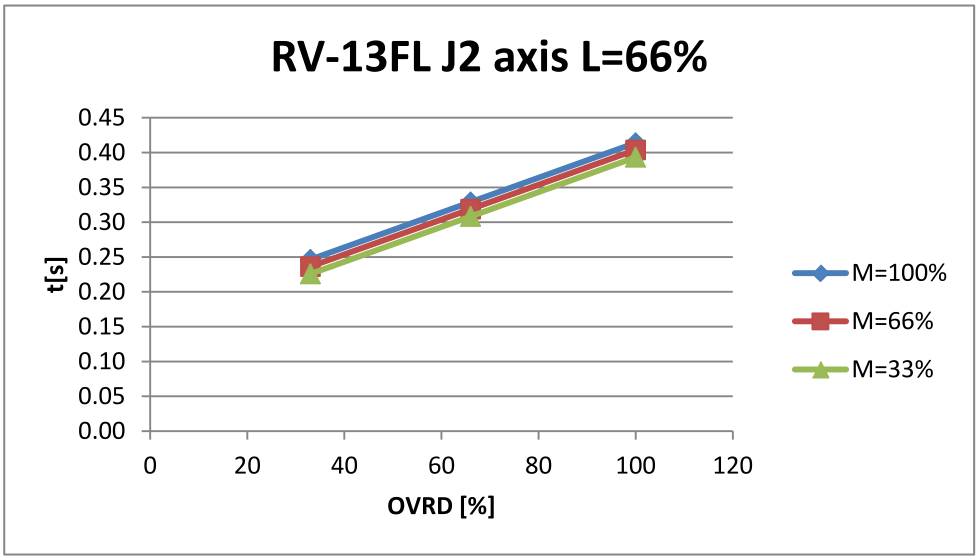


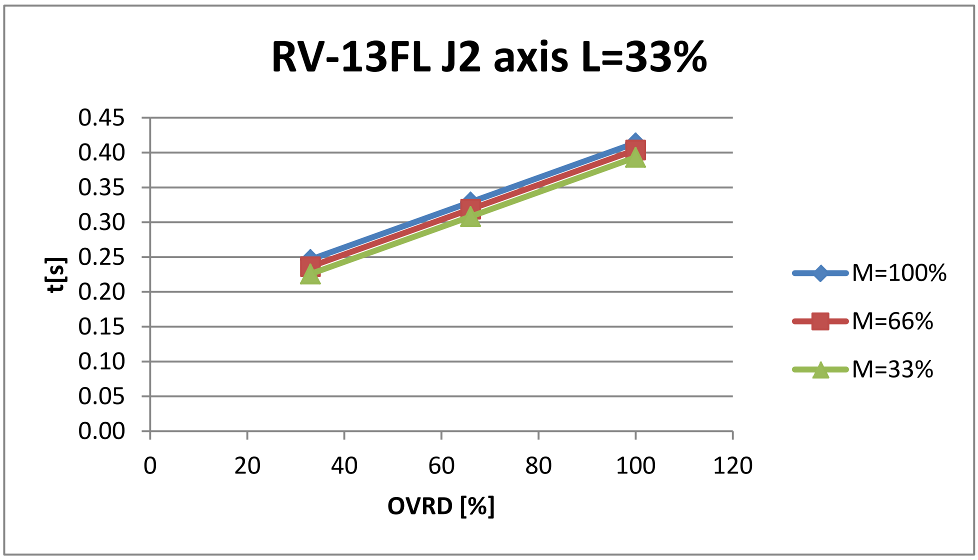




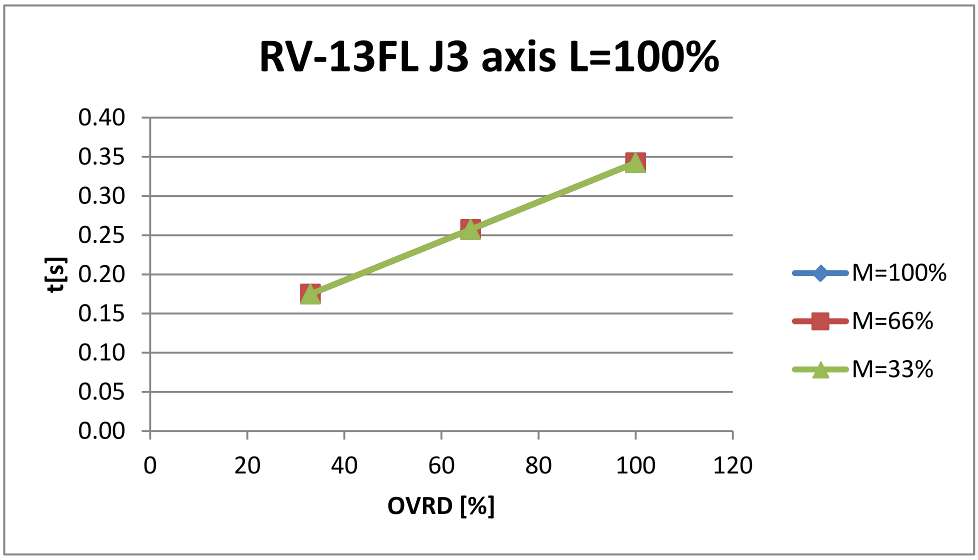
(2) Stopping time of J2 axis



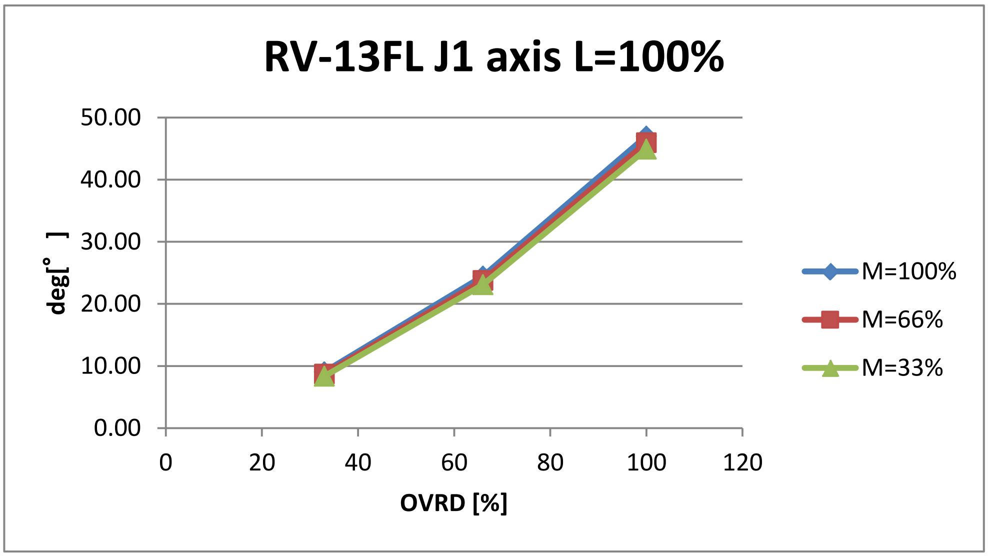


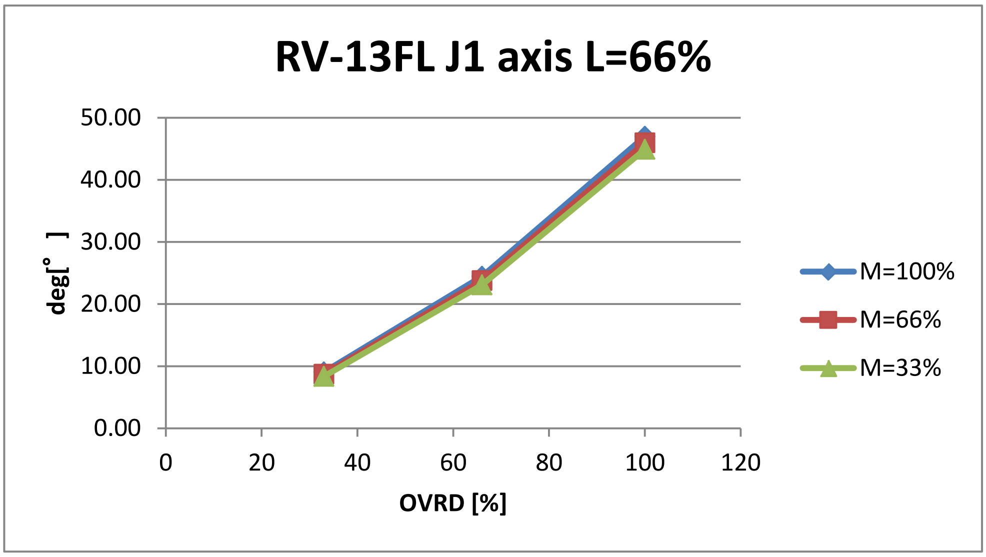


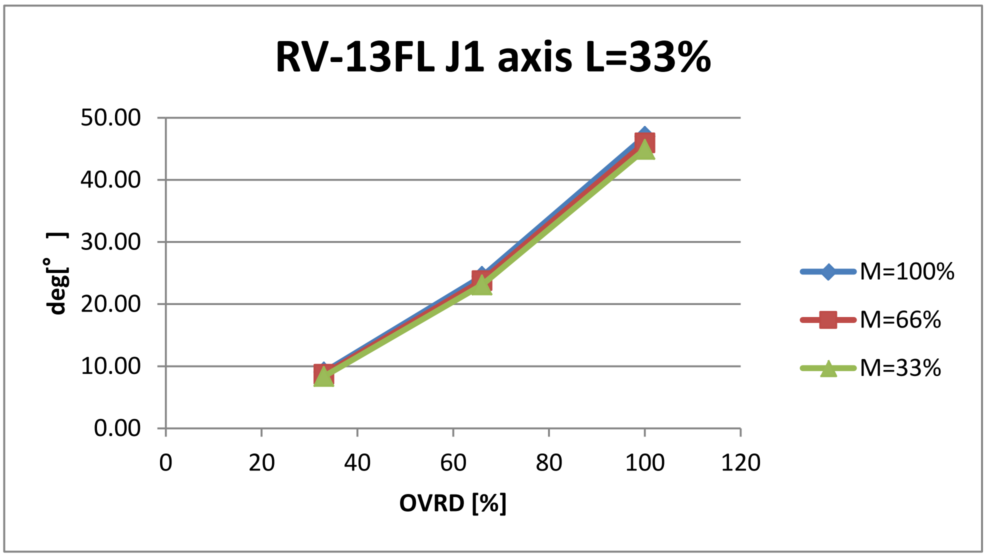
(3) Stopping time of J3 axis



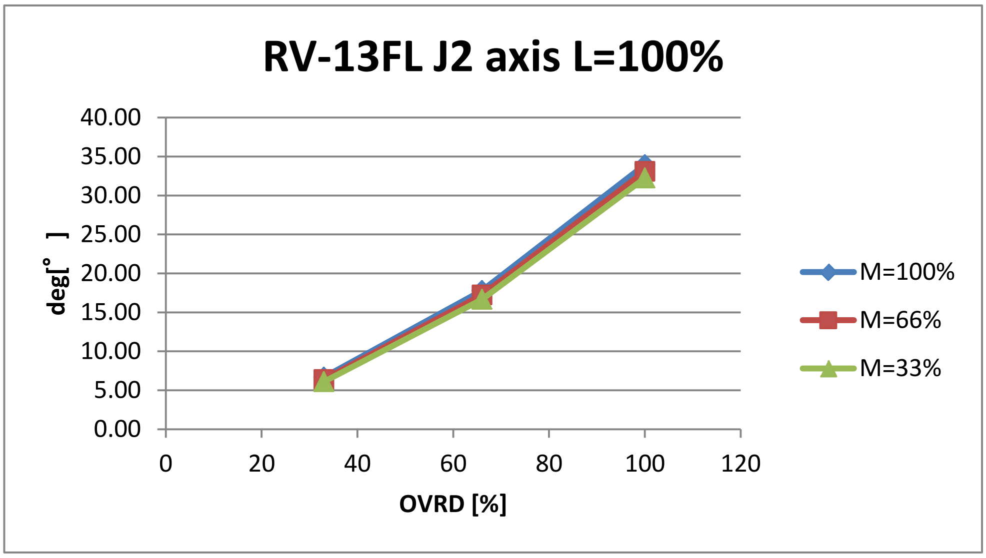
(4) Stopping angle of J1 axis

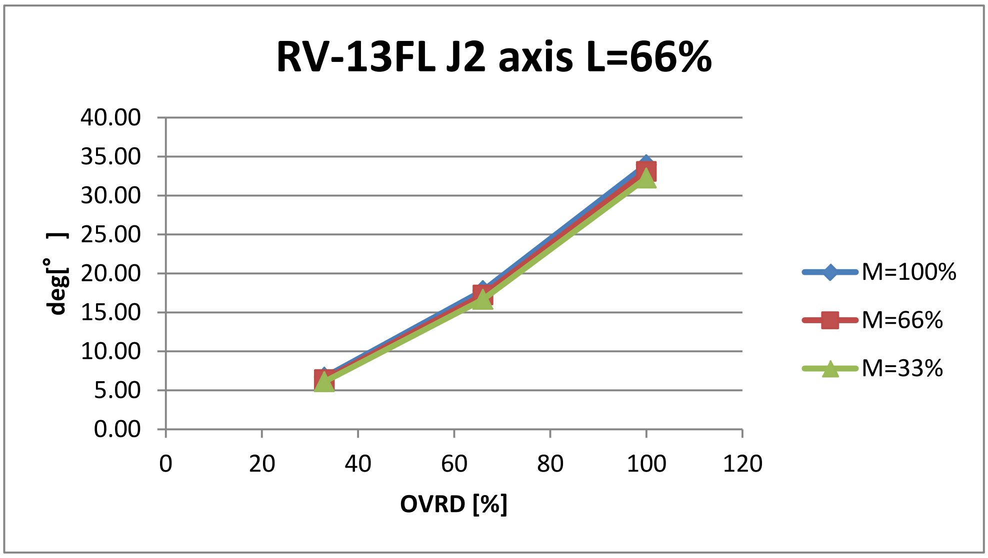


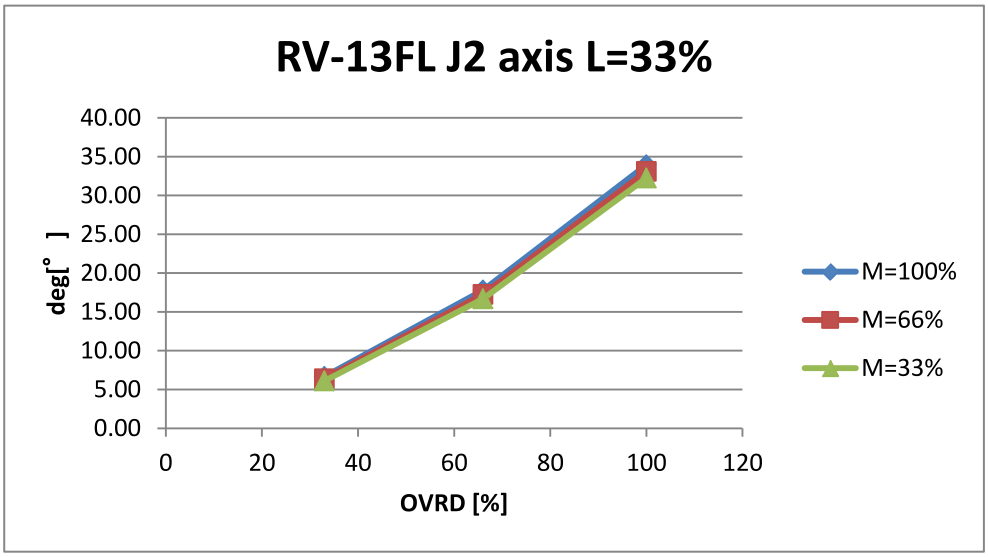




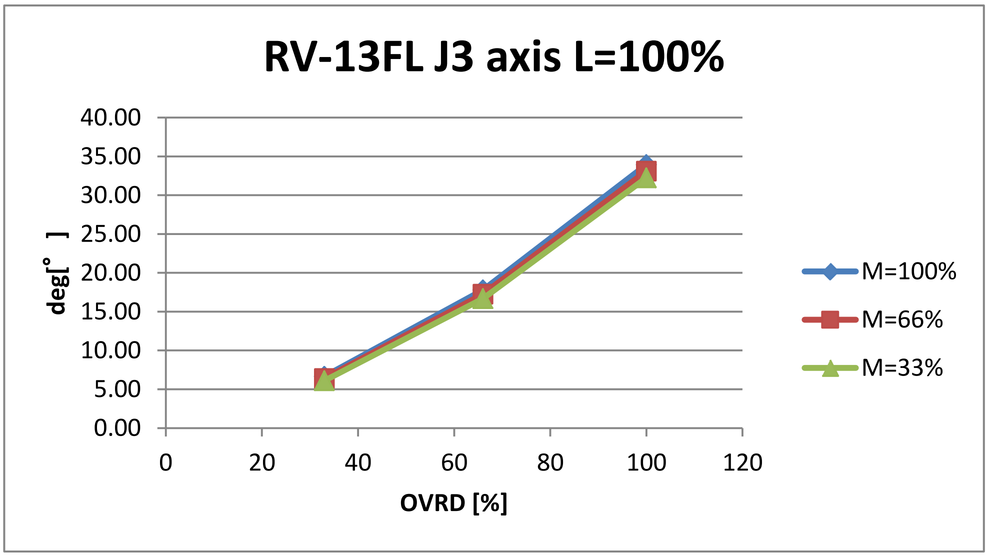
(5) Stopping angle of J2 axis





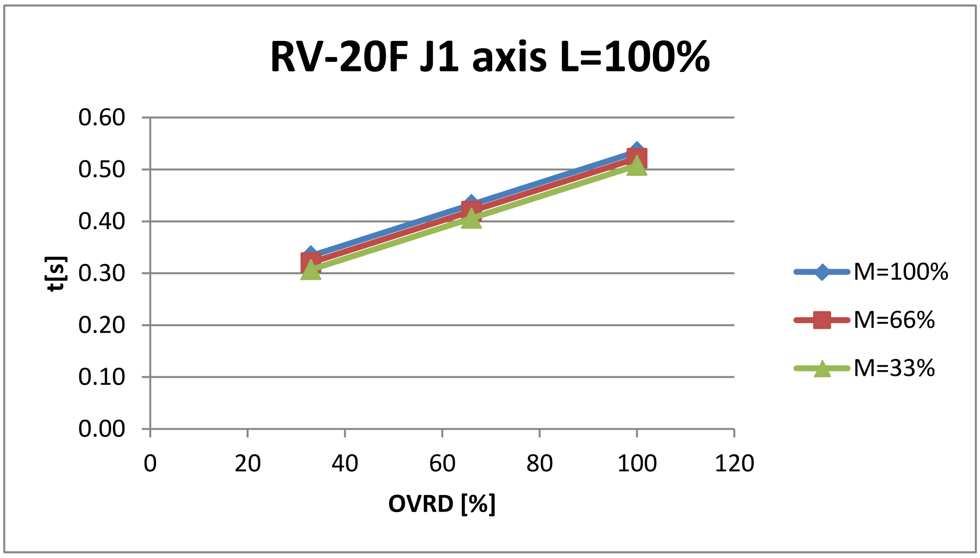


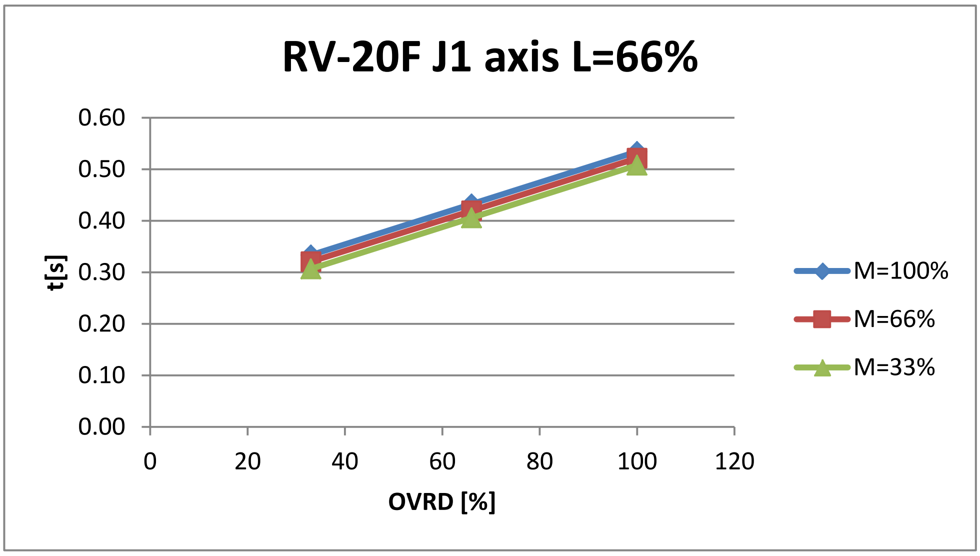
(6) Stopping angle of J3 axis

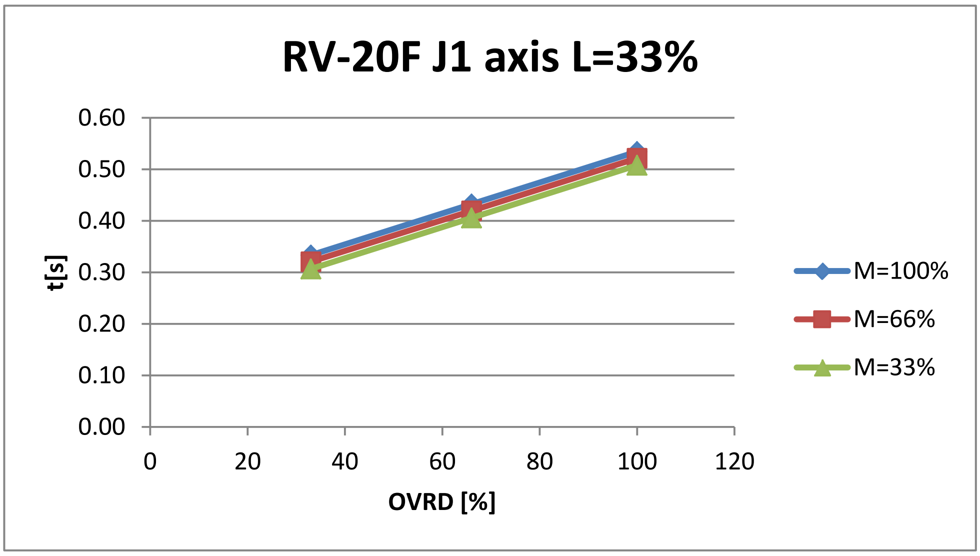


8.4.10 RV-20F

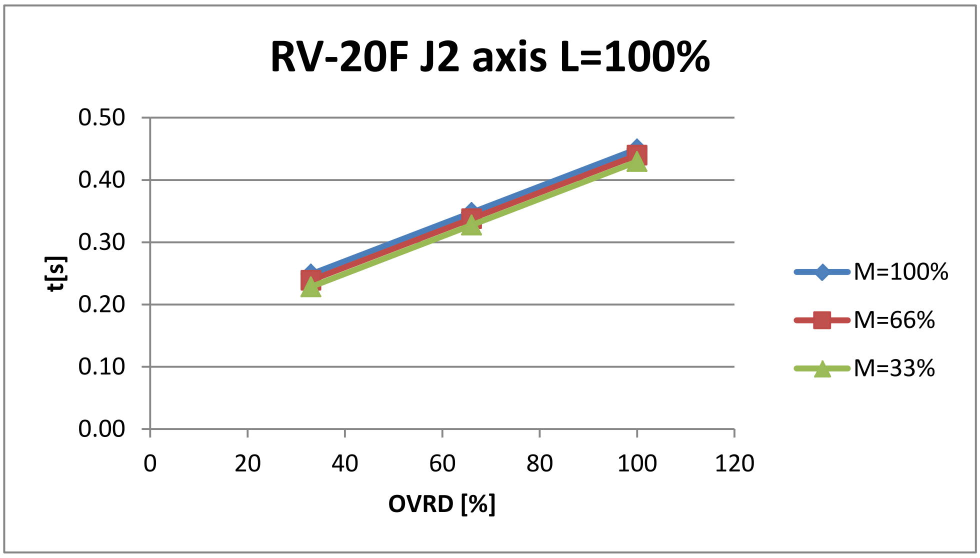
(1) Stopping time of J1 axis

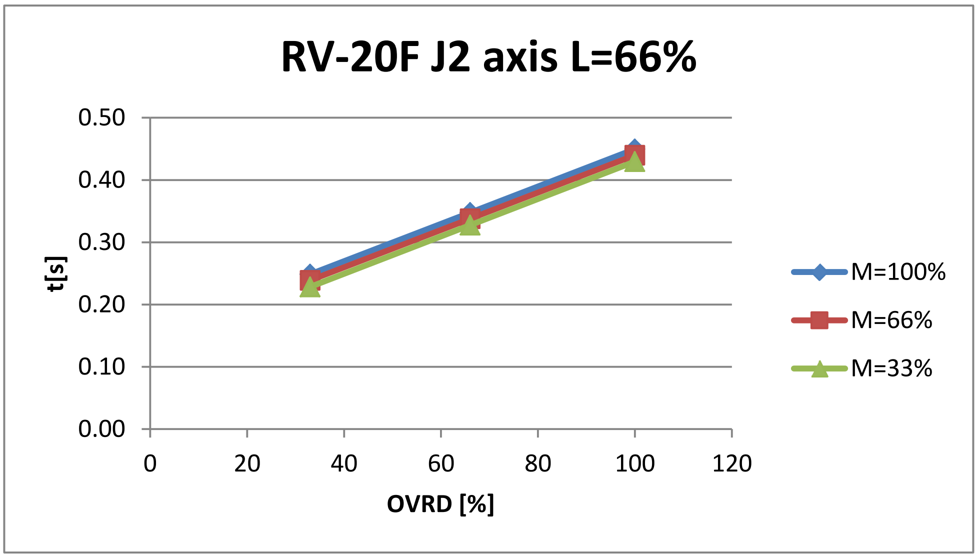


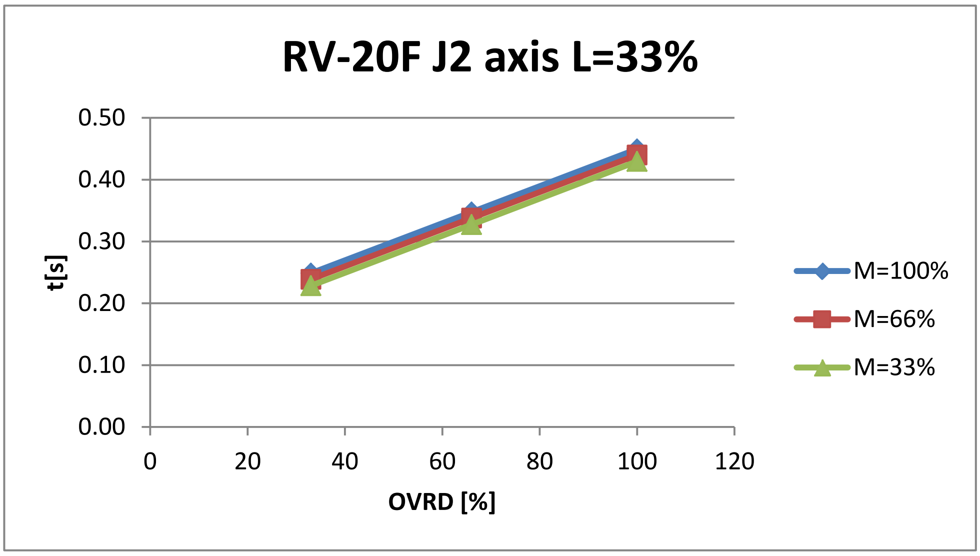




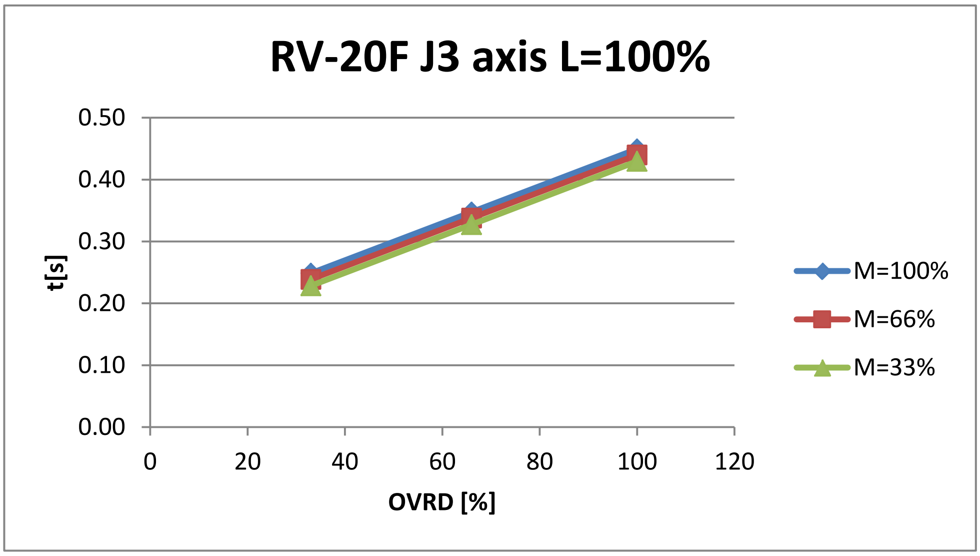
(2) Stopping time of J2 axis



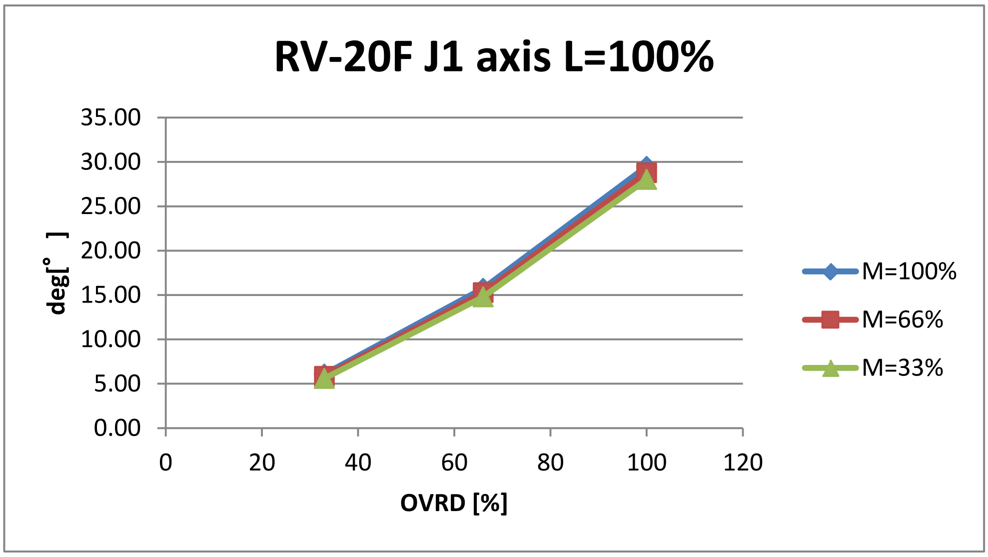


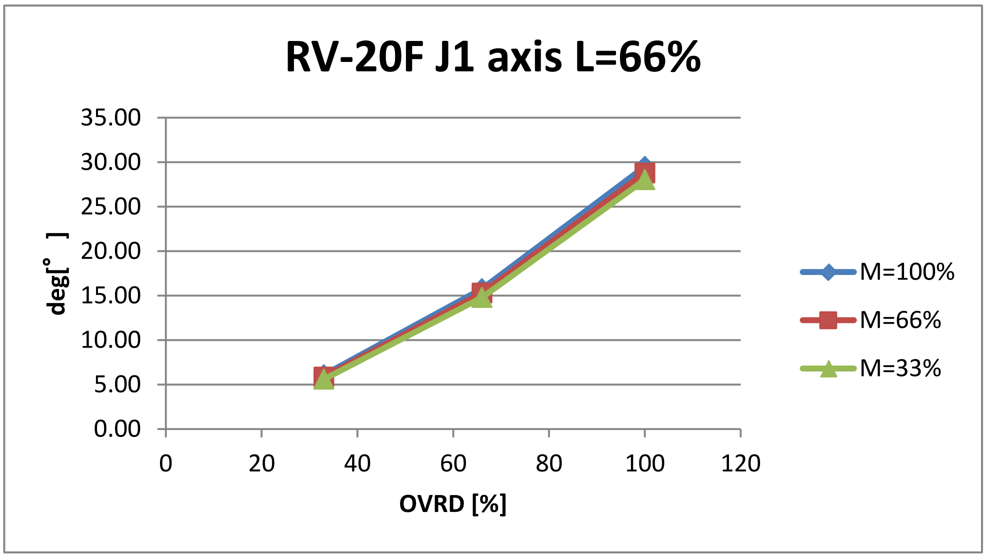


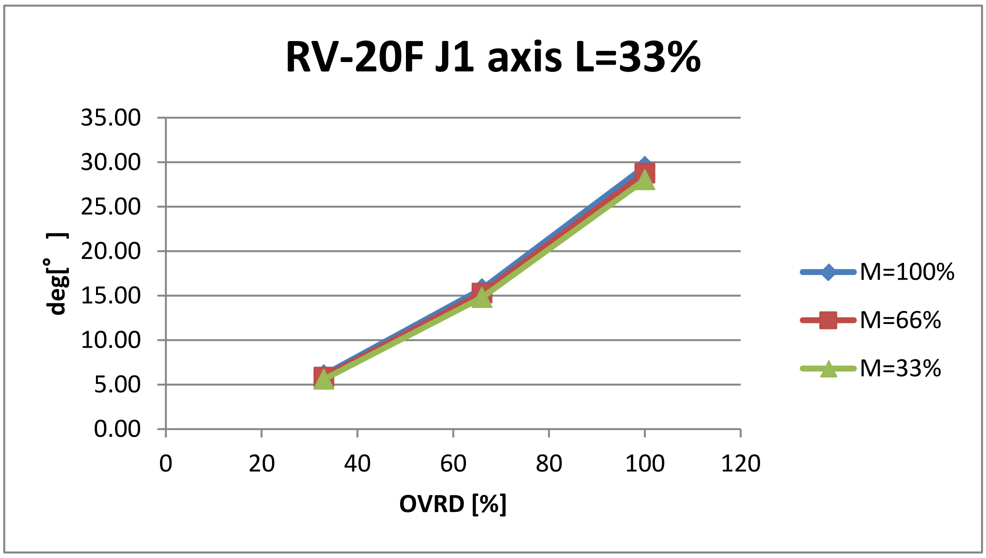
(3) Stopping time of J3 axis



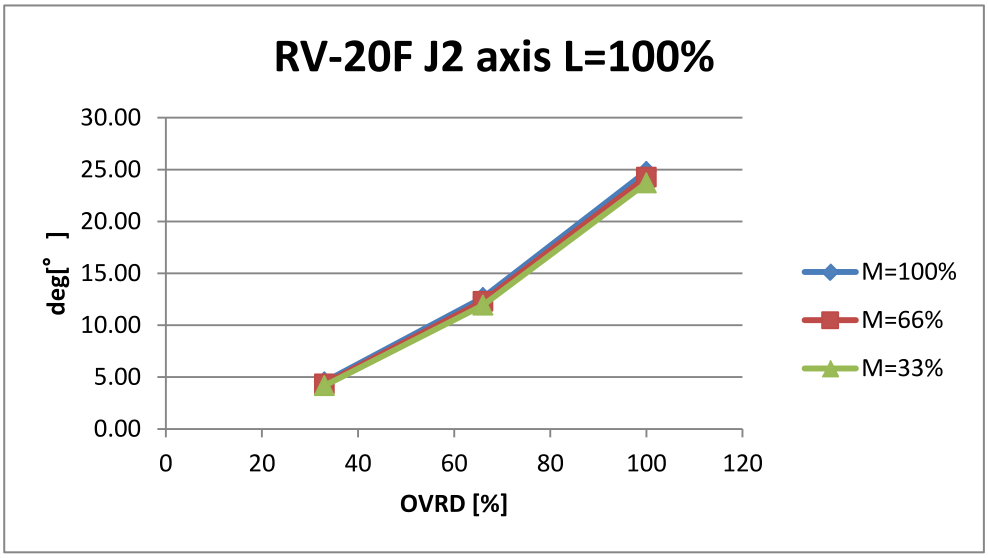
(4) Stopping angle of J1 axis

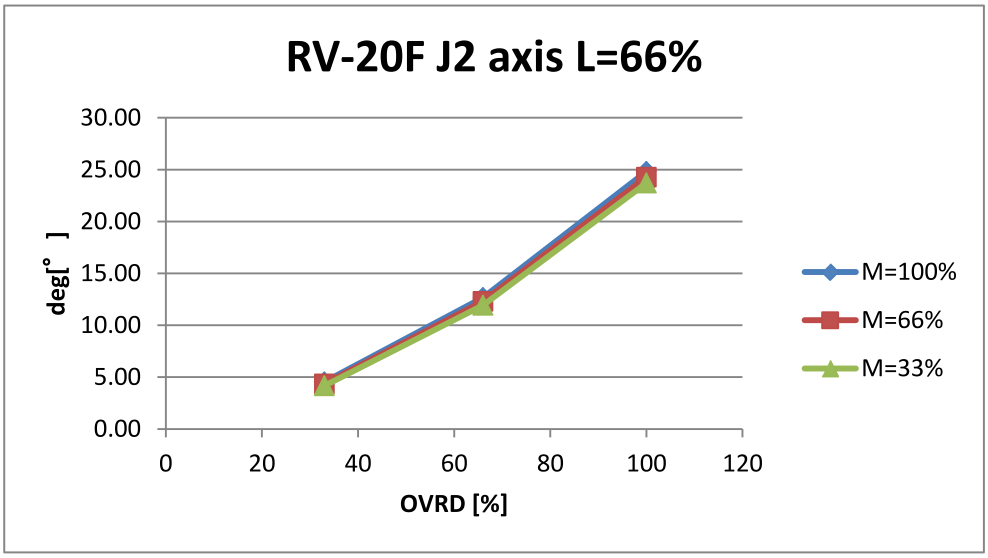


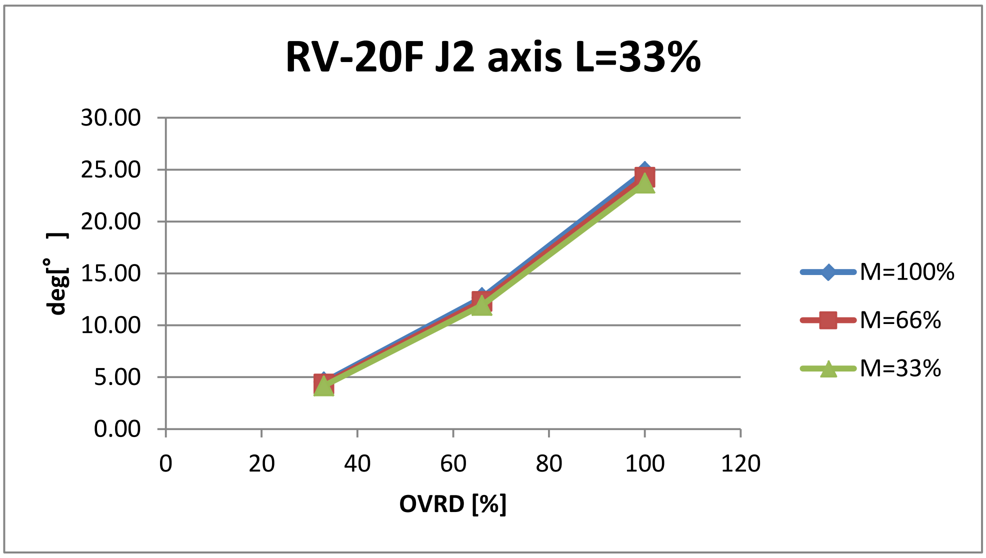




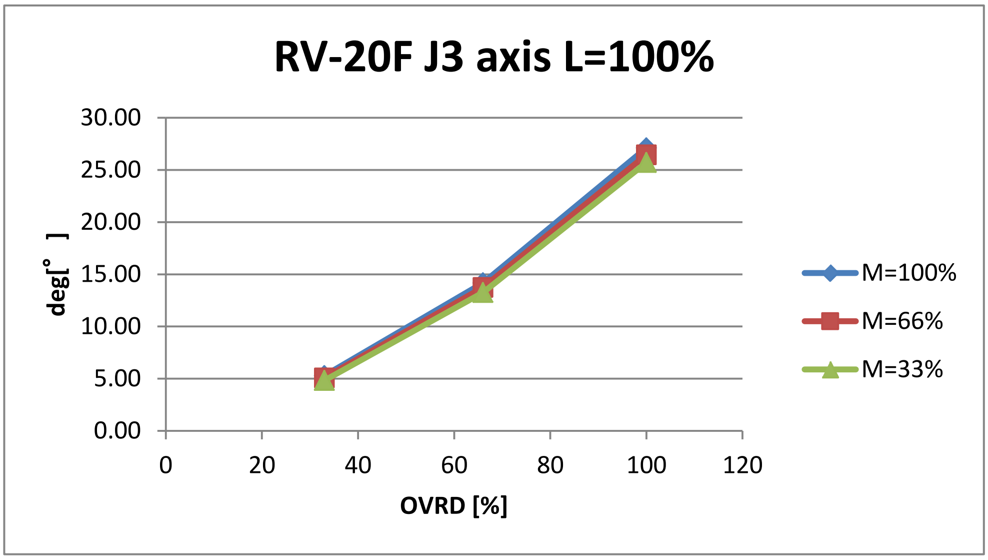
(5) Stopping angle of J2 axis





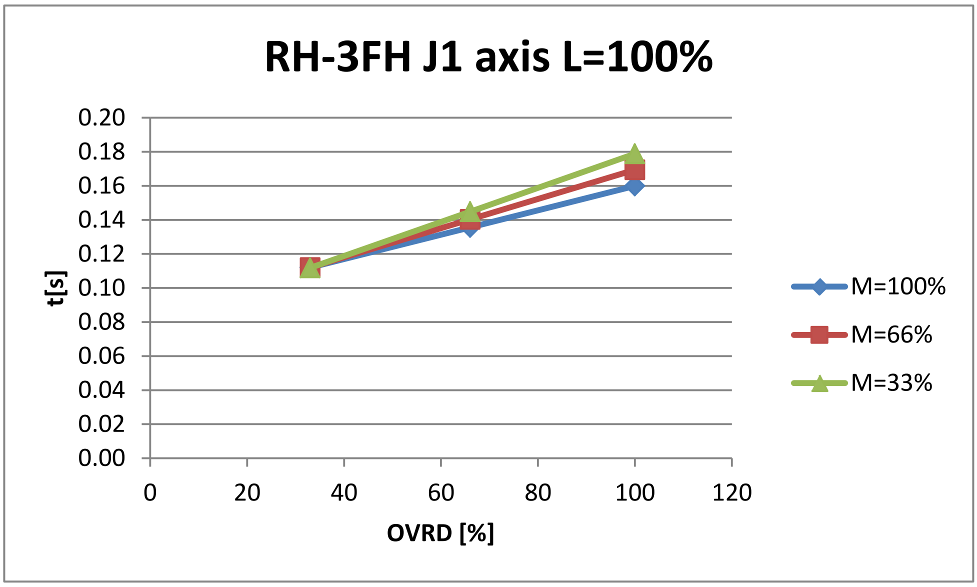


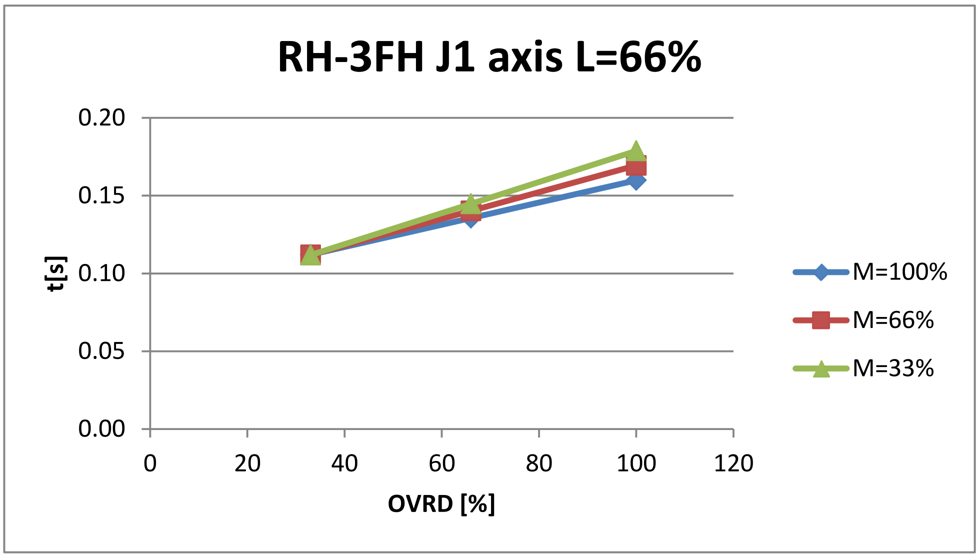
(6) Stopping angle of J3 axis

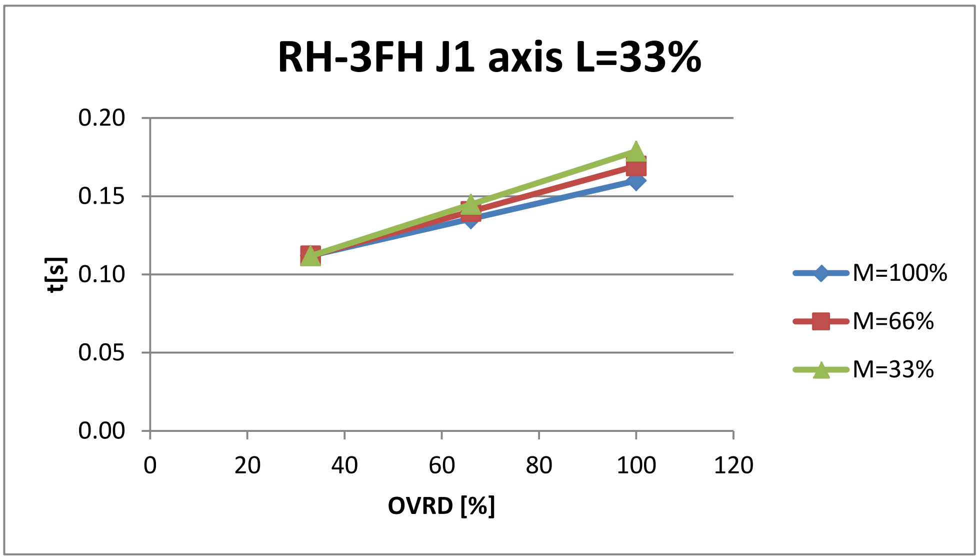


8.4.11 RH-3FH

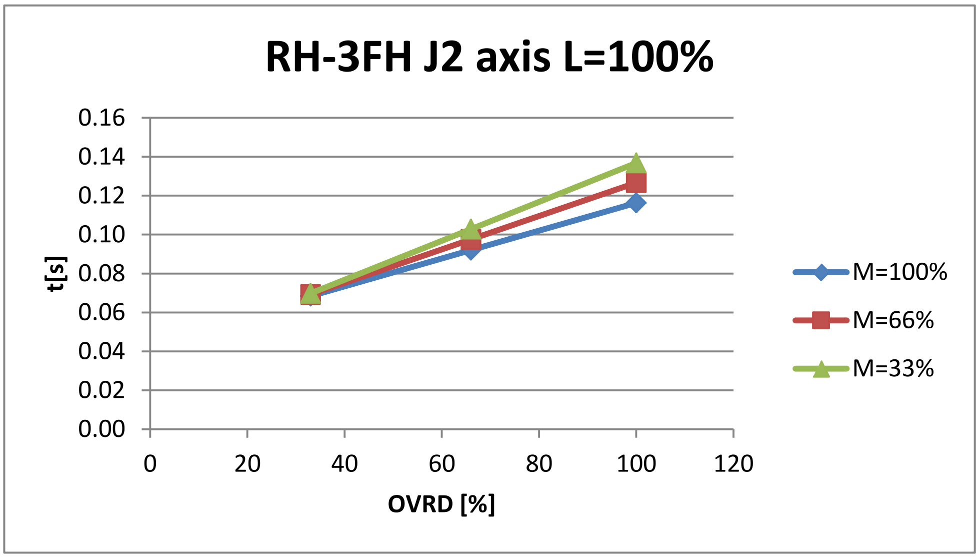
(1) Stopping time of J1 axis



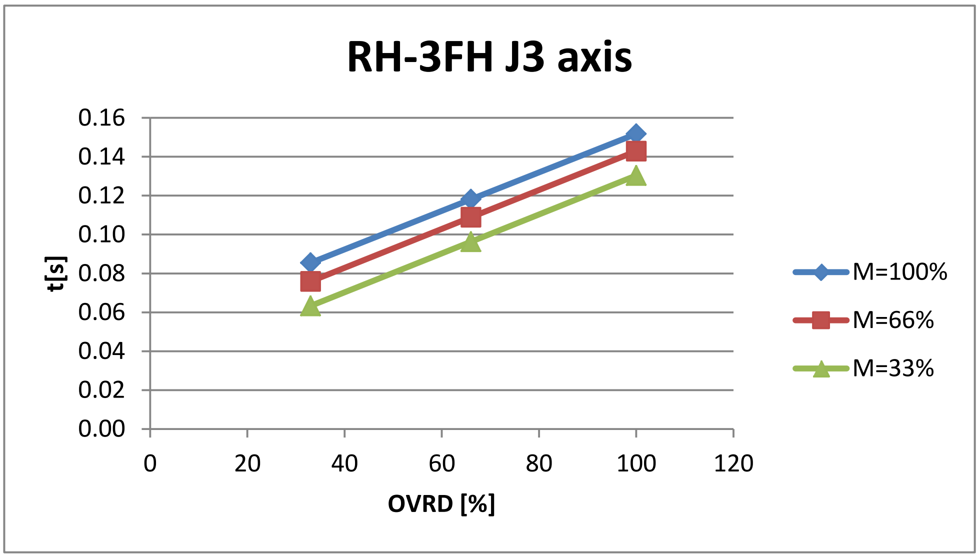




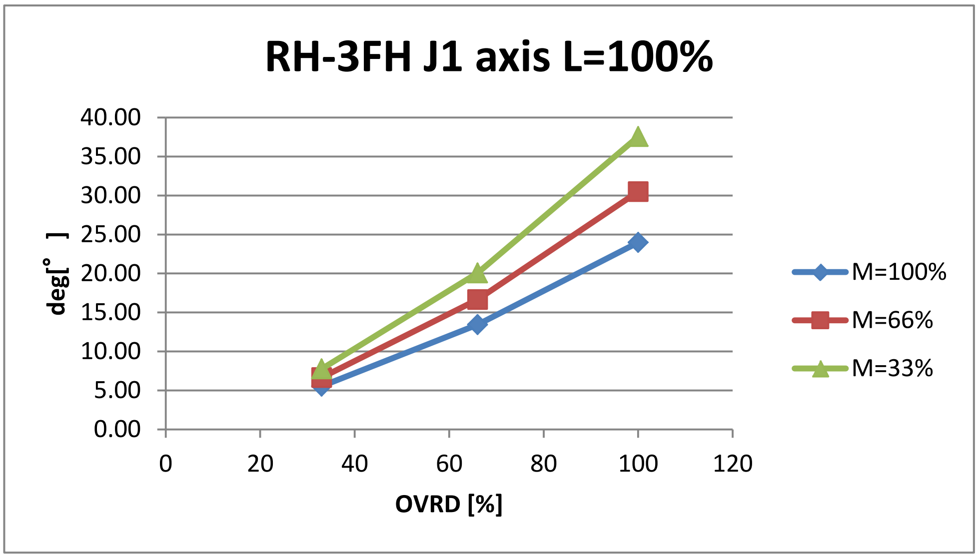
(2) Stopping time of J2 axis

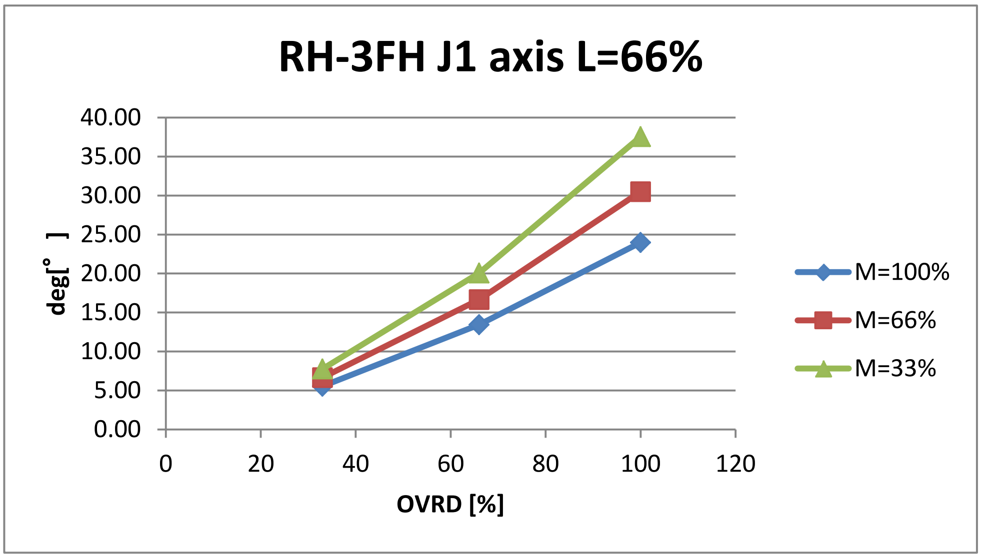


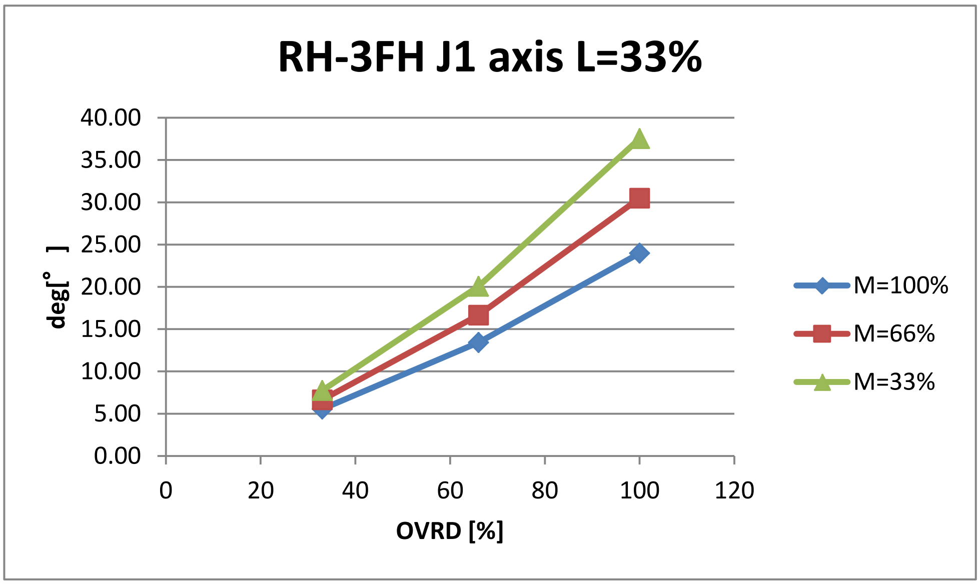
(3) Stopping time of J3 axis



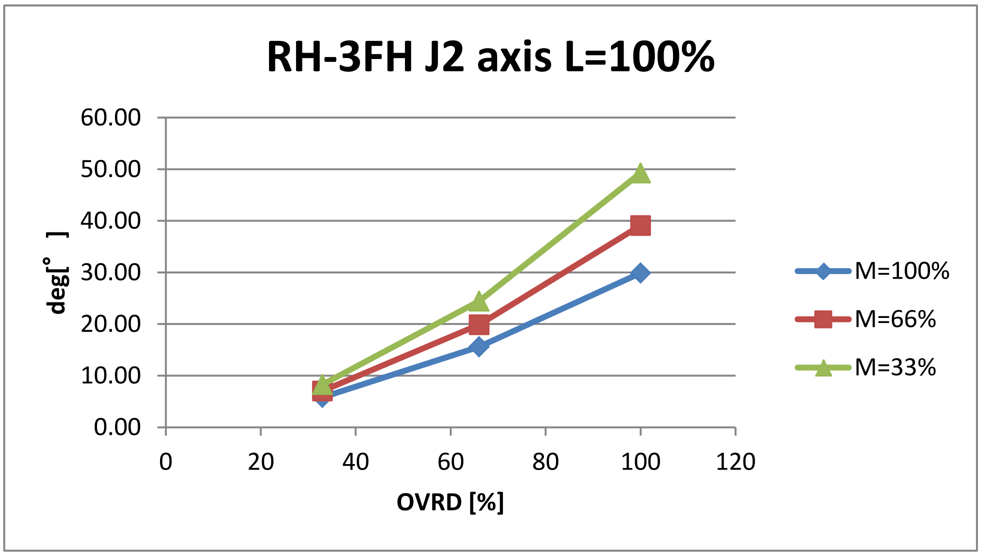
(4) Stopping angle of J1 axis



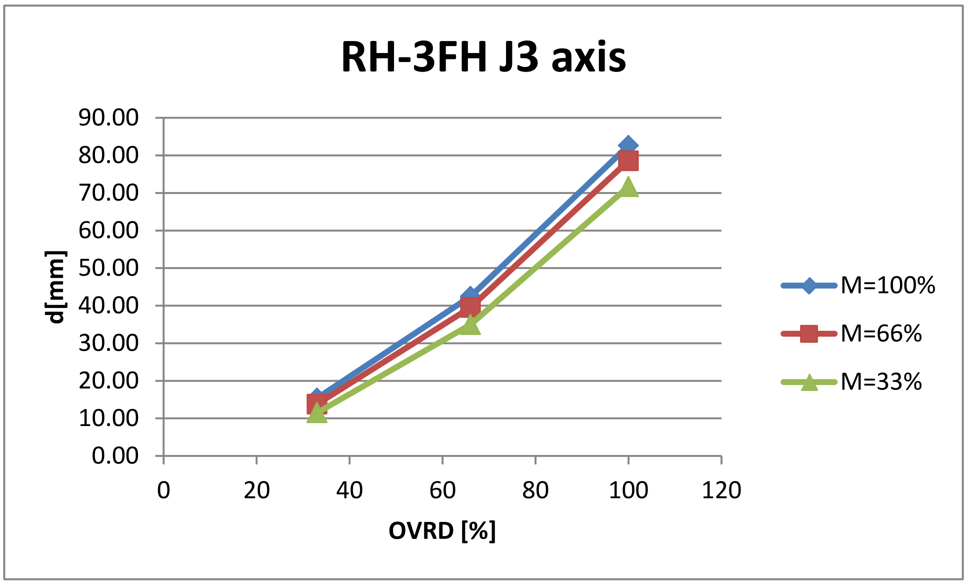




(5) Stopping angle of J2 axis

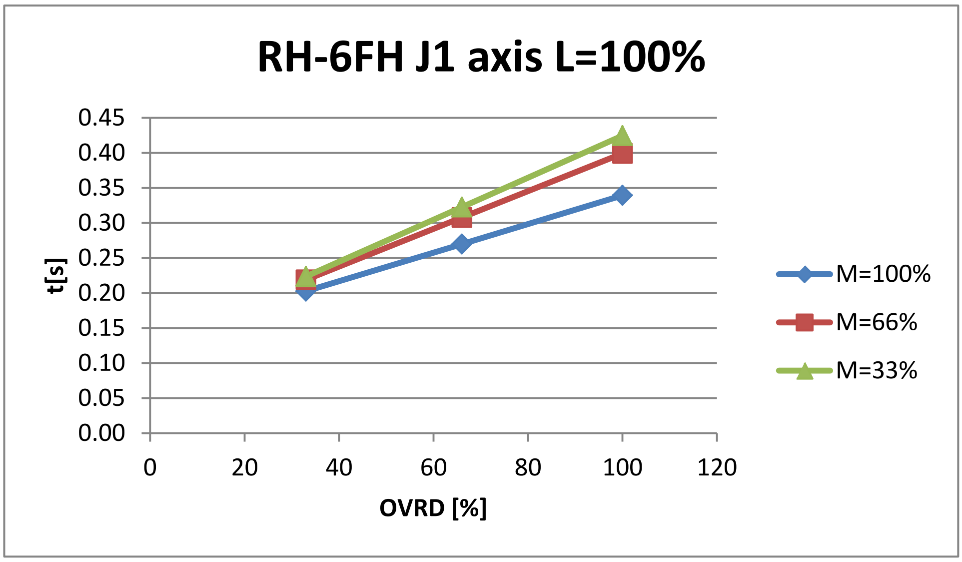


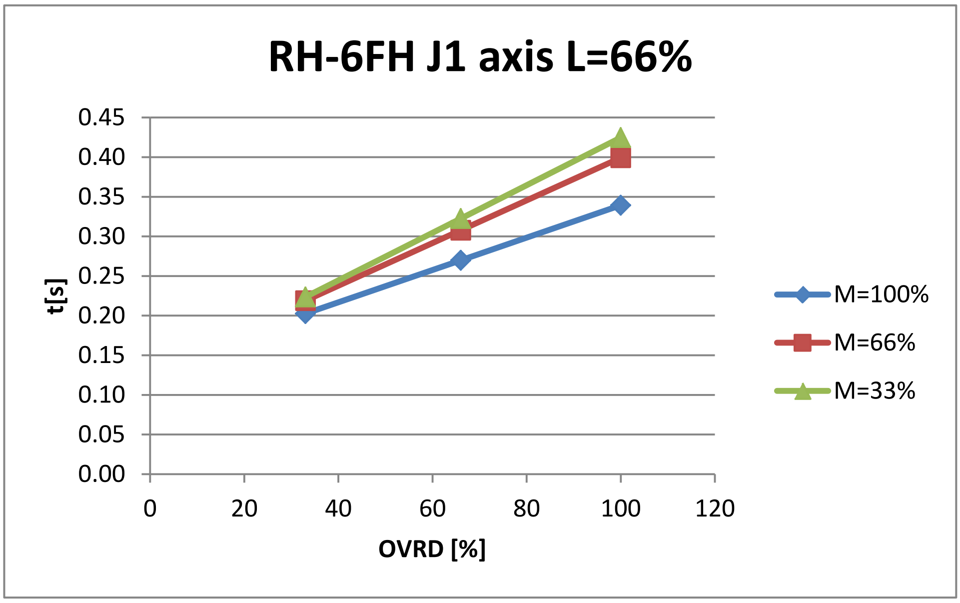
(6) Stopping distance of J3 axis

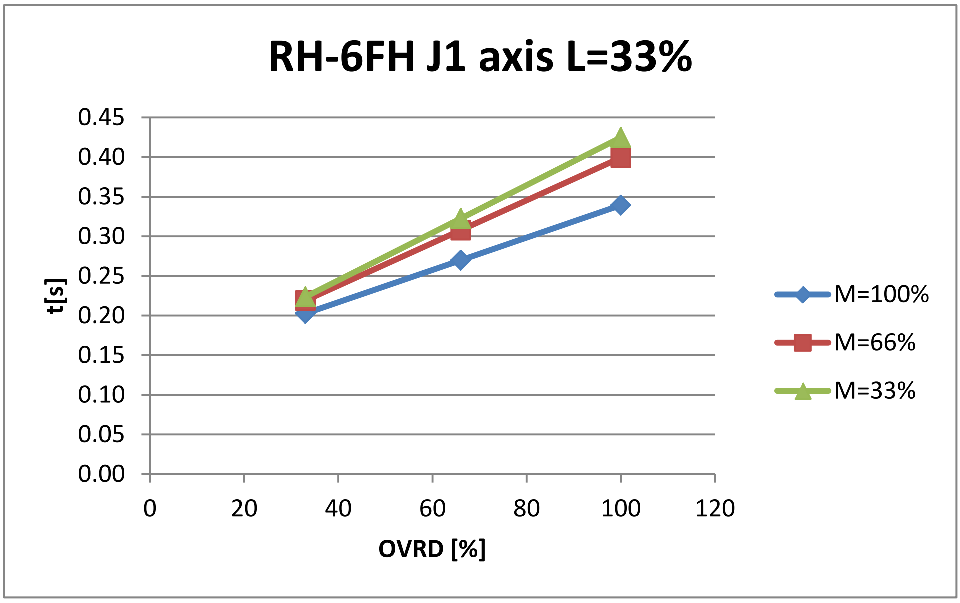


8.4.12 RH-6FH

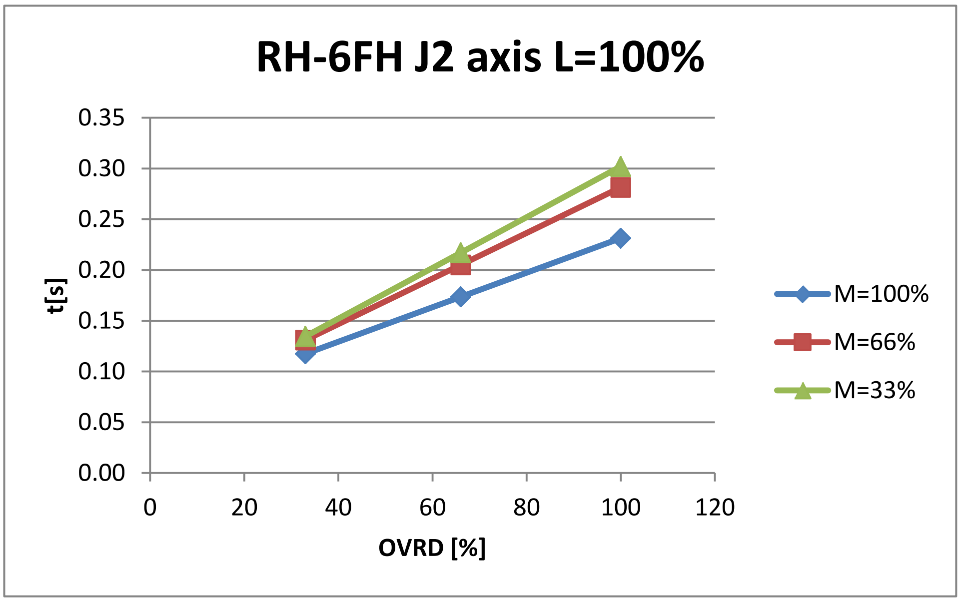
(1) Stopping time of J1 axis



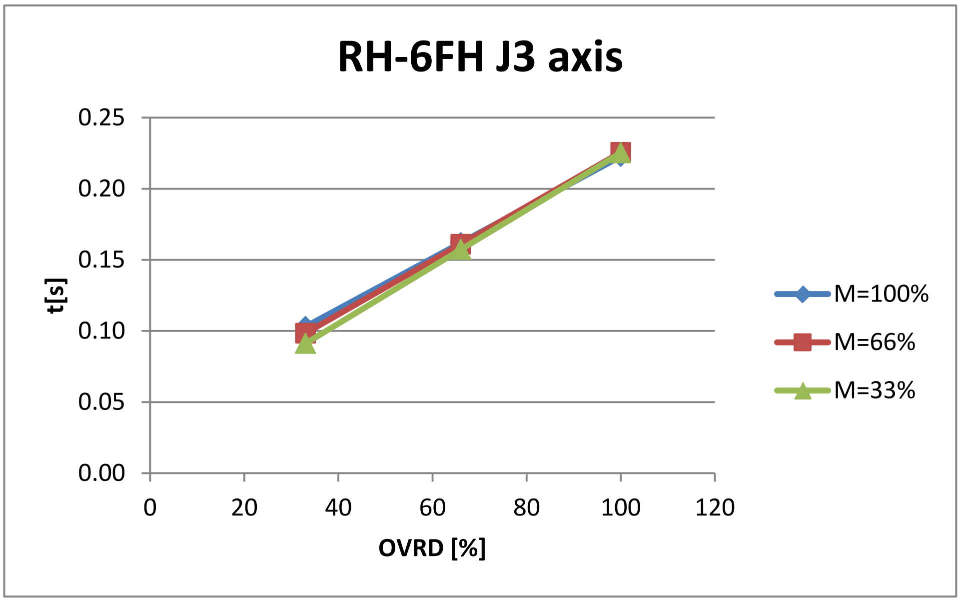




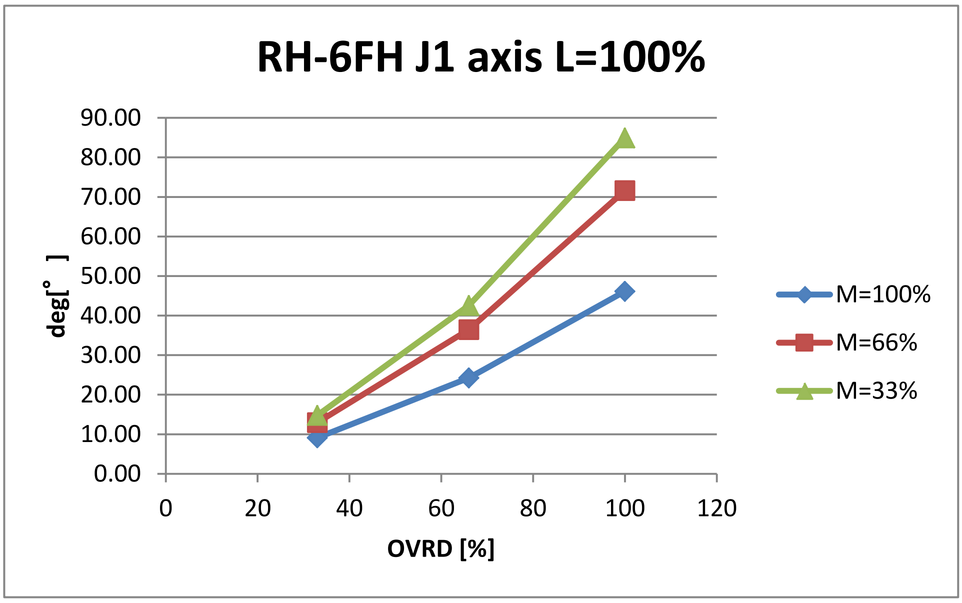
(2) Stopping time of J2 axis

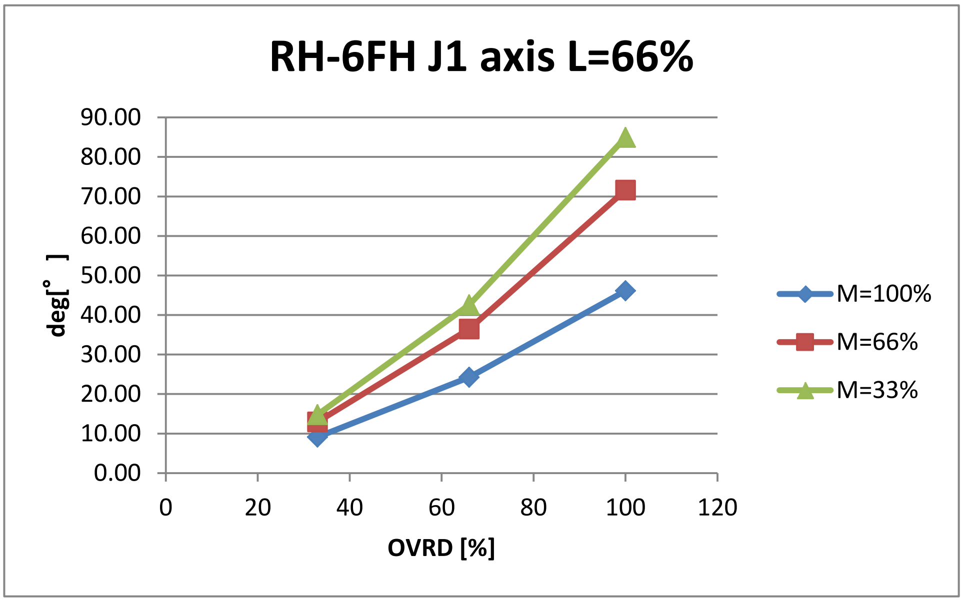


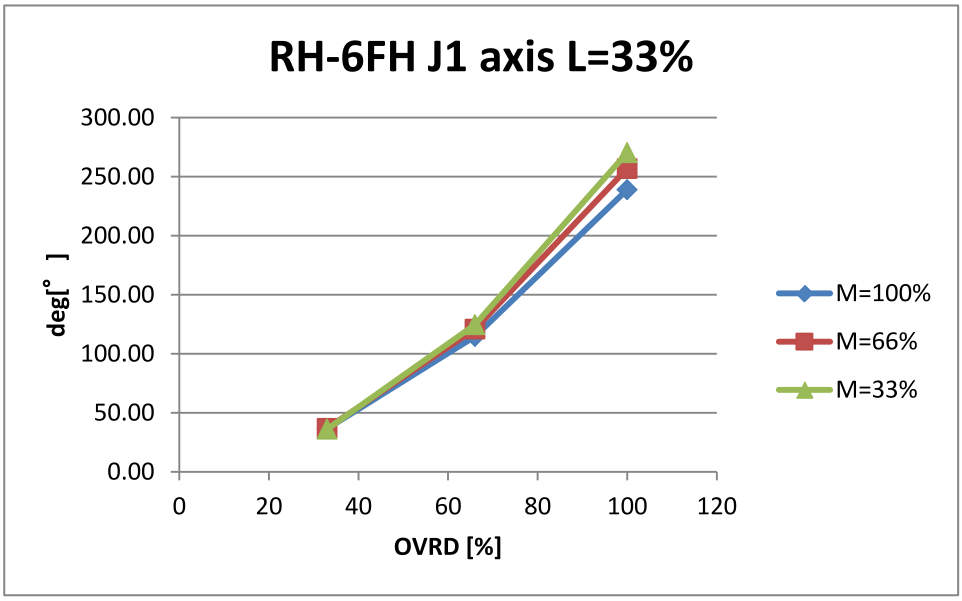
(3) Stopping time of J3 axis



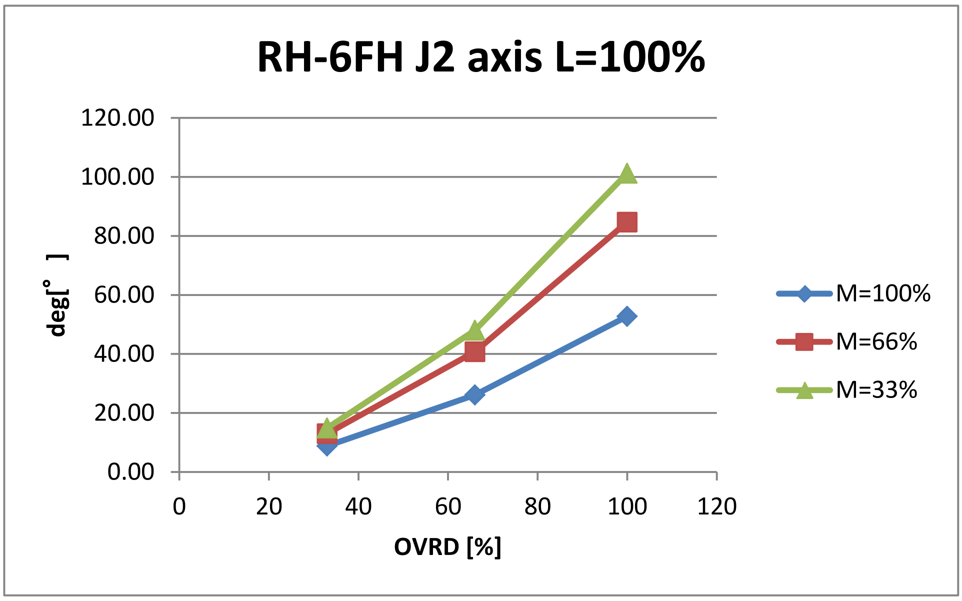
(4) Stopping angle of J1 axis



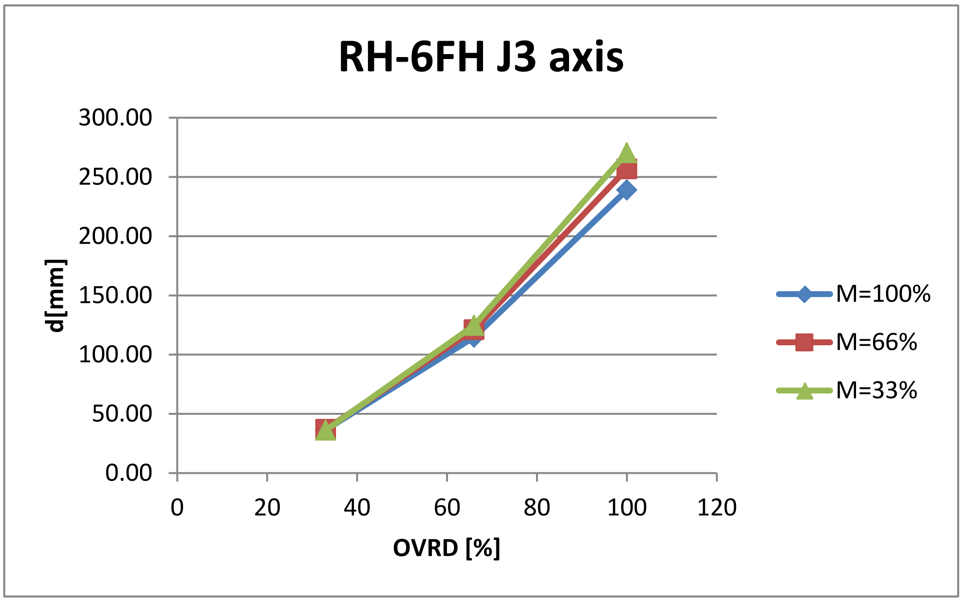




(5) Stopping angle of J2 axis

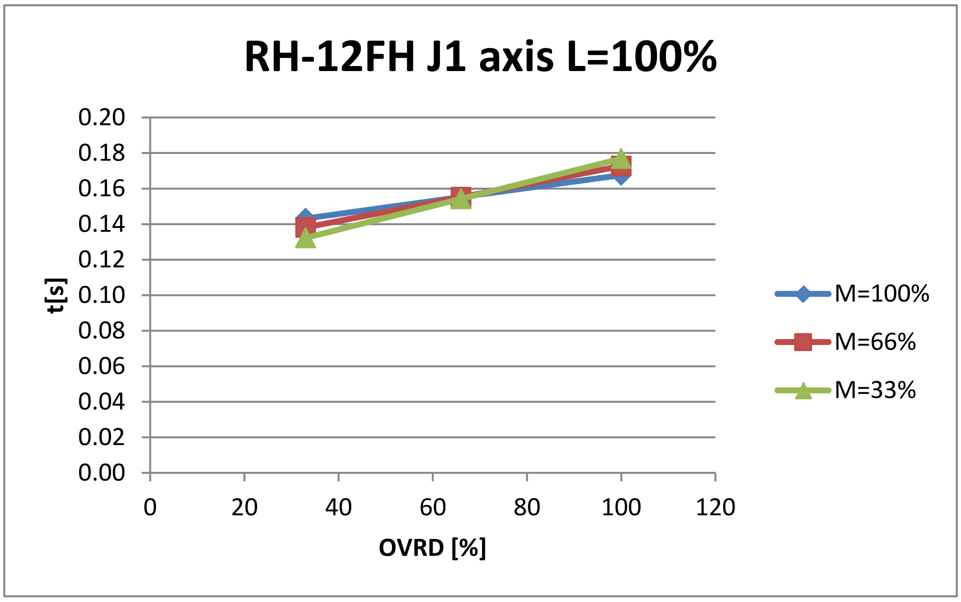


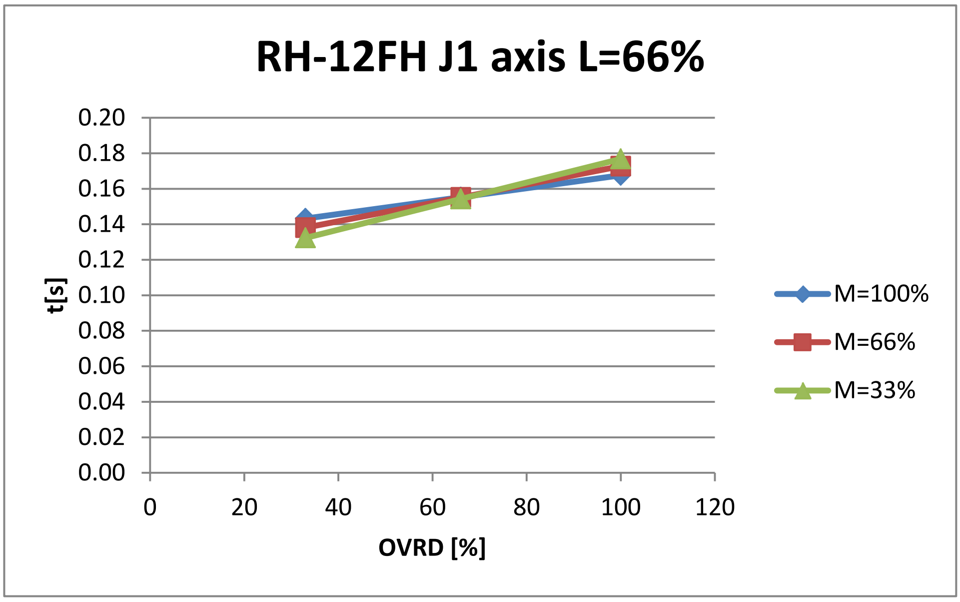
(6) Stopping distance of J3 axis

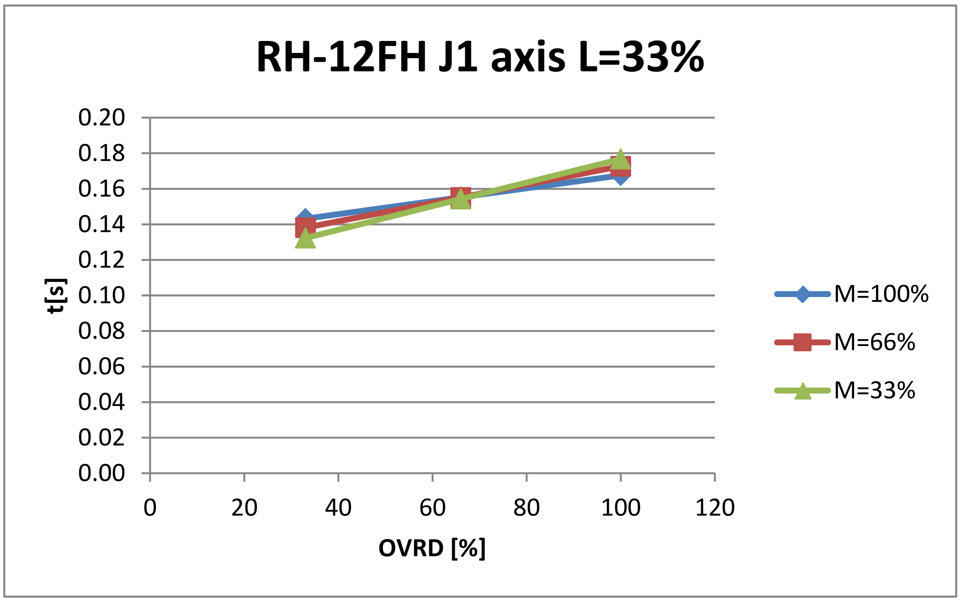


8.4.13 RH-12FH

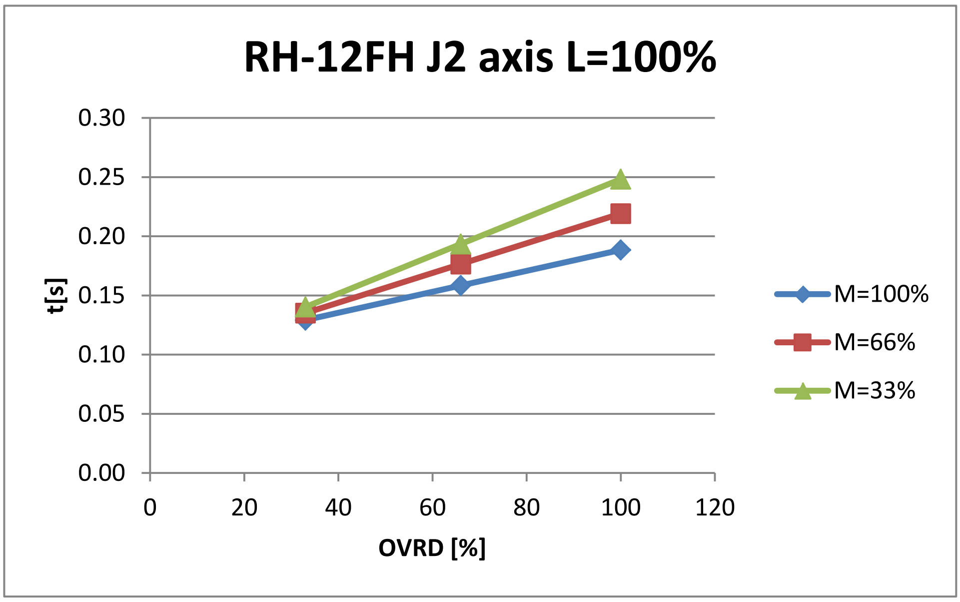
(1) Stopping time of J1 axis



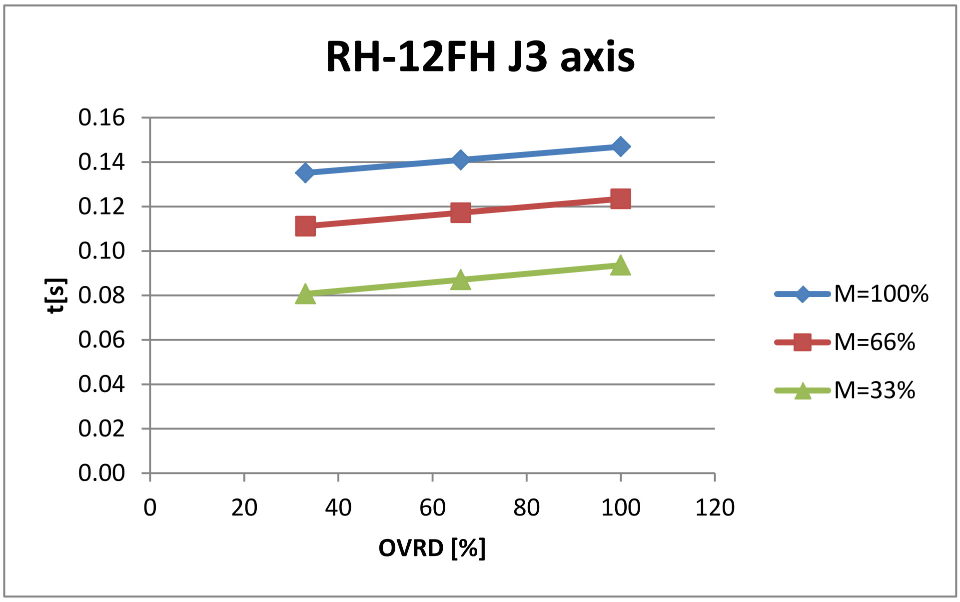




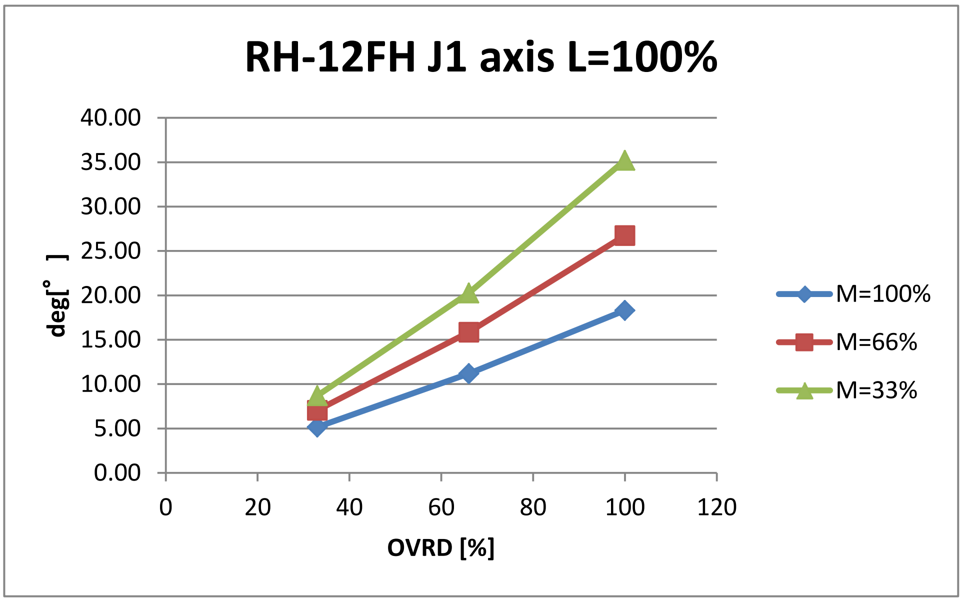
(2) Stopping time of J2 axis

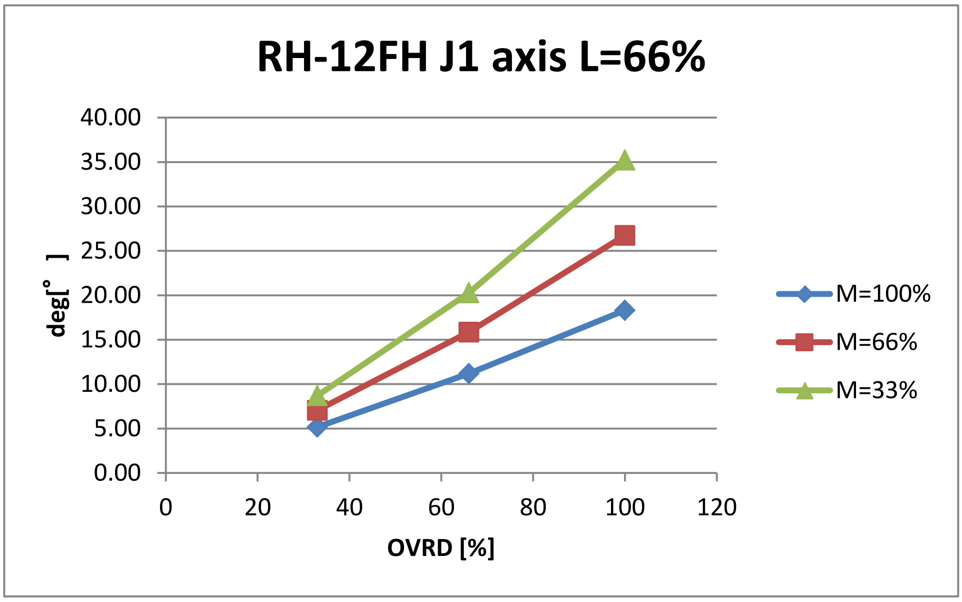


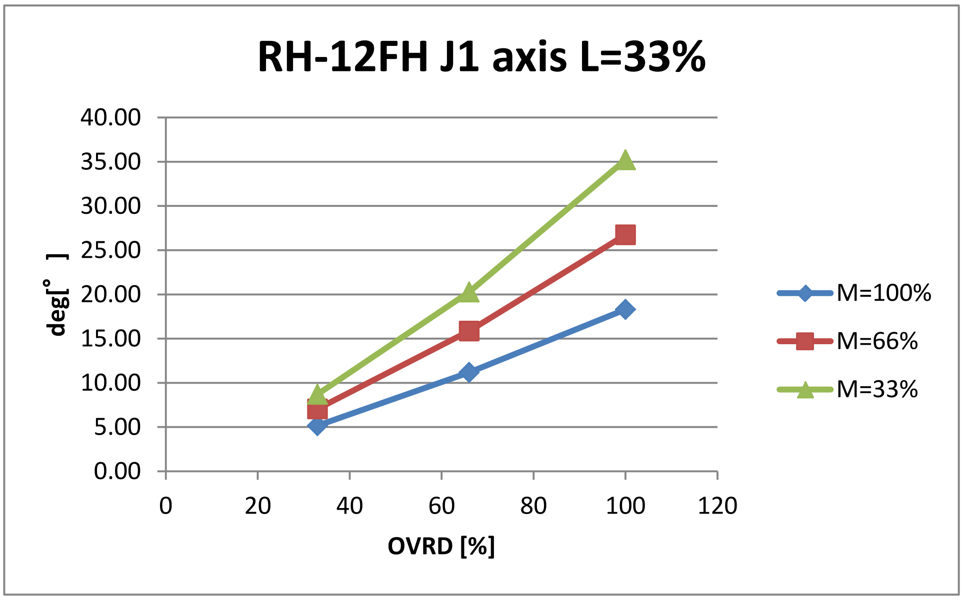
(3) Stopping time of J3 axis



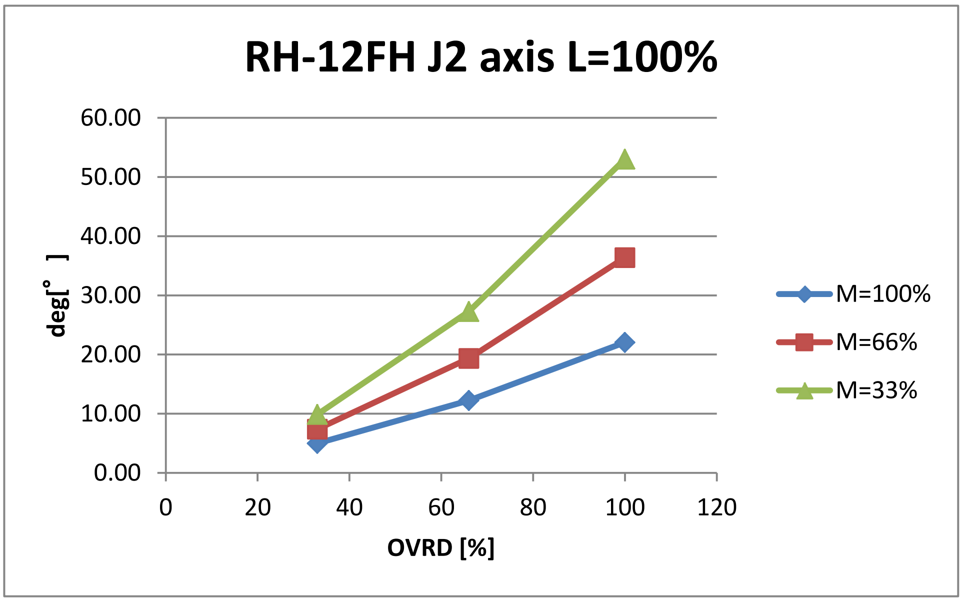
(4) Stopping angle of J1 axis



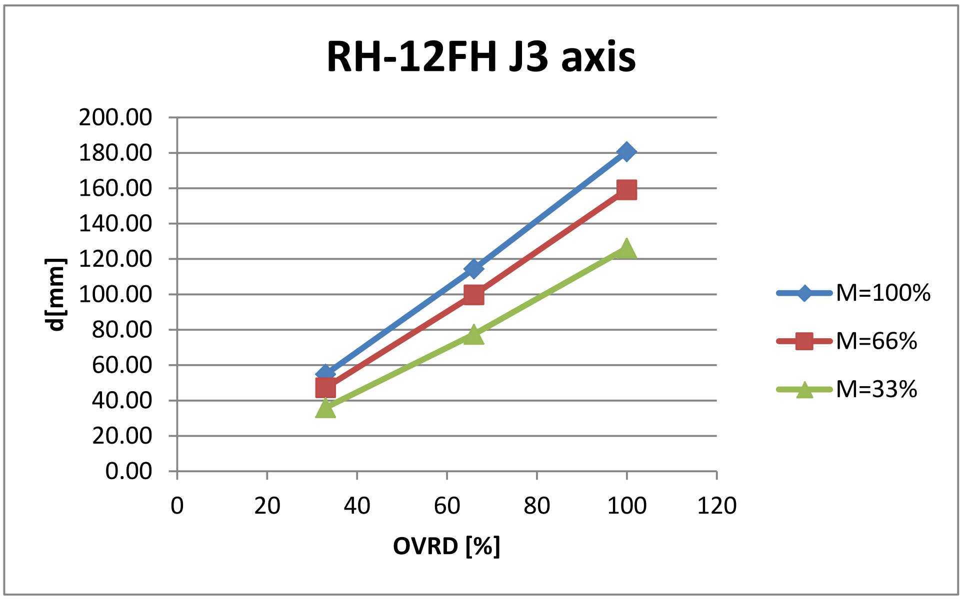




(5) Stopping angle of J2 axis

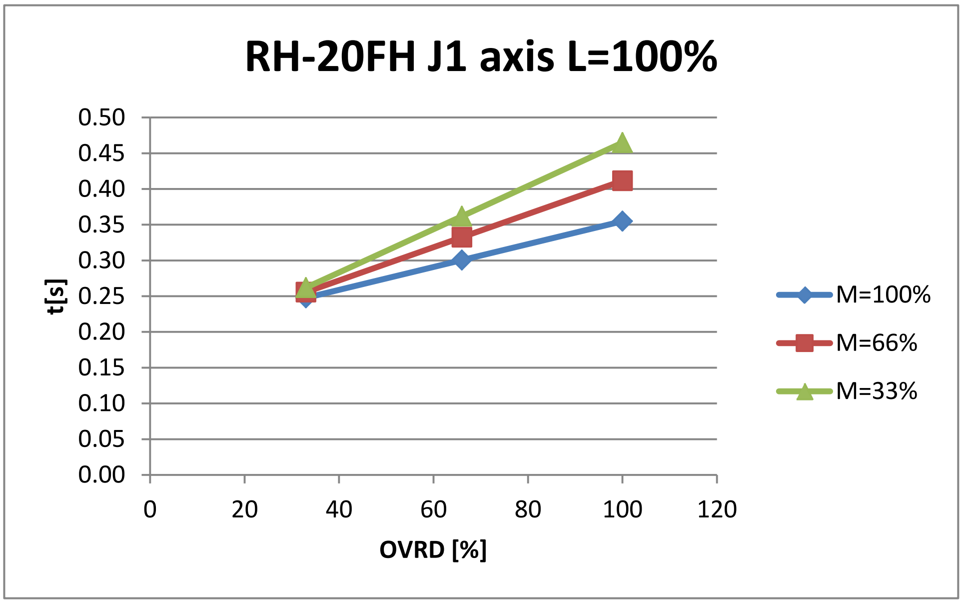


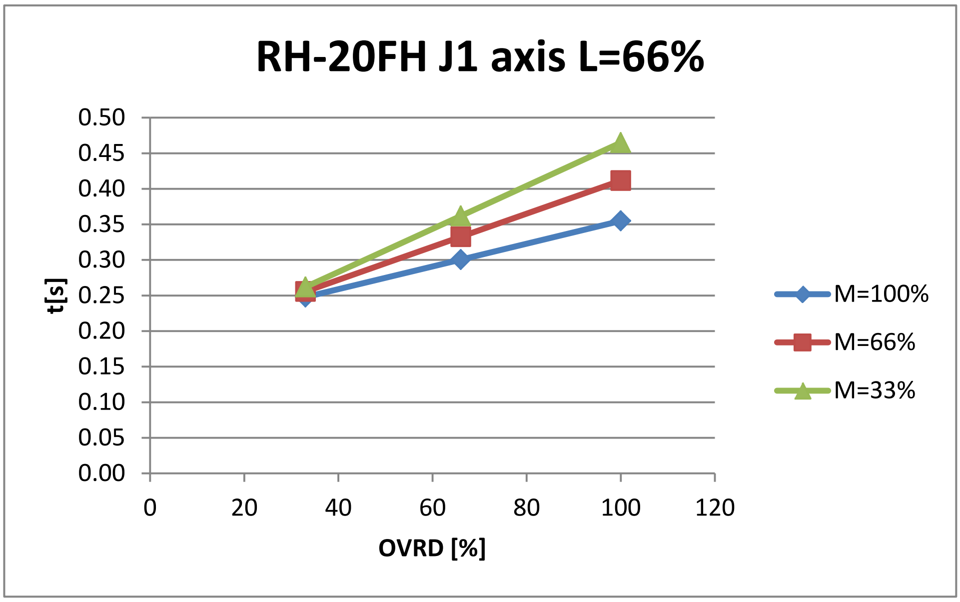
(6) Stopping distance of J3 axis

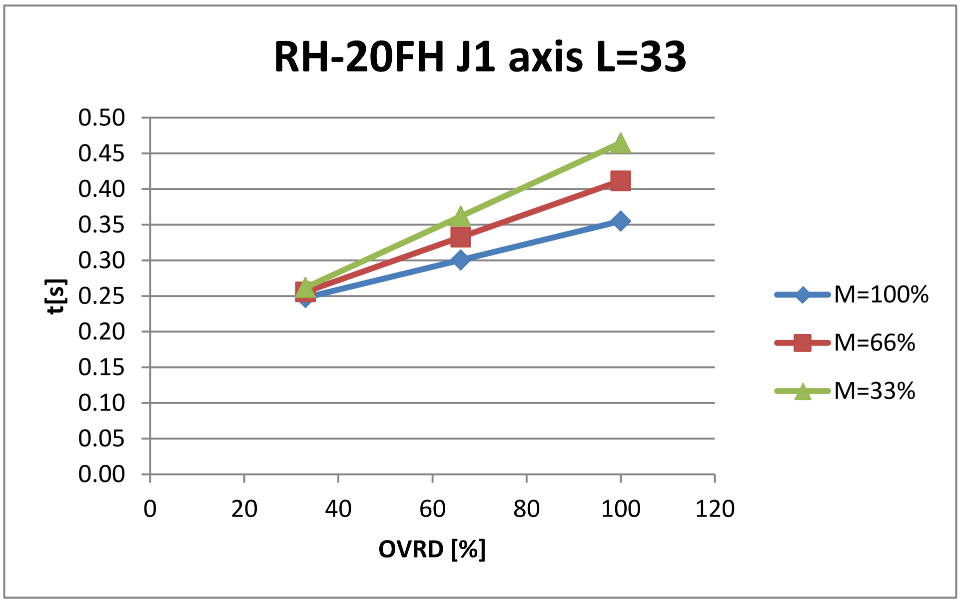


8.4.14 RH-20FH

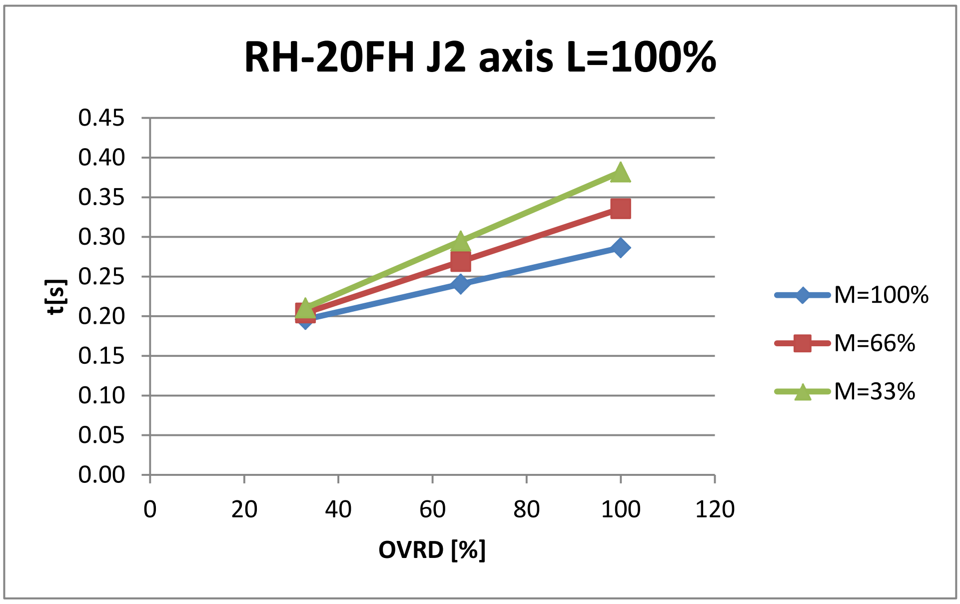
(1) Stopping time of J1 axis



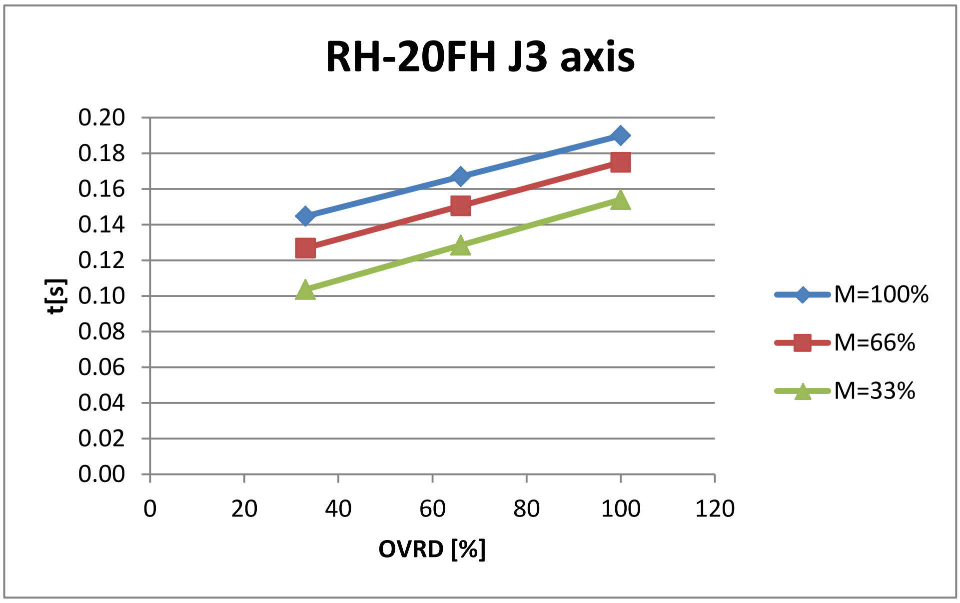




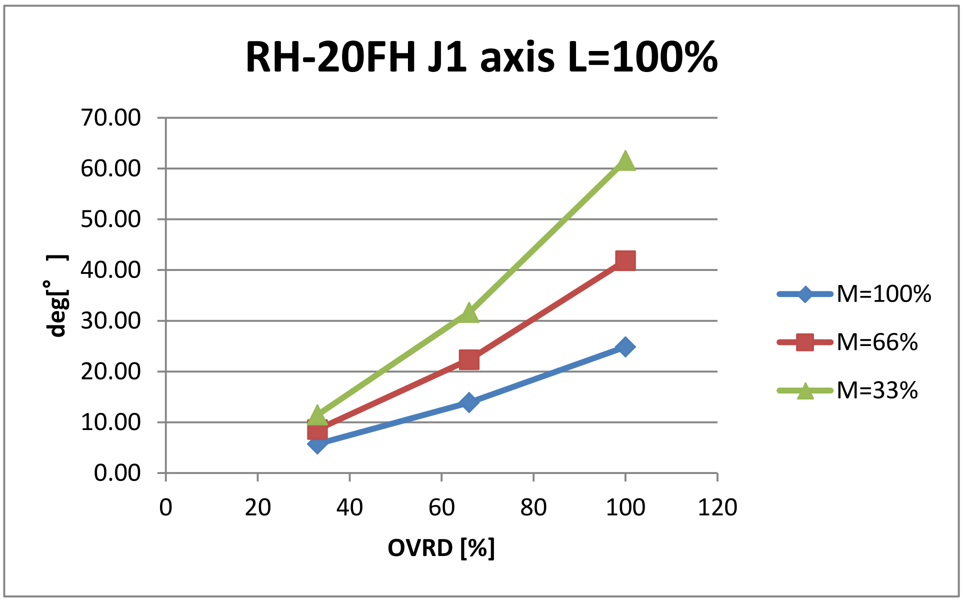
(2) Stopping time of J2 axis

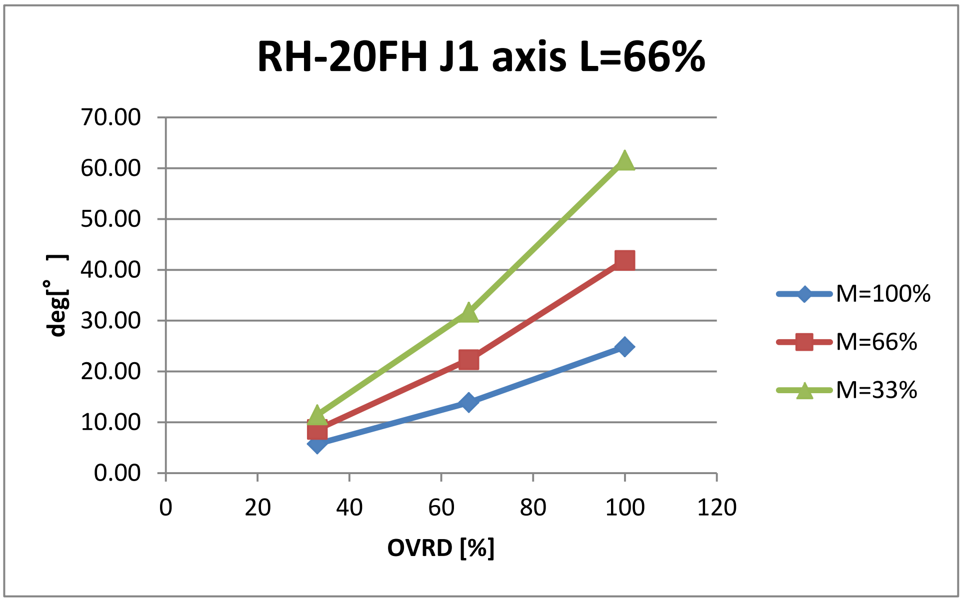


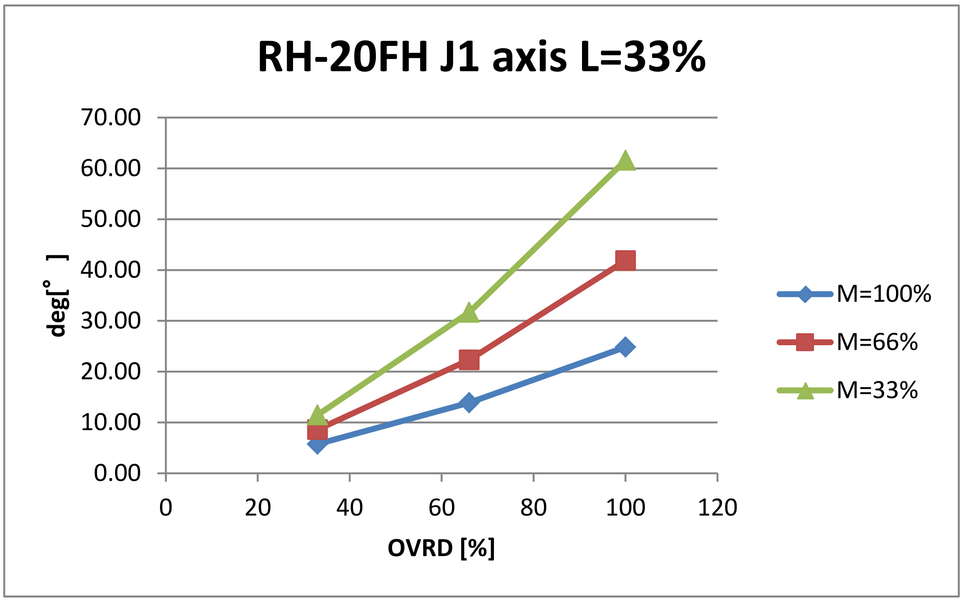
(3) Stopping time of J3 axis



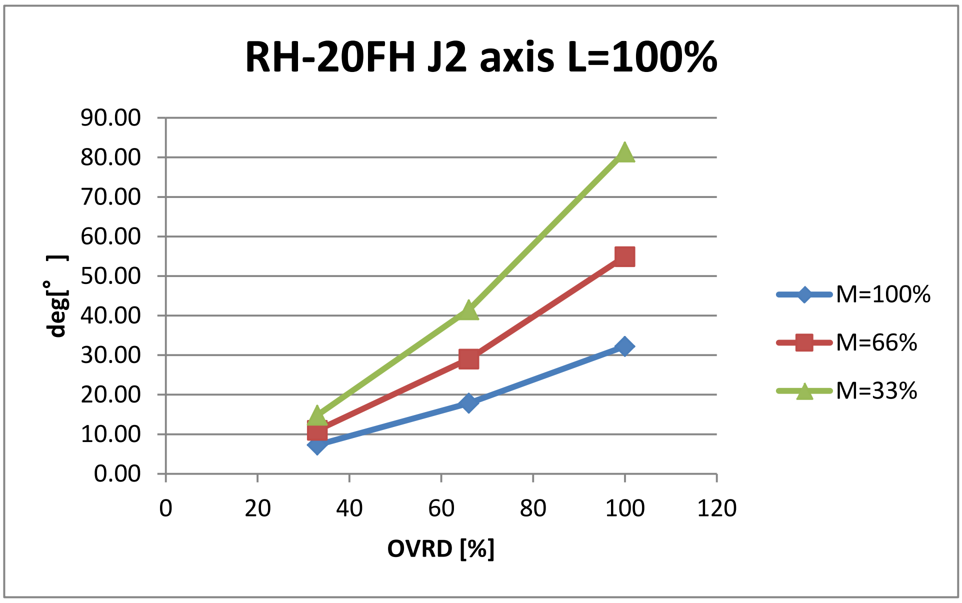
(4) Stopping angle of J1 axis



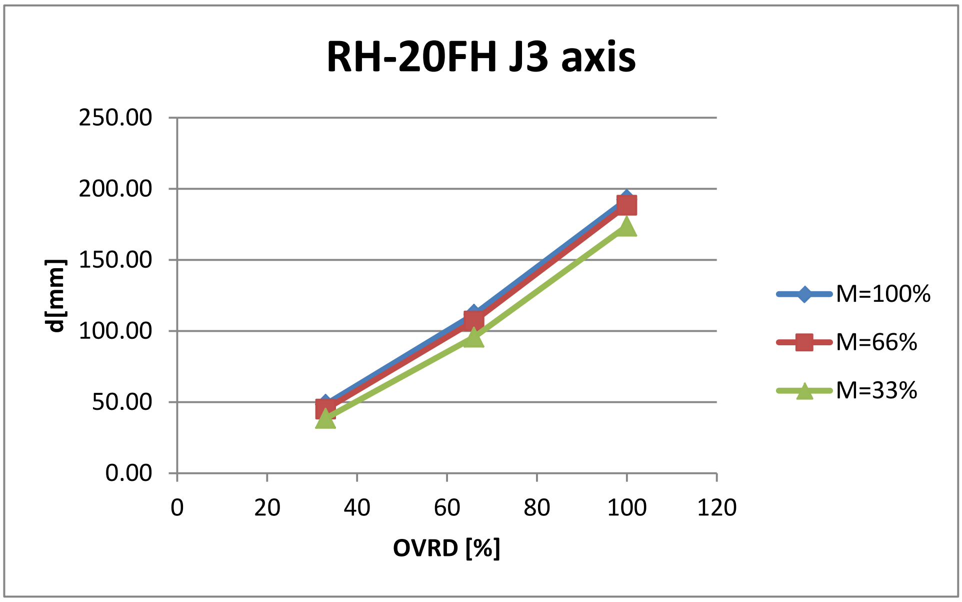




(5) Stopping angle of J2 axis

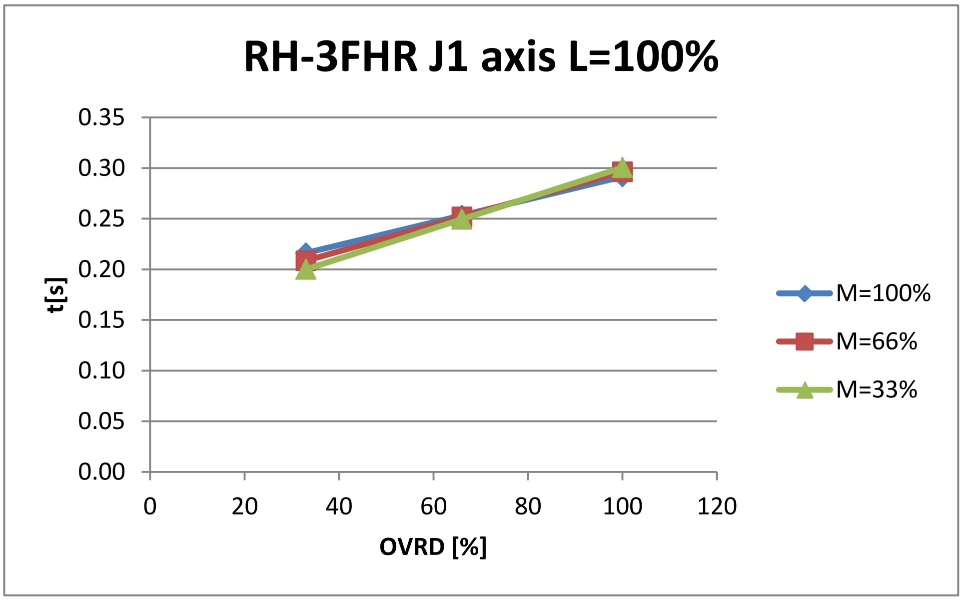


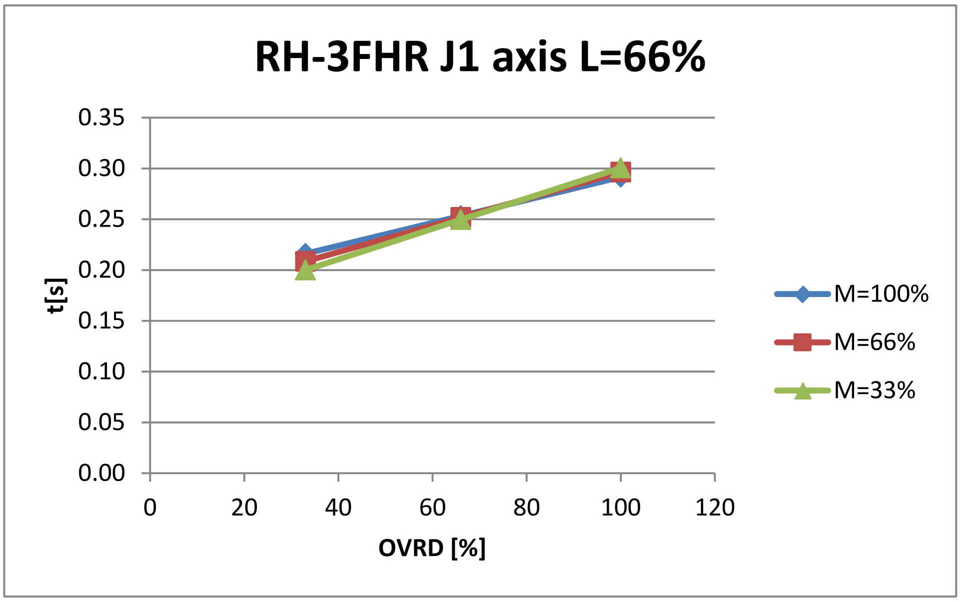
(6) Stopping distance of J3 axis

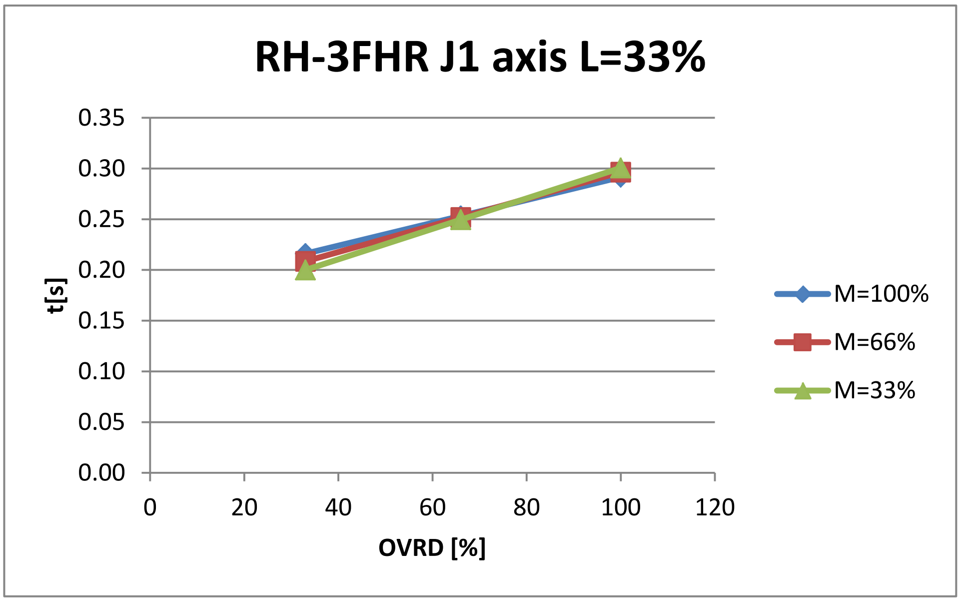


8.4.15 RH-3FHR

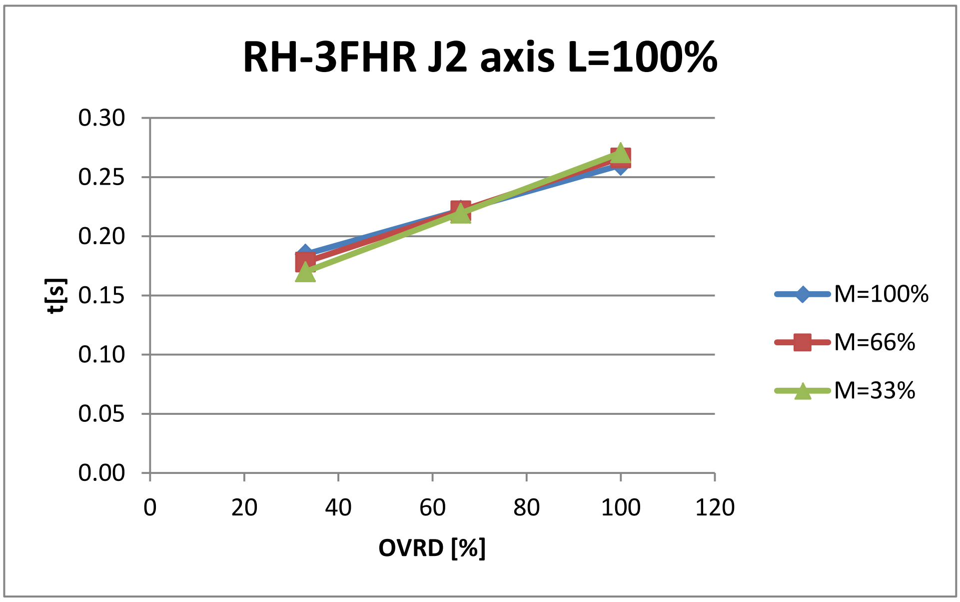
(1) Stopping time of J1 axis



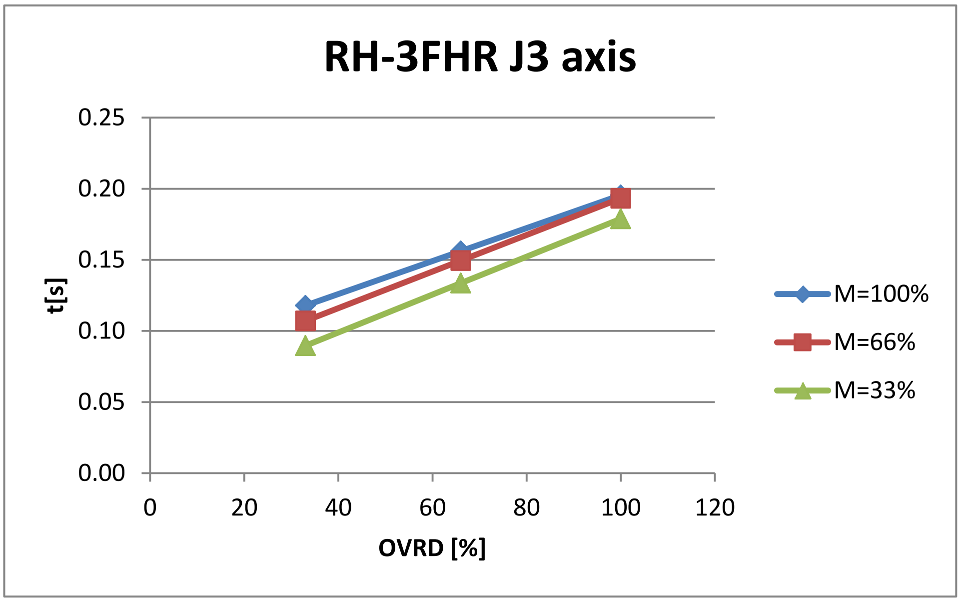




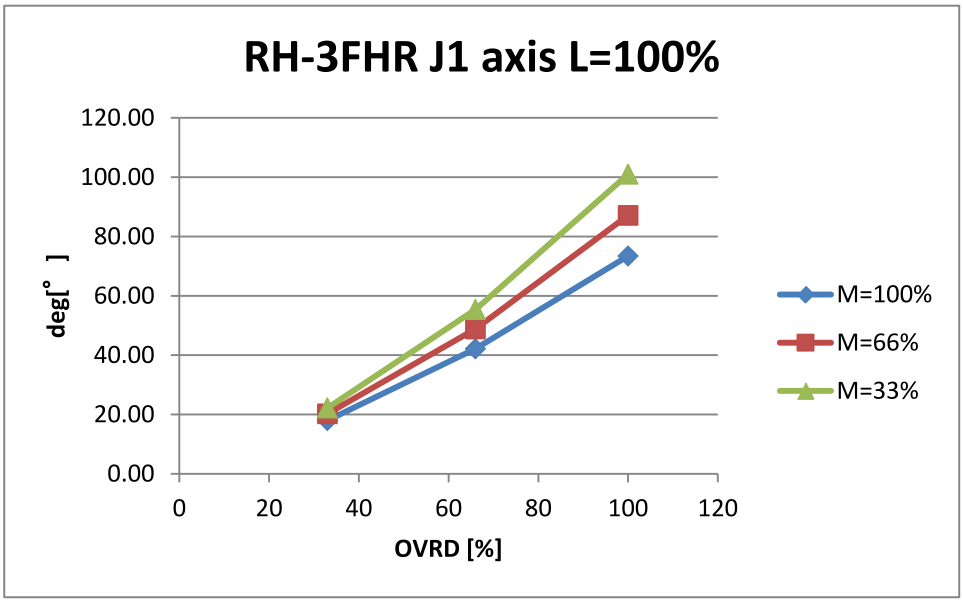
(2) Stopping time of J2 axis

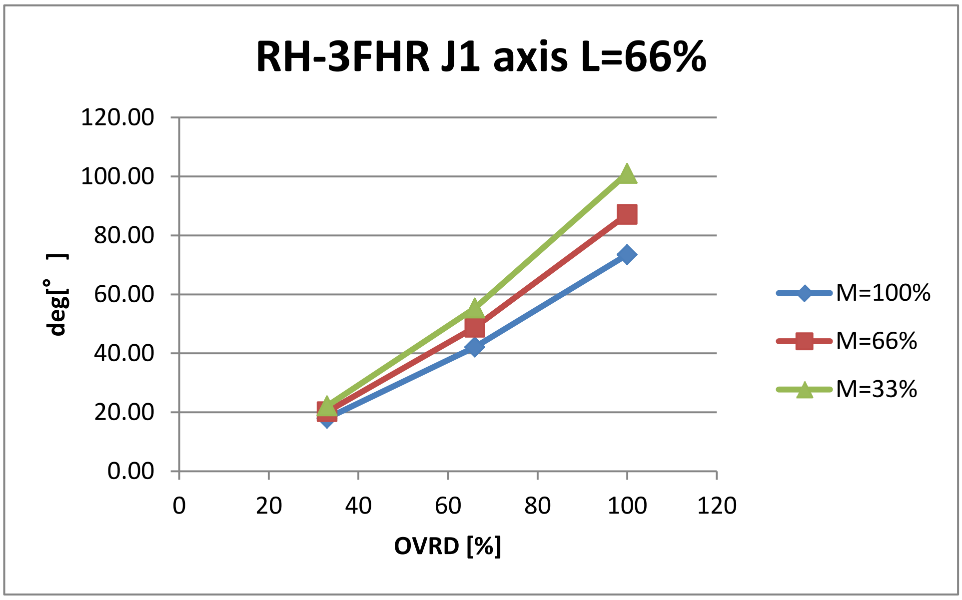


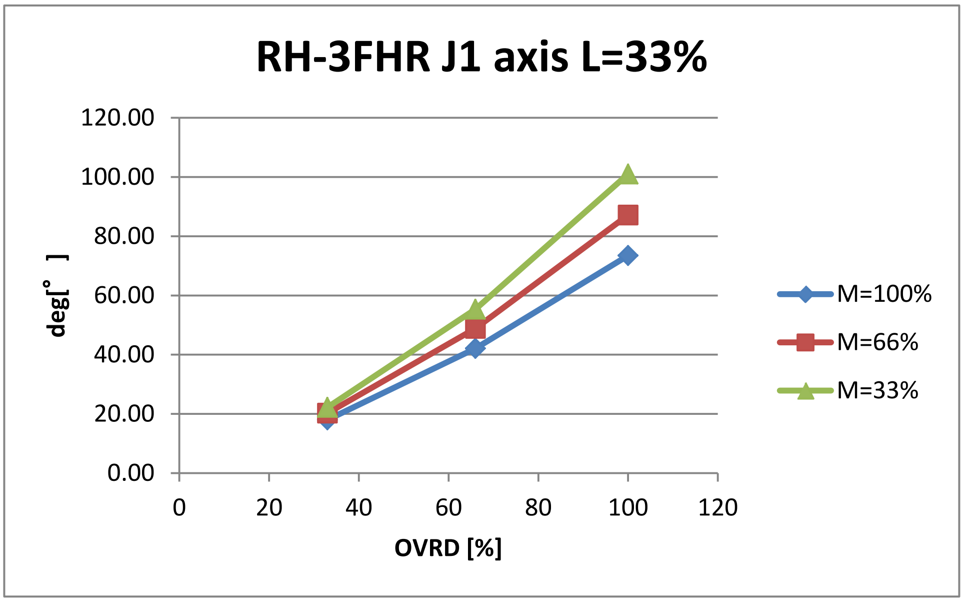
(3) Stopping time of J3 axis



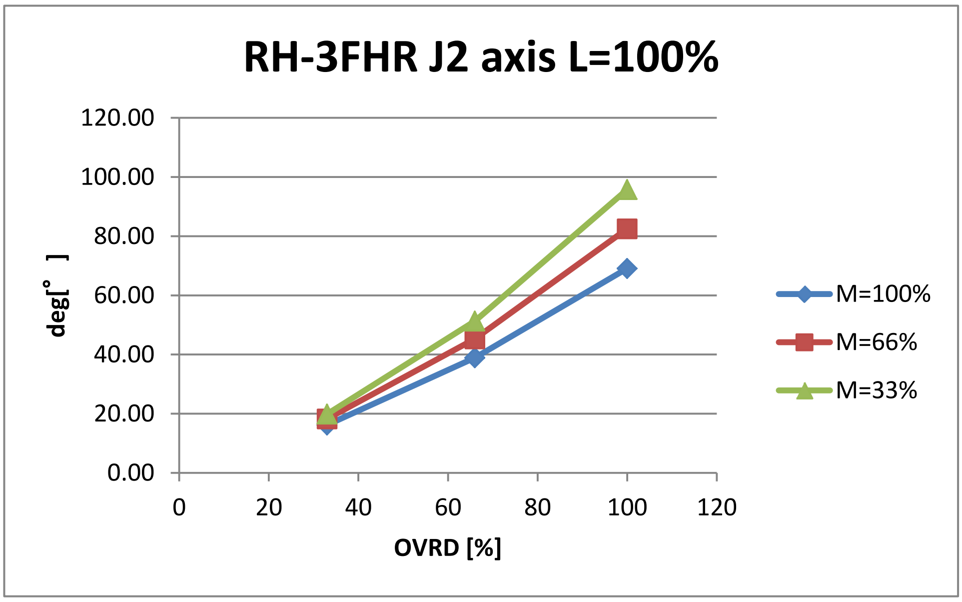
(4) Stopping angle of J1 axis



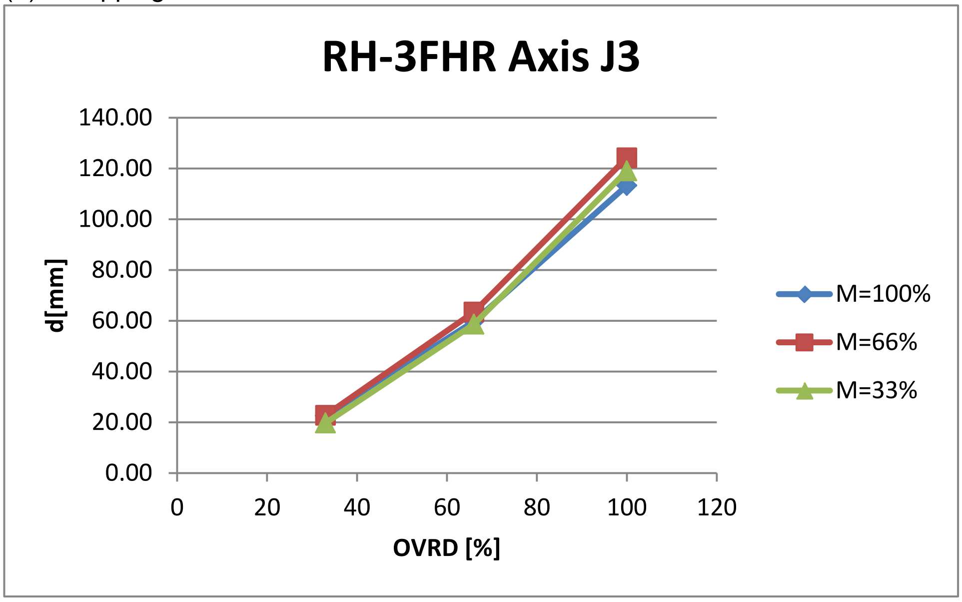




(5) Stopping angle of J2 axis

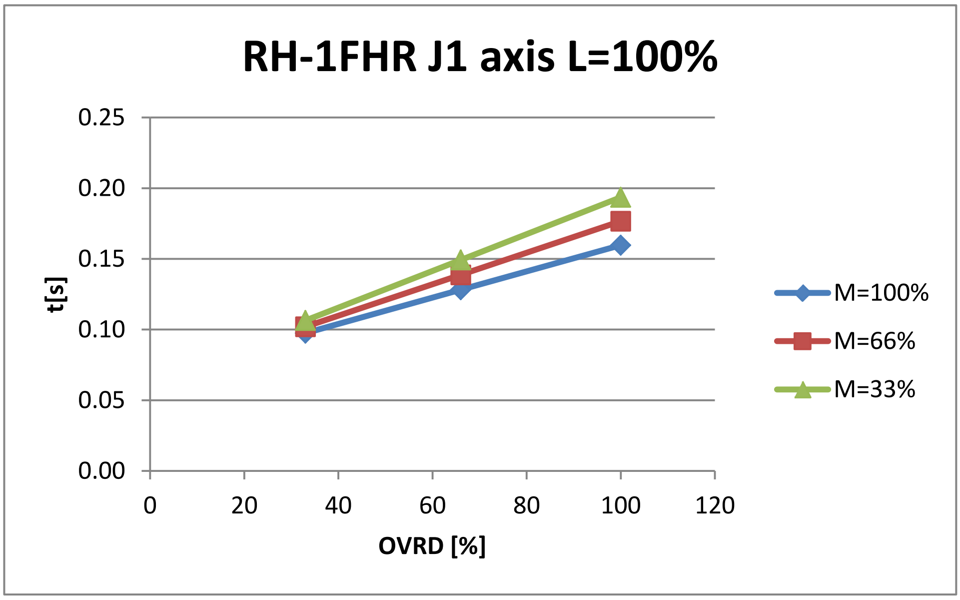


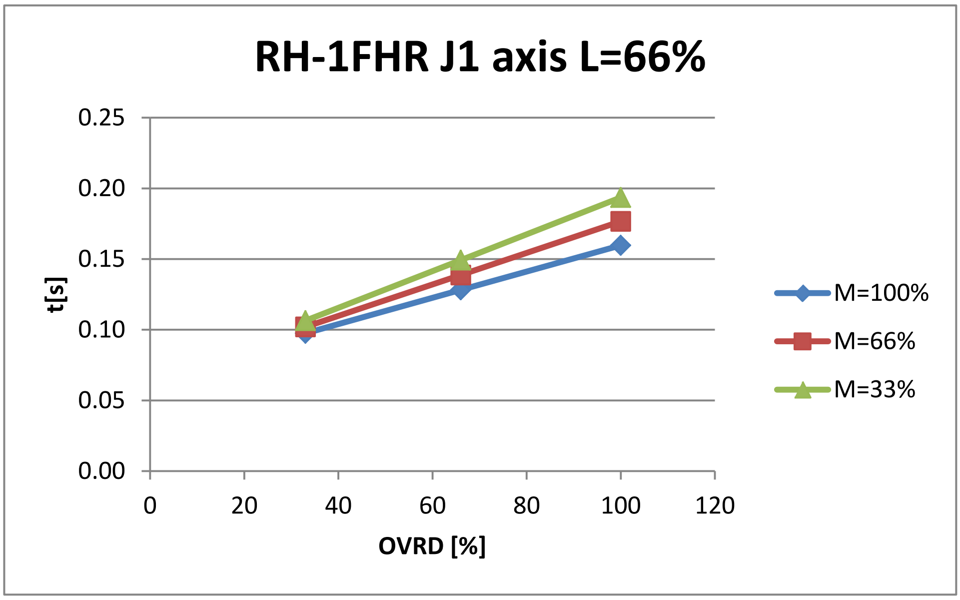
(6) Stopping distance of J3 axis

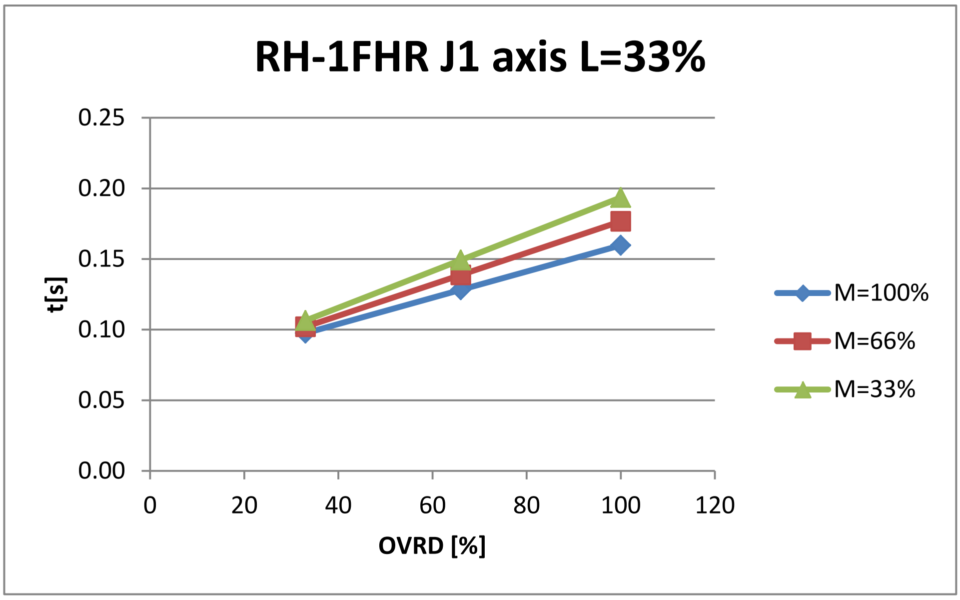


8.4.16 RH-1FHR

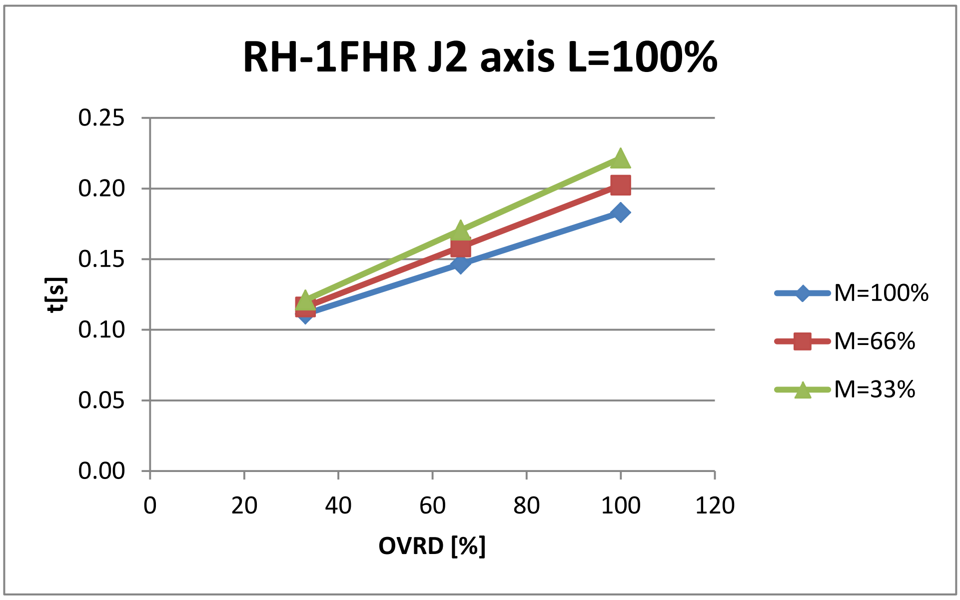
(1) Stopping time of J1 axis



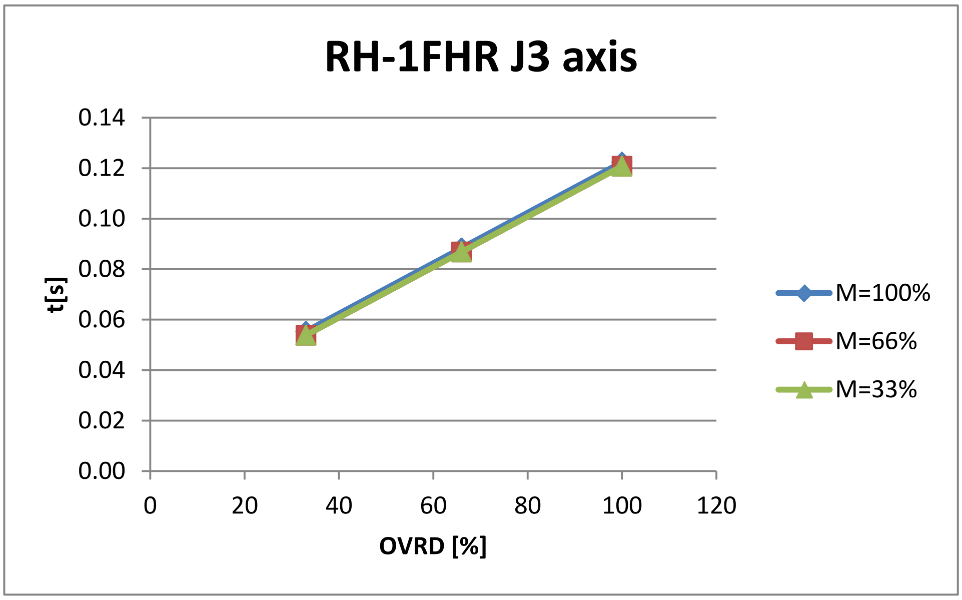




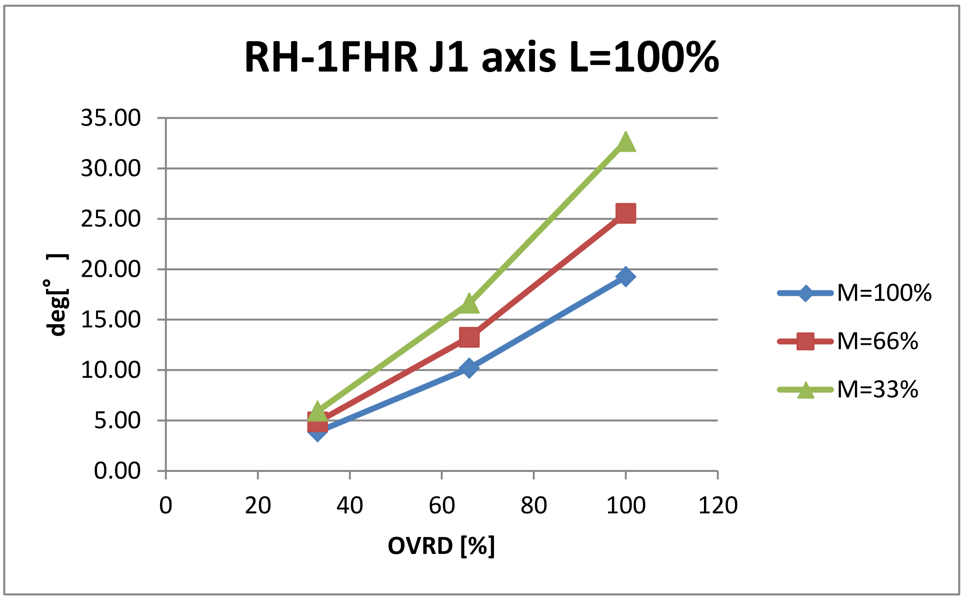
(2) Stopping time of J2 axis

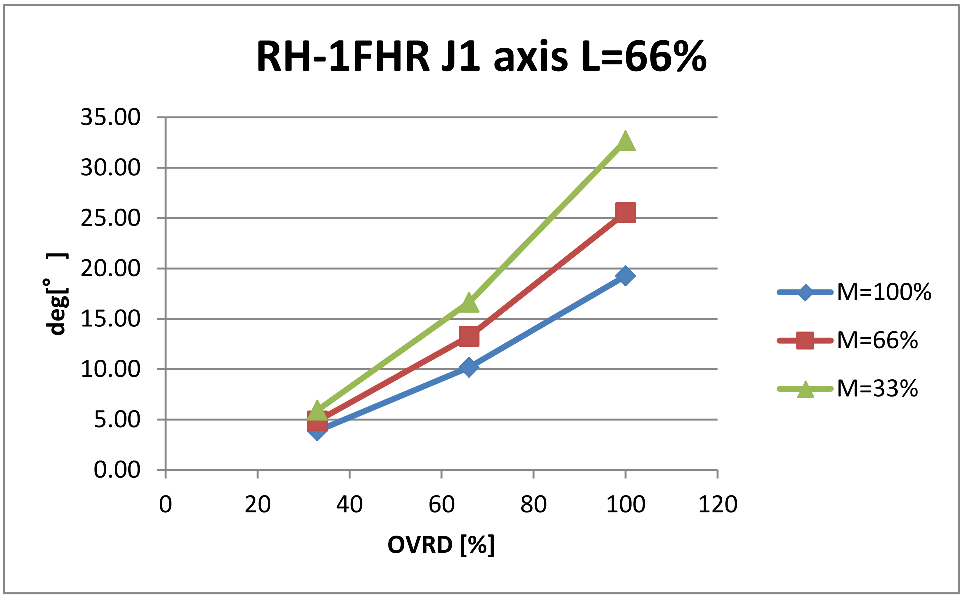


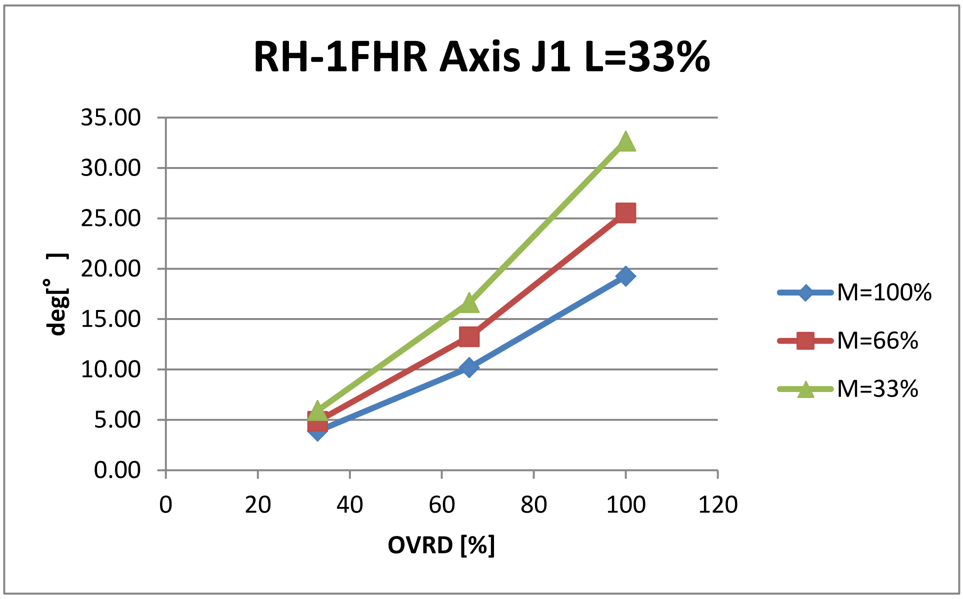
(3) Stopping time of J3 axis



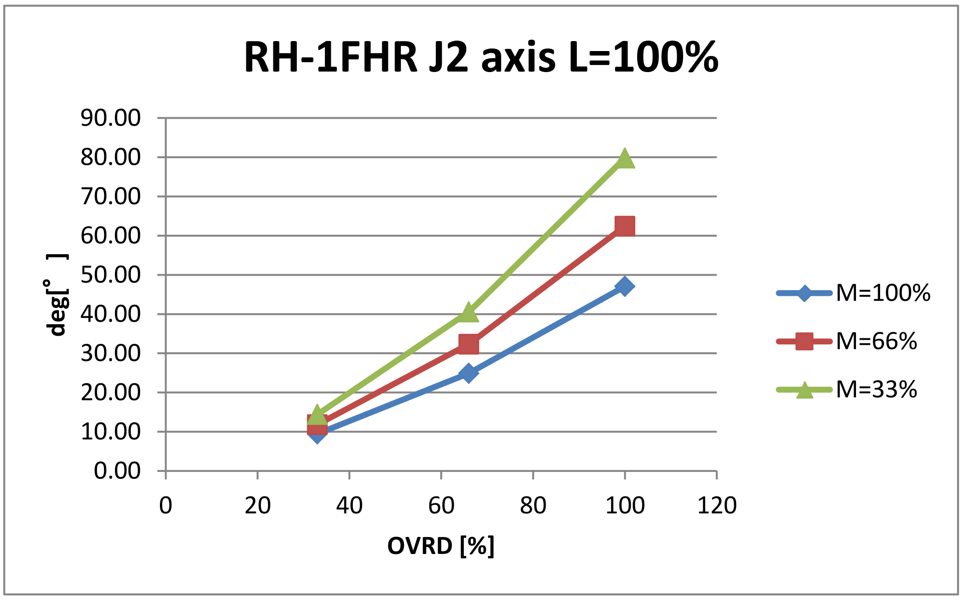
(4) Stopping angle of J1 axis



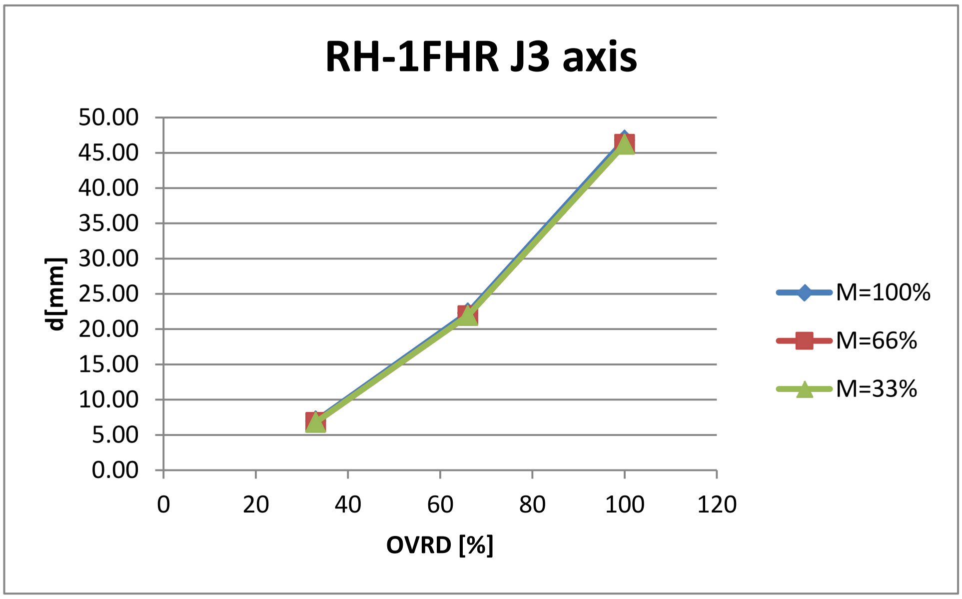




(5) Stopping angle of J2 axis



(6) Stopping distance of J3 axis



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