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INVERSION OF FRUSTA AS IMPACT ENERGY ABSORBERS

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ABSTRACT

In this paper a novel crushing mode of frusta is presented for the first time. The details of the plastic inversion of frusta as energy absorbers are given. The deformation modes of capped frustum are investigated both experimentally and analytically. An Explicit version of ABAQUS 5.7-3 finite element (FE) code is used for computing and describing the proposed deformation mode. Good agreement is obtained between the experimental results and the FE predictions.

KEYWORDS

Energy Absorber, Frusta Inversion, Finite Element.

1. INTRODUCTION

Energy absorbers are systems that convert kinetic energy into other forms of energy, such as elastic strain energy in solids and plastic deformation energy in deformable solids. The converted energy may be reversible, as in pressure energy in compressible fluids, and elastic strain energy in solids, or irreversible, as in plastic deformation. The process of conversion for plastic deformation depends, among other factors, on the magnitude and method of application of loads, transmission rates, deformation displacement patterns and material properties [1].

The predominant domain of applications of collapsible energy absorbers is that of crash protection. Such systems are installed in high-risk environments with potential injury to humans or damage to property. The aim is to minimize the risk of injury or damage by controlling the deceleration pulse during impact. This is achieved by extending the period of dissipation of the kinetic energy of the system over a finite period of time. Cushioning devices on vehicle bumpers, crash retards in emergency systems of lifts and crash barriers used as roadblocks are everyday examples.

Familiar plastic deformable energy absorber units include cylindrical shells [2], wood-filled tubes [3], foam-filled columns [4], sand-filled tubes [5], PVC shells [6], tube inversions [7] and tubular elements [5]. The active absorbing element of an energy absorption system can assume several common shapes such as circular tubes [8], square tubes [9], multicorner metal columns [10], frusta [11] and rods [12]. Axisymmetrical and circular shapes provide perhaps the widest range of all choices for use as absorbing elements because of their favorable plastic behavior under axial forces, as well as their common occurrence as structural elements.

In this paper the selected absorber has a truncated capped frustum shape. Frusta are employed over a wide range of applications, especially in the domains of aerospace and armaments. Common examples occur in the nose cones of missiles and aircraft.

2. AXIAL LOADING OF TUBULAR COMPONENTS

The study of deformation of tubular energy absorbers in general falls into two main categories, lateral, and axial loading. Investigations often lead to accounting for geometrical changes, interactions between modes of collapse, as well as strain hardening and strain rate effects. Johnson and Reid [1] identified the dominant modes of deformation in simple structural elements in the form of circular and hexagonal cross-section tubes when these elements were subjected to various forms of quasi-static loading. They described the load-deformation characteristics of a number of these elements. Thin-walled absorbers having symmetrical cross sections may collapse in concertina or diamond mode when subjected to axial loads. The collapsing of such components by splitting or by inversion is also reported [9].

The behavior of thin tubes (large diameter D/ thickness t), with circular and square cross sections, when subjected to axial loads, has been of particular interest since the pioneering works of Alexander [2]. In fact circular tubes under axial compression are reported to be the most prevalent components in energy absorber systems. This is because the circular tube provides a reasonably constant operating force. Furthermore, circular tubes have comparatively high energy absorbing capacities, and stroke length per unit mass. In comparing lateral with axial compression, the axial buckling mode has a specific energy absorbing capacity, which is approximately ten times that of the same tube when compressed laterally between flat plates. This is due to the fact that all wall material in a tube can be made to participate in the absorption of energy by plastic work in axial loading.

2.1 Thin-Walled Frusta

Frusta are truncated circular cones, see Fig. 1. Literature on the utilization of frusta for dissipation of energy is meager. Postlethwaite and Mills [11] first studied the frustum in this context in 1970. In their study of axial crushing of conical shells they used Alexander's extensible collapse analysis [2] to predict the mean crushing force for the concertina mode of deformation for frusta made of mild steel. Mamalis et al. [13] investigated experimentally the crumbling of aluminum frusta when subjected to axial compression load under quasi-static conditions. They proposed empirical relationships for both the concertina and the diamond modes of deformation. Mamalis et al. [14] extended their experimental study to include mild steel at elevated strain rates. They concluded that the deformation modes of frusta could be classified as a) concertina, b) concertina-diamond, and c) diamond. Mamalis and associates [15] refined the work of Postlethwaite and Mills [11] in using the extensible collapse analysis for predicting the mean crushing load, and fair agreement with the experimental results were reported. In another paper, Mamalis and his group [16] modeled the progressive extensible collapse of frusta and gave a theoretical model that depicts the changes in peaks and troughs of the experimental load-displacement curves. The comparison with the experimental results gave a fair degree of accuracy.

The above studies deal with axial crushing (or crumbling) of frusta between two parallel plates. However, an innovative mode of axial deformation is presented in this paper. This mode is inward (free or direct) inversion. In what follows, results of experimental work as well as finite element modeling conducted on the inversions of capped apex aluminum frusta are presented.

3. FINITE ELEMENT MODELING

The finite element method (FEM) has been used extensively to simulate many applications in structural dynamics [8,17-19]. In the present study, ABAQUS Explicit FEM code (version 5.7-3) is employed to investigate the modes of deformation of frusta under quasi-static loading. Fig. 2 shows the finite element models used in this study for the inversion. An axisymmetric four-noded element, CAX4R, is used for modeling the frustum shown in Fig. 2. About 300 elements are used for the model. Material properties of the model were taken as rigid perfectly plastic with yield strength S_y=125MPa, and density ρ=2800 Kg/m^3. All nodes at the centerline of symmetry were selected to move only in the vertical direction. Both upper and lower surface were set in contact with rigid body surfaces. These rigid surfaces were modeled using two nodal axisymmetric rigid elements, RAX2. A coefficient of friction of μ=0.15 was incorporated between the contact surfaces. A reference node was introduced at the top end surface of the model. This node was set to move at a velocity of 0.01m/s representing quasi-static case. The upper small capped end of the frustum was in contact with a rigid body moving at a constant velocity. The lower end was restrained from moving in vertical and horizontal directions as shown in Fig. 2.

4. EXPERIMENTAL

A large number of frusta, featuring different thicknesses and apex angles were subjected to various loading conditions. The program involved the use of twelve different sizes of aluminum frusta (3 different apex angles and 4 different thicknesses) for inversion. Additional tests were conducted to investigate the effect of impact speed on the inversion process. Tests were conducted by the use of a 50-ton Instron Universal Testing machine (UTM) as well as a falling weight hammer (FWH) of 7 m/s striking speed. Special jig for inversion was manufactured and utilized. The jig consisted of an inversion rod and a base cylinder, as shown in Fig. 1. The upper jaw of the UTM clamped the rod, and the base rested on the lower jaw. The same jig was utilized also with the FWH, in which case the inversion rod was simply attached to the falling weight.

5. RESULTS AND DISCUSSION

5.1 Static Testing

In this section details of the experimental load-displacement curves and finite element results for inversion are presented in details for quasi-static loading. Results of dynamic loading at high impact velocity are summarized in Section 5.2. A apex frustum (Specimen No. 23) was inverted at quasi-static condition using the UTM moving at a cross-head speed of 10 mm/min. The specimen has an angle α=60°, large diameter D=73 mm, small diameter d=22.5 mm, thickness t=1.25mm, height h=64 mm, and mass m=23.72 grams.

Figure 3 shows experimental and finite element (FE) load-displacement curves for the apex aluminum frustum. It can be observed that good agreement is obtained between the experimental results and FE predictions. It can be observed from the figure that the frustum passes through a number of stages. The load rises quasi-linearly from the origin to point (a). The force at point (a) represents the load of instability. Up to this point the deformation is recoverable, i.e. elastic and beyond which plastic behavior sets in. The zone between (a) and

(b) is a zone of incubation, within which the cap of the frustum is deformed in such a manner as to facilitate the inversion type of deformation. Three localized plastic hinges developed from point a to point b and extensible mode of deformation was observed. Point (b) signals completion of the development of the inversion zone. Inversion then proceeds towards the larger (lower) end of the frustum, until point (c) is reached, see photograph in Figure 3. The increase in the inversion force from (b) to (c) is attributed to the progressive increase in the volume of the deformation one with the increasing D/t ratio. Point (c) in Fig. 3 signals the termination of the inversion zone, the bending front having reached the vicinity of the free large end of the frustum. From point (c) to (d) inversion mode changes into flattening mode and the undeformed part of the frustum has the shape of Belleville spring, see photograph in Figure 3. The free end of the frustum is flattened parallel to the shoulder of the jig base. The energy absorbed recorded experimentally by the frustum through this inward inversion is 9.73 J/gm, whereas the predicted energy by FE is 9.47 J/gm.

The FE details of the inversion process can be seen in Fig. 4 that gives the inversion mode of deformation in 9 stages. These stages were captured at the following axial intervals: 0.3, 10, 20, 25, 50, 60, 77, 83, 85mm. The second and the eighth stages show the initiation and termination of the inversion process, respectively. Figure 5 shows half of the frustum (Specimen 21) before and after the inversion as predicted by the FE and the true photograph of the frustum. Excellent agreement between the two deformed shapes is obtained. Frusta made of mild steel, galvanized sheet steel, low carbon steel and PVC were tested successfully. Also, frusta made by riveting, welding, machining and spinning were also tested successfully.

5.2 Dynamic Testing

In order to assess the effect of speed on the process of inversion, identical frusta were tested using UTM at cross-head speeds of 2, 20 and 200 mm/min. Additional tests were conducted on the FWH facility using different falling masses. Impact velocities up to 7m/s were used in these tests. As all specimens in these tests behaved as in quasi-static tests. It was concluded that inversion is not affected by strain rate for low impact velocities. Shapes of the inverted frusta at quasi static condition are very similar to those inverted at dynamic case. Figure 6 shows a photograph of inverted frusta at dynamic conditions using FWH.

The possibility of re-using the inverted frusta was investigated. everal ests were conducted for inversion and then re-inversion of inverted frusta. Figure 7 shows the load displacement curves of the first, second, third and fourth inversions. Results from each experiment show that it is possible to invert and re-invert the frustum. All specimens failed, however, during the fourth inversion.

6. CONCLUSIONS

New mode of axial deformation of frusta is presented. The proposed mode is repeatable and predictable. Although the energy density of this axial mode of deformation is less than that of tube inversion, the inversion of frusta required simpler test rig and no die is required. In fact it was found that a frustum might be inverted several times, indicating that it is possible re-use the same absorber. Since all specimens in the impact tests behaved s n he uasi-static ests, it is concluded that within he xperimental ange f mpact peeds 0-7m/s), he rocess o inversion is not ffected by the speed of deformation. Finally, good agreement was achieved between the experimental results and the predictions by the FE model at the condition investigated.

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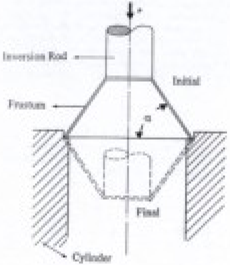

Figure 1. Direct inward inversion of frusta.

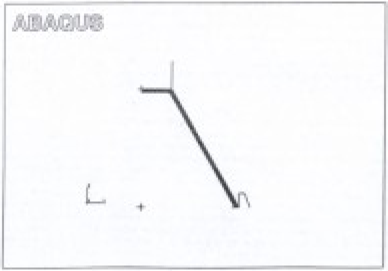

Figure 2. FE model for direct inversion.

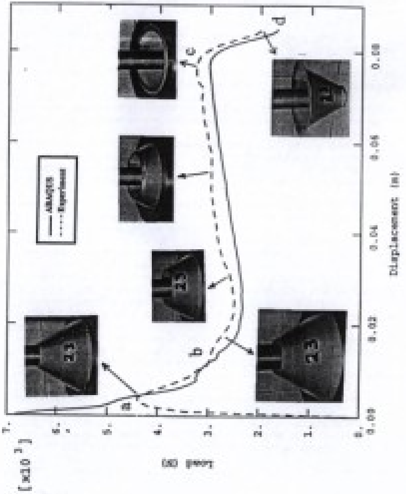

Figure 3. Experimental and FE load-displacement curves for quasi-static inward inversion of capped aluminum frustum.

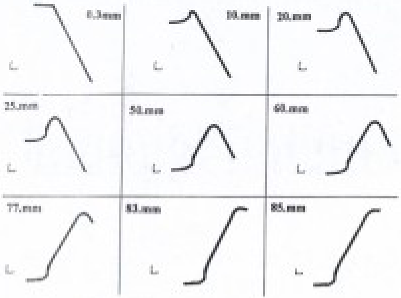

Figure 4. ABAQUS deformed plots for inward inversion of aluminum frustum.

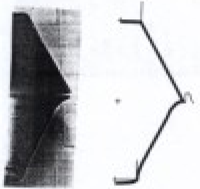

Figure 5. Comparison between the experimental and the FE prediction of a frustum before and after inversion.

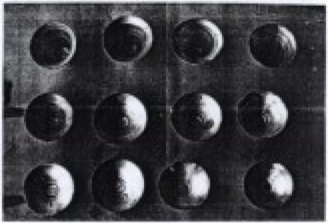

Figure 6. Photograph shows spun aluminum frusta inverted using falling weight hammer.

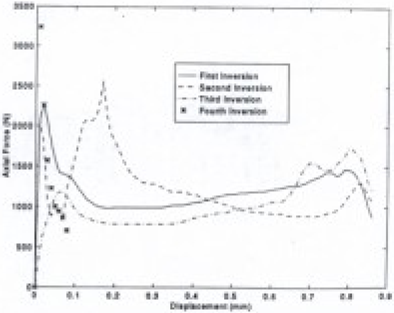

Figure 7. Force displacement curves of inversion and re-inversion processes.

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A RULE - BASED APPROACH FOR THE FORMATION OF MANUFACTURING CELLS

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ABSTRACT

The formation of cells is one of the difficulties encountered during the design of cellular manufacturing systems. The proper formulation of part families and their associated cells represents the most formidable of difficulties in this respect.

The present research assesses the appropriateness of a rule-based system for the implementation of several different techniques for formulating product families and associated cells. To this end, rules are developed for each. In efforts to investigate the validity of these rules, the resulting rules are applied to real factory data. Particular attention is paid to cell formation and the applicability of different procedures to overcome bottle-neck formation within the cell.

It is concluded that rule-based systems can be used effectively for determining the appropriate procedure to be used for overcoming of the bottle-neck situation that arises during cell formation. It is further shown that the use of rule-based systems can lead to significant savings in time during the implementation of these techniques.

1. INTRODUCTION.

Group Technology (GT) is a philosophy that aims at improving productivity of manufacturing systems by exploiting similarities inherent in parts. GT is defined by Groover[1] as a manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in manufacturing and design. The application areas of GT can be classified into several major categories: part design through computer aided design, computer aided process planning, cellular manufacturing, materials management, and quality control. This work is mainly concerned with cellular manufacturing. Cellular manufacturing is the application of GT principles to manufacturing based on classifying parts that require similar processing into part families. Subsequent or simultaneous to the part family determination, the machines required to produce a particular family are determined. The needed machines may then be moved and grouped into machine cells. Thus, each machine cell is dedicated to the production of a particular part families.

Cellular manufacturing involves processing collections of similar parts, so called part families, on dedicated clusters of dissimilar machines or manufacturing processes, called cells, such that a part is completed within a cell or with a minimum number of inter-cell transfers. This implies that parts must be grouped into families to be produced by compatible machines. The machines are arranged to allow for a continuous work flow through the series of operations. Distances between machines are minimized to allow for easy transfer of materials within the cell. A common arrangement is the U-shaped cell, which allows for entry at one end of the U and exit at the other[2].

There are numerous benefits associated with cellular manufacturing. Burbidge[3] categorized the benefits of cellular manufacturing as advantages due to set-up time reductions, group layout, and improved flow control. The benefits associated with reduced set-up time include an increase in capacity, a reduction in the tooling investment, reduced set-up cost, and reduced operation cost because more economical machines can be used as a result of the high aggregate volume of apart family. Gallagher and knight[4] listed a number of the advantages of cellular manufacturing including improved lead times, less work-in-process and finished goods inventories, less material handling, better space utilization, better production planning and control, improved quality and scrap, and reduce production design variety. Wemmerlov and hyer[5] noted that the recent interest in Cellular manufacturing can be attributed to two important factors: major international competitors and the emergence of new technologies.

A problem associated with cellular manufacturing is how to determine part families and machine cells. This problem stems not from a lack of techniques, but rather from the absence of clear guide lines for determining which technique is appropriate for a given situation or a given set of objectives. Steudel and associates[6] offered perhaps the most comprehensive taxonomy of apart family/ machine group formation techniques. These authors first classify part family/ machine group formation procedures as those based on part family grouping, machine grouping, or machine-part grouping.

Important problems encountered in cell formation are recognized as

(1) part family formation,
(2) parts allocation,
(3) machine group formation,
(4) machine allocation, and
(5) machine-part grouping.

Considerable research has gone into this area and several procedures have been developed over the years.

Generally, the parts in one family would have similar geometrical attributes, and or require similar machining processes. Usually, part families are formed in one of two methods, (1) the part family consists of parts which are similar in shape within a certain dimensional range, and have most or perhaps all machining requirements in common, or (2) the pat family consists of parts of dissimilar geometry, but which have some operations in common. The design of part families is usually the first step in cell formation. This alone does not help to achieve the desired objectives of cell formation, unless machines are grouped to manufacture one or more part families.

Parts allocation could arise in two ways : (1) machines have been grouped into cells based into their capabilities to process the parts, and the problem is to allocate parts to the machine groups, (2) new parts are introduced into the system which have to be manufactured. The allocation of

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new part or parts to appropriate machine groups must be done without disrupting the existing configuration. Also, it is helpful to know beforehand if the new part or family of parts could be manufactured within the existing machine cells. This leads to other decisions such as redesigning or subcontracting of the part, or expanding the production facility.

The machine group formation is concerned with the problem of grouping machines into cells. Each cell consist of dissimilar types of machines to efficiently produce a family of parts requiring almost similar machining operations. Designing machine groups essentially means recognizing and using the relationship between machines. This relationship is defined in terms of the parts that have to be processed on these machines.

Machine routings and production requirements of the parts are usually the input information needed to form machine groups. Once machines are grouped into cells, parts are allocated to these cells and the cells are evaluated on factors such as machine utilization.

The most popular method for machine grouping is similarity coefficient methods[7,8]. Similarity coefficient methods for machine grouping are identical to similarity coefficient methods for part family grouping. The only difference is that in machine grouping, the similarity coefficient measures the similarity between pairs of machines. Usually the similarity coefficient between two machines is defined as the number of components visiting both machines divided by the number of components visiting either of the two machines. These similarity coefficients are stored in a similarity matrix. By analyzing this matrix, the similarity coefficient of each pair machines is found. Next, the single linkage cluster procedure is then applied to the similarity matrix and machine groups are formed. Finally, parts are allocated to the identified machine groups.

Machine allocation is an important problem encountered in the planning stage of a cellular manufacturing system as its implications affect any efforts to economize on tooling requirements and improve machine utilization and materials handling. In many firms, the geometric feature-based grouping has been mainly a part of design standardization effort for the various shapes of the parts. The concept has been used in the computer aided process planning area where an attempt to relate the processing steps to geometric features is made to develop computerized system for generating process plans.

Machine-part grouping is concerned with the problem of producing parts with similar processing requirements in machine groups. Each machine group consist of dissimilar types of machines which possess specific manufacturing capabilities to produce one or more part families. This provides an opportunity to reduce set-up times, thus, allowing manufacturers to reduce lot sizes, trim work-in-process inventories, and shorten manufacturing lead times.

The most important task in GT application is to find the families of similar parts and forming the associated groups of machines. This process is called machine-component grouping. There are different approaches[2,7] to machine-component grouping problem. Generally, these approaches can be classified into two categories which are manual techniques, and algorithmic techniques. Using route card data directly, this method proves to be quick and sufficiently accurate to indicate to the company the scope for re-arranging the shop floor into independent manufacturing cells. The basic input data is the list of machines that each component visits, ignoring the exact visitation sequence of these machines. This method is not a one step solution to the creation of cells. It is part of a more comprehensive system design tool called production flow analysis (PFA), which is a method for identifying part families an associated groupings of machine tools. It does not use a classification and coding system and it does not use part drawings to identify families. Instead, PFA is used to analyze the operation sequence and machine routing for the parts produced in the given shop. It groups parts with identical or similar routing together. These groups can then the used to form logical machine cells in a group technology layout.

The cellular manufacturing problem stems from determining the appropriate technique to form part families and machine cells for a given set of objectives. Many approaches have been developed to solve the GT problem such as classification and coding, rank order and direct clustering algorithms, similarity coefficient algorithms, and production flow analysis. Much research has been devoted to the cell formation problem such as those reported in reference[illegible]

The rank order clustering (ROC)[8] represents route card data as a binary matrix. Using a positional weighing technique for the "1" entries in the matrix, the rows and columns are alternately rearranged in order of decreasing rank. The result is a diagonalization of the 1's into several clusters. If independent machine-component groups do exist in the data provided, each machine will occur in only one cluster. Components will be uniquely assigned to any one of the clusters. One of the major advantages that the ROC method has over other methods is that it has the ability to deal with the exceptional elements and bottle-neck machine problems. Using this algorithm, the analyst can obtain a visual assessment of the machine groups and the associated families of parts simultaneously. With such an approach, a very valuable preliminary assignment of machines can be obtained, because if a large number of machines is shared over several clusters, plans for cellular manufacturing can be shelved at the outset.

Direct clustering algorithm (DCA) is a technique which provides a simple and effective way of clustering data directly from any given machine component matrix[11]. The stage preceding group analysis involves the formation of a machine –component matrix with the rows labeled with component numbers and the columns with machine numbers.

The machine and parts data can be classified into three categories, and accordingly, the applicability of the previous approaches can be justified. Firstly, if the available data is mainly about the design and manufacturing attributes of the parts, then the classification and coding approach is the most suitable tool to classify these parts into families. Secondly, if the available data is in the form of machine-part matrix, then rank order or direct clustering algorithm is the appropriate approach to form diagonal clusters which represent part families and machine cells. Thirdly, if the available data details the process routings of each part, then production flow analysis approach can be applied to form part families and their machine cells.

The construction of expert system is, in general a lengthy process that requires prototyping approach. Prototyping is an interactive process involving continuous testing, evaluating, and improving. Knowledge acquisition is the major problem with expert system development. The different stages for expert system prototyping are discussed. Many tools have been developed to shorten the development process and to make expert systems economically feasible. These tools, which are available at different levels of technology, can be used independently, or they can be combined. The major tool concept is the shell, which represents an expert system lesson its knowledge base. LEVELS 5[8] is an expert system shell used in this work. When a shell is upgraded and improved with special capabilities, it can be used to build specific expert systems rapidly and economically.

The manual application of the previous approaches is a tedious and time consuming task when real data is used. Therefore, computer is employed for the fulfillment of this task. Hence, many software tools are developed to aid programmers to structure expertise and knowledge in the form of expert systems which are capable of giving decisions when consulted for GT problems.

The ultimate group technology application in manufacturing is to form manufacturing cells. A sequential or simultaneous approach could be adopted for cell formation. The sequential approach first forms the part families or machine groups followed by machine assignment or part allocation respectively. The simultaneous approach determines the part families and machine groups simultaneously. Although the simultaneous approach is better, it usually suffers from computational difficulties. A rule-based system, presented in summary form below, was developed to overcome these computational problems where it implements both sequential and simultaneous approaches. According to the available data, the system applied the Opitz coding system, or the rank order and direct clustering algorithms, or the nuclear synthesis method.

Depending on the variety of the product mix and the volume of production, traditional approaches to organize the manufacturing system for dissimilar parts manufacture all seem to focus on two strategies. In general, the assembly line method seems to be advocated for organizations manufacturing a few product in large batches, while the job shop configuration is adopted for those companies that manufacture a large variety of products in smaller batches.

The present research assesses the appropriateness of a rule-based system for implementation of several techniques for formulating product families and associated cells. To this end, rules are developed for each of these techniques. In efforts to investigate the validity of these rules, the resulting rules are applied to real factory data. Particular attention is paid to cell formation, and the applicability of different procedures to overcome bottle-neck formation within the cell.

2. THE RULE-BASED SYTEM

Use was made, as summarized below, of the LEVEL5S Expert System software[6] and a commercial data base package[7], to execute structured programs for known techniques for the formation of part families and of cells. Subsequently rule-based procedures were developed for the solution of bottle-neck problems for both machines and for parts.

The rule-based system consists of four sub-systems shown schematically in Fig.1, and written and executed through LEVEL5S Expert System Software. The first sub-system is represented by the classification and coding technique for rotational parts developed by Opitz, and was written in production Rule language (PRL), which is encapsulated in the LEVEL5 software. The second sub-system, consists of two systems written in BASIC, and interfaced with LEVEL5. These two systems represent the rank order clustering and direct clustering algorithms. The third sub-system is represented by the production flow-analysis nuclear synthesis, and was written in PRL. The fourth sub-system consists of six systems for scenarios of the exceptional parts problem, and these were written in PRL.

2.1 COMPARISON OF LEVEL5 AND TURBO PROLOG.

Initial analysis indicated that three factors affect the decision about the most suitable software for the development of the proposed rule-based system. The first factor, is the capability of the software to process data-base (DB) files. The proposed rule-based system requires different arrangements of data files for the parts and the machines required to produce them. Therefore, DB files and the methods of processing them play a major role in the development of the system. LEVEL5 software communicates with DB software, and this is a very good facility, where the power of an independent software can be unified with LEVEL5 software. On the other hand, Turbo prolog Software lacks this facility, and the way it deals with data is to write specific programs to manipulate the data in the required structure. Therefore, for every data structure a separate program is required, and that complicates the task of the development of the rule-based system.

The second factor is the explanation facility. The need for this facility arises when the user of the proposed system requires more information regarding a specific query during consultation. Essentially this facility can fulfil the requirements of the user whenever they arise. Turbo

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prolog Software, which was used for the development of the Opitz system, does not provide the user with supplementary information during consultation unless additional software is written.

A third factor to be considered is the ability to install other software packages. Turbo prolog lacks this facility, whereas LEVEL5 provides the facility to interface with and install up to three different software packages internally, where they can be executed from its main menu. It was decided, therefore, to utilize LEVES5 for the subsequent development of the system.

2.2 RANK ORDER AND DIRECT CLUSTERING ALGORITHMS.

Rank Order Clustering (ROC) is designed to generate diagonal groupings in apart and machine matrix (Fig.1) It requires the paradigm of cell entries in the rows and columns of the matrix to be read as binary words. The corresponding decimal equivalence of these binary words are then used as the basis for the ranking of the rows and columns. The algorithm re-arranges rows and columns in a receptive manner, and eventually produces a matrix in which rows and columns are arranged in an order to decreasing binary values. If the new matrix does not show diagonal groups, then the re-arrangement of rows and columns is repeated until the existence of these diagonal groups. Two programs were developed for the implementation of ROC and DCA in BASIC, and they were interfaced with the LEVEL5 shell.

One of the advantages of the clustering system is its capability to give the user a pre-audit idea about the expected part families and the cells required to produce them. Secondly, the system only requires the matrix incidence for the parts and the machines required to produce them. Application to practical data showed several drawbacks of this system. A serious dis-advantage is that the system lacks the potential to solve the bottle-neck problem. Furthermore, the system does not inspect the loads against the capacities of the machines in the formed cells. Also the developed clustering system are not suitable for real-life problems, since ROC has a memory allocation problem related to BASIC.

It was concluded hence that, although the clustering system does form diagonal groups according to ROC and DCA procedures, it does not solve the exceptional part or machine bottle-neck problems. It was discovered that, when a bottle-neck does occur, the system allocates most of the existing machines to it, and prevents the formation of purely separable groups. The formation of diagonal groups is also interrupted when a machine bottle-neck problem arises. Furthermore, the existence of a bottle-neck, be it due to apart or to a machine, prevents the formation of part families and machine cells, and the system makes one part family and one cell from all the parts and machines in the matrix. Both the ROC and DCA lack the capability to find a part or machine bottle-neck when it exists, and therefore, they do not give any recommendation with respect to the possible procedures to solve this problem.

It must be emphasized that the bottle-neck problem is a very real one, and it is for this reason that it deserves special attention during the development of a practical rule-based system.

2.3 NUCLEAR SYNTHESIS METHOD

A rule-based system was written in production rules languages for the implementation of the nuclear synthesis method (Fig .1) The system consists of four sub-system to fulfil four main stages. The first sub-system calculates the usage frequency for all machines in the DB. The second sub-system locates all nuclear machines in the DB. The third sub-System forms modules from the located nuclear machines and the parts requiring them. The last sub-system groups the related modules to form cells.

We present below one case of practical application of the rule-based system that was developed for this method. To this end, the system was interfaced with the DB used for the storage of real data, for 197 parts, 87 machines and the reprocessing routes, each part requiring 3 operations on the average.

The implementation of the nuclear synthesis method was conducted in two phases:

a) manually and
b) by the use of the rule-based system. The main objectives of the manual implementation, and to check that the outputs of the rule-based system are correct.

The generic procedures for the nuclear synthesis method were implemented manually before structuring them in the form of a rule-based program. The manual application was a very time consuming process, especially the filling of the modular synthesis sheet, where the availability of every machine type and the modules requiring it must be recorded and updated if another module requires that machine type. The time required to fulfil the requirements of this method manually was approximately four weeks.

In the second phase, the implementation of the nuclear synthesis method was undertaken by the use of the computer, utilizing LEVLE5 software for the development of a rule-based system. During the calculation of usage frequencies of 87 machines, the documentation of all process details required three days, when executed by hand. On the other hand, the rule-based system completed this process in one hour. The process of formation of modules is even more labor-intensive, it required approximately one week to form 71 modules by hand. On the other hand, the rule-based system required approximately 2 hours to accomplish the same task. The system formed 71 modules from the 197 parts and the 87 machine types, searching routings data files for every nuclear machine, and listing all parts that require it, and other machine types required by the located parts.

2.4 THE BOTTLE NECK PROBLEM IN MANUFACTURING CELLS

A bottle-neck case can arise when grouping parts and machine families, in most real-life situations. There are two types of bottle-neck problems, i.e., bottle-necks in machines and bottle necks in parts. The bottle-neck in machines problem arises when large numbers of machines are required to process a few number of parts. In other words, when different manufacturing cells require a specific machine type, where the available number of the required machine type is less than the number of cells requiring it, then a bottle neck in machine problem arises. On the other hand, a bottle-neck in parts normally arises when a limited number of parts are to be machined on a large number of machines.

When developing the software for tackling the bottle-neck cases (Fig. 1), a stage by stage approach was adopted. In the first stage, an attempt is made to solve the problem by finding an alternative machine for the bottle-neck machine, and to assign it to the cell which needs it. If this is not possible, the second stage commences, where the system looks for an alternative routing for the part or group of parts which require the bottle-neck machine. If this procedure is unsuccessful, then the system assesses the possibility of sub-contracting the parts requiring the bottle-neck machine to another cell, else the system advises on the possibility of sub-contracting these parts to another company or to re-design the parts to utilize the available machine types if possible, or to purchase an extra machine or machines to overcome this problem.

3. CONCLUSIONS

Two types of non-procedural language software, namely LEVEL5I and Turbo Prolog were compared to justify their appropriateness for the development of the cell formation rule-based system. The procedure for this comparison was to implement the different approaches for cell formation with the aid of two different types of software, and assess their capabilities and limitations. Accordingly, LEVEL5 was chosen for this task.

Next, a study was conducted on the implementation of the classification and coding technique as a solution for the part families and machine groups formation problem. The Opitz code system was mainly used for the classification of parts, where the developed system requires the design attributes of the part to be classified. One of the main advantages of developing the Opitz code by using two different software packages was to judge the appropriateness of Turbo Prolog and LEVLE5 software for the development of the proposed rule-based system. It was concluded that LEVEL5I is the superior of the two packages, and it was decided to rely on the latter software for the subsequent development of the rule-based system.

With respect to the two rule-based ROC and DCA, their validity was verified through the application of examples taken from the literature.

It was observed that the rule-based system for the nuclear synthesis method forms manufacturing cells from part's routings, where it finds nuclear machines, and forms modules around these machines, and then it groups the formed modules into cells. It was likewise noted that the production flow analysis nuclear synthesis method requires a comprehensive set of data about the parts and the required machine to process them. It is concluded hence that this method represents the largest part of the developed system.

It was shown that the output of the nuclear synthesis method, when implemented by using the LEVEL5 software, agreed the output from a manual processing of the same set of data. In addition to that, significant time savings were achieved due to the application of the nuclear synthesis method in the rule-based system. In addition, the possibility of making mistakes was high in manual processing, and not that easy to trace. The rule-based system, on the other hand, was not likely to commit human mistakes once its logic and structure have been tested and fully validated. It was concluded that this achievement of similar output, by he use of the rule-based system, in a much shorter time was due to the logic potential of the rule-based system, and the capability of LEVEL5 software to manipulate up to four DB files in a single procedure.

It was noted that, in real-life situations, the part families and cells formation techniques may encounter a machine bottle-neck, or a part bottle-neck problem, or both of them.

It was necessary, therefore, to develop software to encapsulate such situations, and to offer helpful advice, and to suggest possible solutions. Three approaches were envisaged for such scenarios: alternative machine procedures, alternative routing procedures, and internal sub-contracting procedures. It was concluded that these approaches should be applied in the mentioned order for tackling any bottle-neck problem. When it fails to find a satisfactory solution by the adoption of the above procedure, the system then advises the user to sub-contract the parts requiring the bottle-neck machine to another factory, or to re-design these parts to utilize the available machine types, or to purchase the bottle-neck machine or its alternatives.

4. RECOMMENDATIONS

It is clear that the required time for the system to form cells can be reduced by using faster computer.

The ROC and DCA systems could handle, in the present case, a matrix of 20 machines and 20 parts only, due to a shortage in assigned memory by BASIC, and due to limitations of the visual display unit (monitor). Adoption of more powerful softwares, and the implementation of an on-line printer with large printing paper should overcome these drawbacks.

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HIGH LEVEL COMPUTER VISION

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ABSTRACT

This paper presents the design, implementation and characterization of a novel digitizer. The digitizer can be used by experimenters and researchers in the field of computer vision and image processing. It does not require a large bank of semiconductor memory to store digital image data for subsequent processing. It transfers the digital data of the image directly to the PC's own memory by using the DMA of the PC board. It requires very little hardware and hence is very inexpensive. It can be programmed through software to increase the resolution of the captured image.

1.INTRODUCTION

Computer vision technology develops the theoretical and algorithmic basis for automatically extracting and analysing useful information from the observed image. Extraction of features (for example, edges) and analysis and classification of shape boundaries is useful for a variety of purposes. Edges are useful in matching images, improving the quality of segmentation, texture analysis and extracting shapes of objects in the given images. Shape analysis and classification is useful in a variety of applications including target recognition, character recognition, scene analysis and bio-medical and industrial applications.

The research in the area started twenty years ago. The bulk of work was carried out by mathematicians under the heading Pattern Recognition. Recently much of this work is being done by Electrical Engineers and computer scientists as a field of digital signal processing and computer vision. The availability of high level languages and matured programming techniques, are expediting the research.

The first step in the computer vision technology is to obtain the digital representation of an image. Over the years different approaches have been adopted for capturing image data, resulting into various types of digitizers and frame grabbers. Such commercially available digitizers are quite expensive. A key design criterion in our case was to minimize the hardware, in order to make this system cost effective. All this lead to a small printed circuit board (PCB) plugged on the extended interface signal adapter(EISA) bus connector of the PC and a BNC socket provided for making connection of video output of the camera. For researchers who are interested in shape recognition, the proposed approach is most suitable and easily understandable.

The hardware design of the system is given in the next section. The Flow Chart and the Implementation are given in the succeeding sections. Further improvements are also suggested before concluding the paper.