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Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management —

Part 10: Operational sequence description of data acquisition

Systèmes d'automatisation et intégration — Indicateurs de la performance clé pour le management des opérations de fabrication —

Partie 10: Description de l'acquisition des données relatives aux séquences opérationnelles

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Foreword

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This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 5, *Interoperability, integration, and architectures for enterprise systems and automation applications*.

A list of all parts in the ISO 22400 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document describes the procedure for the determination of key performance indicators (KPIs) by means of examples. The KPIs that are used are given in ISO 22400-2.

Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management —

Part 10: Operational sequence description of data acquisition

1 Scope

This document contains descriptions for the practical use for applying formulae as specified in ISO 22400-2 for key performance indicators for production control and monitoring. This document is intended to be applied in conjunction with the content of ISO 22400-2.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 22400-2:2014, *Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management — Part 2: Definitions and descriptions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 22400-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
planned shut down time
PSDT
time in which the work unit is planned to be out of operation

Note 1 to entry: Corresponds to “no production” as defined in ISO 22400-2.

3.2
planned down time
PDOT
time, included in the planned operation time, in which the work unit is planned for no operations within the operation time period

Note 1 to entry: ISO 22400-2:2014, Figure 3, gives a detailed overview of the used time lines for work units as used for the ISO 22400 series.

3.3
work unit log
data recording of work unit events along with their time stamps

4 KPI calculation examples

4.1 Example setup

KPIs are calculated for different scopes including work unit and production orders. The KPIs are determined from the work unit log.

The example given in Tables 1 and 2 consists of two work units (W1 and W2) within a time period of one calendar day. Two production orders (PO1 and PO2) are executed in this production area within this calendar day. A work unit log for each work unit is produced. Based on the data in the work unit logs, KPIs can be calculated. The scope of the KPI can be the work unit, the production order, the worker etc.

Each Production Order (PO) is composed of two Production Order Sequences (POS):

— PO1: POS 1/1 followed by POS 1/2;

— PO2: POS 2/1 followed by POS 2/2.

In the example POS x/1 is always executed on work unit W1.

In the example POS x/2 is always executed on work unit W2.

The calculation of the KPIs takes place in two steps.

a) Determine KPI elements.

The KPI elements can be determined based on the work unit logs.

b) Calculate KPIs.

The KPIs can be calculated based on the KPI elements.

The details are defined in "comments on the work unit logs". The examples use "pieces" (Pcs) as item unit, however, any kind of item unit can be used.

4.2 KPIs for work unit

From work unit scope the following KPIs can be determined based on the work unit logs:

— Utilization efficiency;

— Setup ratio;

— Technical efficiency;

— Allocation efficiency;

— Availability;

— Effectiveness;

— Quality ratio;

— Overall equipment effectiveness index (OEE);

— Net equipment effectiveness index (NEE);

— Scrap ratio;

— Rework ratio;

— Actual to planned scrap ratio;

— MTBF;

— MTTF;

— MTTR;

— Direct energy consumption effectiveness;

— Direct net energy consumption effectiveness;

— Direct energy efficiency;

— Direct net energy efficiency.

Table 1 — Log of work unit 1

Determination of basics			
APT	=	[06:30 – 07:00] + [07:30 – 08:00] + [08:30 – 09:00] + [09:30 – 10:30] + [15:00 – 17:30] + [18:00 – 19:00] + [20:00 – 20:30]	= 390 min
AUST	=	[06:00 – 06:30] + [10:30 – 11:00] + [14:30 – 15:00] + [20:30 – 21:00]	= 120 min
ADET	=	[08:00 – 08:30] + [19:00 – 19:30] + [07:00 – 07:30] + [09:00 – 09:30] + [19:30 – 20:00]	= 150 min
TTR	=	[07:00 – 07:30] + [09:00 – 09:30] + [19:30 – 20:00]	= 90 min
PSDT	=	[00:00 – 06:00] + [22:00 – 24:00]	= 480 min
PDOT	=	[12:00 – 12:30] + [17:30 – 18:00]	= 60 min
PBT	=	1 440 min – PSDT – PDOT 1 440 min – 480 min – 60 min	= 900 min
AUPT	=	APT + AUST = 390 min + 120 min	= 510 min
AUBT	=	APT + AUST + ADET = = 390 min + 120 min + 150 min	= 660 min
GQ		$GQ_{POS\ 1/1}$ + $GQ_{POS\ 2/1}$ = 450 Pcs + 6 Pcs	= 456 Pcs
SQ		$SQ_{POS\ 1/1}$ + $SQ_{POS\ 2/1}$ = 40 Pcs + 2 Pcs	= 42 Pcs
RQ		$RQ_{POS\ 1/1}$ + $RQ_{POS\ 2/1}$ = 10 Pcs + 0 Pcs	= 10 Pcs
PQ		$PQ_{POS\ 1/1}$ + $PQ_{POS\ 2/1}$ = 500 Pcs + 8 Pcs	= 508 Pcs
PSQ		Planned scrap quantity in % × $PQ_{POS\ 1/1}$ + Planned scrap quantity in % × $PQ_{POS\ 2/1}$ = 5 % × 500 Pcs + 25 % × 8 Pcs	= 27 Pcs
$PEDI_{POS\ 1/1}$	=	0,42 kWh	= 0,42 kWh
$PEDI_{POS\ 2/1}$	=	1,05 kWh	= 1,05 kWh
ADEC		$ADEC_{POS\ 1/1}$ + $ADEC_{POS\ 2/1}$ = 115 m^3 × 0,102 8 kWh/m^3 + 10,5 m^3 × 10 kWh/m^3 + 120 kWh + 4,5 m^3 × 0,102 8 kWh/m^3 + 0,45 m^3 × 10 kWh/m^3 + 4,5 kWh	= 246,28 kWh

Table 1 *(continued)*

Calculation of KPIs			
Utilization efficiency	=	APT/AUBT	
	=	390 min/660 min	= 59,09 %
Setup ratio	=	AUST/AUPT	
	=	120 min/510 min	= 23,53 %
Technical efficiency	=	APT/(APT + ADET)	
	=	390/(390 + 150)	= 72,22 %
Allocation efficiency	=	AUBT/PBT	
	=	660 min/900 min	= 73,33 %
Availability	=	APT/PBT	
	=	390 min/900 min	= 43,33 %
Effectiveness	=	$Effectiveness_{POS\ 1/1}$ + $Effectiveness_{POS\ 2/1}$	
	=	($PRI_{POS\ 1/1}$ × $PQ_{POS\ 1/1}$ + $PRI_{POS\ 2/1}$ $PQ_{POS\ 2/1}$) /APT	
		(0,3 min/Pcs × 500 Pcs + 30 min/Pcs × 8 Pcs)/390 min	= 100,00 %
Quality ratio	=	($GQ_{POS\ 1/1}$ + $GQ_{POS\ 2/1}$)/($PQ_{POS\ 1/1}$ + $PQ_{POS\ 2/1}$)	
	=	(450 Pcs + 6 Pcs)/(500 Pcs + 8 Pcs)	= 89,76 %
OEE	=	Availability × Effectiveness × Quality ratio	
	=	43,33 % × 100 % × 89,76 %	= 38,89 %
NEE	=	AUPT/PBT × Effectiveness × Quality ratio	
	=	510 min/900 min × 100 % × 89,76 %	= 50,86 %
Scrap ratio	=	SQ/PQ	
	=	42 Pcs/508 Pcs	= 8,27 %
Rework ratio	=	RQ/PQ	
	=	10 Pcs/508 Pcs	= 1,97 %
Actual to planned scrap ratio	=	SQ/PSQ	
	=	42 Pcs/27 Pcs	= 155,56 %
MTBF	=	(AUST + APT + TTR)/(Number(FE) +1)	
	=	(120 min + 390 min + 90 min)/(3 +1)	= 150 min
MTTF	=	(AUST + APT)/(Number(FE) +1)	
	=	(120 min + 390 min)/(3 +1)	= 127,5 min
MTTR	=	TTR/(Number(FE) +1)	
	=	90 min/(3 +1)	= 22,5 min
Direct energy consumption effectiveness	=	($PDEI_{POS\ 1/1}$ × $PQ_{POS\ 1/1}$ + $PDEI_{POS\ 2/1}$ × $PQ_{POS\ 2/1}$)/ADEC	
	=	(0,42 kWh/Pcs × 500 Pcs + 1,05 kWh/Pcs × 8 Pcs)/246,28 kWh	= 88,68 %
Direct net energy consumption effectiveness	=	($PDEI_{POS\ 1/1}$ × $GQ_{POS\ 1/1}$ + $PDEI_{POS\ 2/1}$ × $GQ_{POS\ 2/1}$)/ADEC	
	=	(0,42 kWh/Pcs × 450 Pcs + 1,05 kWh/Pcs × 6 Pcs)/246,28 kWh	= 79,30 %

Table 1 *(continued)*

Direct energy efficiency	=	ADEC/PQ	
	=	246,28 kWh/508 Pcs	= 0,485 kWh/ Pcs
Direct net energy efficiency	=	ADEC/GQ	
	=	246,28 kWh/456 Pcs	= 0,540 kWh/ Pcs

Table 2 — Log of Work unit 2

Determination of basics			
APT	=	[12:00 – 12:30] + [13:00 – 14:00] + [14:30 – 15:00] + [16:00 – 16:30] + [18:00 – 19:30] + [20:00 – 21:30]	= 330 min
AUST	=	[11:30 – 12:00] + [16:30 – 17:00] + [17:30 – 18:00] + [21:30 – 22:00]	= 120 min
ADET	=	[12:30 – 13:00] + [15:30 – 16:00] + [15:00 – 15:30]	= 90 min
TTR	=	[15:00 – 15:30]	= 30 min
PSDT	=	[00:00 – 06:00] + [22:00 – 24:00]	= 480 min
PDOT	=	[14:00 – 14:30] + [19:30 – 20:00]	= 60 min
PBT	=	1 440 min – PDBT – PDOT 1 440 min – 480 min – 60 min	= 900 min
AUPT	=	APT + AUST	
	=	330 min + 120 min	= 450 min
AUBT	=	APT + AUST + ADET	
	=	330 min + 120 min + 90 min	= 540 min
GQ		$GQ_{POS\ 1/2}$ + $GQ_{POS\ 2/2}$	
	=	410 Pcs + 4 Pcs	= 414 Pcs
SQ		$SQ_{POS\ 1/2}$ + $SQ_{POS\ 2/2}$	
	=	30 Pcs + 2 Pcs	= 32 Pcs
RQ		$RQ_{POS\ 1/2}$ + $RQ_{POS\ 2/2}$	
	=	10 Pcs + 0 Pcs	= 10 Pcs
PQ		$PQ_{POS\ 1/2}$ + $PQ_{POS\ 2/2}$	
	=	450 Pcs + 6 Pcs	= 456 Pcs
PSQ		Planned scrap quantity in % × $PQ_{POS\ 1/2}$ + Planned scrap quantity in % × $PQ_{POS\ 2/2}$	
	=	5 % × 450 + 25 % × 6 Pcs	= 24 Pcs
$PEDI_{POS\ 1/2}$	=	0,94 kWh	= 0,94 kWh
$PEDI_{POS\ 2/2}$	=	2,10 kWh	= 2,10 kWh
ADEC		$ADEC_{POS\ 1/2}$ + $ADEC_{POS\ 2/2}$	
	=	210 m^3 × 0,102 8 kWh/m^3 + 18,7 m^3 × 10 kWh/m^3 + 222 kWh + 6,6 m^3 × 0,102 8 kWh/m^3 + 0,66 m^3 × 10 kWh/m^3 + 6,6 kWh	= 444,47 kWh
Calculation of KPIs			
Utilization efficiency	=	APT/AUBT	
	=	330 min/540 min	= 61,11 %
Setup ratio	=	AUST/AUPT	
	=	120 min/450 min	= 26,67 %

Table 2 *(continued)*

Technical efficiency	=	APT/(APT + ADET)	
	=	330 min/(330 min + 90 min)	= 78,57 %
Allocation efficiency	=	AUBT/PBT	
	=	540 min/900 min	= 60,00 %
Availability	=	APT/PBT	
	=	330 min/900 min	= 36,67 %
Effectiveness	=	$\text{Effectiveness}_{\text{POS 1/2}}$ + $\text{Effectiveness}_{\text{POS 2/2}}$	
		$\text{PRI}_{\text{POS 1/2}} \times \text{PQ}_{\text{POS 1/2}} + \text{PRI}_{\text{POS 2/2}} \times \text{PQ}_{\text{POS 2/2}})/\text{APT}$	
		(0,3 min/Pcs × 450 Pcs + 30 min/Pcs × 6 Pcs)/330 min	= 95,45 %
Quality ratio	=	$(\text{GQ}_{\text{POS 1/2}} + \text{GQ}_{\text{POS 2/2}})/(\text{PQ}_{\text{POS 1/2}} + \text{PQ}_{\text{POS 2/2}})$	
		(410 Pcs + 4 Pcs)/(450 Pcs + 6 Pcs)	= 90,79 %
OEE	=	Availability × Effectiveness × Quality ratio	
	=	36,67 % × 95,46 % × 90,79 %	= 31,78 %
NEE	=	AUPT/PBT × Effectiveness × Quality ratio	
	=	450 min/900 min × 95,46 % × 90,79 %	= 43,33 %
Scrap ratio	=	SQ/PQ	
	=	32 Pcs/456 Pcs	= 7,02 %
Rework ratio	=	RQ/PQ	
	=	10 Pcs/456 Pcs	= 2,19 %
Actual to planned scrap ratio	=	SQ/PSQ	
	=	32 Pcs/24 Pcs	= 133,33 %
MTBF	=	(AUST + APT + TTR)/(Number (FE) +1)	
	=	(120 min + 330 min + 30 min)/(1 +1)	= 240 min
MTTF	=	(AUST + APT)/(Number (FE) +1)	
	=	(120 min + 330 min)/(1 +1)	= 225 min
MTTR	=	TTR/(Number (FE) +1)	
	=	30 min/(1 +1)	= 15 min
Direct energy consumption effectiveness	=	$(\text{PDEI}_{\text{POS 1/2}} \times \text{PQ}_{\text{POS 1/2}} + \text{PDEI}_{\text{POS 2/2}} \times \text{PQ}_{\text{POS 2/2}})/\text{ADEC}$	
	=	(0,94 kWh/Pcs × 450 Pcs + 2,10 kWh/Pcs × 6 Pcs)/444,47 kWh	= 98,00 %
Direct net energy consumption effectiveness	=	$(\text{PDEI}_{\text{POS 1/2}} \times \text{GQ}_{\text{POS ½}} + \text{PDEI}_{\text{POS 2/2}} \times \text{GQ}_{\text{POS 2/2}})/\text{ADEC}$	
	=	(0,94 kWh/Pcs × 410 Pcs + 2,10 kWh/Pcs × 4 Pcs)/444,47 kWh	= 88,60 %
Direct energy efficiency	=	ADEC/PQ	
	=	444,47 kWh/456 Pcs	= 0,975 kWh/Pcs
Direct net energy efficiency	=	ADEC/GQ	
	=	444,47 kWh/414 Pcs	= 1,074 kWh/Pcs

4.3 KPIs for production orders and production order sequences

From the production order scope the following KPIs can be determined based on the work unit logs:

— Utilization efficiency;

— Setup ratio;

— Technical efficiency;

— Allocation ratio (Production order related);

— Throughput rate (Production order related);

— Effectiveness;

— Production process ratio (Production order related);

— Quality ratio;

— Scrap ratio (Production order related);

— Rework ratio (Production order related);

— Actual to planned scrap ratio (Production order related);

— Fall off ratio (Production order related);

— First pass yield (Production order related);

— Direct energy consumption effectiveness;

— Direct net energy consumption effectiveness;

— Direct energy efficiency;

— Direct net energy efficiency.

Corresponding to “work unit scope” the required basics for the production order or production order sequence (planned time, actual time and logistical sizes) are determined by using the following table. Based on these determinations the KPIs will be calculated by considering the event notifications and messages from the work unit log.

The First Pass Yield (FPY) is described by the relation of Good Quantity [GQ first evaluation] (Good Part [GP]) to the Produced Quantity [PQ] within the evaluation period – related to the first test run for each test piece. A completed reworking the FPY cannot be influenced in the second test run, as opposed to Quality ratio that increases with every successful "verification".

To relate the KPI for each piece it requires a process-related "Serialized/unique-based" flow of products in which only the first test run of the product is used for the evaluation. Reapplication of testing of a product is no longer part of the calculation of a FPY, but improves the quality ratio. For the calculation of the FPY no differentiation takes place for "failed parts" in rework or scrap made by the FPY. If the piece identification is not possible, then the production order-related Good Quantity [GQ last operation] the Good Quantity [GQ first test] be equated as Good Parts [GP].

The calculation example given in Tables 3 to 6 is based on the work unit log of work unit W1 and W2. The quality indicators of the work unit W1 and W2 are determined for the evaluation period of the calendar day.