KNOWLEDGE ENABLED PROCESS ENGINEERING – REVOLUTION OR ADAPTATION

Dr. C.N. Bancroft1, Dr. S.J. Crump2, Mr. M.Jackson1 and Dr. J.P.Tyler1
1 Enabling Process Technologies Limited, Rugby, UK. 2 Airbus , Bristol, UK.

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Abstract

Knowledge Enabled Process Engineering (KEPE) is introduced in the context of its current and potential use for dynamically managing large and complex problem domains, in particular the management of manufacturing induced part distortion in large aerospace components. The paper presents KEPE and discusses its link with Knowledge Based Engineering (KBE). A comparison focuses on KEPE and KBE and looks at similarities and divergence between the practical applications of both methodologies. A brief description of the COMPACT project and the scope of KEPE within COMPACT are presented. To conclude, the paper will present current results and findings related to KEPE within COMPACT.

1 Introduction

Enabling Process Technologies Ltd (EPT) has developed KEPE as a formal method of working within the aeronautics industry. The aim is to ensure appropriately integrated advanced information technology systems meets the actual needs of key stakeholders. It has been developed from experience gained, in the main, from meeting challenging operational demands in the design, development and manufacture of aerospace components and systems. It has been developed through exposure and work share within four aircraft programmes as well as significant research and technology activity in multidisciplinary optimization. In all but research projects customers have been provided with deliverables without knowledge of KEPE, it being used as an internal EPT business process.

KEPE is centred on the integration of people, process, product and technology Fig. 1. The core activity of integration is knowledge based modelling using appropriate toolsets. It is important to note that "appropriateness" is highly organisation dependent and business strategy centric. KEPE has a strong relationship with knowledge-based engineering (KBE) and more broadly design and manufacturing automation and has been strongly influenced by both. If we consider that in simple terms KBE for design and analysis is the combination of product geometry, process configuration, engineering rules and associated data. This provides a semi-automated engineering design environment supporting repeatability, experimentation and consistent application of rules. For the past 12 years Airbus UK has been amongst the world leaders in the industrial application of KBE. Experience has shown impressive results [1, 2, and 3]. Experience however, has also shown that two key related challenges need to be addressed these being process owner detachment and the difficulty of achieving KBE application integration into core capability and key systems. Both challenges exist because in general terms KBE application development techniques lead to process fragmentation through encapsulation. There are many contributing factors but the main one is that the output of a KBE application has traditionally been viewed as more important than how you derive the output. With the process hidden within the KBE application the process owner is responsible for the output integrity without being furnished with the full understanding of how the integrity of the output is achieved. In simple terms this asks the question, is the output correct for the right reasons? A large degree of effort is applied in validation and verification in order to ensure data is fit for purpose.

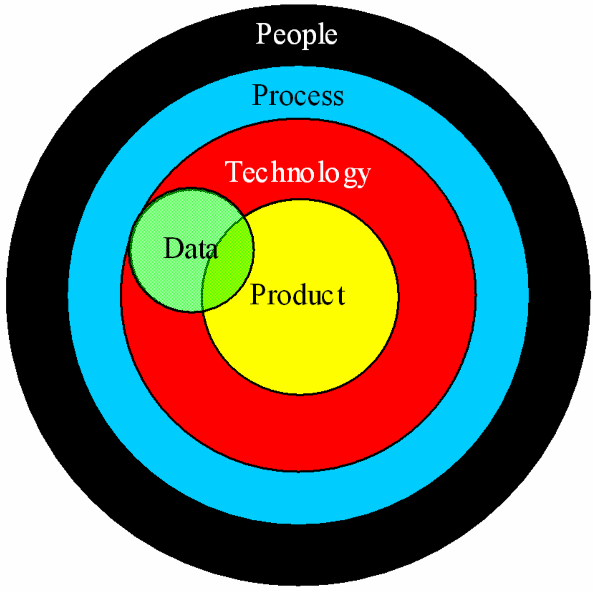

Fig. 1. KEPE integration relationship diagram

KEPE is a people focused approach that adopts process modelling as a common development language. The terms used to describe activities are, for example those of the experts, owners, users and developers, and they are stated in the context of both time and space. Knowledge enriched process models form the spine of a 'navigation' system that enables processes to be linked through common attributes. KEPE identifies where process encapsulation is appropriate and links small packets of KBE together to enable core capability and key system management.

KEPE is to be challenged in a truly concurrent research environment. It is to be used for engineering research management within multi-functional disciplines and to ensure the full integration of these disciplines meet a principle objective within the COMPACT project. The principle objective of COMPACT is to design, develop and plan the exploitation of a knowledge-based advisory system within the Aerospace Industry including the supply chain that is to provide a concurrent approach to managing manufacturing induced part distortion in aerospace components. The body of research encompassed within the COMPACT FP6 project includes; Material Sciences (material manufacturing and residual stress measurement), Manufacturing (machining, forming and post processing), Finite Element Modelling, Design and Knowledge Integration. COMPACT will be described in more detail following a brief comparison between the application of KEPE and KBE.

2 KEPE and KBE, a brief comparison.

KEPE and KBE have some similarities when working within an engineering domain: -

- Best practice processes are supported by both.
- They demand conformance to best practice
- Engineering expertise is required by the application developer.
- Specialist programming skills are required for system integration.
- Knowledge interfaces are similar for a process participant.
- Both have roots in Object Oriented Methods.

There are also many divergences:-

- KBE had roots within Computer Aided Design (CAD).
- Early use focused solely on the Design Engineer.
- Early adopters created detailed localized applications.
- Applications had limited domain coverage.

- KEPE adopts multiple view points within each application. View points such as: -
    - The new graduate / trainee
    - Process Participant
    - Process Owner
    - Process Improver
    - Project Planner
    - Business Manager
- A KEPE Application development process is externalized.
- Multi-disciplinary teams build the process lead by engineers.
- Knowledge Maintenance is supported by the roles of process owner and improver.
- KEPE supports rapid process information creation and utilisation.

3 COMPACT the Project-in brief.

COMPACT is a project with the principle objective to design, develop and plan the exploitation of a knowledge-based advisory system within the Aerospace Industry. The advisory system is to provide a truly concurrent approach to the resolution of manufacturing induced part distortion in large aerospace components. The proposed system is shown in figure 2.

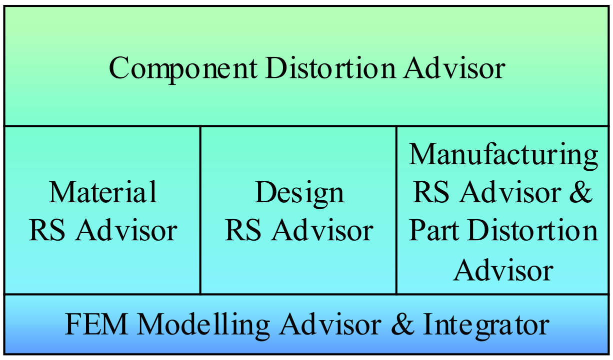

Fig. 2. The Component Distortion Advisor.

The Component Distortion Advisor is to be developed around three fundamental streams of research, Material processing, component design and manufacturing. New knowledge generated in each of these streams will lead to the production of best practice advisors for each stream. Additionally, FEM technology will be used to enable an integrated RS simulation capability across three distinctly different fields. Together this will provide the required knowledge to generate accurate predictions of residual stress levels and identify distortion tendencies in components post-machining.
Ultimately the system will be used to provide a means to minimize part distortion through residual stress management through the systematic evaluation of engineering decisions.
In the following section we will briefly discuss the aims of the three pillars of fundamental research and the structure of the respective advisors in each case [4].
The Materials study is investigating the effect of material manufacture on part distortion induced by residual stress. The key aims are to understand the sources of, and be able to predict the magnitude and distribution of Residual Stress in a specific series of alloy with particular regard to their influence on part distortion, and to develop new methods and strategies for reducing the final level of distortion.
The materials advisor shown in figure 3 will draw on new knowledge to develop two main areas of investigation. These being material production and manufacturing process development for plate materials, and material process development for forged plates.

Supporting both the materials processing and manufacturing activities is the research into residual stress measurement and verification techniques. This provides a necessary means to benchmark existing RS measurement techniques that will enable the best approach to be adopted to facilitate project progress. The specific aim of this work is to research and develop a novel method that allows rapid and accurate RS material profiling to be done in a production environment.

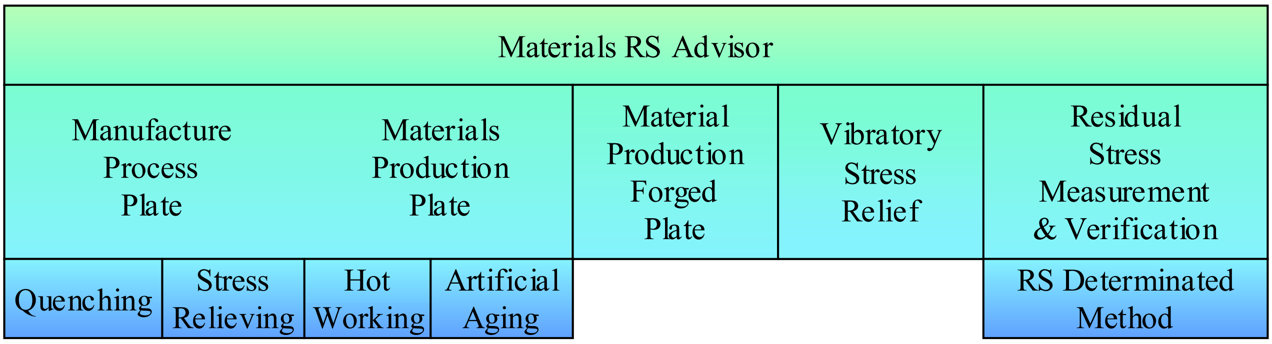

Fig. 3. Materials RS Advisor.

The modeling of vibratory stress relief will also contribute to the body of knowledge.
The design study is investigating the effect of design intent on the redistribution of RS and its impact on parts distortion. The key objective is to ensure a right-first-time philosophy is supported in the design of new aircraft by referencing both up and down stream knowledge and using this to influence decision –making in each phase of design.
The design paradigm under consideration is knowledge-based engineering. In simplistic terms, this is the combination of product geometry, configuration and engineering rules and associated data providing a semi-automated engineering design environment that supports repeatability, experimentation and consistent application of rules of geometry.

The design RS Advisor shown in figure 4 will draw on new knowledge in three key areas. The objective of design option classification activity is to understand and set the boundaries of RS redistribution by identifying the practical constraints that apply to an engineering design decision given current design practice and possible near future developments.

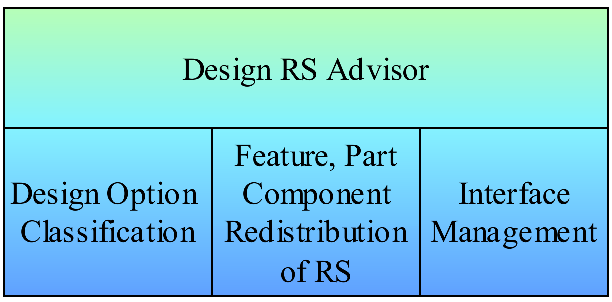

Fig. 4. Design RS Advisor.

The investigation into feature, part component redistribution of RS will also develop simple tools to determine approximate part distortion and define best practice design process.
The establishment of interface requirements placed on design, stress and manufacturing will support knowledge integration.
Two case studies, one for machined parts and one for folded parts will be undertaken to establish proof of concept.

The manufacturing study has three key elements of consideration. These are Machining, bending and Post-Machining Distortion Management. Post machining distortion management is sub divided into mechanical, thermo mechanical and thermo means. The manufacturing RS Advisor is shown in fig 5. For each of these areas of investigation the objective is to understand the influence on RS, develop analytical and numerical models of RS and establish a process and a decision making process for the management of RS,.

The key outputs from the COMPACT project that will be exploited by the members of the consortium and the wider aeronautical industry are as follows:

- A methodology for constructing knowledge based systems for complex products that integrate information from diverse work streams into a single solution.
- A knowledge based system for aircraft components that allows RS to be understood and managed within the manufacturing process.

- Improved capability to simulate manufacturing and material production processes aiding the introduction of process improvement methodologies that will enhance competitiveness.
- Greater understanding and interaction between the design and manufacturing fields to improve the quality of products and reduce development times.
- A portable, efficient and cost effective method for RS measurement that will enable the technology to be transferred to other sectors such as civil engineering (e.g. bridge building).
- Demonstration of the power of knowledge engineering to address significant business problems which are beyond the capability of one organization to solve.

Many of these outputs have a critical dependency on KEPE and the knowledge integration activity.

4 KEPE within COMPACT

Enabling Process Technologies Ltd is responsible for providing knowledge integration services within COMPACT.

Based on practical and research experience in the fields of both knowledge based engineering and knowledge management [5-8] they know that process understanding and representation is crucial to ensuring represented knowledge is contextual in time, place and opportunity.

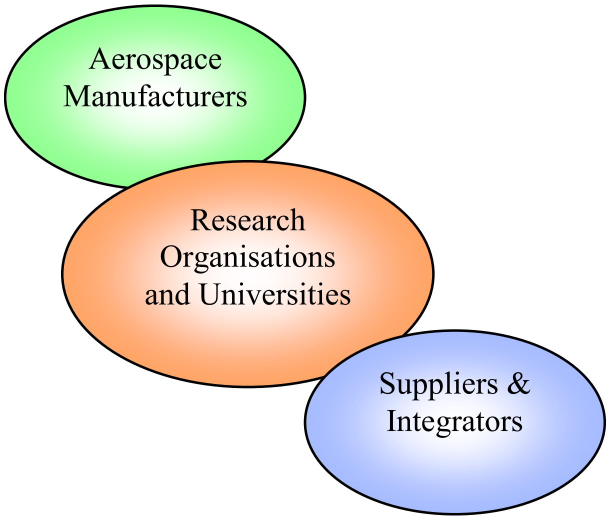

Fig. 6. The COMPACT consortium.

KEPE is the process oriented approach adopted that must address the fundamental challenges of knowledge: acquisition, modelling, reuse, retrieval and extraction, publishing and

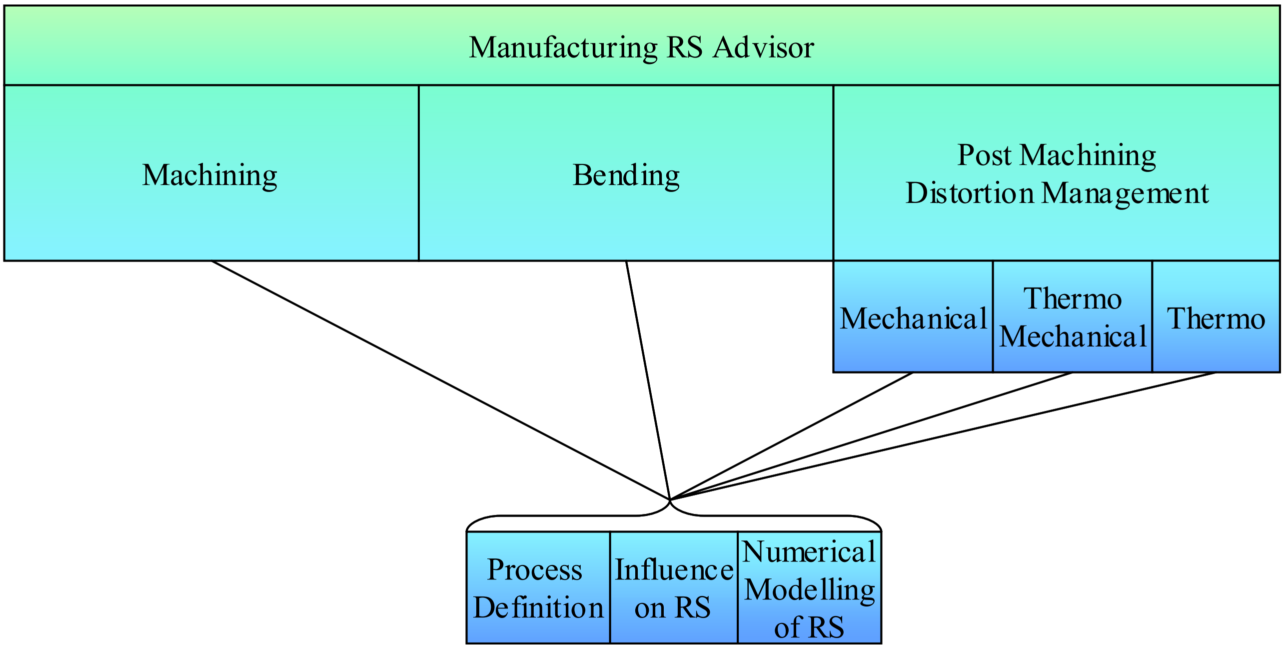

Fig. 5. The Manufacturing RS Advisor

maintenance to successfully address knowledge integration within COMPACT.

The challenges must be met within the COMPACT consortium that consists of Aerospace Manufactures, research organizations and universities and suppliers and integrators. Figure 6. The research disciplines along with the geographical distribution of the associated primary knowledge sources are shown in Figure 7. These sources provide both 'old' and 'new' knowledge in a process spectrum that ranges from relatively mechanical processes to those of dynamic innovation.

Three separate but interrelated hierarchical management streams have been defined to address such an undertaking. The three streams are project, knowledge interface and systems development management. The project management stream defines at a high level of granularity the key project milestones, deliverables and decision points. An appropriate cascade takes place to the other two streams. Knowledge interface management defines interactions between organizations, functions, teams and individuals as appropriate. Roles and responsibilities are defined both individually and jointly. It is at interface points where the knowledge Integrator creates required understanding through an iterative process of capture, define visualise, explain, test, evaluate, verify, validate and improve. It is knowledge interface management that supports team construction and communication. Through building relationships and trust the knowledge integrator can also define the boundaries of knowledge sharing and establish the rational behind their definition. Within COMPACT we must build mono, intra, inter and multi discipline teams. Formal knowledge transfer is in the form of procedures, methods and work instructions. The knowledge integration management activity feeds into the initial investigation for systems development as functional requirements can be gathered without any reference to physical solutions. It must be noted that a formal requirements analysis will be undertaken under the systems development management process. Following an initial investigation an application classification is made to enable an appropriate system development methodology selection.

This knowledge integration activity is to integrate process knowledge and cost models that are deliverables from the primary knowledge sources shown are in figure 7.

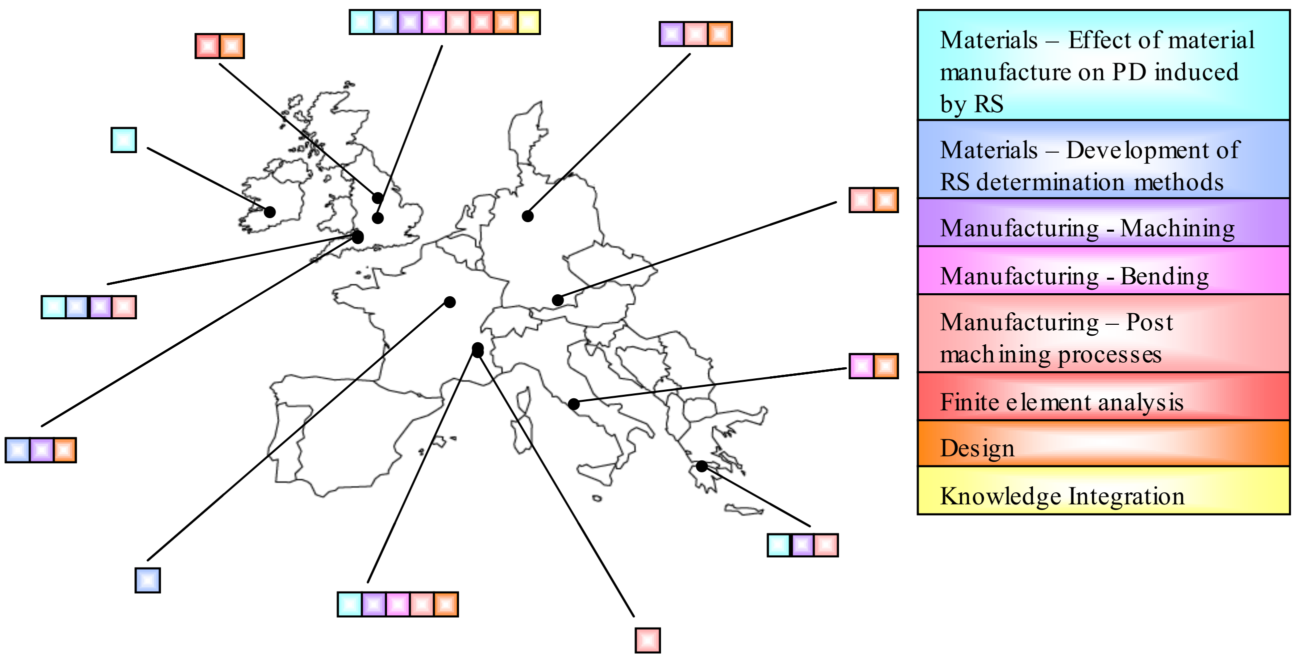

Fig. 7. Distributed Primary Knowledge Sources.

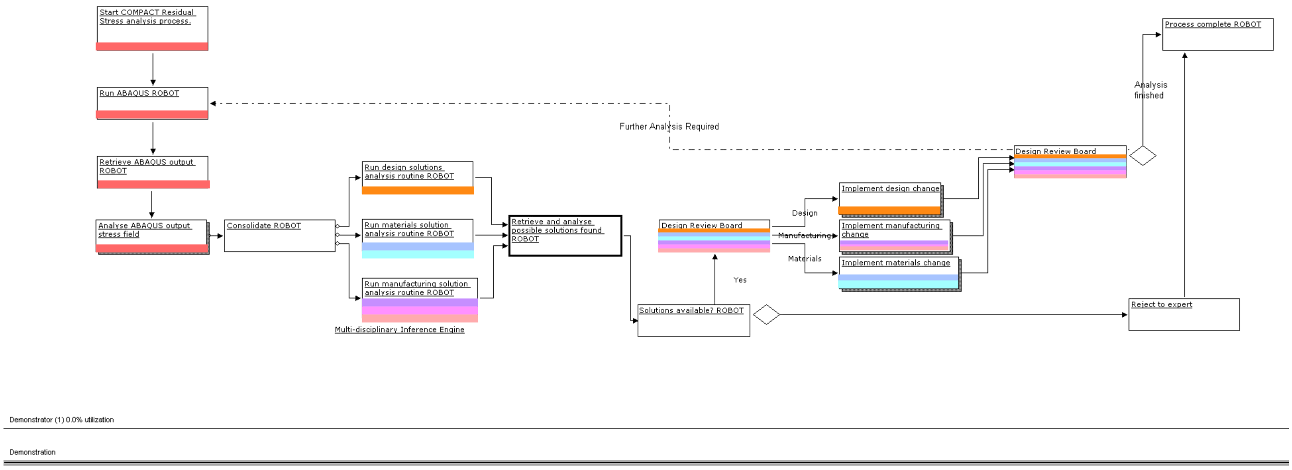

Fig. 8. Draft Integration Framework Process

These integrated deliverables form the knowledge enriched process model that will underpin the functionality of the knowledge based advisory system shown in figure 8.

5 Current Progress

A draft integration framework has been developed for both proving technology support for and creating consortium understanding of a concurrent approach to the management of manufacturing induced parts distortion. A demonstration toolset was used. This consisted of CATIA V5, Visual Basic, SQL Server, EXCEL, Active Modeller and Active Flow. CATIA V5 addresses both CAD and CAM elements of the proposed system. EXCEL is used for stress field calculations; Active Modeler is the process knowledge capture and representation tool, Active Flow the system execution engine, SQL Server the knowledge base. Visual Basic was used to provide pre and post processing capability necessary fro integration and to develop representative user interfaces for supporting integration testing. A multi layered representative process of the advisor shown in figure 8 has been developed. This high level process links into sub processes for stress analysis, materials, design, and manufacturing related domains.

Using the web based execution engine ActiveFlow, the process can be brought to life. The Multidisciplinary process can be deployed across multiple company sites or even continents. Domain experts do not have to be collocated in the same room sitting behing a single terminal. The ActiveFlow system ensures repeatability and conformance to best practice processes.

The strengths of the ActiveFlow system within the context of the COMPACT project is demonstrated by the figures 9, 10 & 11.

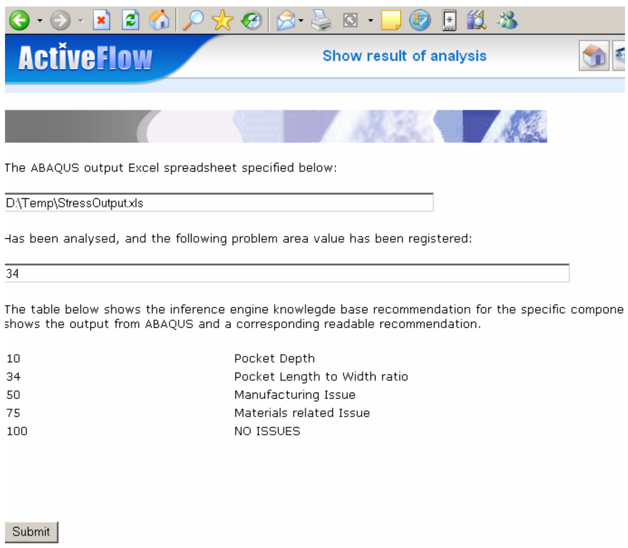

Fig. 9. Information returned by complex knowledge based systems can be presented back to a process participant in a format that cannot

be misinterpreted. Participants can act upon information even if they are not experts within a specific domain. Here a KBE system recommends changing the Pocket Length to width ratio.

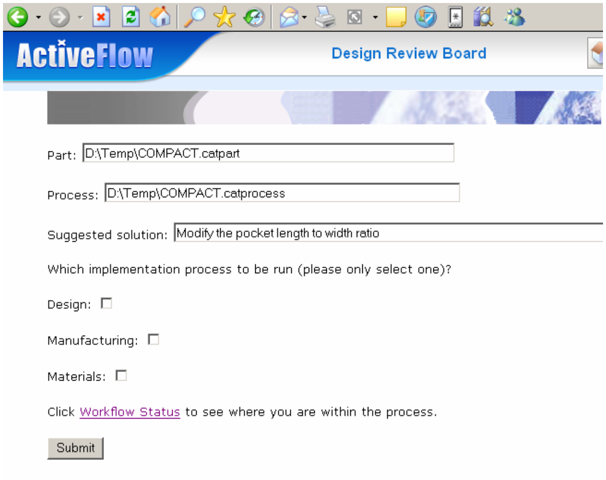

Fig. 10. Here the system restricts the participant to only three options (via tick boxes), as defined in the best practice process.

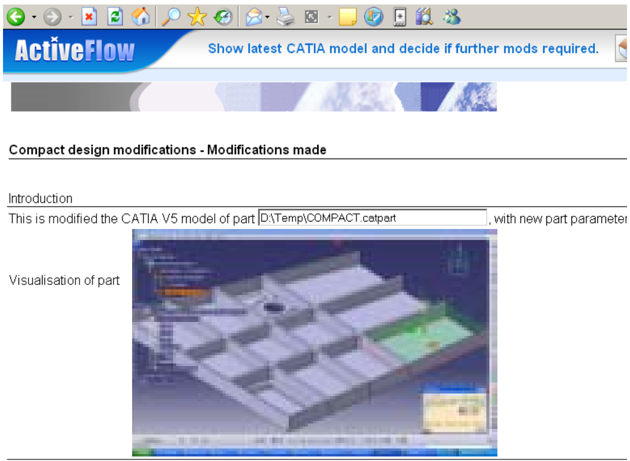

Fig. 11. The web based interface distances process participants from complex specialist applications reducing the reliance on specialist application knowledge and automatically manages data.

The consortium have gained some understanding of KEPE but are anticipating a better understanding as process based advisors are developed specifically to address their specific capability management needs.

Technology integration was satisfied by the development of the draft integration framework. COMPACT is still in the early stages as a project and KEPE will face far sterner test in the near future.

6 Final Comments

KEPE methodology is without doubt an Adaptation. It is based on the experience and learning of the people within Enabling Technologies Limited drawing from many influences. KEPE will always represent a common sense approach to problem solving reflecting the constraints that businesses operate under when developing their core capability.

The application of KEPE to the management of manufacturing induced part distortion of aerospace components offers a significant business and intellectual challenge. If KEPE can effectually provide a truly concurrent system that can manage this type of problem, we can anticipate a significant step change in how businesses manage such capability, if not a revolution. KEPE performance good or bad will be reported on for the next three years.

7 Acknowledgements

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- EADS Corporate Research Centre
- University of Sheffield
- Enabling Process Technology Ltd
- University of Limerick
- University of Patras
- Ultra RS
- Institute Polytechnique de Grenoble

And are all active contributors to this document

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