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Article information:

To cite this document:
Djordje Vukelic Gordana Ostojic Stevan Stankovski Milovan Lazarevic Branko Tadic Janko Hodolic Nenad Simeunovic, (2011),"Machining fixture assembly/disassembly in RFID environment", Assembly Automation, Vol. 31 Iss 1 pp. 62 - 68
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Research article

Machining fixture assembly/disassembly in RFID environment

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Abstract

Purpose – The purpose of this paper is to present a novel approach for identification of machining fixtures, and their elements in an assembly/disassembly process.

Design/methodology/approach – Radio frequency identification (RFID) technology is applied to identification of physical machining fixtures and their basic elements.

Findings – Based on comprehensive testing in industrial conditions it was established by this research that the use of RFID technology contributes to significant reduction of assembly/disassembly time of machining fixtures.

Practical implications – Practical applicability of RFID technology is emphasized and demonstrated in the paper. The suggested system is proven superior in comparison with conventional methods for identification of fixtures/fixture elements which qualifies it for real industrial application.

Originality/value – To the best of authors' knowledge there are no previous reports of successful application of RFID technology on identification of fixtures/fixture elements.

Keywords Radio frequency identification, Assembly, Metal working industry

Paper type Technical paper

Introduction

One of the most critical features of a modern manufacturing system is the ability to design and produce lots of high-quality products in the shortest possible time. Rapid launching of a novel product which beats the competition to the market represents a key factor in providing larger market share, and higher profit margins. All this requires development of flexible, agile manufacturing which is capable of rapid adjustment to novel manufacturing programs (Herakovic, 2007). Owing to stringent market demands and intensive development of science, equipment, and novel technologies, the level and trend of further development of machining processes in the metal cutting industry depend on numerous factors. The factors which most influence quality of machining process are: type of blank, machining technology, operations, sub-operations, machine tools, cutting tools, fixtures, measuring devices, etc. In order to bring the machining process to a higher level, all these elements must be optimized.

Within a number of factors which influence output effects of manufacturing process, machining fixtures play prominent role. Novel fixture design solutions consist of two inseparable entities: fixture design process, and fixture assembly/disassembly process. The process of fixture design requires selection of fixture elements in order to allow generation of engineering documentation (2D and 3D fixture drawings, bill of materials, etc.). In the course of fixture assembly process, fixture elements are selected and then integrated into a single functional unit. Fixture disassembly process is the opposite of fixture assembly (Marcincin, 2003). Feasibility is achieved when a maximum number of elements, which are used in one fixture, can be used in another, after disassembly. After use, fixtures are returned into assembly/disassembly work unit, disassembled, and stored away according to their applicability into predefined places. Newly required fixtures are assembled from elements of disassembled fixtures. In this way, the "circular process" provides rational usage of fixture elements.

In the so far research in the field of fixture design, various approaches have been used. Generally, several fields of research have been present in this area. Majority of them refer to development of fixture design systems and development of methodologies for fixture design optimization. Various techniques have been used for optimization of fixture

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Assembly Automation
31/1 (2011) 62–68
© Emerald Group Publishing Limited [ISSN 0144-5154]
[DOI 10.1108/01445151111104182]

design: finite element analysis (FEA) (Ratchev *et al.*, 2007; Satyanarayana and Melkote, 2004) genetic algorithms (GA) (Kaya, 2006; Kulankara *et al.*, 2002), combination of artificial neural networks (ANN) and GA (Subramaniam *et al.*, 2001), FEA and GA (Chen *et al.*, 2008), FEA and ant colony algorithm (Padmanaban *et al.*, 2009), etc. These papers deal with the question of optimal positions of fixture elements (locating and/or clamping elements). Most often, minimization of workpiece deformations under machining forces has been adopted as the goal function. In this way, it is possible to define positions of particular fixture elements. However, one major deficiency of these efforts has been the fact that they neither select concrete fixture elements nor produce final fixture design. As regards fixture design systems, it is possible to distinguish between several mainstreams of research: ANN system (Lin and Huang, 1997), case-based reasoning systems (Boyle *et al.*, 2006; Li *et al.*, 2002), virtual reality-based system (Peng *et al.*, 2009), expert systems (Kumar *et al.*, 1992; Pham and Sam Lazaro, 1990), as well as other knowledge-based systems (Cecil, 2004; Hunter *et al.*, 2005; Vukelic *et al.*, 2009). These systems allow generation of conceptual, partial, or complete fixture design solutions. Each approach has its advantages and disadvantages. Information on these, and other numerous examples in the field of fixture design and optimization are given in more detail in Bi and Zhang (2001), Cecil (2001), Leopold and Hong (2009), Nee *et al.* (1995), Pehlivan and Summers (2008), Rong and Zhu (1999) and Rong *et al.* (2005).

As can be concluded, focus was placed on fixture design system and fixture design optimization. The problem of machining fixture assembly and disassembly was far less a subject of systematic research. Several methodologies have been developed for fixture assembly planning, such as the feature-based methodology (Ma *et al.*, 1998; Liou and Suen, 1992), fastener-based methodology (Yi and Nekey, 1996), knowledge-based methodology (Kakish *et al.*, 2000), geometry-based methodology (Dai *et al.*, 1997; Kumar *et al.*, 2000; Wu *et al.*, 1998), and virtual reality-based methodology (Peng *et al.*, 2008, 2010). These approaches were mostly based on geometric and functional restrictions which are present in a fixture assembly. On the other hand, the developed methodologies for fixture assembly were predominantly based on an interactive fixture assembly in CAD systems.

The problems of physical assembly/disassembly processes have so far been relatively little considered by the researchers. This paper focuses on the processes of machining fixture assembly/disassembly in real manufacturing conditions, when a worker takes particular fixture elements and physically assembles/disassembles a fixture. The assembly/disassembly processes have a growing impact in the area of fixture exploitation, bearing in mind that the complexity of fixture increases with the complexity of fixture elements. Thus, some modern fixture designs can contain over a hundred elements. In principle, large number of fixture elements prolongs the assembly/disassembly processes. The purpose of this paper is to present a novel approach for identification of machining fixtures, and their elements in an assembly/disassembly process.

Analysis of time required for assembly and disassembly process of machining fixtures

In order to establish efficient measures for rationalization of fixture assembly/disassembly processes, the first step is to analyze present situation in real industrial conditions. The results of numerous investigations conducted in the region are shown in Figure 1. The analysis encompassed 1989 various fixture design solutions which are used in machining operations in five manufacturing systems. The times required for fixture design, as well as the times required for fixture assembly/disassembly were measured. As shown in Figure 1, the percentage time share for fixture design ranged between 70 and 78 per cent, while the percentage share of times required for assembly and disassembly of fixtures equalled 22-30 per cent.

Figure 2 shows the time required for assembly/disassembly of analyzed fixtures. Owing to a large volume of measurement data, five group intervals were formed (1 h each). The times measured were classified according to these group intervals. It is evident that the aggregate assembly/disassembly time spans several hours. For the majority of fixtures the aggregate assembly/disassembly time equals 2-3 h, i.e. 3-4 h. These times are considerable and should be taken into consideration. As total costs increase with the increase of

Figure 1 Minimum and maximum percentage time share for particular phases of fixture life cycle

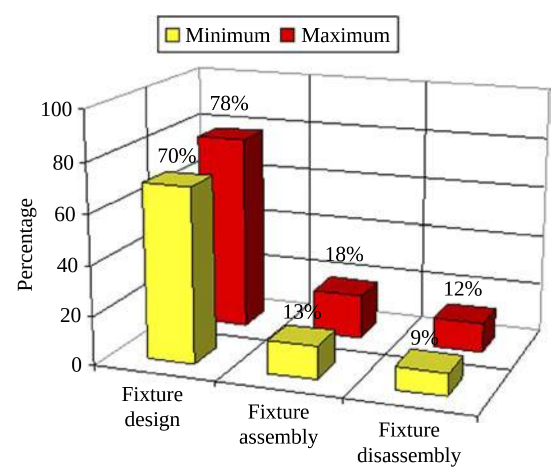
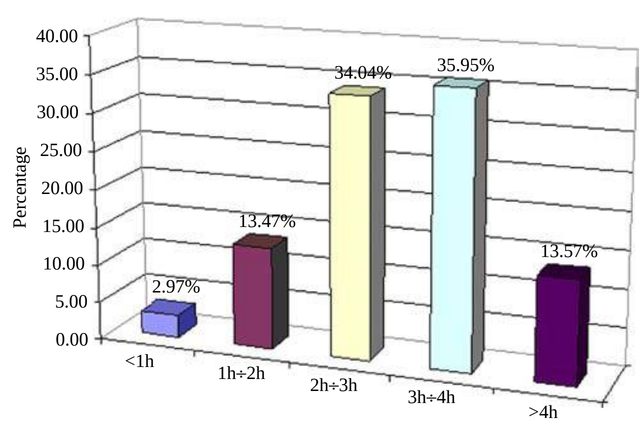


Figure 2 Mean fixture assembly/disassembly times



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time, manual operations should be replaced with automated ones whenever possible, in order to decrease auxiliary (non-productive) times and increase productivity of the machining process as a whole.

This research showed that special emphasis should be placed on the process of efficient fixture assembly/disassembly, to increase productivity and reduce total production costs. Bearing in mind that fixtures are an important segment of the process, automation of their design, assembly/disassembly, and identification can be realized so as to significantly advance the complete production process. One segment of that automation is the automatic fixture identification during assembly/disassembly. In this paper, an attempt is made to shorten the time required for identification of fixtures and fixture elements.

The structure and functioning of RFID system for machining fixture assembly/disassembly

Radio frequency identification (RFID) stands for a system of automated data acquisition which uses wireless, radio communication for data transfer in a production environment. From the moment when a fixture is designed, to the moment of its assembly, RFID technology allows real-time identification during delivery, warehousing, or any other process within the production system. Via radio waves, data are transmitted and received between manufacturing and management sectors in real time. This unique way of tagging is adapted in such a way to allow direct correspondence between information on a particular fixture and information from the production system database. RFID technology allows equipment (fixtures, etc.) to be tracked with minimum human intervention. This fact has the potential to influence lower operating costs within fixture life cycle.

RFID system consists of: a computer (or programmable logic controller (PLC)), RFID reader, antenna (which can be integrated in a RFID reader) and transponder – tag (Figure 3) which is placed on a fixture element. The antenna is used to amplify the signal, which is emitted by the reader to the tag, as well as the signal, which is returned to the reader by the tag, which increases the tag-reading range. RFID reader can be a stationary or a portable device, which can activate and pick up the signals emitted by the tags. It consists of the power unit, antenna, and a PC board, and its primary role is to receive and send RF signals to the tags by means of antenna. From a computer or a PLC, the reader receives instructions generated by the dedicated software. The control unit inside the reader executes the received instructions (Mehrjerdi, 2008; Stankovski *et al.*, 2009).

The readers differ by the range and operating frequency. Similar to the tags, the readers can have short range (up to several centimetres), medium range (up to 1 meter), and long range (tens of meters, with an additional antenna). Besides, there are readers equipped with potentiometer for range regulation. The tags consist of a microchip (which stores alpha-numerical code for product/fixture labelling), an antenna (copper wire – coil) and an optional power source (e.g. battery). They exist in a variety of forms: various pendants, circular or square plates, magnetic cards, or some other form, depending on the area of application. Smart labels are a special type of tags which can be placed on, or built into a palette or any sort of product/fixture. Once the RFID tag enters the reader's operating range, the reader detects its activation signal. The reader then decodes the data coded in the tag's integrated circuit and the data are transferred to the computer for processing. Significant advantage of RFID systems is that they do not require contact for proper functioning. Tags can be read in any industrial environment, which can involve snow, fog, ice, colour stains, dirt, and similar. RFID tags also read fast – in most cases the response is faster than 100 milliseconds. New generation of readers have the ability to simultaneously read several tags. Thus, whole storage area can be read at once instead of scanning each article individually (Mehrjerdi, 2008; Stankovski *et al.*, 2009).

The concept solution of a system, which utilizes RFID technology for fixture assembly/disassembly, is shown in Figures 4 and 5. The tags used for this application are in the form of ISO/IEC 15693 smart labels. Operating frequency of the used reader is 13.56 MHz and the operating range is short. The same technological system can be used to perform both assembly and disassembly of fixtures, in accordance with requirements of the process plan for the fixture arriving at a particular work station.

The concept solution of the assembly system is shown in Figure 4. A conveyer belt brings in the parts tagged with RFID. The RFID tag with an unique identifier (UID) is read upon arrival of the part at the first working place. The read out UID is compared to the UID from the database, after which the database issues a number of instructions for assembly presented graphically on-screen to the operator. The instructions are presented in a sequential manner, and are executed by taking the appropriate tool. Upon return of the tool to its previous position, next assembly instruction is initiated.

If a sequence requires no tool, then the next instruction must be initiated manually. Upon completion of the operation (all sequence of operation), the sequence of instruction for that particular working place is finished. The fixture is placed

Figure 3 Basic components of RFID system

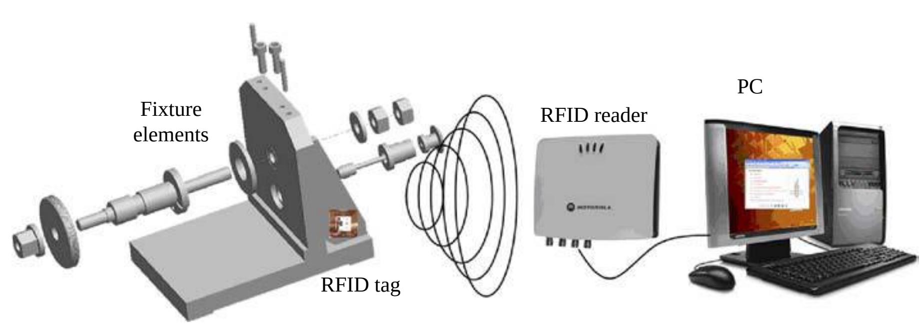


Figure 4 Concept solution of RFID system in fixture assembly process

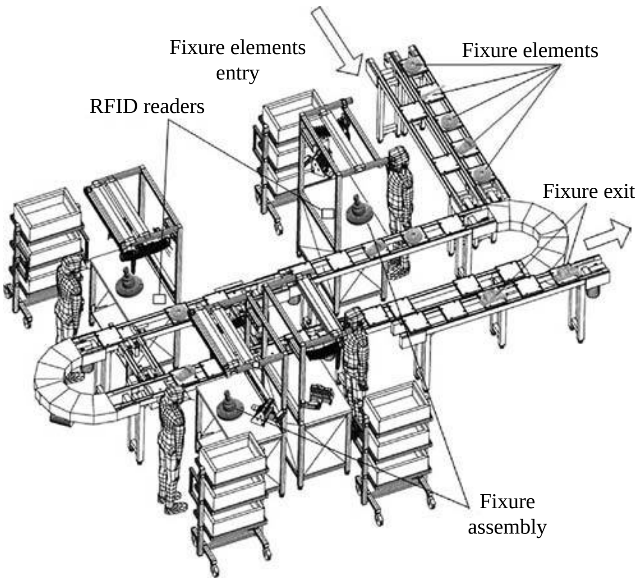
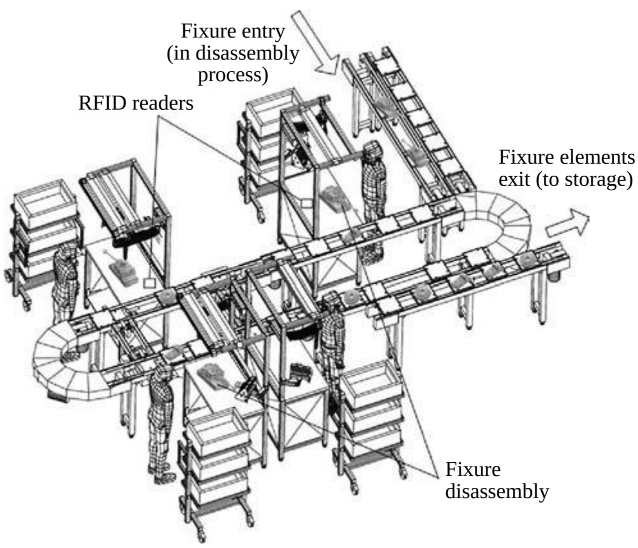


Figure 5 Concept solution of RFID system in fixture disassembly process



on the conveyor belt, travels along, and gets identified by RFID once again on another working place. If the fixture is to be machined at that particular working place, the signal light flashes and the operator takes the fixture off the conveyor belt. The process continues like in the previous operation with a number of instructions coded for that working place and that fixture. In case all working places are currently busy, the fixture circles on the conveyor belt until a vacancy appears. The RFID tag is always placed on the base part. Thus, prepared fixture is transported on the conveyor belt past a number of machine tools which perform machining operations.

Placed beside each machine tool is a RFID reader, which reads out the data off the RFID tag, which is placed on the fixture front. Upon comparing the data read off the tag with the data from the database on the fixture, which arrived, a decision is made whether the fixture is meant for the local machine tool or not. If the answer is positive, the signal lamp turns on, the data on the particular machine is entered into the fixture database, and the operator takes the required fixture and places it on the machine tool. In case of a negative answer, the fixture is forwarded by a conveyor belt, running along until being taken off by an operator at a particular working place. After the fixture has served its purpose, its RFID tag is updated with information on its service record, and it is forwarded by the conveyor belt to the system for disassembly. In case it is possible to use the fixture on some other machine, without additional change of the fixture elements (which is also coded within the RFID tag), the fixture is forwarded to the next machine, where the process of identification, data read out, and data write in is reiterated as previously explained.

An example of a disassembly is shown in Figure 5, running as follows: to the working place are coming fixtures whose RFID tags are read out and one of the tag-stored strategies is adopted. The adopted strategy is written to the RFID tag and then the fixture is placed back onto the conveyor belt and forwarded to disassembly area. Beside the usage strategies, the RFID tag reader also reads the UID and adopts the appropriate sequence of disassembly operations, presenting them on-screen to the operator. The instructions are presented in a sequential manner, and executed by taking the appropriate tool. Upon return of the tool to its previous position, next disassembly instruction is initiated.

If a sequence requires no tool, then the next instruction must be initiated manually. Upon completion of the operation, the sequence of instruction for that particular working place is finished. The fixture is placed on the conveyor belt, travels along and, gets identified by RFID once again on another working place. If the fixture is to be machined at that particular working place, the signal light flashes and the operator takes the fixture off the conveyor belt. The process continues like in previous operation with a number of instructions coded for that working place and that fixture. In case all working places are currently busy, the fixture circles on the conveyor belt until a vacancy appears.

If at some working place a component is disassembled which, according to selection strategies, can be re-used, then at that particular working place the component is labelled with a RFID tag, and the data on the component's previous usage are written in. Upon this, the component is transported to the place where (after the RFID tag data are read out) it is directed towards component warehouse for re-use, using the same conveyor belt for finished products, just as the assembly process, the only difference being that, instead of being directed to a machining process, the components are directed appropriate containers.

The fixture elements, for which a reconstruction strategy has been chosen, are transported on a palette to an appropriate container, which is then transported to the warehouse for reconstruction. The materials which are to be recycled (secondary materials), are directed to containers for the secondary materials.

Results of experimental investigation

Principal functioning of a fixture assembly/disassembly system in RFID environment was presented in the previous section.

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In order to obtain relevant data on system efficiency, it was necessary to test the system in real industrial conditions. This section presents the test results obtained for specific examples of fixture assembly/disassembly. Immediately prior to verification, a detailed analysis of system was performed. Fixtures and operations required for their assembly/disassembly were identified. In addition, various strategies for the selection of fixtures and fixture elements were also analyzed. Fixtures were grouped according to similar sub-operations, which take sequence in the process of assembly/disassembly. Verification of the proposed system was performed in laboratory conditions (Figure 6) on a total of 418 fixture design solutions. All fixtures were designed for operations of drilling holes/openings on prismatic workpieces.

Measured in these experiments were the times required for assembly/disassembly of each particular fixture using manual and RFID identification, respectively. To facilitate data review (due to large number of measurements) fixtures were classified according to relative complexity, i.e. number of constituent elements, into five groups:

1. fixtures consisting of <25 elements (a total of 63 fixture design solutions were subject to experiments);
2. fixtures consisting of 25-50 elements (a total of 97 fixture design solutions were subject to experiments);
3. fixtures consisting of 51-74 elements (a total of 123 fixture design solutions were subject to experiments);
4. fixtures consisting of 75-100 elements (a total of 101 fixtures were subject to experiments); and
5. fixtures consisting of more than 100 elements (the experiment included a total of 34 fixture design solutions).

Experimental results are shown in Table I and in Figures 7-8. Table I shows the results of minimum, mean, and maximum time required for fixture assembly/disassembly with manual and RFID identification for various fixture groups (number of fixture elements). Figures 7 and 8 show percentage reduction of fixture assembly/disassembly with RFID technology for experimental results given in Table I.

The results lead to following conclusions:

- mean time difference between fixture assembly with manual and RFID identification ranges between 18 and 31 per cent in favour of RFID;
- mean time difference between fixture disassembly with manual and RFID identification ranges between 13 and 25 per cent in favour of RFID; and
- as the complexity of fixture grows, i.e. with the increase of number of fixture elements, mean time difference between fixture assembly/disassembly with manual and RFID identification grows larger in favour of RFID identification.

The results point out to substantial time savings thanks to RFID technology which was used to identify fixtures and their elements in assembly/disassembly operations.

Conclusion

The concept of the proposed system allows total control over material flow (fixtures, and their elements) which is not limited to assembly/disassembly but also includes its environment. In addition, it makes available the detailed data on the number of fixtures which are sent to assembly/disassembly, reusable fixture elements (which are already in storage, or on its way), fixture elements which can be redesigned, types and quantities of elements for recycling (types and quantities of secondary materials). Based on laboratory testing, it is notable that the percentage ratio varies – in some cases even more than 30 per cent, but always in favour of RFID identification, which justifies application of RFID technology in these operations. Furthermore, the system thus designed has an increased degree of flexibility regarding its ability to storage and machine various types of fixtures, as well as other parts.

One of the basic problems in operation of such system is to maintain continuous flow of the same type of fixture, except when the system is dedicated to such type of production. Also required is an analysis to establish justification of introducing RFID technology into systems for fixture assembly/disassembly. Such analysis is specific to each particular case, and depends on: the number of work stations which require

Figure 6 Experimental system for application of RFID technology in machining fixture assembly/disassembly

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Table I Minimum, mean, and maximum time required for manual and RFID identification for various fixture designs, depending on the number of fixture elements

		Time (min/fixture)					
		Assembly			Disassembly		
Number of elements (elements/fixture)	Identification type	Minimum	Mean	Maximum	Minimum	Mean	Maximum
<25	RFID identification	39	43	45	36	38	40
	Manual identification	46	52	56	41	44	47
25-50	RFID identification	56	59	62	52	55	57
	Manual identification	67	73	79	59	64	68
51-74	RFID identification	74	76	81	65	69	67
	Manual identification	92	98	106	76	83	83
75-100	RFID identification	78	85	89	74	79	82
	Manual identification	104	116	125	91	100	107
>100	RFID identification	81	88	95	75	83	89
	Manual identification	118	132	146	100	111	122

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Figure 7 Percentage reduction of fixture assembly mean time due to application of RFID technology, depending on the number of fixture elements

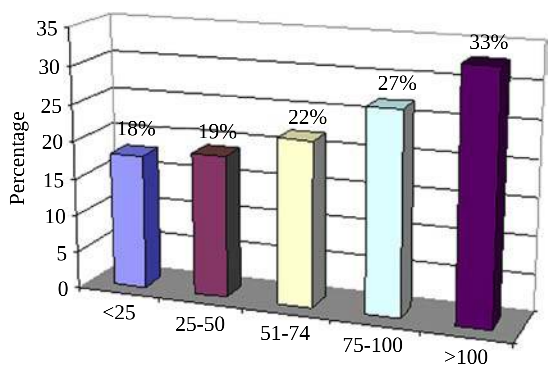
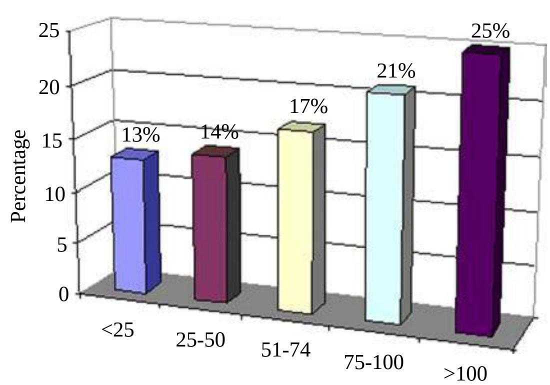


Figure 8 Percentage reduction of fixture disassembly mean time due to application of RFID technology, depending on the number of fixture elements



installation of complete equipment for RFID identification, number of fixture elements which need to be RFID-tagged, as well as the complexity of fixtures (total number of fixture elements), accessibility of particular surfaces on fixture elements for RFID tagging, etc.

Finally, the authors conclude that the proposed system tested satisfactorily with various types of fixtures which are grouped based on similarity of assembly/disassembly operations. It allows time reduction of assembly/disassembly procedure thus directly influencing the increase of total productivity.

References

Bi, Z.M. and Zhang, W.J. (2001), "Flexible fixture design and automation: review, issues and future directions", *International Journal of Production Research*, Vol. 39 No. 13, pp. 2867-94.

Boyle, I.M., Rong, K. and Brown, D.C. (2006), "CAFixD: a case-based reasoning fixture design method-framework and indexing mechanisms", *Journal of Computing and Information Science in Engineering*, Vol. 6 No. 1, pp. 40-8.

Cecil, J. (2001), "Computer-aided fixture design – a review and future trends", *The International Journal of Advanced Manufacturing Technology*, Vol. 18 No. 11, pp. 790-3.

Cecil, J. (2004), "Tamil: an integrated fixture design system for prismatic parts", *International Journal of Computer Integrated Manufacturing*, Vol. 17 No. 5, pp. 421-34.

Chen, W., Ni, L. and Xue, J. (2008), "Deformation control through fixture layout design and clamping force optimization", *The International Journal of Advanced Manufacturing Technology*, Vol. 38 Nos 9-10, pp. 860-7.

Dai, J.R., Nee, A.Y.C., Fuh, J.Y.H. and Kumar, A.S. (1997), "An approach to automating modular fixture design and assembly", *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, Vol. 211 No. 7, pp. 509-21.

Herakovic, N. (2007), "Computer and machine vision in robot-based assembly", *Strojniški Vestnik-Journal of Mechanical Engineering*, Vol. 53 No. 12, pp. 858-73.

Hunter, R., Vizan, A., Perez, J. and Rios, J. (2005), "Knowledge model as an integral way to reuse the knowledge for fixture design process", *Journal of Materials Processing Technology*, Vol. 164, pp. 1510-18.

Kakish, J., Zhang, P.L. and Zeid, I. (2000), "Towards the design and development of a knowledge-based universal modular jigs and fixtures system", *Journal of Intelligent Manufacturing*, Vol. 11 No. 4, pp. 381-401.

Kaya, N. (2006), "Machining fixture locating and clamping position optimization using genetic algorithms", *Computers in Industry*, Vol. 57 No. 2, pp. 112-20.

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Kulankara, K., Satyanarayana, S. and Melkote, S.N. (2002), "Iterative fixture layout and clamping force optimization using the genetic algorithm", *Journal of Manufacturing Science and Engineering*, Vol. 124 No. 1, pp. 119-25.
Kumar, S.A., Fuh, J.Y.H. and Kow, T.S. (2000), "An automated design and assembly of interference-free modular fixture setup", *Computer-aided Design*, Vol. 32 No. 10, pp. 583-96.
Kumar, S.A., Nee, A.Y.C. and Prombanpong, S. (1992), "Expert fixture-design system for an automated manufacturing environment", *Computer-aided Design*, Vol. 24 No. 6, pp. 317-26.
Leopold, J. and Hong, L. (2009), "Clamping modelling: state-of-the-art and future trends", *Industrial Robot: An International Journal*, Vol. 36 No. 3, pp. 249-54.
Li, W., Li, P.G. and Rong, Y. (2002), "Case-based agile fixture design", *Journal of Materials Processing Technology*, Vol. 128 Nos 1-3, pp. 7-18.
Lin, Z.C. and Huang, J.C. (1997), "The application of neural networks in fixture planning by pattern classification", *Journal of Intelligent Manufacturing*, Vol. 8 No. 4, pp. 307-22.
Liou, F.W. and Suen, D. (1992), "The development of a feature-based fixture process planning system for flexible assembly", *Journal of Manufacturing Systems*, Vol. 11 No. 2, pp. 102-13.
Ma, W., Lei, Z. and Rong, Y. (1998), "FIX-DES: a computer-aided modular fixture configuration design system", *The International Journal of Advanced Manufacturing Technology*, Vol. 14 No. 1, pp. 21-32.
Marcincin, J.N. (2003), "Automated disassembly and their place in process of products recycling", *Manufacturing Engineering*, Vol. 2 No. 1, pp. 43-6.
Mehrjerdi, Y.Z. (2008), "RFID-enabled systems: a brief review", *Assembly Automation*, Vol. 28 No. 3, pp. 235-45.
Nee, A.Y.C., Whybrew, K. and Kumar, S.A. (1995), *Advanced Fixture Design for FMS*, Springer, London.
Padmanaban, K.P., Arulshri, K.P. and Prabhakaran, G. (2009), "Machining fixture layout design using ant colony algorithm based continuous optimization method", *The International Journal of Advanced Manufacturing Technology*, Vol. 45 Nos 9-10, pp. 922-34.
Pehlivan, S. and Summers, J.D. (2008), "A review of computer-aided fixture design with respect to information support requirements", *International Journal of Production Research*, Vol. 46 No. 4, pp. 929-47.
Peng, G., Gao, J. and He, X. (2009), "Towards the development of a desktop virtual reality-based system for modular fixture configuration design", *Assembly Automation*, Vol. 29 No. 1, pp. 19-31.
Peng, G., He, X., Yu, H., Hou, X. and Khalil, A. (2008), "Precise manipulation approach to facilitate interactive modular fixture assembly design in a virtual environment", *Assembly Automation*, Vol. 28 No. 3, pp. 216-24.
Peng, G., Hou, X., Wu, C., Jin, T. and Zhang, X. (2010), "Fast collision detection approach to facilitate interactive modular fixture assembly design in a virtual environment", *The International Journal of Advanced Manufacturing Technology*, Vol. 46 Nos 1-4, pp. 315-28.
Pham, D.T. and Sam Lazaro, A. (1990), "Autofix-an expert CAD system for jigs and fixtures", *International Journal of Machine Tools & Manufacture*, Vol. 30 No. 3, pp. 403-11.
Ratchev, S., Phuah, K. and Liu, S. (2007), "FEA-based methodology for the prediction of part-fixture behaviour and its applications", *Journal of Materials Processing Technology*, Vol. 191 Nos 1-3, pp. 260-4.
Rong, Y. and Zhu, Y. (1999), *Computer-aided Fixture Design*, Marcel Dekker, New York, NY.
Rong, Y., Hou, Z. and Huang, S. (2005), *Advanced Computer-aided Fixture Design*, Academic Press, New York, NY.
Satyanarayana, S. and Melkote, S.N. (2004), "Finite element modeling of fixture-workpiece contacts: single contact modeling and experimental verification", *International Journal of Machine Tools & Manufacture*, Vol. 44 No. 9, pp. 903-13.
Stankovski, S., Lazarevic, M., Ostojic, G., Cosic, I. and Puric, R. (2009), "RFID technology in product/part tracking during the whole life cycle", *Assembly Automation*, Vol. 29 No. 4, pp. 364-70.
Subramaniam, V., Kumar, S.A. and Seow, K.C. (2001), "A multi-agent approach to fixture design", *Journal of Intelligent Manufacturing*, Vol. 12 No. 1, pp. 31-42.
Vukelic, D.J., Zuperl, U. and Hodolic, J. (2009), "Complex system for fixture selection, modification, and design", *The International Journal of Advanced Manufacturing Technology*, Vol. 45 Nos 7-8, pp. 731-48.
Wu, Y., Rong, Y., Ma, W. and LeClair, S.R. (1998), "Automated modular fixture planning: geometric analysis", *Robotics & Computer-integrated Manufacturing*, Vol. 14 No. 1, pp. 1-15.
Yi, C. and Nekey, G.A. (1996), "Assembly planning for modular fixtures", *Proceedings of the 1996 IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS 96, Osaka, Japan*, pp. 704-11.

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3. Branko Tadic, Branislav Jeremic, Petar Todorovic, Djordje Vukelic, Uros Proso, Vesna Mandic, Igor Budak. 2012. Efficient workpiece clamping by indenting cone-shaped elements. *International Journal of Precision Engineering and Manufacturing* **13**:10, 1725-1735. [CrossRef]
4. Onder Ondemir, Mehmet Ali Ilgin, Surendra M. Gupta. 2012. Optimal End-of-Life Management in Closed-Loop Supply Chains Using RFID and Sensors. *IEEE Transactions on Industrial Informatics* **8**:3, 719-728. [CrossRef]
5. Onder Ondemir, Surendra M. Gupta Optimal Management of Reverse Supply Chains with Sensor-Embedded End-of-Life Products 109-129. [Abstract] [Full Text] [PDF] [PDF]
6. Re-Machining Parameter Optimization Using Firefly Algorithms 186-202. [CrossRef]

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