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Disassembly and aggregation in computer aided overhaul preparation

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Analysis and modelling

ABSTRACT

Purpose: Disassembly and aggregation procedures are main aspects of an overhaul process. The paper presents the example of an application that solves automation of technical mean recirculation procedures. Automation in the aspect of overhaul process preparation should be obtained through new tools specially oriented to refurbish mechanically used or damaged components.

Design/methodology/approach: Methodology is based on complex overhaul process analysis that conclude technical mean recirculation method. This method brings technical mean back to operation with procedures (like: disassembly, aggregation, examination, preparation of refurbishing technology, overhaul process report generation) determined in specific order.

Findings: Method of technical mean refurbishing with computer aid application. Proposition of automation in aspects of: disassembly (disassembly correct sequence) and aggregation procedures (which elements should be examined).

Research limitations/implications: Important limitations are: disassembly based on assembly order, automation widest range possible when disassembly and aggregation is based on existing documentation. Aggregation algorithm based on machined type of elements.

Practical implications: Nowadays overhaul processes are based directly in most cases on leading technologist experience. Elaborated method and application leads to more objective solutions (decisions) based on algorithms results.

Originality/value: CAO is an original and new approach that should be considered especially in heavy industry. Nowadays subjective decisions about how to refurbish in overhaul processes could be replaced by automated computer aided solutions. Positive economic impact to future and present overhaul processes execution in industry.

Keywords: Disassembly; Replacement; Refurbishing; Overhaul; CAO; Automation

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1. Introduction

Presented in this paper program modules are parts of advisory software, in overhaul process preparation. Selected tool's are shown in Fig. 1. This combination gives wide range of possible implementations in future, based on Visual Studio environment. Selected SIEMENS NX software is one of common used CAPP software, that gives various automation possibilities according to program libraries access. Third part of combination is data base software that retain data what eliminate need to use parametric files. Database overcomes parametric files and is more efficient reachable through local or internet connection. Visual Studio is giving a possibility to create advanced interface according to needed control and expends programmer solutions by possibility to implement new libraries to existing system library. Advisory overhaul process software were built in the base of author's Technical Mean Recirculation Method (Fig. 2). The method is an preposition of computer aided overhaul preparation and new author's approach to technical mean. recirculation with main scope targeted to computer aided refurbishing (CAR). As shown in Fig. 2 the basis is to get information about technical mean or targeted assembly structure. Then as an input data a list of damaged or used elements is delivered from diagnosis. The reference technical documentation if possible is needed. The input technical mean structure and the list of damaged/used elements helps to solve problem of correct sequence of disassembly procedures. After disassembly aggregation is performed. First step is to provide relative cost estimation [9,10,12], which can be based on element complexity and mass of an element. Initial decision is made according to aggregation documentation.

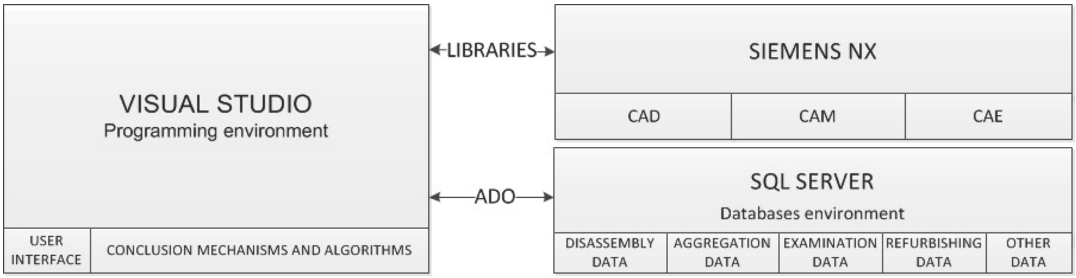


Fig. 1. Tools selected to build author's advisory software

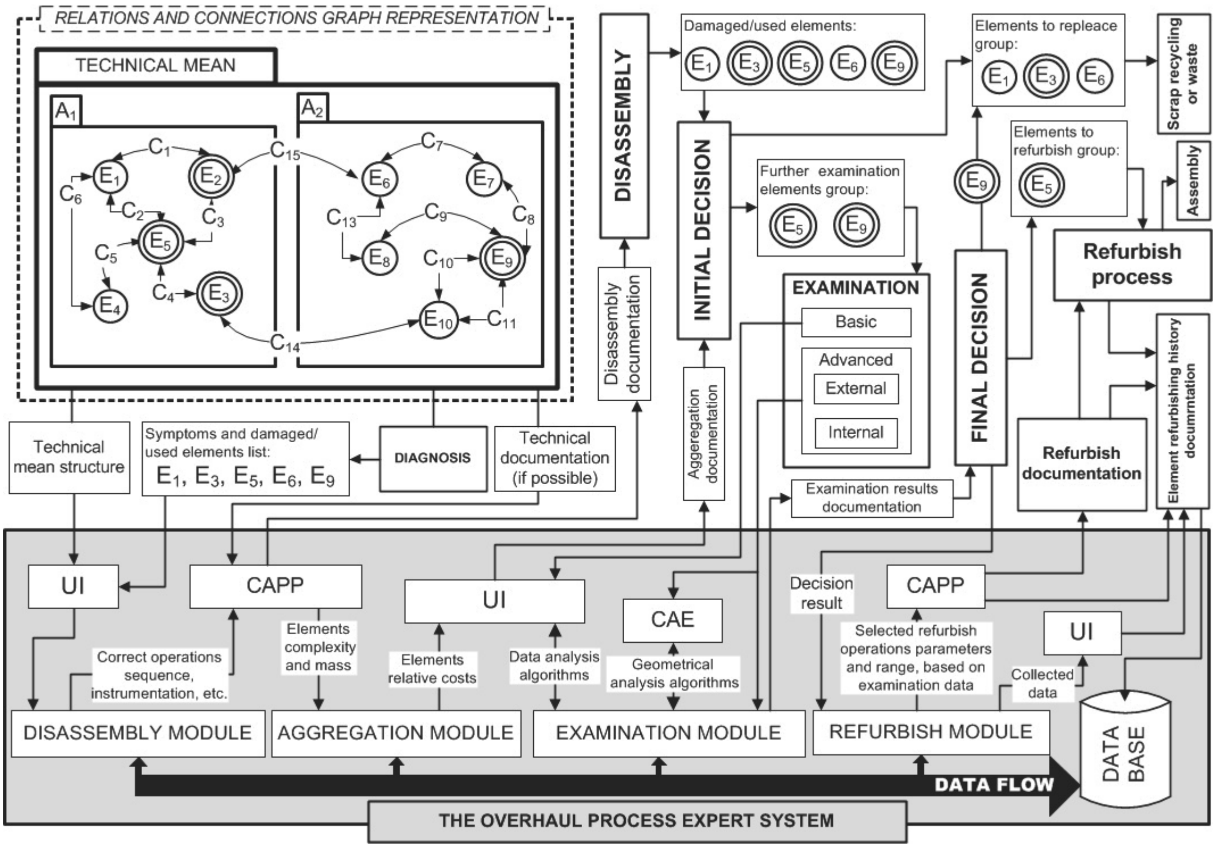


Fig. 2. Technical mean recirculation method (TMRM): A_n - assembly, E_n - element, C_n - connection between elements for ex.: joint, weld etc., UI - user interface, CAPP - Computer Aided Production Planning (CAD and CAM), CAE - Computer Aided Engineering, circled elements - catalogue/normalized, double circled elements - manufactured, CAPP and UI blocks should be treated as one

2. The disassembly module

Disassembly module is applied to solve the disassemble process as it is presented in introduction. According to the method provided solution is based on technical mean structure [7]. First important step is to get structure from technical mean documentation or CAD program as assembly tree-view structure. It's possible to select only specific assembly from technical mean especially when all damaged or mechanically used elements are located in that assembly of technical mean. Elimination, in that matter, is the most important target. Disassembly module will be presented using the example which is an hydraulic actuator with complete technical documentation needed for disassembly case as assembly drawing (Fig. 3) [8].

Disassembly module contains two separate sub modules. The first structure module helps to create the technical mean structure on which further procedures are based. The most important approach is to input the structure, but with sequence according to assembly sequence and with form character connections between elements. Nowadays the connections between elements in CAD software are presented as geometrical relations for example: face to face, perpendicular, parallel, concentric etc. in aspect of touch or align constrains. Constrains solve placement of elements in assembly according to specify correct degree of freedom for particular element which corresponds to other elements surfaces [5,15]. The basic difference between CAD software constrains and expert system joins, is that the second solution gives possibility to analyse the assembly structure. Example of form joins are: shape contact between MRA and MRS elements, weld between MRA and SP (weld itself also included and treated as element), SP and MRS. CAD programs are similarly in technical mean or target assembly structures presentation. Most often used method is an tree-view solution. That can be used for automation sending structure from tree-view presentation in CAD program to tree-view presentation in the overhaul process expert system.

The structure input has been made using STRUCTURE sub-module in DISASSEMBLY module. This module is shown as one dialog window that contains tree-view graphical field. This field can contain various structures representation with any depth that is needed (integer limitation in programming language). According to example presented in Fig. 4 level depth equals 2.

Right from tree-view sub-window, the Create structure panel is placed. This panel can be used to add elements, assemblies (subassemblies) and technical means as needed to create an element hierarchical structure. User also have a possibility to load structure from database using LOAD button. This button is located on Load structure panel. Further on the right Create joins panel is placed. If it is needed user just select Assembly A and B from combo-box controls and then select proper elements from instant shown list. Subsequently user selects the proper join by pressing button with graphical representation.

Join selection can be made by application joins menu icons (Fig. 5). The first three icons represent: fit connections between elements (in order: loose, mixed, tight; as tolerance fields distribution placement - black horizontal bars). The fourth icon shows shape join connection between elements. The fifth represents thread, next icon: roll join. The seventh represents screw join, next glue and next to last represents weld like join. The last icon is reserved for those joins that cannot be described by previous ones. List below icons menu reveals joins that were inputted in the assembly procedures order. Simultaneously each join inputted to the list is automatically recorded in a database. When the structure is loaded from database according to technical mean ID list of joins is updated simultaneously. Apart from described list result an structure graph can be automatically generated as is shown in Fig. 6. On the graph main circle represent the technical mean, smaller circles shows assemblies with elements circular symbols in them. Also division to manufactured or normalized/catalogue elements is applied.

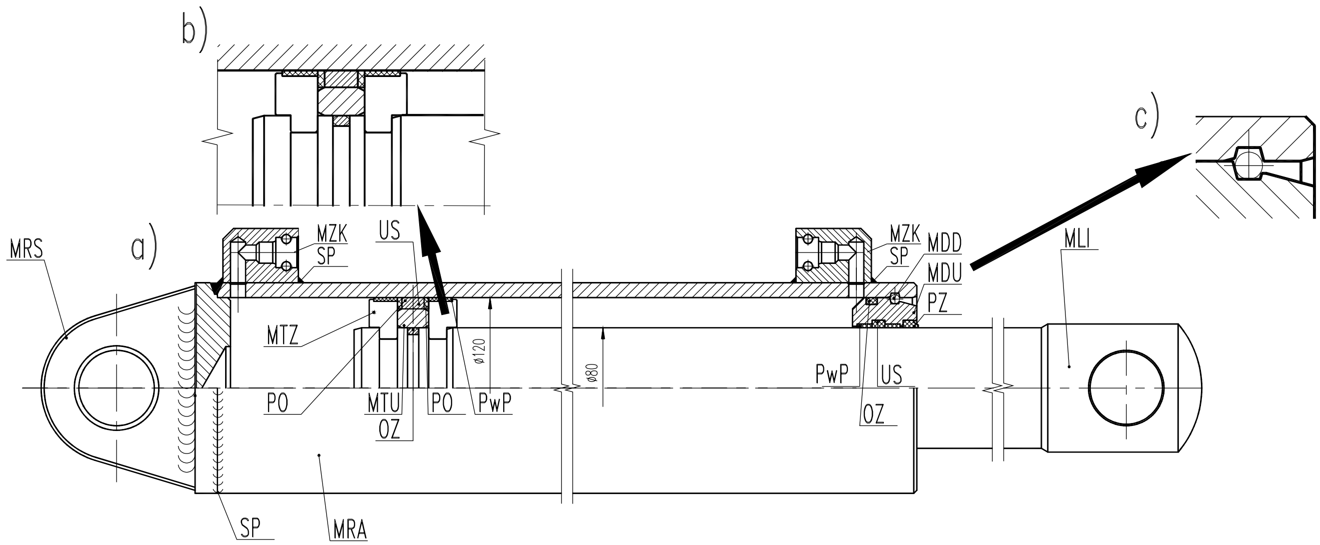


Fig. 3. Hydraulic cylinder design generated using the modular system program [1,2,6]

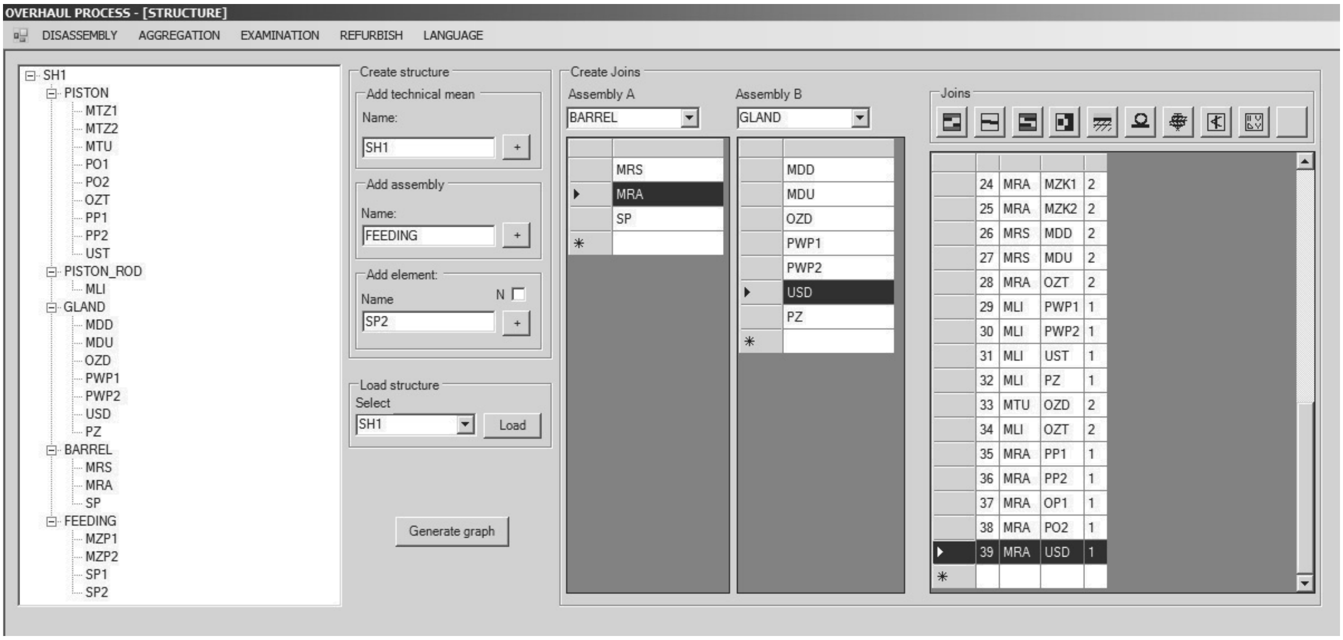


Fig. 4. Structure UI dialog

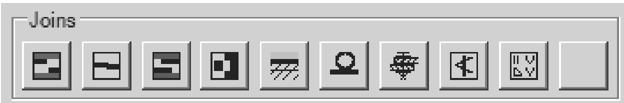


Fig. 5. Joins menu icons

Type of join is visualized with the symbol that is placed in the middle of connection line. Legend in the left bottom corner contains short description of used symbols. The graph can be used as simplified form of technical mean structure and elements relations presentation. User can easily locate specific elements that characterize an higher quantity of connections, (their disassembly process has to be concluded with proper amount of disassembly operations). Main disadvantages of presented relational graph are:

a) only two levels structures presentation is possible (graph should be used especially for target assemblies), according to tree-view,
b) connections lines intersections (based on application tests: the graph contains 65 intersections with circular distribution in comparison to 89-178 range intersections in random distribution). Lines intersections can be reduced with application of Simulated Annealing Algorithm [15].

The next step is to apply inputted data in disassembly operation correct sequence preparation. The proper sequence of disassemble operations are prepared in the SEQUENCE sub-module. In the sub-module symptom definition is initially implemented. Symptom solves problem of mechanically used or damaged elements classification to proper case of technical mean failure. Simultaneously user should be aware of difference between mechanical usage and damage. Damage should be treated as stochastic occurrence, unpredicted in time and place as well as range, unlike mechanical usage that should be treated as predicted occurrence in time and place as well as range (possibility of monitoring and based on experience data collecting).

User can define the symptom as needed, with subscription. Symptom can be applied in different versions (different quantity of mechanically used or damaged) and by this better adapt to real situations (failures). Author algorithm of disassembly automation is based on disassembly operations oriented to subassemblies placement changes recognition. When operation oriented to subassembly placement is recognized, automatically a proper position in disassembly sequence order is assigned. Algorithm recognizes previously inputted joins subscriptions, for ex.: if recognized is weld join: user is informed that information should contain "cut" word, if shape joint - "disassemble word" etc. UI sequence dialog is presented in Fig. 7. At start user select technical mean from database. Symptoms are also automatically updated from database. When symptom ID is clicked on the list automatically lists of mechanically used and damaged elements is updated from the database. Simultaneously program updates lists of sequences as well as sequence according to assembly and after reduction. User has also possibility to input new symptoms in the add symptom UI group and according to diagnosis and assign element to particular symptom. SEQUENCE sub-module, output is the disassembly documentation generated automatically, but user has an influence to generated operations contents. This difference is noticeable after compare of Fig. 7 and Fig. 8.

User also has to input personal data and times values like: preparation-finish time and singular time for each operation added. The total time is calculated automatically. When last operation is added automatically disassembly sheet is generated (Fig. 9). Generated sheet can be supported with additional documentation: two types of graphs with circular and tree distribution.

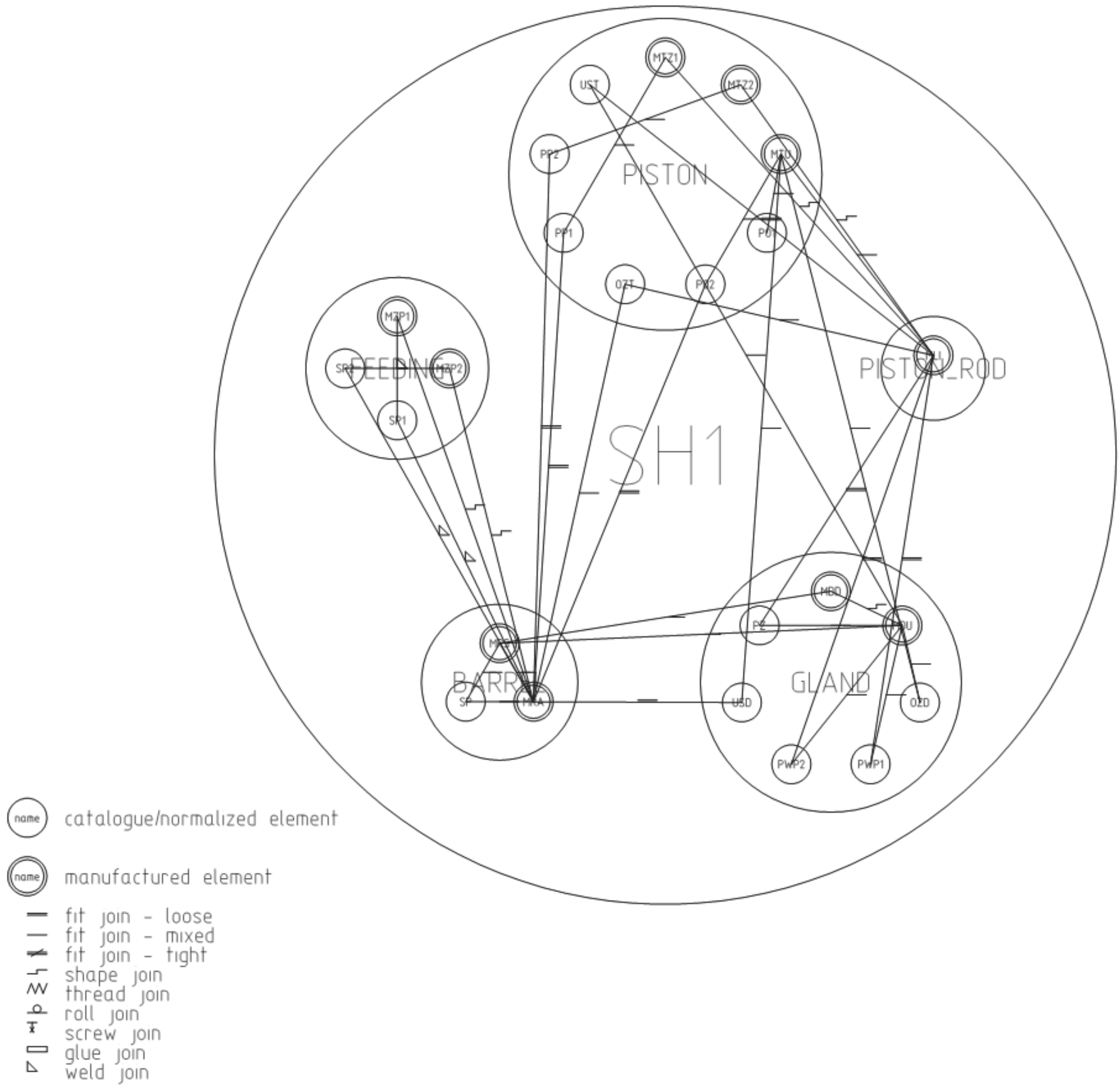


Fig. 6. Automatically generated relational graph based on circular distribution

Graphs presented in Fig. 10 and Fig. 11 are useful for independent analysis and also overall scope to problem of disassembly oriented to specific technical mean. The second type of graph is similar to relational graph from STRUCTURE program module. Difference shows exactly structure according to disassembly process. Presented solution reviles initial pioneer approach to resolve problems of disassembly preparation. Presented documentation at the further procedures should be send to disassembly station (according TMRM to Fig. 2) Worker should use disassembly sheet document as primary guidance, and be equipped with technical drawing assembly sheet. When worker is trained in matter of disassembly according to specified symptoms, disassembly process should be improved in the aspect of predicted total disassembly time. All sheets can be easily managed as it is shown in the Fig. 12. As it is presented in source box user can select one of sheets and then send to local, remote printer or save on disk as an *.xps file.

3. The aggregation module

The Second main module in the Overhaul Process Expert System is the AGGREGATION Module. The module is a proposition to initial decision approach oriented to elements refurbishing [3,4]. If damaged or mechanically used elements are disassembled, these elements can be categorized as: normalized or catalogue elements (NCE) and manufactured elements (ME). NCE's should be in most cases directly replaced in technical mean for ex.: screws, gaskets, guidance rings etc.. NCE's are typically mass production elements. Unlike NCE's, ME elements are typically more complex, what has an important impact to overall cost of an element, (especially machined elements) for ex: piston rods, gears hafts, stabilizer coupler's arm etc.. Fig. 15 presents UI of the AGGREGATION module. In this module user selects Technical mean, then symptom. After symptom selection is completed automatically the mechanically used and damaged element list is loaded from database. Simultaneously list of elements in reference model features group is updated with same elements. Additionally user has a possibility to add other elements to aggregation from technical mean by selecting proper assembly in elements panel. Next step is to collect data from each element by selecting 3D model of an element in NX graphical display (when element is selected automatically changes colour to red - Fig. 14) and then use decoding option. Before any data can be decoded material assignment is needed [14]. Material assignments are made with authors library. Decode option gets all information about reference model needed in aggregation. When decode is provided all important data is presented in Reference model features group like: surfaces quantity, total surfaces area, volume, material, mass. Additional information is an element status which can be described as {0,1,2} assignment. Assignment describe state as:

a) 0 - acceptable,
b) 1 - mechanical use,
c) 2 - damage.

As presented above the description is selected by the user in element status list in reference model features. This particular data is not considered during aggregation process. User has also possibility to manually input data if there is no possibility to retrieve documentation or 3D model.

When all data are decoded or inputted by the user, for particular element (for ex. MDD element - Fig. 13), the data can be recorded in aggregation data collection, what is visualized in Elements aggregation list. When user decides that list is complete, can execute aggregation procedure. In a result user retrieve information about each element ratios and relative costs according to specified group (author algorithm). Visualization on chart reveals which element can be send to further examination. It the decision group according to Fig. 2, to replace list which is automatically updated with NCE's elements and user decide which of ME's elements can be send to examination by elimination of low relative cost ME's.

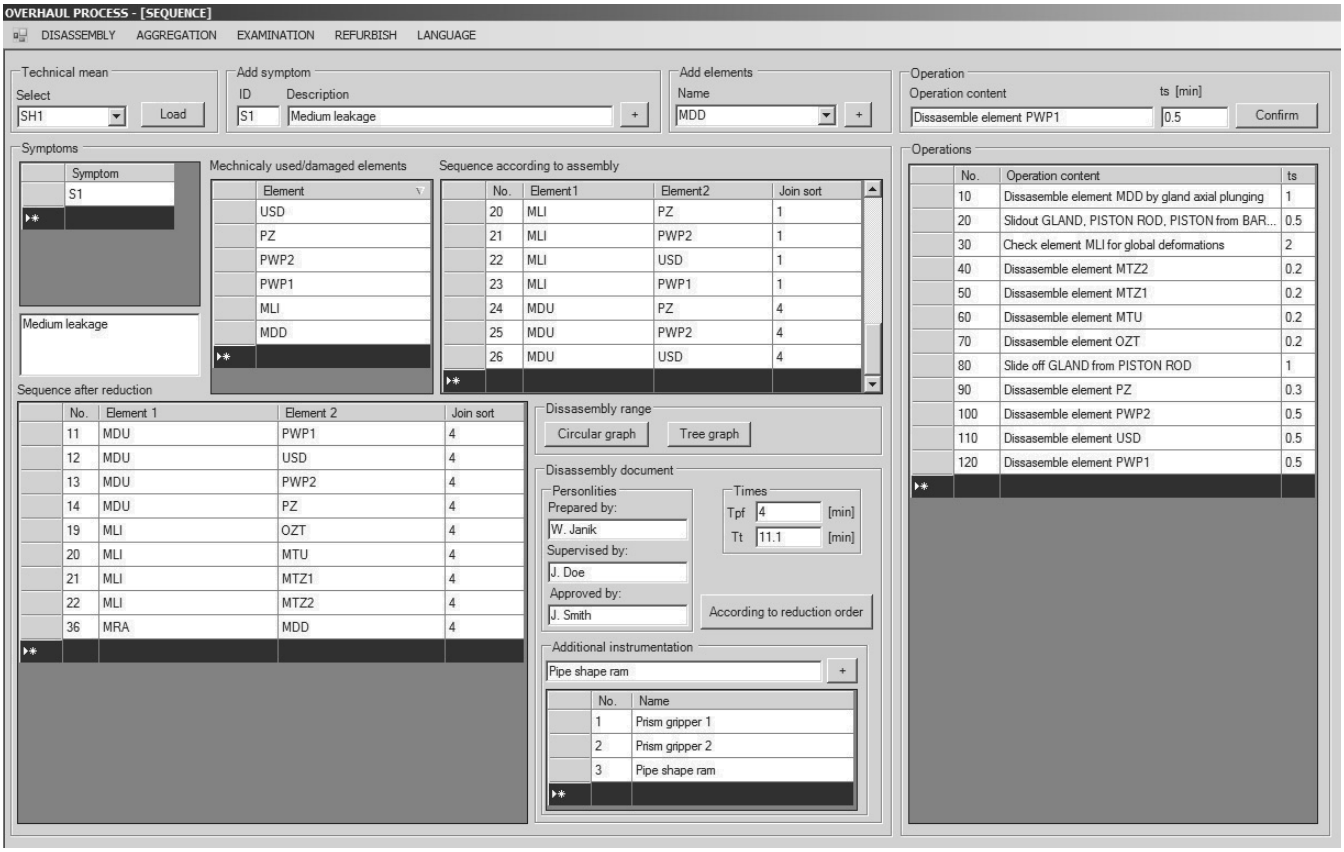


Fig. 7. Sequence UI dialog: T_{pf} - preparation-finish Time, T_t - total time, t_s - singular time

If ME element has low value of relative cost (element MDD - Fig. 14) it should be selected from further examination list and eliminated by clicking "+" button. Simultaneously element is added to "To replace" list. All assigns are stored in database and can be used in the further procedures according to TMRM. Selected group of elements added to aggregation can be different, as example selected group will be upgraded with other ME's elements.

On Fig. 16 an upgraded group of elements was set. This set improve correctness of aggregation. As it is presented in comparison to the chart in Fig. 15, value of MLI element relative cost is changed. When group is wider the collection result is more efficient. What reveals here is that: MRA, MLI elements are now in target of refurbishing. Of course disassembled element group doesn't contain MRA element, but for more reliable result is better to select other elements, especially elements, that characterize lager dimensions. Combination of basic four ratio's gives possibility to visualize element "spectrum" for example comparison of MLI and MRA elements. As it is shown surfaces quantity are quite low in comparison to the total surface area ratio for MRA. Unlike MLI presented difference proves that MRA is a pipe-form element. In the consideration of further examination all ratios that consist to relative cost should be rated by user especially in comparison to other elements.

No.	Operation content
10	Dissasemble element MDD
20	Dissasemble sub-assembly
30	Check element MLI
40	Dissasemble element MTZ2
50	Dissasemble element MTZ1
60	Dissasemble element MTU
70	Dissasemble element OZT
80	Dissasemble sub-assembly
90	Dissasemble element PZ
100	Dissasemble element PWP2
110	Dissasemble element USD
120	Dissasemble element PWP1

Fig. 8. Automatically generated operations contents

Institute of Engineering Processes Automation and Integrated Manufacturing Systems Silesian University of Technology	DISASSEMBLY SHEET	TECHNICAL MEAN NAME: SH1	DISASSEMBLED ELEMENTS COUNT: 9

No	Operation content	ts[min]:	No	Operation content	ts[min]:	No	Instrumentation:
10	Dissasemble element MDD by gland axial plunging	1					
20	Slideout GLAND, PISTION ROD, PISTON from BARREL	0.5					
30	Check element MLI for global defomations	2					
40	Dissasemble element MTZ2	0.2					
50	Dissasemble element MTZ1	0.2					
60	Dissasemble element MTU	0.2				3	Pipe shape ram
70	Dissasemble element OZT	0.2				2	Prism gripper 2
80	Slide off GLAND form PISTON ROD	1				1	Prism gripper 1
90	Dissasemble element PZ	0.3					Tpf[min]: 4
100	Dissasemble element PWP2	0.5					
110	Dissasemble element USD	0.5					∑ts[min]: 7.1
120	Dissasemble element PWP1	0.5					
							Tpf+∑ts[min]: 11.1

Prepared by: W. Janik	Supervised by: J. Doe	Approved by: J. Smith	Sheet/Sheets:

Fig. 9. Disassembly documentation sheet

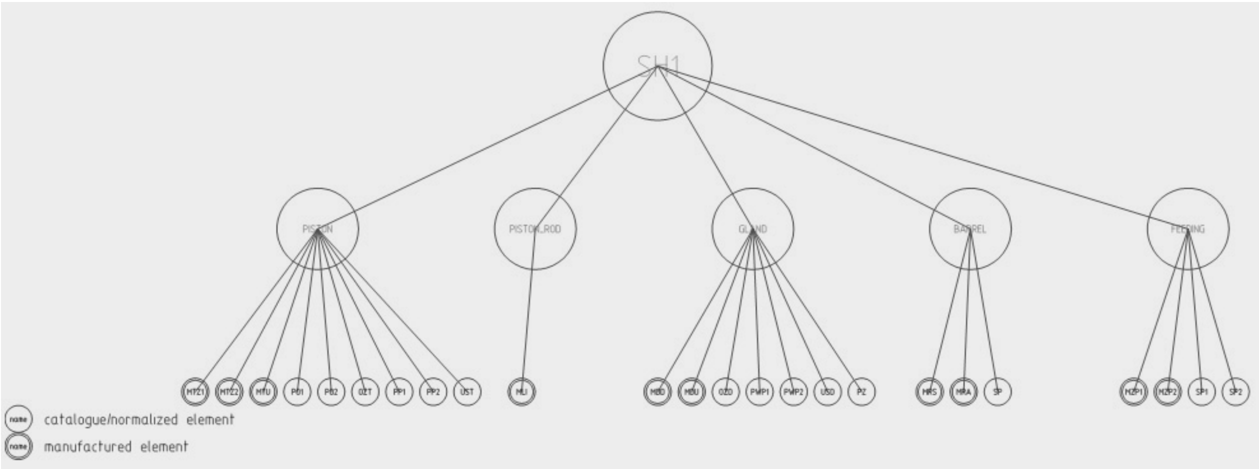


Fig. 10. Tree disassembly graph sheet with colour assignment: blue - elements not included to disassembly process, green - elements included to disassembly process, red - damaged or mechanically used elements that's have to be disassembled

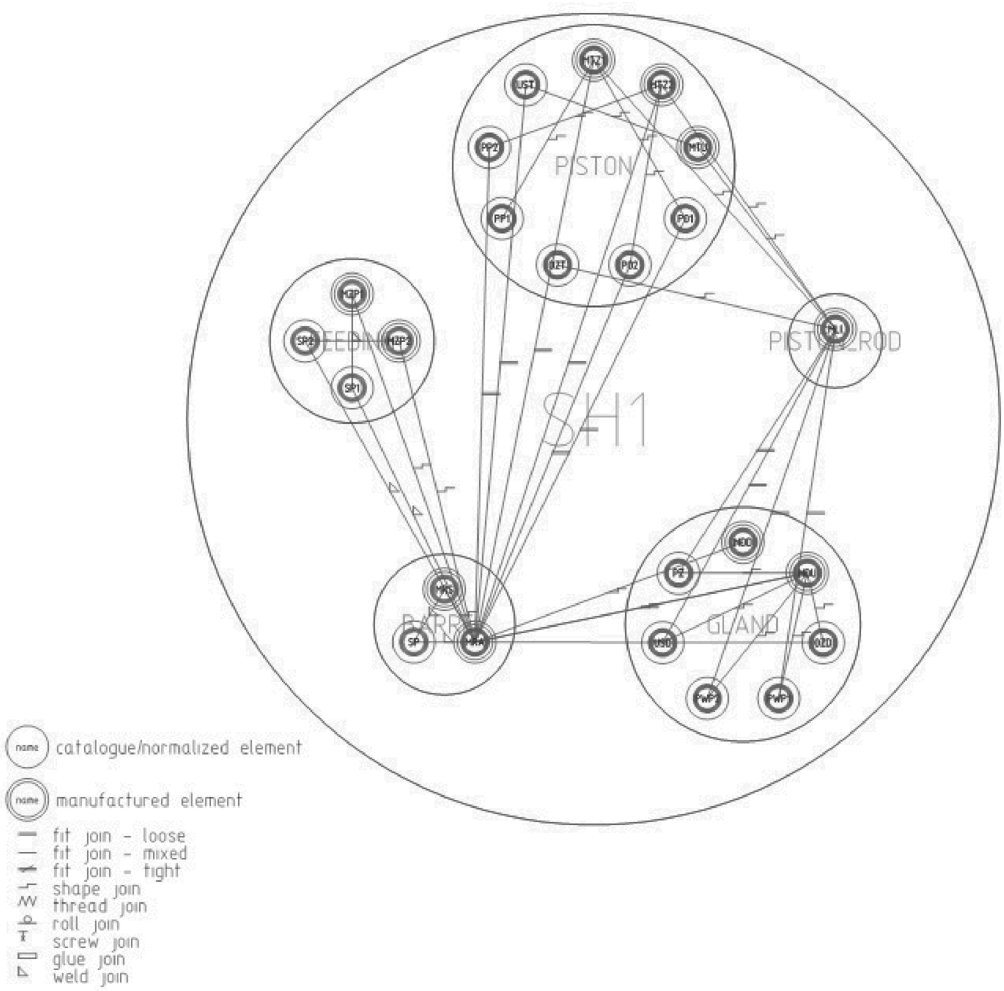


Fig. 11. Relational disassembly graph sheet with colour assignment: blue - elements not included to disassembly process, green - elements included to disassembly process, red - damaged or mechanically used elements that's have to be disassembled

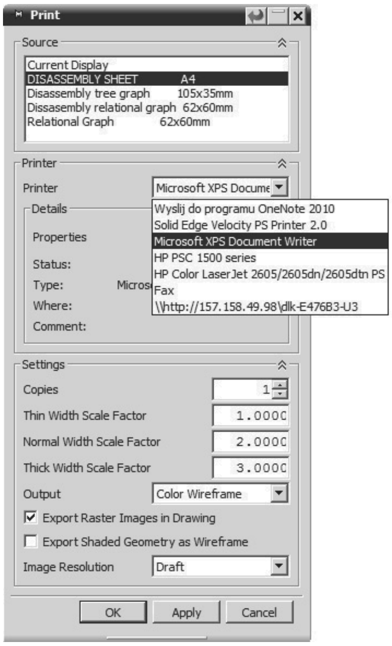
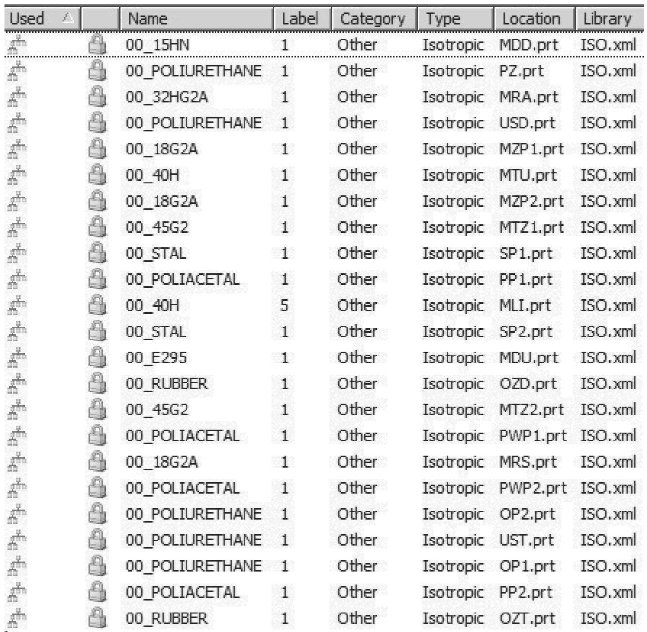


Fig. 12. Print UI (NX software)



Used		Name	Label	Category	Type	Location	Library
		00_15HN	1	Other	Isotropic	MDD.prt	ISO.xml
		00_POLIURETHANE	1	Other	Isotropic	PZ.prt	ISO.xml
		00_32HG2A	1	Other	Isotropic	MRA.prt	ISO.xml
		00_POLIURETHANE	1	Other	Isotropic	USD.prt	ISO.xml
		00_18G2A	1	Other	Isotropic	MZP1.prt	ISO.xml
		00_40H	1	Other	Isotropic	MTU.prt	ISO.xml
		00_18G2A	1	Other	Isotropic	MZP2.prt	ISO.xml
		00_45G2	1	Other	Isotropic	MTZ1.prt	ISO.xml
		00_STAL	1	Other	Isotropic	SP1.prt	ISO.xml
		00_POLIACETAL	1	Other	Isotropic	PP1.prt	ISO.xml
		00_40H	5	Other	Isotropic	MLI.prt	ISO.xml
		00_STAL	1	Other	Isotropic	SP2.prt	ISO.xml
		00_E295	1	Other	Isotropic	MDU.prt	ISO.xml
		00_RUBBER	1	Other	Isotropic	OZD.prt	ISO.xml
		00_45G2	1	Other	Isotropic	MTZ2.prt	ISO.xml
		00_POLIACETAL	1	Other	Isotropic	PWP1.prt	ISO.xml
		00_18G2A	1	Other	Isotropic	MRS.prt	ISO.xml
		00_POLIACETAL	1	Other	Isotropic	PWP2.prt	ISO.xml
		00_POLIURETHANE	1	Other	Isotropic	OP2.prt	ISO.xml
		00_POLIURETHANE	1	Other	Isotropic	UST.prt	ISO.xml
		00_POLIURETHANE	1	Other	Isotropic	OP1.prt	ISO.xml
		00_POLIACETAL	1	Other	Isotropic	PP2.prt	ISO.xml
		00_RUBBER	1	Other	Isotropic	OZT.prt	ISO.xml

Fig. 13. Material UI (NX software) - material assignment

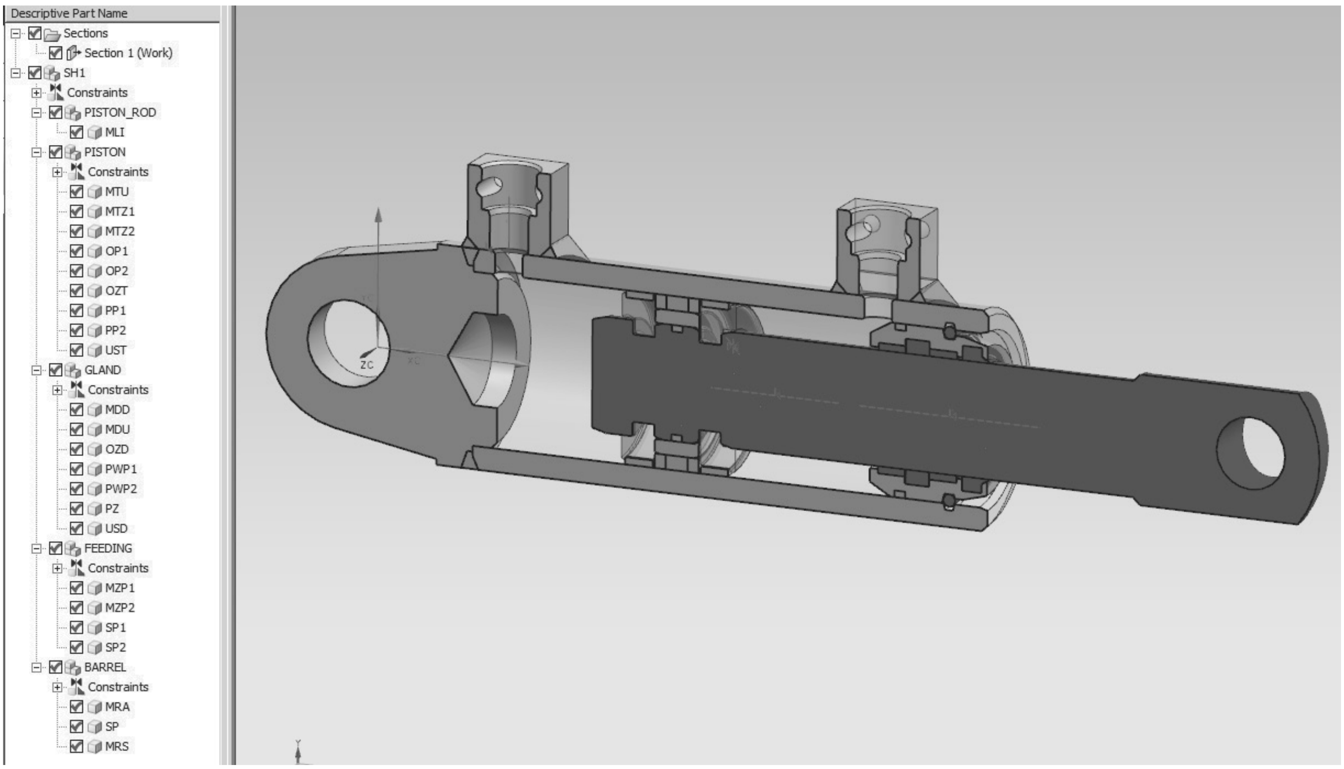


Fig. 14. Example hydraulic actuator solid section with full structure tree and red coloured aggregation elements

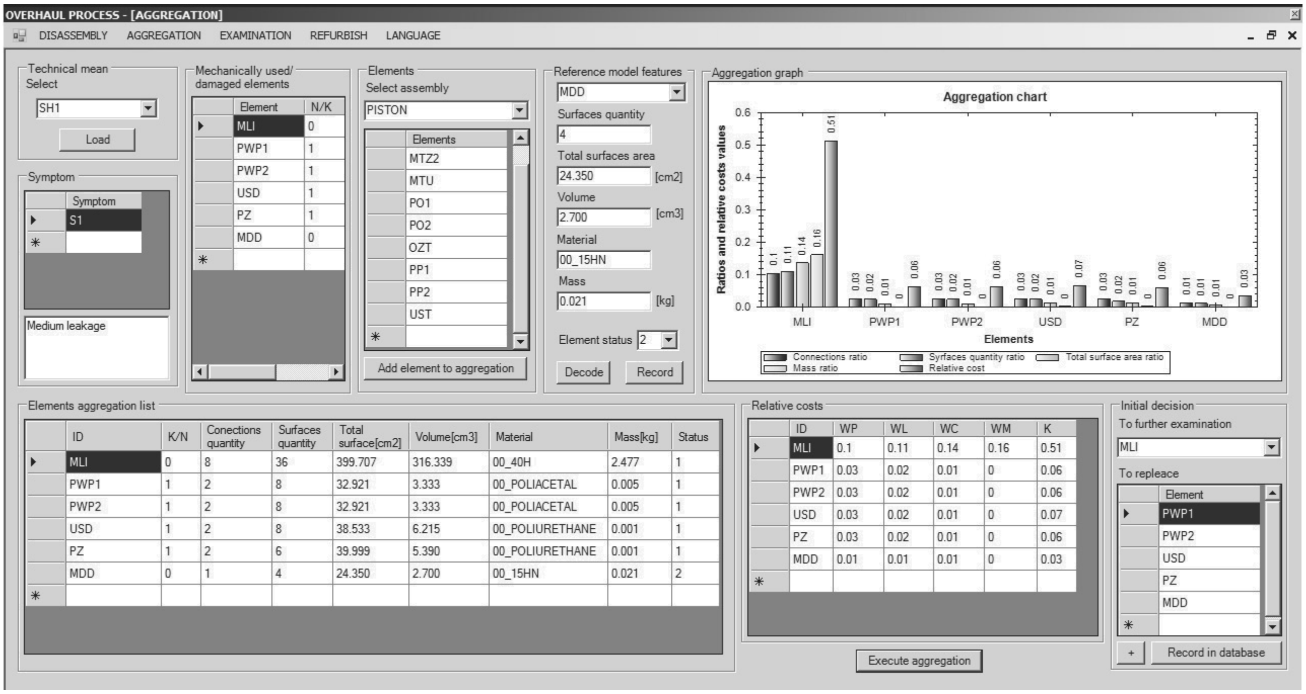


Fig. 15. Aggregation UI Dialog: WP - connections ratio, WL - surfaces quantity ratio, WC - total surfaces area ratio, WM - mass ratio, K - relative cost

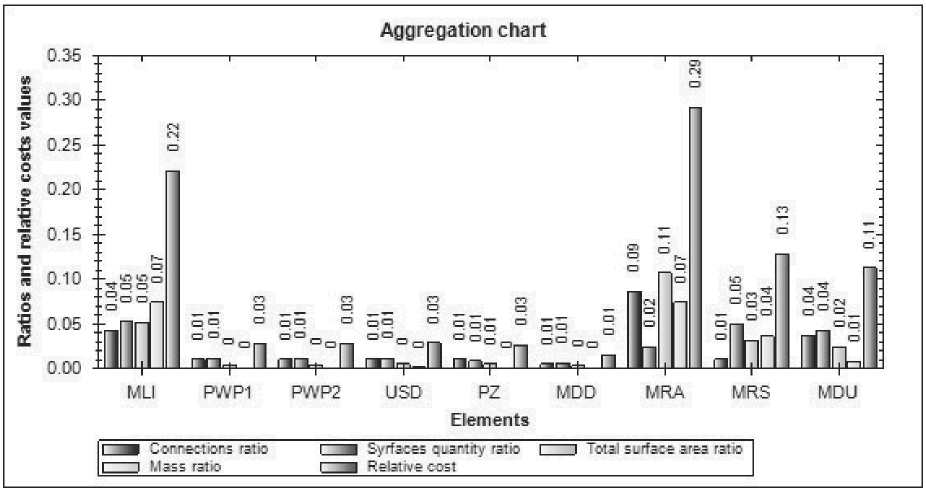


Fig. 16. Aggregation chart with additional elements

4. Conclusions

Software oriented to overhaul process development, helps to improve objectiveness of decisions. Furthermore helps to organize and analyse historical data of element. Lack of technical documentation is one of the most critical barrier in the TMRM. This disadvantage have to be minimized by among others reverse engineering techniques. Presented software is only a preposition and it's still in develop process. Perhaps shown solutions could be considerate in especially heavy industry. Overhaul processes application can be profitable what is greatly proven in US industry - "$33.3 M over ten years" [13]. Nowadays approach of producers is oriented unlike overhaul, to categorize only in two states: new technical mean or damaged/used technical mean. Fortunately possibility of automation end computer aid, can effectively support overhaul processes. Presented disassembly module target is to prepare documentation that can be directly applied at disassembly station. Main document which is the disassembly sheet, completes that target. Additional support of graphs can improve disassembly process. Aggregation module helps make an initial decision, which element should be send to further examination. Presented charts visualize element relative cost. As were shown in Fig. 15 and Fig. 16 difference of gained results depends on collection quantity. Aggregation can also be provided on every element in technical mean to get full image of relative costs. Current aggregation module version is oriented to mainly machined elements [16]. Further development of aggregation module will be oriented to weight equations according to specified ratios, because of difference in estimation for ex.: machine element and injected element (not important quantity if surfaces in case of injected element). In the case of disassembly module further development will be oriented to add new methods operation order generation and implementation of technical mean history knowledge based algorithms.

Acknowledgements

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